Plastics and Rubber Sri Lanka

The Journal of the
Plastics and Rubber Institute
of Sri Lanka

PRI
SRI LANKA

TECHNOLOGY REVOLUTION FOR INDUSTRY GROWTH

2019
VOLUME 18

- Rubber World View
- Innovative Compounding
- Recycling and Green Concepts
- Integrated Systems
- Novel applications of NR

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PRIM Diamond Jubilee International Rubber Conference 2020

The PRIM's Diamond Jubilee International Rubber Conference (PDJIRC)

The Plastics & Rubber Institute Malaysia (PRIM) has come a long way since its formation 60 years ago as a chapter of the former Institute of Rubber Industry, UK and later PRI which subsequently merged with other professional bodies forming the current IOM3 headquartered in London. Over the last six decades, PRIM has supported the rise of the Malaysian rubber industry to international importance.

PRIM, a member of International Rubber Conference Organisation (IRCO), has played a key role to promote and enhance the practice of polymer science and technology through various educational activities to fulfil the professional needs of the members and industry. With success in organising the IRC 2018, PRIM takes pride in organising the PRIM Diamond Jubilee International Rubber Conference (PDJIRC) in September 2020 that provides an excellent platform for rubber scientists, technologists, academicians and industrialists to share knowledge and coupled with interaction and networking at various social events throughout.

PDJIRC is concurrently held with 10th IRGCE 2020 and 2nd IRICE 2020 from 8 to 10 September 2020. In conjunction with PDJIRC, the International Symposium of Polymeric Materials (ISPM) will be held on 10 September 2020 at the same venue. The ISPM is a premier international symposium that provides an avenue for networking among students, graduates, academicians and researchers to exchange new knowledge, ideas and frontier research findings.

This will be a joint international conference on rubber and related materials encompassing 2nd IRICE 2020 and PDJIRC 2020 with a common theme **"Rubber Product Manufacturing: Creating the Eco-System to Move Forward"**.

Call For Papers

Invitations are NOW OPEN for submissions of conference papers with regards to the subject categories.

Kindly submit the title, a one-page synopsis/ summary and CV to the Organiser via email to primy@prim.org.my by 31 January 2020.

For more details of the PDJIRC, please contact the PRIM Secretariat.

URL: http://www.prim.org.my

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President's Message

Dear Members

I am pleased to convey, this message to the 18th Volume of the Journal of the Plastics and Rubber Institute of Sri Lanka, (PRISL), which will be officially launched during the Annual Awards Night of our prestigious institute. Being a professional body, primarily devoted to the educational and professional development in the polymer industry in Sri Lanka, the Annual Journal serves to disseminate knowledge gathered from local and overseas academics and professionals in various disciplines related to the polymer industry. The Journal also provides a corridor for researchers, to publish their findings, which help our members to gain an insight in to the latest developments in the polymer field.

The Annual Awards Ceremony is the premier social event of PRISL, where the institute felicitates those students who have successfully completed its educational programmes, and also recognizes those who have made outstanding contributions to the industry. It has also become the much-sought socializing and networking forum for the industry stake holders and well-wishers.

I am also very happy to highlight the achievements of the new Council of Management, which took over the reins, in May 2019. The core activity of PRISL, namely the educational programmes, Certificate, Diploma and Graduate courses have proceeded steadily according to the educations calendar. The 6th Edition of the Complast and the 3rd Edition of RUBEXPO was held successfully at the BMICH on 9th to 11th August 2019. This event was jointly organized by the PRISL and Smart Expos India. A Memorandum of Understanding was signed between PRI Malaysia and PRISL during the same event.

The Two day Workshop on Tyre Technology and Compound Developments, supported by the Export Development Board, with the assistance of three resource peroneal from India facilitated by the Indian Rubber Institute was conducted on 26th and 27th July 2019 at the Taj Samudra, with record participation of 110.

The Annual Family Picnic was held at the Thotupla Lake Resort, Piliyandala on 22nd September 2019,with the participation of a large number of members and their families.

The Finite Element Analysis and Simulation Centre, established as a Public Private Partnership during August 2018, is gradually progressing on steady path in expanding its activities. MOUs have been signed with the National Chamber of Exporters and SCF, and Global Rubber Industries, for technical collaboration and sharing the resources also with SSF.

I wish to congratulate, the Merit Award recipients, Members who were upgraded in their membership status and all the students who are receiving the certificates today. I take this opportunity to express my gratitude to the members of the Council of Management, the Social and the Editorial, Seminars and Promotions Committees and all other sub Committees, and the administrative Staff, for their dedication and commitment for arranging the programs to the highest professional standards. A special word of thanks to all our Patron Members foe their generous sponsorships and committed support.

Kaushal Rajapaksa
President PRISL

Message from the Secretary

I consider it a pleasure and a privilege, as the Secretary of the Plastics and Rubber Institute of Sri Lanka, to pen down a congratulatory message for the 18th Edition of the annual journal of our prestigious institute. It is very encouraging to note that the new brigade, which was entrusted with the responsibility of managing the editorial activities has done a highly commendable task, in bringing forth this new edition to our esteemed members.

On perusing the array of articles, which cover wide range of topics relevant to the needs and expectations of the day, it is my view that the Editorial Team has made a tremendous effort to render justice to the theme, " Technology Revolution for Industry Growth". Having headed the editorial activities of the PRISL for the past eight years, I am fully aware about the challenges and hurdles in undertaking a task of this nature.

PRISL is currently on the correct path of assigning the responsibilities, of managing the affairs of the institute to young professionals. I think it is fitting at this juncture, to quote G.K Chesterton, (1874 -1938), the English writer and philosopher :

"Don't ever take a fence down until you know the reason it was put up."

I am encouraged to note the progress made by the new Editorial Team, and I am confident that they will continue the dedicated and untiring commitment for many years to come.

P.P. Perera
Hony: Secretary

Note From the Editor's Desk

The Seminars, Publications, and Image building Committee of the PRISL has the pleasure and privilege to present the Annual Journal for 2019. For its esteemed members and the wider readership across the country and the globe. It aims at disseminating innovative and high-quality research articles that enhance conceptual and empirical knowledge in the broad areas of rubber and plastic studies.

The Journal comes to at an appropriate time, when the Country is looking forward to a new era of facing and overcoming the enormous challenges both locally and globally.

The Journal, as we believe, marks another milestone of the long history of the PRISL. We put all our efforts to establish the culture of a true peer-reviewed Journal, although it was a difficult and time-consuming journey.

The 18th Issue of the Journal of the PRISL comes to our esteemed members, with the timely theme of "Technology Revolution for Industry Growth". We have made efforts to provide insights in to emerging technologies such as Innovative Compounding, Recycling and Green Concepts and Integrated Systems etc.

We express our gratitude to the contributors of the articles and organizations who generously supported us financially, despite the current adverse economic climate.

The guidance and the advice offered by the President and the EXCO Members and the support and the commitment of the Administrative Staff is highly appreciated. A special word of thanks to the Mr.P.P. Perera, Secretory of PRISL for his enormous guidance and advice and the dynamic members of the Seminars, Publications and Image Building Committee who rendered their untiring efforts with a high sense of commitment to make the Journal a reality.

Prabath Jayasinghe
Chairman: Seminars, Publications and Image Building Committee

50 years celebrating Kelani Cables wins World Class Global Performance Excellence Awards for the second time

Kelani Cables was awarded the World Class Award at the Global Performance Excellence Awards (GPEA) for the second time in 2019. The company previously won the world class award at GPEA 2017 cycle. GPEA is organized by Asia Pacific Quality Organization (APQO) in which USA, Australia, China, Korea, New Zealand, Mexico, Russia, Singapore etc. are core council members. The award ceremony was held in Bali, Indonesia on 15th October 2019. Organizations who has won National Quality Award in the respective country are eligible to apply to GPEA. Kelani Cables was awarded the prestigious National quality award 2016, hosted by Sri Lanka Standards Institution (SLSI). Kelani Cables is the first cable manufacturer to have won the National Quality Award and the only cable company to win twice in 2006 & in 2016.

An organization has to be performing well in seven quality criteria to be awarded National Quality Award and Global Performance Excellence Award. The seven criteria are Leadership, Strategy, Customers, Measurement, analysis and knowledge management, Workforce, Operations and results. These criteria are the same in Malcolm Balridge National Quality Award in USA, one of the most stringent set of quality requirements in the world.

In a performance excellence organization, leadership focuses on vision, mission and values, communication and organizational performance, governance and societal responsibility. Its strategic direction guides strategy development process, strategic objectives, action plan development, and deployment. Customer focus is vital to a performance excellence organization that will have strong focus on knowing the voice of the customer, customer listening, identifying potential customers, determination of customer satisfaction and engagement, product offerings and customer support, customer relationships. Measurement, analysis, and knowledge management direct performance measurement and analysis, performance improvement, organizational knowledge, data and information technology. Workforce development is a must to achieve workforce capability, capacity and climate, workforce engagement, performance and leader development. Operations management is also key to realize organizational excellence.

Kelani Cables is a renowned brand for superior quality power & telecommunication cables and enamelled winding wires. Kelani Cables are certified to Sri Lanka Standards SLS 412 - Auto cables, SLS 733 - Building wires, SLS 750 - Overhead conductors, SLS 1504-flexible cords and SLS 1186 - armoured cables). Kelani enamelled winding wires are an Underwriters laboratory certified product. Cables manufactured by the company comply with British Standards (BS), European Norms (EN), International Electro technical Commission (IEC), Australia/New Zealand standards (AS/NZS) and Indian Standards (IS).

Kelani Cables PLC is a one hundred percent Sri Lankan company serving the nation for 50 years manufacturing power & telecommunication cables and enamelled winding wires. The company is ISO 9001, ISO 14001 and Responsible Care certified. . The company clinched Taiki Akimoto 5S Gold award in 2007, CNCI industrial excellence award consecutively for 3 years from 2006 to 2008 and for this achievement was recognized with CNCI industrial excellence crystal ward in 2008, National Safety Gold Award in 2010, SLIM brand excellence 2013 Gold award in B2B category and SLITAD people development Gold award in 2013. In 2015 and in 2016 Kelani Cables was awarded Asia's Best Employer Brand Award. The company won Best Green Reporter Gold award at 2016 Presidential Environmental Awards and 2016 National HR excellence Silver award. Kelani Cables was awarded the prestigious National Quality Award in 2016 for the company's sustained business excellence. Company won the SLIM Brand Excellence awards 2018- CSR brand of the year (Silver award). The company won the Gold Award for B2B Brand of the year at the SLIM Brand Excellence in 2013 and 2017. Kelani Cables also won Gold Award for the Industry Sector of National Chamber of Export 2017 and World Class award in Global Performance Excellence awards 2017.

A tribute by a Patron Member

It was no once upon a time but a sheer dedication to the cause; Textrip (Pvt) Ltd .,

The ever-appreciating role model of PRI where we members always stand to gain therefrom is one which needs to be hailed as a leading contributing body in the plantation industry and in particular in polymer sector. The history of PRI and its cherished activities never had an easy road but faced vicissitudes of ground scenarios. The past and present officials and staff have braved the weather to make it to an apex body which we are amply proud of.

Textrip (Pvt) Ltd., in the context is taking liberty to publish its achievements where the role played by PRI is clearly visible. The long chequred history of Elasto Ltd., the parent company of Textrip (Pvt) Ltd ., and its pioneers notably Gunesekera brothers; the late Engineer Donald and Late business magnate, Wilson paved way for a first Sri Lankan footwear industry in the southern costal belt which was later to become a household name much to be admired by Sri Lankan community.

Footwear with the advent of globalization the, protective trade practices being removed found difficult to manage the manufacturing activities dear to global market and therefore changed to different brands of activities under Textrip (Pvt) Ltd which now propels its products portfolio under TEXSTRETCH Brand Progressive Resistance Bands swinging its feathers in 27 Countries to become a regular prize winner in the export of rubber and allied products. In this stride it secures the Silver Award at the Large Category- Provincial Level – and Bronze- Large Category- at National Level at the CNCI Achievers Awards 2019, and the Silver Award at the 27th Annual NCE Exports- Medium Category Awards -2019 (this indeed is a repeat performance of the year 2018 where we won the same NCE Award). These are in addition to regular reckoning by the Productivity Secretariat for being a productive institution attracting its special recommendation for two consecutive years.

Textrip (Pvt) Ltd., enjoys its working environment with two internationally acclaimed ISO 9001; 2015 QMS Certificate and ISO Certification of 14001; 2015 EMS. Mr Mangala Gunasekera, Managing Director of Textrip (Pvt) Ltd., and Elasto Group has this to say. **‘’We appreciate and thank all those external agencies and the internal stake holders and above all our loyal customers for what we have achieved up to now. We, as a Patron Member, salute once again the PRI for its standing and its contribution to the industry”.**

Kulathunga Rajapaksa Chairman DSI Samson Group, conferred with Honorary Doctorate

Kulathunga Rajapaksa, Chairman of the DSI Samson Group and respected business leader was conferred with the honorary title Doctor of Philosophy for his exceptional contribution to Sri Lanka's business community. The prestigious recognition was bestowed on him by the University of Sri Jayewardenepura, which also took into account his visionary leadership in making the DSI Samson Group a respected and successful business conglomerate it is today.

Dr. Kulathunga Rajapaksa is an accomplished entrepreneur and a pragmatic leader. He is a popular and widely known business leader who has won many prestigious business accolades including the award for "Entrepreneur of the Year". Till his recent appointment as Chairman, he was the group Managing Director of the DSI Samson Group for the past 35 years, during which time the Group saw rapid development and diversification.

During his formative years in business, he was fortunate to work closely with his father and founder of the DSI Samson Group, the Late Mr. D Samson Rajapaksa. This enabled him to inculcate the vision, identity and philosophy of the founder into the core values of the organisation, as it stands today.

In addition to giving astute leadership to a group of successful and diverse business enterprises, he also divides his time in contributing to important national interests. Whist being a popular and astute speaker at many business forums, he is widely respected for his perceptive business acumen and understanding on current business affairs. He is a past president of the National Chamber of Exporters of Sri Lanka, the Sri Lanka Association of Manufacturers and Exporters of Rubber Products and a President of the Sri Lanka Footwear Association. He has also served as an honorary council member of many prestigious universities.

He is currently an Executive Committee member of the National Chamber of Exports of Sri Lanka and is a Director of the Mawbima Lanka Padanama. He also serves as a member of the Advisory board of the All Ceylon Buddhist Congress.

Barry Juriansz – 23rd September 2019

Plastics and Ru
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Evaluation of Potential of Two Natural Proteins as Surface Modifiers to Enhance Reinforcing Action of Silica in Natural Rubber Latex Films

R.W.D.H.S. Rajasekara, H.P.D.K. Randeepa and N.M.V.K. Liyanage

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Katubedda, Sri Lanka

Abstract

It is well known that self aggregation of silica is a serious issue in NR latex compounding since silica has to be added as an aqueous dispersion. Maintaining the colloidal stability of latex compounds after blending with silica is also not that easy. In the present study, applicability of two natural polymers, zein and soya protein, in modifying silica particle surfaces and thereby preventing self aggregation of silica particles was evaluated. The modified fillers were characterised by FTIR spectroscopy. The performance of protein modified silica in vulcanised latex films was evaluated using a selected latex compounding formula at two different level of additions; 2.5 and 5.0 pphr. Of the two proteins tested soya protein was found to be better than zein in terms of conferring colloidal stability to aqueous silica dispersions. However, the physical properties of vulcanized latex films containing zein modified silica were found to be better than those of similar films containing soya protien modified silica.

Keywords - Natural rubber Latex, Zein protein, Soya protein Modified silica

1. Introduction

Natural Rubber Latex (NRL) is a colloidal emulsion of *cis* 1,4 – polyisoprene tapped from *Hevea brasiliensis*. In addition, it contains non rubbers such as proteins, lipids, carbohydrates, enzymes, mineral salts, resins and carotenoids etc.[1]. Strength properties of gum compounds based on NR are quite adequate for many applications when compared with those of synthetic rubbers. However, for certain applications like physiotherapy exercising bands and tourniquets, reinforced NRL vulcanisates would be more suitable.

Silica is one of the most widely used reinforcing fillers in natural rubber based products. Low colloidal stability of NR latex compounds filled with reinforcing fillers has been a critical issue faced by many NR latex based product manufactures. Furthermore, incompatibility with isoprene polymer and self aggregation resulting from surface functional groups, make incorporation of silica into NR latex compounds a significant problem.

A considerable amount of research is being conducted to address this issue which involve blocking of the surface functional groups with materials having many different structures, including some having hydrophobic units as well. In the present study two natural proteins extracted from two abundant sources were used as the surface modifiers for silica. The silica surface modification was confirmed by FTIR spectroscopy. Colloidal stability of aqueous modified silica dispersions was monitored and subsequently the influence of modified silica on, tensile and tear properties of NR latex vulcanisates, turned out from a selected latex compounding formulae was evaluated.

2. Experimental Procedures

2.1 Materials

A high ammonia Natural rubber (NR) latex concentrate obtained from Lefern Laboratory (Pvt) Ltd. was used throughout this study. Corn Gluten Meal and soy powder were obtained from New Hope Lanka Ltd. in Ekala. Precipitated silica(Ultrasil VN3) was supplied from Colombo Chemical Industries(CIC). All the other chemicals were obtained from local chemical suppliers.

2.2 Methods

2.2.1 Extraction of zein from corn gluten meal(CGM)

CGM powder was sieved using an appropriate sieve to obtain a powder with a particle size less than 250 ɥm. 23g of CGM powder was mixed with a mixture of 140g of 70% (v/v) aqueous ethanol and 0.25%(w/v) NaOH aqueous solution. The mixture was stirred for 2 hours at 60 ^{0}C and then allowed to cool down to room temperature. After cooling, the mixrure was centrifuged at 5,330 rpm for 7 minutes. The remaining solids were allowed to settle and the supernatant liquid was separated and kept at -18 ^{0}C over a night to allow zein to precipitate out from alcohol. Separated wet zein was dried in a vaccum oven at 60^{0}C. A yellow color powder was collected as the zein protein.

2.2.2 Extraction of soya protein from soya bean powder

50 g of dry soya powder free from foreign matter was finely powdered and sieved to obtain a powder with a particle size less than 250 ɥm. Fine soya powder particles were then reacted with 250 ml of 0.05N NaOH solution at 30^{0}C for 15-16 minutes while stirring. A solution of 0.1N Hydrochloric acid was stirred in to the resultant mixture to reduce the pH of the mix to 8. It was then centrifuged at 5,300 rpm for 5 minutes and supernatant liquid was removed. The pH of supernatant liquid was further reduced down to 5.3 with the addition of 1N hydrochloric acid. The insolubilized protein curd which precipitated out was separated by centrifugation. Protein precipitate was dried in a vacuum oven at 50-60^{0}C.

2.2.3 Preparation of dispersions of compounding ingredients

Two aqueous dispersions(I & II) of all the vulcanising chemicals were prepared as per the formula given in Tables 2.1 and 2.2. with the aid of a pot mill. The milling time was 36 hours for dispersion 1 and that for dispersion 2 was 24 hours.

Table 2.1 Formulation used for preparation of dispersion I

Ingredient	Weight,g
Sulphur	67.6
ZDBC	24.8
Tamol	6
Water	201.6

Table 2.2 Formulations used for preparation of dispersion II

Ingredient	**Weight,g**
ZDEC	38
ZnO	38
ZMBT	12.2
Tamol	6
Water	170

2.2.4 Preparation of unmodified filler dispersion

Precipitated silica was used as a 15% aqueous dispersion and the formulation used for the preparation of unmodified silica dispersion is given in Table 2.3

Table 2.3 Formulation used for preparation of unmodified filler dispersion

Ingredient	**Weight,g**
Silica	7.5
Dispersing agent	0.5
Water	42
Total	50

2.2.5 Preparation of modified filler dispersions

Filler modification was allowed to occur during preparation of filler dispersion by mixing 5%(by weight of filler) of modifier, i.e. a protein, to the filler dispersion mixture at the commencement of milling. The formulation used for preparing zein modified and soy protein modified silica dispersions is given in Tables 2.4. In each case milling time was 10 hours.

Table 2.4 Formulations used for preparation of dispersion of filler modified with 5% protein

Ingredient	**Weight, g**
Zein or Soy protein	0.375
Silica	7.5
Dispersing agent	0.5
Water	41.625
Total	50

2.2.6 Preparation of latex compounds

The formulation used for making the latex compounds is given in Table 2.5. Addition of ingredients was done as per the order given in the formulation. Finally total solid content of each compounded latex was adjusted to 40% by adding required amount of water. Resultant latex compounds were allowed to mature for 24 hours, at room temperature.

After maturation, required amount of dispersions of either modified or unmodified filler was added at two different levels, i.e. 2.5 pphr and 5.0 pphr. separately and all the compounds were mixed thoroughly before being used for film casting.

Table 2.5 Formulations used for Latex Compounding

Ingredient	Dry Weight, g		
NR Latex (60%DRC)	100	100	100
15% KOH solution	0.8	0.8	0.8
21% Potassium laurate solution	0.7	0.7	0.7
32.8% dispersion1	2.5	2.5	2.5
35.65% dispersion 2	2.5	2.5	2.5
15% filler dispersion	0	2.5	5.0
Water	To 40% total solids		

2.2.7 Latex film casting

Latex films casting was done by pouring 40-45g of compounded latex into casting moulds made of polystyrene placed on a leveled glass plate to obtain films of thickness(dry) between 1mm – 2mm. Latex compounds in moulds were left undisturbed until they are completely dry to form latex films of uniform thickness.

2.2.8 Vulcanization of NR latex films

The dried films were leached in hot water at 80 ^{0}C for 20 minutes and then were hung on a line for 24 hours for drying. The air dried films were then vulcanized in a hot air oven at 105 ^{0}C for 20 minutes.

2.2.9 FTIR analysis

KBr pellets of extracted proteins, unmodified filler and modified filler samples were prepared separately and the Fourier transform infrared (FTIR) spectra of them were run using a ALPHA FTIR spectrophotometer to confirm the structures of proteins as well as the interactions between the polymer and silica particles.

2.2.10 Dispersion Stability test

A small portion was withdrawn from each modified and unmodified silica dispersions separately into small bottles having same dimensions and, left undisturbed to observe signs for phase separation.

2.2.11 Measurement of physical properties of vulcanised latex films

Tensile and tear properties of the NRL vulcanizates were measured using a Hounsfield H10KT tensile testing machine following relevant standard test methods for latex films (ISO 37, 2011 and ISO 34-1, 2010, respectively).

3. Results and Discussion

3.1 FTIR analysis of protein structures

Amongst the nine characteristic IR absorption bands of polypeptides in proteins, amide I and II bands are the two most prominent vibrational bands of the protein backbone. The absorption associated with the Amide I band leads to stretching vibrations of the C=O bond of the amide(1600-1690 cm^{-1}) and absorption associated with the Amide II band leads primarily to bending vibrations of the N—H bond(1480-1575 cm^{-1}).

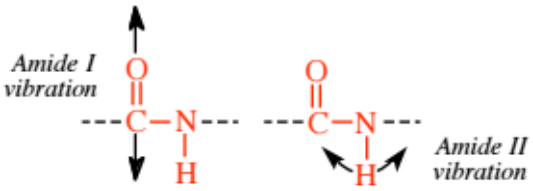


Figure 3.1 The vibrations responsible for the Amide I and Amide II bands in the infrared spectra of proteins and polypeptides.

FTIR spectra of soy protein and zein protein are given in Figs. 3.2 and 3.3. respectively.

In both spectra there is a prominent peak between 1600-1690 cm^{-1} and these peaks represent the amide I vibration. The peak between 1480 and 1575cm^{-1} represents the amide II vibration. FTIR analysis of extracted materials proves the presence of peptide bond.

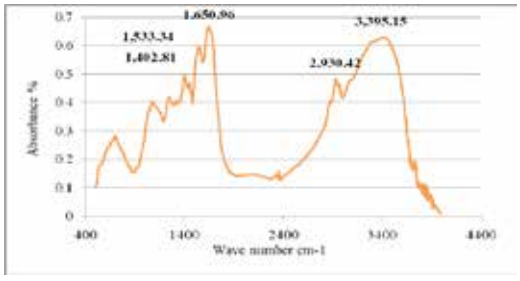


Figure 3.2 FTIR Spectrum of soy protein

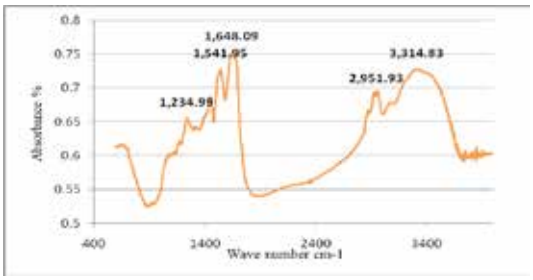


Figure 3.3 FTIR Spectrum of zein protein

3.2 FTIR analysis of unmodified and modified fillers

FTIR spectra of unmodified filler, filler modified with soy protein before and after washing to remove unreacted proteins are illustrated in Figure 3.4 and the corresponding spectra for filler modified with zein protien are illustrated in Figure 3.5.

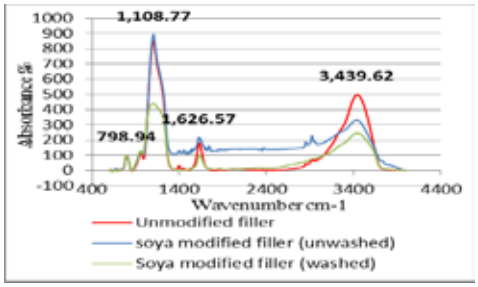


Figure 3.4 : FTIR spectra of unmodified filler, filler modified with soy protein before and after washing

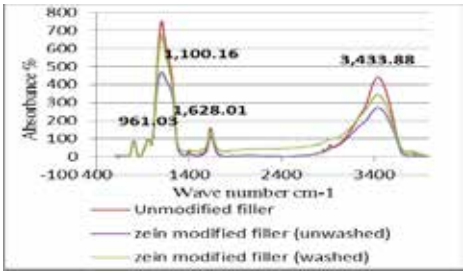


Figure 3.5 : FTIR spectra of unmodified filler, filler modified with zein protein before and after washing

Normalisation of the spectra was done with respect to the peak corresponding Si-O-Si stretching vibrations.

IR spectra of modified fillers show absorption peaks corresponding to both silica and protein peaks as shown in Figs.3.4 and 3.5. These peaks could be seen even after ethanol washing of modified fillers. The shoulder like peaks appear between 1600 cm^{-1} and 1690 cm^{-1} represent amide I vibration and peaks between 1480 cm^{-1} and 1575cm^{-1} represent amide II vibration in both cases proving the presence of peptide bonds. The broad peak which appears at around 3400 cm^{-1} due to the to the stretching vibration of hydrogen bonded hydroxyl groups (-OH) of silica and the NH stretching of protein. In modified silica the peak around 3200-3600 cm^{-1} is much broader in indicating the presence of proteins.

The minute peaks at around 1735-1750 cm^{-1} (Figure 3.6) may be an indication of the ester linkages formed between carboxyllic groups of proteins and OH groups of silica[2].

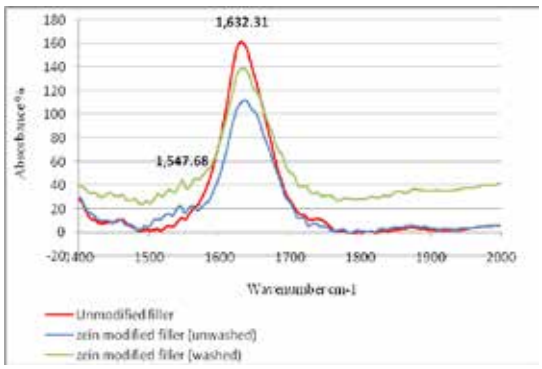
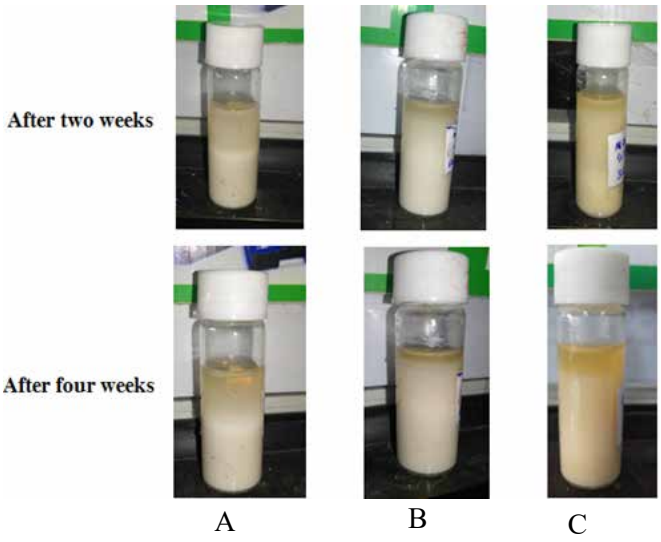


Figure 3.6: Enlarged FTIR spectrum of zein modified filler within wavelength range from 1400 to 2000 cm-1

3.3 Dispersion stability of filler dispersions

Results obtained for the tests done to evaluate colloidal stability of filler dispersions are illustrated below;



A - unmodified silica B - soya modified silica
C - zein modified silica

Figure 3.7 : Stability of filler dispersions

As evident from Figure 3.6 stability of modified filler dispersions is much better than that of unmodified filler dispersion. Phase separation observed for soya protein modified filler dispersion was much less than that observed for zein modified filler dispersion even after 4 weeks of preparation.

3.4 Physical properties of vulcanised latex films

Tensile and tear properties of vulcanised latex films containing filler at two different levels of addition ; 2.5 pphr and 5.0 pphr separately are shown from Figures 3.8 to 3.11 together with those of unfilled vulcanised latex films.

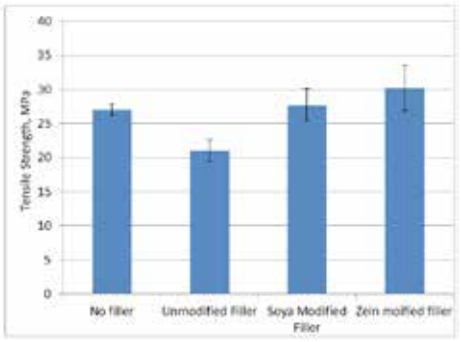


Figure 3.8 : Effects of added fillers on tensile strength of vulcanised latex films at 2.5 pphr level of addition

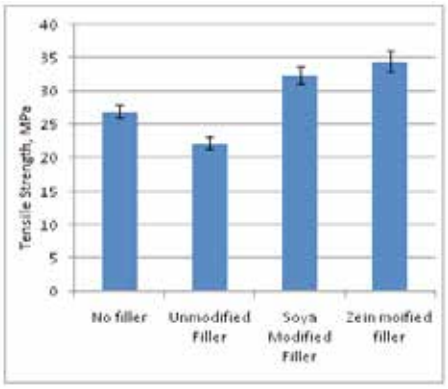


Figure 3.9 : Effects of added fillers on tensile strength of vulcanised latex films at 5.0 pphr level of addition

It is clear from Figs 3.7 and 3.8 that the modified fillers are capable of enhancing the tensile strengh of latex films and the extent of enhancement increases significabtly when level of filler increased from 2.5 to 5.0 pphr. This observartion may be consequence of the blocking of surface -OH groups of silica via hydrogen bonding with either -NH or carbonyl groups of added proteins which in turn prevents filler-filler aggregation.

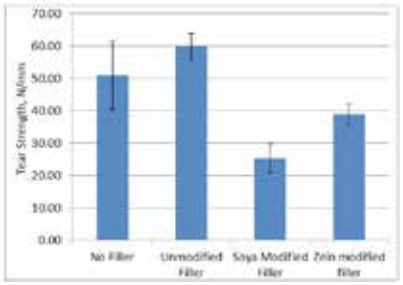


Figure 3.10 : Effects of added fillers on tear strength of vulcanised latex films at 2.5pphr level of addition

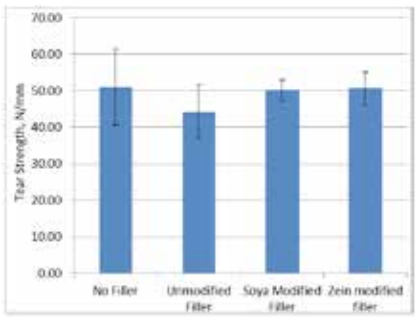


Figure 3.11 : Effects of added fillers on tear strength of vulcanised latex films at 5.0 pphr level of addition

No improvement in tear strength of filled vulcanised latex films could be observed with surface modification of silica. In fact, at the 2.5 pphr level of addition, tear strength of filled films was even lower than that of unfilled latex films. Furthermore, at this level of addition, latex films filled with unmodified filler showed highest tear strength indicating that the fine aggregates which may form in these films are capable of functioning as barriers for crack propagation. However, when the amount filler is increased, possibility for formation of much larger aggregates of unmodified filler is higher and that may disturb its uniform distribution within the rubber matrix. [3]

This explanation is complimented by the ultimate elongation results of the same films illustrated in Figures 3.12 and 3.13. The elongation at break of ummodified filler added films decreased with increasing the level of filler while that of the all the other films remained almost unchanged.

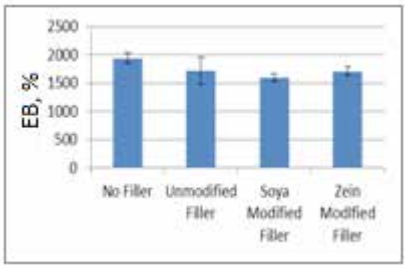


Figure 3.12 : Effects of added fillers on elongation at break of vulcanised latex films at 2.5pphr level of addition

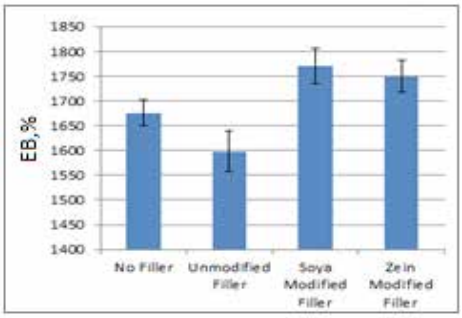


Figure 3.13 : Effects of added fillers on elongation at break of vulcanised latex films at 5.0 pphr level of addition

Furthermore, it was also observed that unmodified filler added films tend to separate into two layers with the application of tensile stress indicating the poor rubber filler interactions present in these films. Modified filler added films, at both levels of addition, remained as one layer up to the breaking point.

4. Conclusion

Proteins like soya protein and zein extracted from natural resources could be used as effective surface

modifiers for silica. Such modifications are useful in discouraging aggregation of silica filler particles which is very important in making stable aqueous dispersions of silica. Such dispersions are capable of reinforcing rubber latex films improving certain physical properties like tensile and tear strengths when they are present in appropriate levels.

Acknowledgments

The authors would like to thank the technical staff of the laboratories of Materials Science and Engineering Department of University of Moratuwa and the research staff of Rubber Technology and Development Department of Rubber Research Institute for their assistance during this work.

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What is the problem with rooftop solar systems?

Dr Tilak Siyambalapitiya

All problems have solutions; some solutions are unknown, yet to be discovered or invented. Other solutions are known, but there may be technical or commercial limitations. The debate on how far to go with rooftop solar PV, is in the second category for which solutions are known, with a flavor of the first category.

In 2008, the Ministry of Power and Energy requested for Government approval to introduce "net metering". The approval was received and implemented from 2010. A "net metered" customer may produce electricity using any form of renewable energy (solar, wind, hydro, wood, waste), use the amount of electricity he wants at that moment, and send the surplus electricity to the grid. Renewable resources of energy have many strengths, but they also have many weaknesses: seasonality and intermittency, absence of dynamically stored energy. The customer can use the grid as an energy "bank" to overcome this weakness; deposit his surplus energy and take that back when required. When cloud movement is erratic or wind flow changes by the minute, the "net metered" customer is not affected. The grid looks after his supply and keeps it stable. So the grid is a bank, an energy bank.

Grid is the Bank

This is different to a bank where funds are deposited. This is an energy bank and it has to provide the required capacity and energy, right at the instant the customer asks for it, at the flip of a switch. Therefore, the grid requires to have a strong source of generation, a source not subject to the same uncertainties of wind or solar energy, or the seasonality of hydropower.

So this brings us to the question: why should more new power plants be built? Why can't we produce all electricity from solar? This is because the bank (meaning the grid) should have adequate and strong capacity to look after "solar" customers. Otherwise the whole electricity supply system will collapse, and no one will have electricity. This means, if more solar and wind have to be used for electricity production, they have to be backed with strong sources of generation at the grid. What are these strong sources the grid can have: anything that does not have the weaknesses of wind, solar, hydro, biomass, water. That is basically electricity production that has storage: oil, coal, gas or nuclear power, where the fuel can be stored; fuel shortages can be replenished by purchasing. We cannot buy wind, because it flows freely. When there is a shortage of gas, we can buy gas or oil or coal, and bridge the gap.

Customer's own bank

A customer who has a rooftop solar electricity system, too, can have his own "strong" source, and disconnect from the grid. What are they? He can have a battery, to store his surplus energy, and use it when there is a shortage. What if there would be several consecutive days of poor sunshine, and the batteries are fully drained out? Then the customer can also keep a diesel generator, to help him to supply electricity.

Now, the customer is off-grid. He is no longer a "net metered" customer, and he has his own bank.

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The batteries and the standby generator have costs: investment, maintenance and replacement. Additionally, they need some regular care.

Many customers therefore, would like the grid to continue to be his bank, and save him from the trouble of buying batteries and a generator, and maintaining them. Especially, the smaller household customers would prefer reliable and hassle -free electricity supply. In fact, rooftop solar panels have attracted the households to fix them, because they have no moving parts, nothing to maintain or lubricate. Simply plug and use.

An estimated 20,000 households in the country now have solar panels on their rooftops. They use the strength of the grid, use it as a bank, but pay nothing to the grid. This is because they bank their surplus electricity during the day, use it in the night, and hence their electricity bill is nearly zero. However, the grid has to be maintained, and users have to pay such costs. As they are not presently required to pay but use the grid, who pays their cost contribution to the grid?

Who pays?

The cost of keeping the grid is paid for by people and companies who do not have the means to buy solar panels, or who do not have a roof (because they live in apartments), or whose roof is not strong enough to mount the panels. They pay the costs of the grid for those who are using the grid as the bank. Countries have resolved this problem by changing the electricity pricing structure, with a split between capacity costs (this is a fixed cost) and an energy cost (a variable cost). Thus, if a customer has an electricity connection, a fixed cost per month has to be paid, irrespective of whether he takes energy from the grid, puts energy back into the grid, or does both.

In the Sri Lanka context, such costs are called capacity costs. In 2017, the last time it was calculated by the regulator PUCSL, it worked out to about Rs 3225 per kilowatt of peak coincident demand per month, per customer. An urban customer uses about 1 kilowatt at peak, but a rural customer uses only about a quarter of that. So, simply put, an urban customer has to pay Rs 3225 per month, and a rural customer has to pay Rs 800 per month, and thereafter, the rest of the bill can be zero, if his solar panels produce all the electricity he needs. For commercial buildings with solar panels, the fixed cost will be somewhat lower, because they use electricity only during the day.

Banked during the day and used in the night.

The second problem

A fundamental requirement of an electricity system is to be in dynamic equilibrium. This requires a certain amount of stored energy available in the grid, to be immediately converted to electricity. I am not referring to the fuel in tanks or coal in the stockpile. The extra power should be available instantly, as soon as a cloud covers the solar panels. There is no time to wait, even for one second.

Advanced power systems have 8 to 10 seconds of stored energy. This means, if there is a sudden shortage of electricity production, either on customer's solar panels or the electricity supplier's power plants, this "stored" energy will immediately be converted to electricity to keep the supply stable, until more fuel can be supplied to power plants, to raise their outputs.

When doing this, the supplier's generators will slow down, and release their stored energy as electricity. They will be restored to their normal speed within a few minutes, once more fuel is brought into the system. The initial few seconds is critical; if the supply is not assisted with more "instant" electricity production, the entire grid risks a collapse.

Then we call it a national blackout.

Generators with large dynamic storage required to provide that stored energy are nuclear, coal, gas or oil-burning rotating generators. They rotate at speeds up to 3000 revolutions per minute, and work as the "flywheels" of the grid. Any shortage or surplus of electricity production will be instantly corrected, preventing the grid drifting toward a blackout situation. This happens many times a day, and such events are not even reported, because that's how a grid is designed to operate.

Operate to keep the electricity supply reliable, cherished by customers.

The above would be useful to those in society to understand how a grid operates and the role of renewable energy on it. I have not elaborated the benefits of renewable energy, which are well known.

Profile of Courage: Manjula Rajapaksa

Narrative by P.P.Perera
Hon. Secretary PRISL

Here is the story of a person, who sold home-grown vegetables and ran a small tea shop to support his family in his school days, later reaching the pinnacle of entrepreneurial success and making his mark in Sri Lanka's flourishing plastics industry.

I could not think of a better title for this article than the above, which I coined burrowing through the pages of ***Profiles in Courage.*** It's a 1957 volume of short biographies describing acts of bravery and integrity by eight United States Senators, authored by then Senator John F. Kennedy, who won the Pulitzer Prize for the work.

There are many outstanding personalities in Sri Lanka who have served as game changers in the rubber and plastics industry in the country and reached the pinnacle of success.

As William Shakespeare said: "Some are born great, some achieve greatness, and some have greatness thrust upon them." The same is true of professional success as well**.** While some are born with the proverbial silver spoon, some have success thrust upon them by sheer luck and a third category of people achieve success through hard work, persistence and perseverance, going through all the blood, sweat, tears and heartache involved in climbing up the ladder.

It's no exaggeration to say that Manjula Rajapaksa belong to the third category of people who trod the road to self-made success with rare distinction.

Manjula's career in the polymer industry, spanning a quarter century, is a narrative of hard work and determination. Over the past 59 years, Plastics and Rubber Institute of Sri Lanka (PRI) has been instrumental in grooming several key personalities, who have since made immense contributions to the national economy. This year, the Institute is proud to honour Manjula Rajapaksa, one of its illustrious working products.

Humble beginning

Born in 1974 at Dunuwela, a remote hamlet in Ruwanwella area, Manjula had a humble beginning in life. His father was an employee at the Cooperative (Samupakara), while his mother was a housewife attending to family chores. His father died in the very same year in which Manjula was admitted to a village primary school in 1980.

Thereafter the responsibility of bringing up the children fell on the fragile shoulders of his mother, who struggled to eke out a living by selling "kadayappam" and doing a little bit of farming. This had an indelible impression on Manjula, who was the eldest of his parents' four children.

Manjula passed the 5th Std Scholarship in 1985 and got admitted to Tholangamuwa Central in 1985. His life in the school hostel provided him with an opportunity to learn the rudiments of self-management, with the little scholarship money he used to get. In order to assist his family, he used to do trivial jobs such as selling home-grown vegetables to the lorry going to the Negambo Fair during weekends, and this way he was able to fulfill some of the requirements of his family .

Manjula successfully completed the GCE OL with Credits in all subjects and in 1993 he completed ALs in Agricultural Science. His leadership qualities came to the fore even during his school days when he served as the Class Leader and the Head Prefect of the Science Section and was also a member of the Buddhist Society. He also ventured into running a small tea kiosk after doing his ALs.

Dawn of a booming career

Call it fate or coincidence, Manjula's career started in 1994 as an Assistant Production Supervisor at the Lalan Rubber Glove Factory at Danowita, Warakapola, where Mr Jayawardana, the Factory Manager, was an alumnus of his school. We sometimes need the helping hand of an associate or friend to make a head-start in life and Manjula was fortunate to have such a grooming from Mr Jayawardana.

During his tenure at Lalan, Manjula had the opportunity to work with Dr Gamini Seneviratne, the then Director of the Rubber Research Institute of Sri Lanka (RRISL), in the installation of the company's Effluent Treatment Plant.

Manjula was also greatly inspired by Mr Lalith Hapangama from whom he learnt many valuable lessons in entrepreneurship. This motivated him to start a small rubber wood treatment unit to provide brush handles to Harris Brushes.

His baptism in the plastics industry occurred in 1998 when he got involved in the setting up of the Lalan Polythene Factory at Warana. He considers this as a rare opportunity to get deeper insight into the problems and challenges in the plastics industry.

His association with the PRI dates back to the year 2000 when he did a Certificate Course in Plastics Technology. He reverentially remembers the guidance given to him by Mr Dheerasekara in polytrhene extrusion which later became his forte. In 2004, he did a one-year Diploma Course in Ingrin Institute in order to sharpen his knowledge and skills.

Evolution of an entrepreneur

Manjula's foray into the challenging and exciting world of entrepreneurship started in the year 2007 when he purchased some old equipment and started a small poly bag factory in an abandoned rice mill at Yattogoda in Kegalle with only two people. He started supplying to the SMEs and in the process learnt the crucial importance of customer relationships. He won the IDB Entrepreneur Award for 2008/2009 in Sabaragamuwa Province. By then he had 15 employees.

Manjula hit another milestone in his entrepreneurial career in 2012 when he set up Clean Packaging (Pvt) Ltd, as a state-of-the-art triple laminate factory, at Galigamuwa Industrial Zone. Its current client base includes John Keells, Raigam, Bahira etc.

The ensuing years saw the gradual expansion of the factories. His Yattogaoda factory now has on its roll 40 employees, while the Galigamuwa factory has a workforce of 160. He still retains 10 of the employees who were with him from his humble beginnings.

He also established an environment-friendly custom-designed furniture company called No Wood in 2015. He always used to stress the importance of maintaining good relationships with the banking sector which was one of the secrets of his business success.

His business enterprises won many accolades for outstanding performance, which include the Shrma Abhimana Sammanya in 2012, Best Entrepreneur at Deyata Kirula 2015, and the Best Entrepreneur Award of the Ceylon Chamber of Commerce in 2017. Clean Packaging is among the first 10 companies of its kind in Sri Lanka.

Manjula got married in 2002 and his wife is a teacher. They have two children who are studying in Kegalle.

Pursuit of perfection

In keeping with the dictum that it's never too late to learn, Manjula is committed to enhancing and expanding his professional knowledge despite his official preoccupations, and is currently following a HND in Industrial Management at the University of Colombo. He has plans to do his post graduation and also an MBA.

He currently serves in the Council of Management of the PRI and is an active member of its Exhibitions and Events Committee. He is a member of the Lions Club of Galigamuwa and is actively participating in Buddhist activities.

Manjula envisages diversification into innovative and environment-friendly technologies while improving the social and economical development of the employees. He is pursuing this goal with a missionary zeal.


CAMSO
ROAD FREE COMPANY

An Introduction to Reach Regulations

W A D C Rodrigo
Manager – Laboratory, Dipped Products PLC

The Reach Regulation (EC) 1907/2006

Chemicals are indispensable in our society. They play an important role in the economy. There are international rules to assess, control and reduce the risks of chemicals. On June 1, 2007, the 'new' European Chemicals Regulation (EC) 1907/2006 commonly referred to by the acronym 'REACH' came into force. The REACH Regulation aims to improve the protection of human health and the environment through the better and earlier identification of the intrinsic properties of chemical substances. This is done by the four core processes of REACH, namely the Registration, Evaluation, Authorization and Restriction of Chemicals.

It is important to understand how the European REACH legislation on chemicals can affect companies throughout the supply chain.

The regulation fundamentally changed the way that chemicals were regulated in the region

With the launch of REACH, this principle was significantly changed, effectively meaning that chemical manufacturers and importers had to demonstrate to the regulators that the substances they supplied did not pose unacceptable risks to human health or the environment.

It is important for each organization to identify its role within the REACH process in order to determine what actions it would need to take. There are four major categories, and it is possible for any organization to be more than one. Some larger organizations may have responsibilities under all four:

- Chemical manufacturer or importer: Any company manufacturing chemicals in Europe (which are prepared from raw ingredients – whether mineral or organic), or importing chemicals into Europe, will need to register each chemical it manufactures or imports. For the purposes of REACH, an importer of a chemical has the same obligations as that of a manufacturer.

- Supplier of preparations: A 'preparation' is a mixture of chemicals. In the case of a preparation, each individual chemical present should be registered separately. Examples of preparations could include waterproofing sprays, cleaners and leather polishes. Any substance that is supplied in quantities of one tonne per annum or greater by a single company will require registration, if present as an individual chemical or as part of a preparation.

- Downstream users: Chemicals and preparations can be used to make products. During this process, the workers in factories that use these are referred to as 'downstream users'. REACH requires detailed information on the exposure of downstream users to be available as part of the registration process. Therefore, chemical suppliers need to understand how their products are being used by their industrial customers, in order for them to supply relevant and accurate information.

- Suppliers of articles: This category is for the companies that are producing physical products or materials in the EU, or importing them into the EU. It includes footwear and other consumer goods, as well as tanned leathers, finished textile clothes and components. There is no need to register, but there are two distinct sets of requirements that apply to substances in articles.

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Positions:	President – Sri Lanka Association for Testing Laboratories (SLATL)
	A member of Technical Advisory Committee in the field of Mechanical Testing for the Sri Lanka Accreditation Board (SLAB)

In REACH, these are covered by Annex XVII (mandatory restrictions) and the Candidate List of Substances of Very High Concern (SVHCs).

If anyone needs to identify whether any of the SVHCs (Substances of very high concern, as defined under REACH), are contained in an article or in a chemical mixture, following procedure can be adopted:

Compliance can be demonstrated through a programme of check testing, or by a comprehensive audit of the raw materials and production processes used.

STEP 1

Theoretical assessment, based on information from your supplier:

Does the supplier communicate the presence or not of any SVHC in the product?

If not: Is there any probability that SVHC are present in the product taking into account:

The materials used;

The manufacturing procedures applied;

The suppliers involved.

If the presence of candidate substances is confirmed or has to be suspected:

Will the threshold of 0,1 mass% of each SVHC be exceeded?

Is there a ban or any other restriction of that SVHC in chemical mixtures or for manufacturing process?

In addition, Chemical Assessment to identify potential risk materials due to the likely presence of restricted/hazardous substances in each of the materials listed in your product's bill of materials

STEP 2

If information from step 1 results in an unclear situation, testing may be needed.

This can be the case if no information is available, e.g. if the supplier does not reply, or if there are doubts on reliability of existing information.

A test is performed for identification and quantification of any SVHC in the article or in the chemical mixture. The test program will be different per material (e.g. plastic, glass, wood, metal, etc.), based on general knowledge on which SVHC could be part of which basic material. Similar materials can be grouped together and considered as one testing sample.

This test can deliver the information of whether the threshold of 0.1 % per SVHC in the article is respected, which can help you to identify if you have to fulfill certain legal obligation (communication or notification) according to REACH.

In both case, it is essential to have a clear understanding of the product and good communication and cooperation throughout the supply chain. This is because not all of the 69 entries are applicable to all product types. Some entries are specific to certain types of material, due to the chemical reactions involved in the production process, while others will only be present if certain treatments have been applied. It is therefore crucial to have an understanding of how various materials are used in the construction of a product in order to develop a targeted approach to check testing, or to organize a thorough and efficient audit.

Manufacturers and importers of substances and chemical mixtures have to register all chemicals at the European Chemical Agency (ECHA) if produced or imported in the EU in an amount of >1 tonne per year.

How Reach Annex XVII Applies to the Manufacture of Consumer Products

The main entries in Annex XVII for textiles, leathers and polymers are brief in table 1.

Table 1: Key restricted substances relevant to consumer goods

Material	Applicable restricted substances	Annex XVII entry number	Maximum permitted limit
Textiles	Aromatic amines (azo dyes)	43	30mg/kg
	Organotin compounds	20	1,000mg/kg
	Perfluorooctanoic acid (PFOA) – only applicable if a repellency treatment has been applied	68	25µg/kg
	Formaldehyde	72	75mg/kg
	Nonylphenol ethoxylates	46	100mg/kg
Leather	Aromatic amines (azo dyes)	43	30mg/kg
	Organotin compounds	20	1,000mg/kg
	Perfluorooctanoic acid (PFOA) – only applicable if a repellency treatment has been applied	68	25µg/kg
	Dimethyl fumarate	61	0.1mg/kg
	Pentachlorophenol	22	1,000mg/kg
	Chromium VI	47	3mg/kg
Polymers	Organotin compounds	20	1,000mg/kg
	Cadmium	23	100mg/kg
	PAHs	50	100mg/kg

Restricted Substances in Plastics and Polymers

Polymeric materials such as plastics and rubbers have very different compositions. Therefore different chemicals types are used in the manufacturing process of polymers. The difference is the use of pigments rather than dyes to add colour to polymeric materials. This means that testing for aromatic amines derived from azo dyes is not applicable. The pigments used may contain other restricted chemicals, such as the metallic element cadmium. This is commonly used in certain pigments, and can also be used as a stabilizer in the formulation. Cadmium is toxic to humans and is classified as a carcinogen. Like Pentachlorophenol, it is also a bio accumulator, and so presents environmental concerns. Because of these factors, it is restricted to less than 100mg/kg in plastics and synthetic rubbers.

Another family of restricted substances which may be present in polymeric materials are polycyclic aromatic hydrocarbons (PAHs). These substances are naturally in coal, crude oil and petrol, and they can also be formed during the incomplete combustion of fossil fuels. Therefore they could be present as impurities in carbon black pigment or extender oils. They would not be intentionally introduced during manufacturing, but arise as contaminants. As a result, chemical testing is recommended to show compliance. PAHs are suspected of causing cancer through long-term exposure, and they are restricted in materials which come into long term contact with the skin, as well as in materials which have repeated, short-term skin contact. There are eight PAHs listed in REACH Annex XVII, all of which are restricted to less than 1mg/kg.

The majority of the substances listed in REACH Annex XVII are incorporated into products as a result of contamination, or from chemical reactions occurring during or after the production process. A select few of the chemicals listed may be, however, purposely added to the product in order to confer desirable characteristics. Examples include the use of dimethyl fumarate (DMFu) as a biocide to prevent mould growth during transportation and the application of perfluorooctanoic acid (PFOA) as a water or stain repellency treatment. In 2009, DMFu was considered to be the cause of a series of very severe allergic skin reactions in upholstered leather furniture, and an immediate ban on the substance was implemented. Following evaluation, DMFu was added to REACH Annex XVII in 2012, with a maximum permitted limit of 0.1mg/kg. PFOA is one of the more recent additions to Annex XVII. This chemical is a carcinogen, and is also highly persistent in the environment and within the human body. As a result, it will be restricted to a maximum of 25µg/kg in final products from July 2020.

Another prominent example is the use of flame retardants to improve flammability performance. The use of these chemicals is often needed to safeguard consumers against the risks of flammable materials in products such as domestic furniture or protective garments for firefighters. However, studies have shown that certain brominated flame retardants have toxic properties and can build up in fatty tissues within the human body. For this reason, two of these flame retardants, octabromodiphenyl ether and decabromodiphenyl ether, are restricted to a maximum of 1,000mg/kg in final products.

Because chemicals present in treatments will only be present in products if they have been deliberately introduced, they do not need to be considered if the supplier can confirm they have not been used. This is a good example of a case where cooperation across the supply chain can help to inform the strategy for demonstrating compliance.

REACH Annex XVII is continuously developing and additional substances are regularly added to the list as 'substances of very high concern' (SVHCs) are evaluated and other potentially hazardous chemicals are identified. A significant update to Annex XVII was the addition of entry 72, which was published in October 2018, and will come into force in November 2020. This imposes restrictions on a number of chemicals that are carcinogenic, mutagenic or toxic for reproduction in clothing, footwear and textiles which come into contact with the user's skin.

One of the most significant additions to Annex XVII included within entry 72 is formaldehyde, as this will be the first European-wide restriction imposed on this substance in articles. Formaldehyde may be used in the textile industry to improve the resistance to creasing, and can also be used as a preservative – particularly for natural textiles. Nevertheless, at high concentrations, formaldehyde is capable of causing severe skin burns or damage to the eyes. Even at low concentrations, formaldehyde presents a risk to human health, as it is a prevalent allergen and some individuals are allergy even at very low concentrations. The maximum permitted amount of formaldehyde in textiles will be 75mg/kg as per the entry number 72.

The purpose of REACH Annex XVII is to protect consumer health and the environment by placing restrictions upon harmful chemicals in consumer products. Manufacturers, importers and distributors have a legal obligation to meet the requirements specified in Annex XVII, and retailers also have a responsibility to make sure that they only place compliant products on the market.

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1. htpps://echa.europa.eu
2. Satra Spotlight Articles

Testing of Raw materials, Compounds and finished Products in Solid Tire Manufacturing Process.

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To assess the quality and to maintain uniformity in quality of the products regular testing of the raw material, compounds and vulcanized are needed. The manufacturer has to assure himself that the product that he has made, meets the limits imposed by the specifications and customer requirement. In order to meet this specifications, it is essential to establish document implement and maintain a quality management system such as ISO 9001.

Solid tire manufacturers in Sri Lanka, ensuring their product is high-quality and functioning to its fullest potential is extremely important to maintain their market share in the world market. Quality has a lot of weightage, especially in products that play a critical role in high end applications, like tires.

From raw material testing to testing the finished product tests are crucial for manufacturers. Hence Testing in solid tire industry can be divided in to three categories, namely

- Raw material testing,
- In processes material testing and
- Finished product testing.

Raw materials such as Rubber (Natural and Synthetic) ,recycled rubber, carbon black, mineral fillers, various types processing aids, antioxidants, antiozonants, waxes, vulcanizing agents and accelerators are used to make compounds. Such raw materials are analyzed by using physical and chemical methods.

Determination of the melting point, moisture content, dry mass volume, ash content, volatile maters in dry materials and determination of viscosity, effective substance volume, refractive index, acid value and heavy metals in liquids are the main parameters tested for liquids. These test can be performed as raw material quality control tests in Solid tire industries.

The quality of the finished products depends not only on the quality of the starting materials but also on the correct operation of the various processing steps. Processing errors committed during the manufacture can seriously affect the properties of the final product. For example, too much milling of the rubber in the mixing mill or in the internal mixer can give a product of low strength.

Testing of rubber compounds and vulcanizates during processing are done to control of quality of semi products and component during manufacturing. These testing gives an idea about process ability, indication of quality of final product and serviceability of products. More attention has to be given on this area in the manufacturing process.

Under testing of rubber compounds, testing of reheological properties of the compounds, testing of vulcanizates and Dynamic Mechanical thermal

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analysis of vulcanizates can be done.

Testing of final products are done in Final inspection area under defined test procedures. Static measurements as well as Dynamic measurements can be taken. Specially performed ultrasonic test to find out porosity in solid Tyres layers which leads to service failure.

A test method is a method for a tests in manufacturing industry, such as a physical test, chemical test and specialized testing. Physical content of raw materials are directly give an idea of purity of the used raw materials while Chemical tests give an idea of vulcanizates. Complex testing methods and instruments are being used to chemical analysis. Specialized testing can be performed to measure and identify defects in finished products.

In order to ensure accurate and relevant test results, a test method should be "explicit and experimentally feasible." as well as effective and reproducible.

A test can be considered an observation or experiment that determines one or more characteristics of a given sample, product, process, or service. The purpose of testing involves a prior determination of expected observation and a comparison of that expectation to what one actually observes. The results of testing can be qualitative (yes/no), quantitative (a measured value), or categorical and can be derived from personal observation or the output of a precision measuring instrument.

Using a standardized test method, perhaps published by a respected standards organization, is a good place to start. Sometimes it is more useful to modify an existing test method or to develop a new one, though such home-grown test methods should be validated and, in certain cases, demonstrate technical equivalency to primary, standardized methods.

However, even more important is choosing a method of measuring the correct property or characteristic.

- Test results of a raw material should connect with tests of a component made from that material. Evaluation of the physical properties of rubber materials can be used to predict the durability and performance for use in a multitude of final product applications.
- test results of a component should connect with performance testing of a complete item
- results of laboratory performance testing should connect with field performance

Raw Material Testing

Standard test methods are used to evaluate quality of Raw materials

Melting Point: (ASTM D 1519)

The melting point can be used to identify a substance and as an indication of its purity. At the melting point the solid and liquid phase exist in equilibrium. Impure solids melt at lower temperatures and may also melt over a wider temperature range, known as melting point depression. The melting point range for pure solids is narrow, usually only 1 to 2 °C, and known as a sharp melting point. Impurities cause structural defects that make the intermolecular interactions between the molecules easier to overcome. Melting point is determined at Accelerators, antioxidants and others.

Softening or Dropping Point: (ASTM D 36/D36 M-14e1)

Softening point is the temperature at which a substance begins to flow under given test conditions.

In particular for polymers, raw polymers, waxes, polyolefins, paraffins, lubricant greases, organic powders, petroleum resin and oils and related substances, the dropping point is used for characterization and quality control.

Volatile matters: (ASTM D 3175-18)

Volatile matter is an unstable material or compounds that are released from a sample. Most of the cases it is water or volatile organic compounds. The weight loss is equivalent to the volatile matter content. Volatile matter is determined at Carbon black, silica, accelerators, antioxidants etc.

Ash Content test: (ASTM D 4574)

An Ash content test is used to determine if a material is filled. The test will identify the total filler content. It cannot identify individual percentages in multi-filled materials without additional test procedures being performed. This is defined for Carbon black, organic chemicals, fillers and rubber additives. The ash content of petroleum products is generally low.

Viscosity: (ASTM D 5478-13)

The viscosity of a fluid is a measure of its resistance to deformation at a given rate. By increasing the temperature the viscosity of a fluid decreases due to increase in molecular motion. Pressure doesn't have very much effect but slightly effect when high pressure is applied.

Ford cup and Brookfield viscometer can be used.

Acid No: (ASTM D 664-18e2)

Also it is define as the mass of Potassium hydroxide (KOH) in milligrams that is required to neutralize one gram of chemical substance. Acid value is called as neutralization no or acid no or acidity

The acidity of oil is due to hydrolysis or oxidation of oil by atmospheric moisture leading to the formation of fatty acids. Lubricants oil with acid values greater than 0.1 corrode metals, form gum and sludge during operation.

Saponification value: (ASTM D 5558-95)

This value represents the number of milligrams of potassium hydroxide required to saponify 1g of fat under the conditions specified. It is a measure of the average molecular weight (or chain length) of all the fatty acids present.

Iodine Value: (ASTM D 5554-15)

Iodine numbers are often used to determine the amount of unsaturation in fatty acids. This unsaturation is in the form of double bonds, which react with iodine compounds. The higher the iodine number, the more C=C bonds are present in the fat.

Testing For Carbon Black

Carbon Black used as filler in compounds in order to optimize mechanical properties in the compounds. Rubber/Polymer and carbon interaction is very important and it depends on three factors.

Intensive factor (surface activity)

Geometric factor (structure of carbon black)

Extensive factor (surface area of carbon black).

Testing for carbon black is typically performed during formula investigations and reconstructions or as a quality control. Determination of pH of carbon black ,determination of volatile substance ,ash content, Sieve residue analysis, oil absorption number, iodine adsorption number ,tint strength, pallets hardness pour density ,Powder density and surface area can be conducted for carbon black. Therefore performing above tests very much help full to control quality of semi products and final products.

The following standards are used in testing of Carbon black.

Pelleted Fines and Attrition ASTM D1508

Iodine Adsorption Number ASTM D1510

Sieve Residue ASTM D1514

Oil Absorption Number (OAN) ASTM D2414

Total and External Surface Area by Nitrogen Adsorption ASTM D6556

Plasticity Retention Index: (ASTM D3194-17)

Plasticity Retention Index (PRI) is used to analysis of heavy metals in rubbers. At the increase of temperature heavy metals dropping down molecular weight of polymer and its effect to physical mechanical properties. PRI is low when sample is having low amount of heavy metals.

Thermo Gravimetric Analysis: (ASTM e1131 ,ISO11358)

This is a method of monitoring of sample volume changes in depending on its temperature Composition of the rubber compound and vulcanizes can be analyzed. Percentage volatile materials, rubber , carbon black and ash in the sample can also be determined. Ashes can be from polymer, minerals such as Clay, CaCo3, ZnO or filler.

Incoming Testing of Reclaim rubber, crump rubber and Devlucanised rubber can be performed by using this test method.

Testing of Semi products and vulcanizes in solid tire manufacturing process.

Test results of Raw materials connect with compounds/ components made from it. Errors can be occurred at chemical weighing, mixing and operations (temperatures) as lot of people involved and raw material pass lot steps in between Raw material to mixing.

Testing of Rubber Compounds

Mooney Viscosity*: *(ASTM D 1646 / DIN 53 523/ ISO 289)

Determination of Mooney viscosity is the widely use method in process. It is based on torque measurement of shearing disc and the temperatures of the chamber. Small as well as large rotors are available. Viscosity gives an idea of mechanical processing ability.

Rheometer Test: (ASTM D 6204-19)

Rheometer is mainly used to determine vulcanization

behavior of rubber compounds. In other words, the rehometer test allow us to determine cure characteristics of rubber compounds. The cure or vulcanization curve is called the rheograph. From the graph, rubber compound characteristics such as TS2 (Scorch time), TC90 (optimum cure), M0 (Initial torque), ML (minimum torque) and MH (maximum torque) can be obtained.

Testing Of Rubber Vulcanized

Physical testing of the rubber vulcanized is required to find out the short falls in processing methods, to control and maintain the quality of the products. Even though it is true that the basic polymer properties have a g profound influence on the actual service life of a product, it also depends on processes involved in the fabrication of the product. In certain products like tires, the design of the product also equally affects the final performance. The important basic tests done on vulcanized are the Stress train tests, ageing tests, hardness tests, specific gravity test, tear test, resilience test, etc. The tests which are related to the performance tests are abrasion tests, flexing tests, compression tests etc.

Tensile Test*: *(ASTM D 412)

Tensile strength is defined as the force per unit area of original cross section of the sample, required to stretch the rubber test piece to its breaking point. Modulus is the tensile stress required to stretch a rubber test piece to a predetermined elongation. Elongation at break is the maximum elongation, expressed as the percentage of the original length, prior to the rupture of the sample.

The tensile test results can be used to evaluate the strength of the vulcanized and the degree of cure of the vulcanized. This gives an idea of mixing quality of rubber mixes.

Tear Test: (ASTM D 624)

Tear strength is defined as the force per unit thickness required to cause a nick out in a rubber when it is stretched, under constant rate, in a direction substantially perpendicular to the plane. Tear tests give an indication of the behavior of the vulcanized in tear initiation and tear propagation. The tear test can be performed using the tensile testing machine.

Hardness Test*: *(ASTM D 2240-15e1)

Hardness test involves the measurement of the depth of penetration of an indenter of specified dimensions under the application of a load either by a dead weight or by a spring. The indentation hardness is a measure of the elastic modulus of the material under conditions of small strain. Hardness is an important property to the compounded since its specification imposes limits upon the type and quantity of certain compounding ingredients like fillers, plasticizers and also gives an idea of curative dispersion etc. in a particular compound.

This test can be used as a quality control test in the production process, here rubber compound sample can be vulcanized at elevated temperature within short period of time and measure hardness before product move one to another work station. A Portion of Same sample can be used to measure density/Specific gravity of the particular compound.

Specific Gravity Test: (ASTM D 792)

Specific gravity is the ratio of the density of a substance to density of reference substance. (Specific gravity is the ratio of the weight of a volume an equal volume of the reference substance.

Rebound Resilience Test: (ASTM D 7121-05)

Rebound resilient refers to compound ability to regain its original size and shape after temporary deformation. Rebound resilient defined as the ratio of energy given up in recovery to the energy required to produce the deformation. It gives an idea of heat buildup.

Accelerate Ageing Tests: (ASTM D572 -04 /ASTM D573-04)

The natural deterioration of the Vulcanized under the action of heat, UV light, oxygen, ozone etc. is termed as 'ageing'. Accelerated ageing tests magnify the influence of one or more of the above agents which affect the service life of the products. The fall in properties from the initial value or the change in appearance gives an indication of the resistance of the rubber vulcanized to that particular factor.

Compression Set*: *(ASTM D395-18)

Compression set in rubber may be defined as the amount (percent) by which a standard test piece fails to return to its original thickness after being subjected to a standard compressive load or for a specified period of time. Compounds specially use as inner heel and heel need to be tested. The set value should be very low. Usually high loading of reinforcing fillers and under curing of the compound give high set values.

Abrasion Test*: *(ASTM D 5963)

Abrasion resistance defined as the resistance of the rubber vulcanized to wearing away by rubbing or impact during service. The loss due to this rubbing is then

calculated and expressed as loss in weight. Abrasion test gives an indication of the resistance of the compounds to abrasive wearing on tread compounds.

Dynamic Tests

Tyres are dynamically loaded during service and material detrition occurs under dynamic condition. Due to this reason, dynamic properties of side wall and middle compounds to be evaluated. Flex resistance test can be performed to evaluate dynamic properties.

Flex Resistance: (ASTM D 4482-11)

Products like tires, are subjected to repeat flexing during service. This repeated flexing may gradually lead to failure of the product. This is because, repeated flexing of a rubber vulcanized causes cracks to develop in that part of the surface where tension stress is set up during flexing or if that part contains a crack or cut. Causes the crack to extend in the direction perpendicular to the stress. This test is used for evaluation of tire tread and side wall compounds.

Resistance to flex cracking is composed of two parts

(1) Resistance to crack initiation and

(2) Resistance to crack growth.

Peeling Test (Compound to compound and compound to metal): (ASTM D 429)

Tire is a composite material which is composed from different compounds and materials. Life of the tire depend on their mutual adhesiveness is between layers as well as self-adhesion and it can be evaluated by performing adhesion test for compounds and compound to metal.

Dynamical Mechanical Thermal Analysis: (ASTM D4065, D4440,D5279)

Dynamical Mechanical Thermal Analysis (DMTA) Test is also used to analyze Dynamic properties of rubber vulcanizates. DMTA is the application of the oscillation fore on sample and analysis of the material response.

Testing Of Finished Products.

Basically two type of finished products types available namely resilient and press on tyres. Outer surfaces of tires undergo a visual attribute inspection to ensure the surfaces of the rubber parts are acceptable. Inspectors review the parts for surface defects like knit lines, cuts, de molding damages, Short molds, flash open and foreign material etc.

After the finished rubber products are tested for visual defects, tires are tested for dimensions and weight... Part qualification/Defective tires are crucial for manufacturers and should be taken very seriously to ensure each product is of the highest quality and is free of defects. Implementing a qualification system into your facility will reduce the risk of customers receiving low-quality products that don't meet their standards.

Hardness test perform for all tire categories while ultra-sonic test is done for resilient tires but can be extent to Press on tire inspection too. Test like Caliper test, and bad bond tests are performed for Press on tires. In the case of assembles, rim /wheel dimensions are very critical and procedures to developed to inspect.

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Competency of Sri Lankan natural rubber for electrolytes in energy storage devices

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Abstract

Natural rubber which is obtained from latex of rubber tree is widely known as an insulator and an elastomer. But, now it has been found out that it is a viable substitute for commercial polymers and as such, it can be employed for preparation of electrolytes. This paper is about an investigation carried out to prepare an electrolyte with Sri Lankan natural rubber (NR) and the salt, ammonium trifluoromethanesulfionate ($NH_4(CF_3SO_3)$). The electrolyte showed an ionic conductivity of 3.8 x 10^{-4} S cm^{-1} at room temperature which is of utmost importance to be considered for applications. A super capacitor was fabricated using two conducting polymer electrodes. A single electrode specific capacitance value of 20.13 F g^{-1} was obtained upon analyzing the impedance data. At low frequencies, capacitive features were dominant well matching with theoretical explanations. The results are very encouraging and can be used to make the way for a conceptual revolution for natural rubber in the arena of power and energy challenging the traditional views.

Key words : natural rubber, conductivity, electrolytes, super capacitors, single electrode specific capacitance

1. Introduction

Much of the world's natural rubber (NR) is made from the latex found in the sap of the tree 'rubber' (Hevea Brasiliensis) even though there are a lot of trees that has the latex. It is inherently a polymer consisting with the monomer, isoprene as the building block [1]. Due to the polymeric nature, NR is known as an insulator as well as an elastomer. NR is being used for a diverse range of products covering vehicle tyres, erasers, water proof clothes and shoes etc.

Thailand, Indonesia, India, Malaysia and Sri Lanka are considered as some of the giant NR producers in the globe. But unfortunately, NR production in Sri Lanka has gone down at an alarming rate due to the fluctuations of price which seriously affects the lifestyle of so many people. Since the introduction of this crop to the country in British colonial era, rubber cultivation has been done in small, medium and large scales. Not only the export process but also the other manufacturing industries have been severely hit by the lowering of production. Under this scenario, attempts should be launched to add value to Sri Lankan NR in many other ways.

In the recent past, NR has been identified as a viable substitute for commercial polymers use for preparing electrolytes. With that, research groups in many countries have focused their attention on this line [2,3]. However, being an insulator, NR should be modified to serve as an electrolyte. Basically, two methodologies are in practice namely methyl grafting and epoxidization [4]. The latter results in slightly sticky samples and hence, methyl grafting has been the promising and accepted method of modification in the field of electrolytes. Different amounts of methyl groups are grafted to the polyisoprene backbone to obtain methyl grafted (MG)

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NR. Almost all the research groups which are engaging in investigating NR for electrolytes have employed NR from India and Malaysia. Sri Lankan NR rubber has not yet been considered by none. We have commenced investigations on using Sri Lankan NR for preparing electrolytes to be used for electrochemical devices such as batteries and super capacitors [5,6].

This paper reports about an investigation carried out on an electrolyte with NR and ammonium trifluoromethanesulfionate ($NH_4(CF_3SO_3)$) and its application in a super capacitor.

2. Experimental

NR samples were obtained from Associated Speciality Rubbers (PVT) Ltd, Undugoda, Kegalle, Sri Lanka. Required amount of NR sample was weighed and minced into tiny pieces. Tetrrahydrofuran (Aldrich) was added and left overnight for dissolving NR. Stirring was done using a magnetic stirrer. Ammonium trifluoromethanesulfionate ($NH_4(CF_3SO_3)$), (Aldrich) was mixed with the NR solution and magnetic stirring was continued further allowing NR and the salt to be mixed well. The homogeneous resultant solution was poured in to a glass petry dish and allowed solvent evaporation under normal atmospheric conditions. A circular shaped sample was cut from the electrolyte film and loaded in between two stainless steel (SS) electrodes in a brass sample holder. Impedance measurements were taken using a frequency response analyser (Metrohm Autolab – M101). Sample thickness and diameter were measured before taking impedance data.

Pyrrole (Aldrich) was polymerized in the presence of propylene carbonate (Aldrich) and $NH_4(CF_3SO_3)$ on two fluorine doped tin oxide (FTO) glass slides. The area and the thickness of the electrodes were of 1 cm^2 and 1 μm respectively.

An electrolyte sample was sandwiched between two polypyrrole (PPy) electrodes to fabricate a super capacitor. Impedance data were collected in the frequency range from 0.0025 Hz to 0.4 MHz at room temperature using a frequency response analyser (Metrohm Autolab – M101).

3. Results and Discussion

Conductivity (σ) of the electrolyte was calculated using the equation, $\sigma = (1/R_b)(t/A)$ where R_b is the bulk electrolyte resistance obtained from impedance data, t and A are the thickness and the cross sectional area of the electrolyte respectively [8]. The resulting conductivity was 3.8 x 10^{-4} S cm^{-1}. This is an alluring value for a sample to serve as an electrolyte. Apart from the conductive nature, the electrolyte was a mechanically stable thin film. This is also a key feature to be used for applications.

Fig 1 shows the impedance plots resulted for the super capacitor.

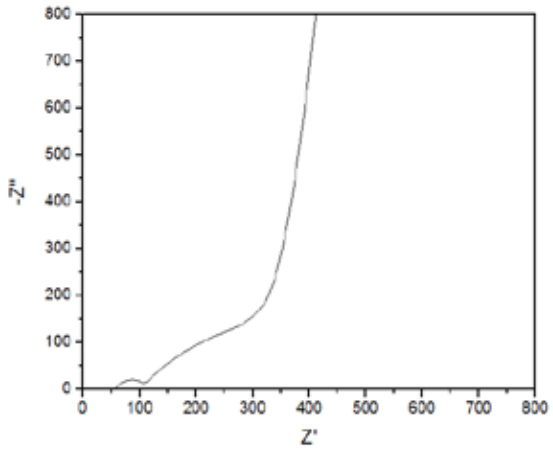

Fig. 1 Nyquist plot of the super capacitor in the configuration, PPy / NR based electrolyte / PPy

In general, an impedance plot of a super capacitor should consist with two spikes having different inclinations at low frequency range [9]. Among them, the one at the lowest frequency region should preferably be vertical highlighting the capacitive properties. According to the resulting Nyquist plot, both those spikes are visible. The lowest frequency region does not have a perfect vertical line due to non-uniformity of the electrode pore size as well as electrode surface roughness.

Fig. 2 shows the bode plot drawn between the real capacitance and the frequency using the impedance data taken for the super capacitor at room temperature.

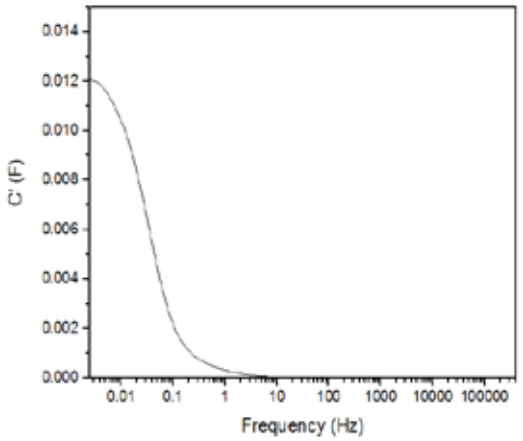

Fig. 2 Variation of real capacitance with the frequency for the super capacitor in the configuration, PPy / NR based electrolyte / PPy

The peak of the curve is related to the capacitance of the super capacitor [7]. This value was divided by the mass of a single electrode to calculate the single electrode specific capacitance. The resulted value is 20.13 F g^{-1}. Though the resulting value is somewhat lower, it is a significant value attracting consideration on the possibility of using NR for such applications. As per our literature survey, no any other group has engaged in searching avenues to employ NR in the field of power and energy and also Sri Lankan NR has not been used by any international research group in this line. In addition, almost all groups have paid their attention to apply NR based electrolytes only for batteries.

Conclusion

A Sri Lankan NR based electrolyte with $NH_4(CF_3SO_3)$ was successfully prepared having a conductivity of 3.8 x 10^{-4} S cm^{-1} at room temperature. The resulting film was mechanically stable and thin. A super capacitor was fabricated using two polypyrrole electrodes and it showed a single electrode specific capacitance of 20.13 F g^{-1}. Further studies are in progress to enhance the performance of the electrolyte as well as the super capacitor.

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Advantages of Using Natural Rubber Latex to Manufacture Gloves and Unique Properties of Natural Rubber Gloves*

ENG Aik Hwee[1]

There are several advantages of using natural rubber (NR) latex in the glove manufacturing process compared to that of synthetic latexes due to certain unique properties of NR latex which are not found in synthetic latexes. These include lower surfactant content, longer shelf life, much better wet gel strength and film formation properties than synthetic latexes. In addition, NR latex can be fully vulcanised in latex state, making it less susceptible to temperature fluctuation in the curing oven. Most rubber glove users like the performance properties of NR gloves because they are generally softer, more elastic than the synthetic gloves, which provide good comfort, low hand fatigue and good tactile sensitivity to the user. They are also more durable, have good resistance against polar solvents such as alcohol. The tear resistance of NR gloves is the highest among the common rubber glove materials. In addition, NR gloves also have the ability to reseal a small hole when punctured by a sharp object. NR gloves are generally cheaper than most synthetic gloves and are of low carbon foot-print products, and are biodegradable. Therefore, the use of NR gloves helps to reduce the impact of global climax change.

Keywords: Natural rubber, gloves, advantages, manufacturing, using

Profile of Eng Aik Hwee

Dr. Eng Aik Hwee graduated from University of Malaya, Kuala Lumpur with an upper second-class honours degree in chemistry in 1986 and Master's degree in natural rubber chemistry in 1989. In 1990, he was awarded the Mombugakusho scholarship by the Japanese Government to pursue his doctorate in functional material engineering at the Faculty of Engineering, Tokyo University of Agriculture and Technology and graduated in 1994. In the same year, he joined the Latex Science and Technology Unit of Rubber Research Institute of Malaysia (RRIM).

In 2001, Dr. Eng left RRIM to join the Science and Technology Department of Ansell, a multinational rubber glove company as a Module Director. He is an inventor of 5 patent applications of which 2 have been granted; co-authored review chapters of 4 books; and 35 journal articles.

Dr Eng left Ansell in 2016 and joined Malaysian Rubber Export Promotion Council (MREPC) in January 2017 as an independent advisor on part time basis. He left the company in December 2018 but continues the technical training for their industry members on assignment basis. In addition to the MREPC training programmes, Dr Eng has been conducting technical training for the Plastic Rubber Institute of Malaysia's members since 2012, University of Kuala Lumpur (UniKL) under the Professional Graduateship of Rubber Technology Programme, Universiti Sains Malaysia, Universiti Perlis Malaysia, and several private companies. He also frequently travels overseas to give educational talks on medical gloves and infection control under the MREPC's educational programmes.

Currently, Dr Eng is a committee member of the Malaysian Rubber Board's Academi Hevea Malaysia Training Programme Review Committee, a Fellow of Malaysian Institute of Chemistry, a Technical Committee Member of International Rubber Conference and Exhibition 2020

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INTRODUCTION

Materials for rubber glove applications must be able to form thin and flexible barrier films to provide the users the required good comfort and protection. Currently, the major rubber materials are NR, carboxylated acrylonitrile butadiene copolymer (nitrile rubber), polychloroprene (chloroprene rubber), polyvinyl chloride (vinyl), and polyethylene. Other rubber materials such as synthetic polyisoprene, styrene-isoprene block copolymer, polyurethane, butyl rubber, and other copolymers are also being used to manufacture rubber gloves. Despite the strong competitions from the synthetic rubbers, NR is still being widely used in the manufacturing of rubber gloves. This paper reviews some of the advantages of manufacturing and using NR gloves.

DISCUSSION

MANUFACTURING NR GLOVES

Long Shelf Life of Latex Concentrate

When a NR latex concentrate is well preserved with good stabilising systems, such as ammonia, the mechanical stability of the latex improves during storage even after a year. This is partly due to the hydrolysis of phospholipids to form hydrogen phosphate and free fatty acids as shown in the reaction scheme in Figure 1.

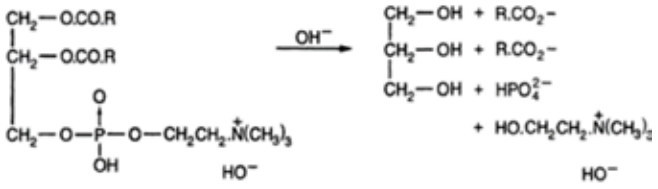

Figure 1: Hydrolysis of Phospholipid in natural rubber latex

Hydrogen phosphate is known to form precipitate with the magnesium ion in the latex to form insoluble magnesium hydrogen phosphate which then sinks to the bottom of the latex as sludge. Magnesium ion is one of the ions that is known to reduce the latex stability.1 The quantity of magnesium ion in NR latex is normally high because it is required in the biosynthesis of the rubber molecule in the rubber tree. The free fatty acids released from the hydrolysis of phospholipids could form fatty acid soaps with ammonium ion which further imparts stability to the latex.[2]

In addition to the latex stability, the presence of natural occurring antioxidants such as free and esterified tocotrienols helps to reduce the oxidative degradation of the rubber molecules.[3-5]

During the long term storage of NR latex, it must be regularly agitated to prevent the latex from creaming due to the lower density of the latex particles. The shelf life of synthetic latexes, on the other hand, is normally shorter, typically no more than six months.

Fully Prevulcanised Latex

NR latex concentrate can be fully prevulcanised in latex state. After prevulcanisation, the latex can be used to produce NR gloves without further vulcanisation. In commercial prevulcanised latex, the excess vulcanising agents are removed after prevulcanisation by low speed centrifugation. This gives the latex a longer shelf life and pot life because the latex will not undergo significant vulcanisation during storage or production of latex products. When the vulcanising agents are not removed, continuous vulcanisation in latex during production of rubber gloves would lead to different levels of pre-cured latex and eventually render the latex over-vulcanised or over-cured resulting in poor mechanical properties. As the prevulcanised latex is optimally vulcanised, the mechanical properties are less susceptible to variation in dipping time, and the fluctuation of oven temperature, leading to more consistent product quality. Therefore, it is possible to dry prevulcanised latex film with one oven temperature setting. Synthetic latexes, on the other hand, cannot be fully prevulcanised, have a shorter pot life, normally require multiple oven ozone for gradual drying and curing.

Good Wet Gel Strength

NR latex is known to have much better wet gel strength than synthetic latexes.[6] Wet-gel strength is the strength of a wet latex film after coagulant but before drying. Good wet gel strength is needed to prevent the latex wet film from tearing or cracking during processing such as wet gel leaching, beading and drying. A good wet gel strength property allows the latex film to be dried at a high speed without the film cracking issue. Rubber gloves with poor wet gel strength properties may crack during leaching or drying especially when the speed of production line or temperature is high. It may also tear easily during beading.

Low Surfactant

NR latex contains native stabilising agents such as proteins, phospholipids, fatty acid soaps. Therefore, additional surfactant required to stabilise the latex system is much lower than that of synthetic latexes. The low surfactant makes it easier to leach the latex film and helps in inter-particles integration. This also results in lower chemical oxygen demand (COD) value of the leaching water and effluent. The general observation

that leaching could significantly improve the tensile properties of latex film indicates the advantage of NR latex having low surfactant content as shown by its good wet gel strength and high tensile properties with just moderate leaching process. High surfactant as in the case of synthetic latexes, will not only inhibit inter-particles integration and poor wet gel strength, it will also cause excessive foaming resulting in holes and pinholes formation in the gloves. High residual surfactant in the gloves will also increase the risk of skin reactions, such as irritant contact dermatitis.

Low shrinkage

Due to the broad particle size distribution (0.3 – 2μm),[7] the particles in NR latex film could be closely packed resulting in a lower shrinkage during drying compared to synthetic latex films. This is because the smaller particles could occupy the space in between the large particles. In addition, the lower surfactant content also contributes to the lower shrinkage of the latex film during drying. In the case of synthetic latexes such as nitrile latex (0.07 – 0.13 μm), the higher surfactant (5 – 8 phr, parts per hundred rubber) and homogeneous particle distribution lead to a high shrinkage ratio of the latex film during drying. A high shrinkage glove is expected to pose a higher risk in cracks formation.

Simple Procedure

NR latex has been used to produce latex products for a long time. In the case of natural rubber surgical glove, it was commercialised in 1964 by Ansell.[8] As such, the formulation, machine design, processing conditions are simple and have been well studied and published. The availability of commercial prevulcanised natural rubber latex further simplifies the glove manufacturing process. On the other hand, synthetic gloves, particularly medical gloves, were manufactured and marketed to replace natural rubber gloves about 30 years ago due to the latex protein allergy issues. Therefore, the information on synthetic rubber gloves manufacturing is less readily available in the literature.

USING NR GLOVES

Soft Products

Except for synthetic polyisoprene gloves, NR gloves are much softer than most of the synthetic rubber gloves, due to the low glass transition temperature. This is reflected in the low stress value at 300% or 500% elongation and the high elongation at break value which is generally above 800%. The highly stretchable property of NR gloves will result in lower hand fatigue, better fit and good comfort when the products are used for a long time. Because of these, most glove users prefer to use NR gloves in the healthcare settings.[9]

High tensile and Tear Strength

The tensile strength of NR gloves is normally higher than the synthetic gloves due to the ability of the rubber to undergo stretch-induced crystallisation. Because of this, the ASTM tensile requirements for NR examination and surgical gloves are significantly higher than those of synthetic rubber gloves. The tear strength of NR gloves is also better than most of the synthetic rubber gloves.[10-11] It is worth noting that synthetic polyisoprene gloves, although having the similar chemical structure as NR, have poorer tensile and tear strengths than NR gloves.[12] Glove tearing is one of the most common quality issue faced by the thin glove users. A glove having good tensile and tear strength such as NR gloves, will give a better protection to the glove users.

Excellent Barrier Protection

Due to the good wet gel strength and film formation properties, NR gloves generally have a lower defect rate than synthetic gloves. In addition, NR gloves have also been found to have the unique ability to reseal when punctured by needles. This provides additional barrier protection against transmission of infectious pathogens. This is well-demonstrated by two studies that reported significant viral and bacterial leaks in synthetic gloves such as vinyl, chloroprene and nitrile gloves when punctured with an injection needle. NR gloves, on the other hand, could "self-reseal" resulting in significantly less viral and bacterial penetrations as observed during the laboratory tests.[11,13]

Alcohol Resistance

NR is a non-polar material. As such, the alcohol resistance of NR gloves is much better than some polar rubber gloves such as nitrile gloves. Alcohol resistance is an important properties of medical gloves because the use of alcohol in medical settings is very common. CDC guidance recommends the disinfection of gloved hands by multiple applications of alcohol-based hand rub (ABHR) following the care of a patient with Ebola, before glove doffing.[14] It is therefore important for medical gloves to remain intact in the presence of alcohol. Any degradation of glove during the disinfection by alcohol may expose glove user to pathogens in the healthcare settings.

Sustainable Material and Low Carbon Foot Print

NR gloves are made from NR latex which is produced by the Hevea brasiliensis tree. As such, NR latex a sustainable material and the carbon foot print of NR

gloves is much lower than that of synthetic rubber gloves.

CONCLUSION

NR gloves have been used for protection against biological and chemical contaminants for many years. They have been reported to possess many superior properties that synthetic glove manufacturers are trying to replicate. Although synthetic polyisoprene can provide the similar fit and feel, the material cost is very much higher than that of NR, making the polyisoprene gloves unaffordable to many users. Moreover, the tear resistance of synthetic polyisoprene gloves is still very much inferior to that of NR gloves.[7] As more users consider sustainability of material as an important factor when choosing a product, NR gloves which are made of a plant based material, will remain relevant in the glove industry for many years to come.

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https://www.cdc.gov/vhf/ebola/healthcare-us/ppe/guidance.html

Dynamic Properties of Polymer Materials and their Measurements

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Dynamic Properties of Polymer Materials and their Measurements

1.1 Polymers

Polymer materials in their basic form exhibit a range of characteristics and behavior from elastic solid to a viscous liquid. These behavior and properties depend on the temperature, frequency and time scale at which the material or the engineering component is analyzed. The viscous liquid polymer is defined as by having no definite shape and flow deformation under the effect of applied load is irreversible. Elastic materials such as steels and aluminium deform instantaneously under the application of load and return to the original state upon the removal of load, provided the applied load is within the yield or plastic limits of the material. An elastic solid polymer is characterized by having a definite shape that deforms under external forces, storing this deformation energy and giving it back upon the removal of applied load. Material behavior which combines both viscous liquid and solid like features is termed as Viscoelasticity. These viscoelastic materials exhibit a timedependent behavior where the applied load does not cause an instantaneous deformation, but there is a time lag between the application of load and the resulting deformation. We also observe that in polymeric materials the resultant deformation also depends upon the speed of the applied load.

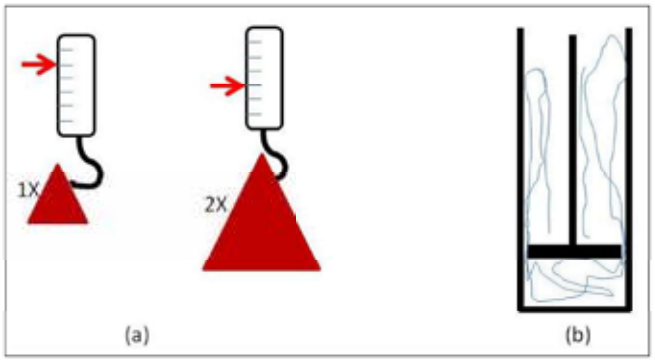

Figure 1.1: Linear Elastic and Non-linear Viscous Materials

Consider a spring based weighing scale as shown in Figure (1.1). If we put a fixed load on the scale such as a weigh bar we get a fixed amount of deflection and the needle points to point 2. Using an exactly double weight the needle moves twice as far upto point 4 and comes to rest. When we remove the weights the needle returns back to O position or the no-load position. The energy we put into the spring based weighing scale to cause deflection is equal to the energy the spring fully gives up when the needle moves back to 0. This concept gives the spring perfectly linear properties and 100% efficiency. If we are to consider a situation where if we were to put our weight on the scale slowly such that it takes ten minutes before the needle comes to the 2 point mark, and if we did the same action in thirty seconds, one

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minute, and five minutes? The needle would still come to rest at the 2 point mark. This shows that when we double the load, the needle pointer moves twice as far as originally meaning the response of the weighing scale is linear. We can also observe that the weighing scale takes the same time or the deformation rate remains the same even if we apply the weight at different times. This shows that the deformation is independent of the rate of the loading. The weighing scale thus obeys Hooke's laws and is a perfect Hookean spring. The deformation energy is always stored as elastic energy and is fully given up upon removal of the load.

Consider a tall cylindrical jar filled with 5W40 engine oil as shown in Figure (1.lb) . At the bottom of the jar is a round disc. The disc is slightly smaller than the inside of the jar so that the oil can move around this disc. Applying an X amount of force we can see that it takes 2 minute to extract the disc from the jar. To decrease the time taken by the disc to extract from the jar by 1 minute we see that we need to apply a higher force and to extract the disc in 30 seconds we need to apply an even higher force.

If the disc is moved from the bottom of the center of the jar to the center of the jar and let it rest, it remains in the same spot and after some time under the force of gravity it starts sinking to the botoom. We can feel that by moving the disc through the engine oil we are applying force or putting work into the oil system by shearing it between the disc and the wall of the jar. The faster we try to move the disc, higher the force required. Unlike the independent nature of the force in the weight scale, the amount of force required for the oil system now becomes rate dependent. e.g. It now depends upon how fast or slow we want to move the disc. The amount of force is not always proportional to the speed and now this becomes a non-linear relationship.

When we moved the disc from the bottom of the center of the jar, it stayed there and did not sink immediately to the bottom of the barrel. We put energy into the system but none of it was given back. All energy put into a viscous oil system is lost. The ideal viscous material is sometimes referred to as a Newtonian system.

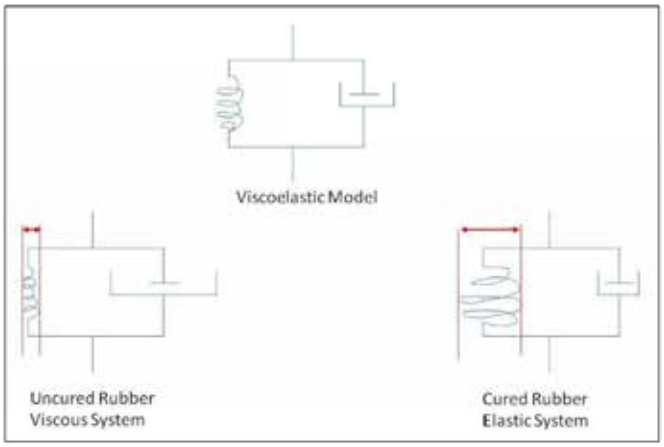

Figure 1.2: Viscous and Elastic Phases making up the Kelvin-Voigt Viscoelastic System

To summarize the response of the phases; The elastic response is linear and all the work input into the system is given up upon removal of applied load. The viscous response on the other hand is non-linear with the force and the deformation dependent upon the rate of the loading and the time. Joining the two phases; we now have a visco-elastic material that is graphically represented by a Hookean spring in parallel with a Newtonian dashpot, defined as the Kelvin-Voigt model as shown in Figure(1 .2). When the viscous and elastic components are joined, we can simultaneously put energy into both of them, but the response of each phase is almost on opposites. In uncured rubber, the viscous phase dominates as evidenced by the flow of the material in the mold. As the rubber is cured during vulcanization the elastic phase slowly begins to emerge and starts dominating the deformation characteristics.

Hookes law for an elastic solid states that stress is linearly related to strain,

$$\sigma(t) = E\varepsilon(t); \qquad (1.1)$$

Or

$$\frac{d\sigma}{dt} = E\frac{d\varepsilon(t)}{dt} \qquad (1.2)$$

Newtons law for a viscous liquid states that;

$$\sigma(t) = \eta\frac{d\varepsilon(t)}{dt}; \qquad (1.3)$$

Combining equations (1.1 and 1.3), we get the Kelvin-Voigt model for a linear viscoelastic material;

$$\sigma(t) = E\varepsilon(t) + \eta\frac{d\varepsilon(t)}{dt}; \qquad (1.4)$$

1.2 Viscoelastic Properties

Figure 1.3 shows the regimes of a typical polymer material from the glassy to liquid state. The material is in the glassy state below the glass transition temperature, and the modulus of the material as high as 3 GPa. The material practically behaves as a hard elastic material in this state. As the temperature increases the regime changes to glass transition stat and the material modulus decreases from 3 GPa to approximately 10 MPa. Subsequently, the material enters the rubber regime or rubbery plateau and is effectively at room temperature. Most of our applications of polymer materials to engineering components fall within this plateau regime. Below the rubbery plateau is the viscous regime where the modulus of the material further decreases causing the material to flow like a liquid. Processing of plastic or rubber materials in a compression-transfer mold or injection mold takes place in this regime. Below the viscous regime in the region of decomposition and complete breakdown of the polymer material and its ingredients.

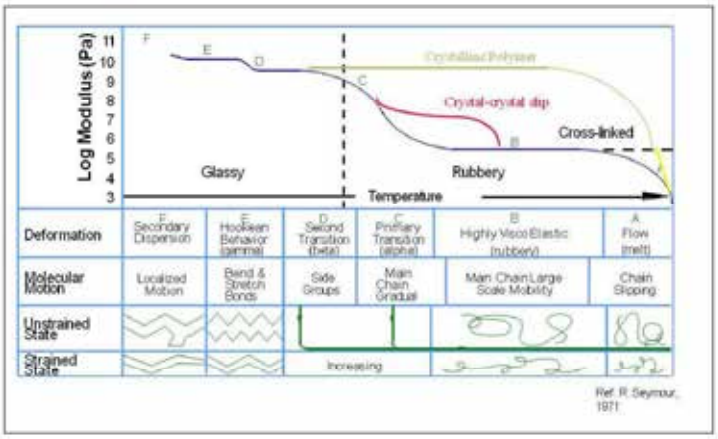

Figure 1.3: Different States and Modulus Regimes in Polymer Materials

Polymer materials by their very nature exhibit linear and nonlinear viscoelasticity. Linear viscoelastic behavior is exhibited by a material that is subjected to a deformation that is either very small or very slow on the application time scale. It can said that the nature of the deformation can be predicted using a linear theoretical expression. While the application of polymers to a rapid rate of flow and deformation or sudden temperature cycling to the extremes results in deformation patterns that cannot be predicted by linear expressions, and the behavior is said to exhibit nonlinearity.

1.3 Dynamic Properties

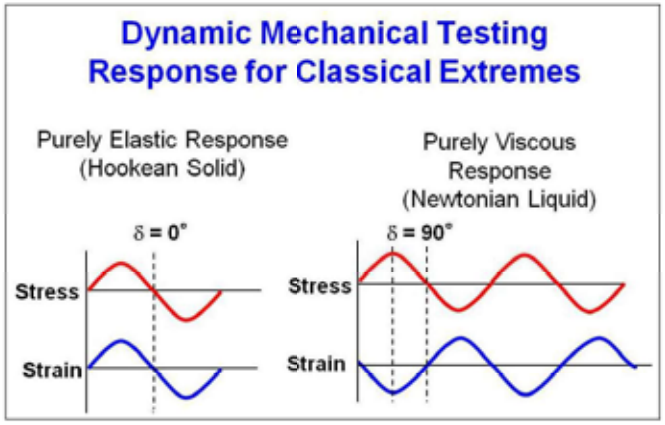

Figure 1.4: Purely Elastic and Purely Viscous Responses of Materials

Characterization of dynamic properties play an important part in comparing mechanical properties of different polymers for quality, failure analysis and new material qualification. Figures 1.4 and 1.5 show the responses of purely elastic, purely viscous and of a viscoelastic material. In the case of purely elastic, the stress and the strain (force and resultant deformation) are in perfect sync with each other, resulting in a phase angle of 0. For a purely viscous response the input and resultant deformation are out of phase by 90° . For a viscoleastic material the phase angle lies between 0 and 90° . Generally the measurements of viscoelastic materials are rerepresented as a complex modulus E* to capture both viscous and elastic behavior of the material. The stress is the sum of an in-phase response and out-of-phase responses.

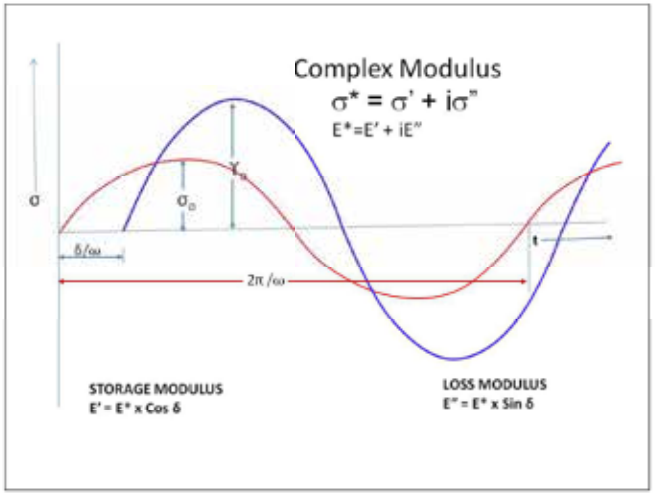

Figure 1.5: Viscoelastic Response of a Polymer Material

Figure 1.5 shows that the resultant strain lags the applied stress and can be written as,

and the stress can be written as

$$\varepsilon(t) = \varepsilon_o Sin\omega t \tag{1.5}$$

and the stress can be written as

$$\sigma(t) = \sigma_o Sin(\omega t + \delta) \tag{1.6}$$

where θ_0 is the stress amplitude and ω is the angular frequency. Expanding the equation, it can be expressed as

$$\sigma(t) = \sigma_o Cos\delta Sin\omega t + \sigma_o Sin\delta Cos\omega t \tag{1.7}$$

The $\sigma_o Cos\delta$ t term is in phase with the strain, while the term $\sigma_o Sin\delta$ is out of phase with the applied strain. The modulus E' is in phase with strain while, E" is out of phase with the strain. The E' is termed as storage modulus, and E" is termed as the loss modulus.

$$E' = \frac{\sigma_0}{\Upsilon_0}\cos\delta$$

$$E'' = \frac{\sigma_0}{\Upsilon_0}\sin\delta$$

$$E' = \frac{In-phase\ stress}{Maximum\ strain} = \}\text{Storage Modulus}$$

The storage modulus deails with the elastic modulus part, where the deformations are fully recoverable at the end of the displacement cycle.

$$E'' = \frac{Out\ of\ phase\ stress}{Maximum\ strain} = \}\text{Loss Modulus}$$

The in-phase stress and strain results in completely recoverable elastic energy while the out-of-phase stress and strain results in the dissipated energy termed as loss. Both the storage modulus and the loss modulus are functions of the applied frequency ω.

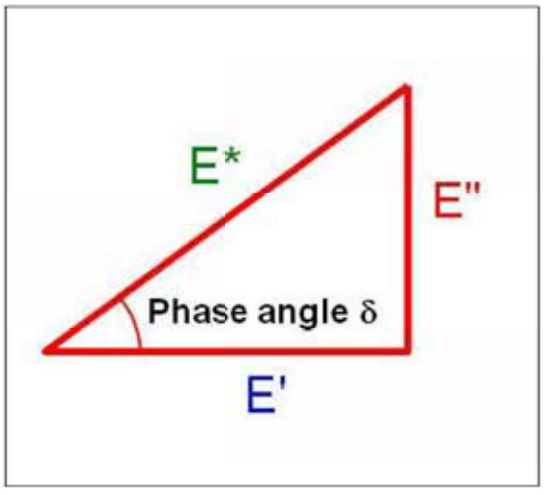

Figure 1.6: Concept of Complex, Loss and Storage Modulus

Figure 1.6 shows the graphical representation of the loss modulus, storage and complex modulus. The loss tangent or the damping coefficient is defined as

$$tan\delta = \frac{E''}{E'} = \frac{Loss.Modulus}{Storage.Modulus} \tag{1.8}$$

Figure (1.7) shows the concept of loss and storage modulus from the example of a rubber ball. The ball when bounced off the ground from a height does not bounce to the level from where it was dropped but bounces only to a level lower. This loss of height can be defined as the energy that has been lost in energy disspation due to deformation of the rubber.

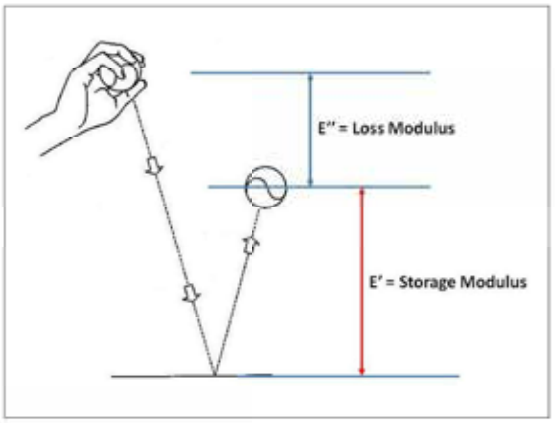

Figure 1.7: Loss and Storage Modulus in Elastomers

Polymer materials exhibit strong time and rate dependent properties. Studying these time and rate dependent properties is necessary to predict the performance of engineering components.

To accurately characterize the viscoelastic properties of polymers, the generally used technique is that the material is sinusoidally deformed and the resulting stress is recorded. The deformation can be applied in tension, compression or shear mode depending on the geometric design or the application condition of the engineering component.

1.4 Stress Relaxation

Stress relaxation is a viscoelastic viscoelastic property of an elastomeric material. In a stress relaxation experiment, the sample is rapidly stretched or compressed to a predefined strain and held constant. The stress is then recorded as a function of time. Creep experiments are carried out in a similar manner but instead of the application of a constant strain, a constant stress is applied and the deformations or the resultant strain is studied as a function of time.

The stress relaxation modulus may be define as

$$E_{rel.}(t) = \sigma(t)/\varepsilon_0 \qquad (1.9)$$

If there is no viscous flow in the material, the stress decays to a finite value for polymeric materials. For amorphous linear polymers at high temperatures, the stress may eventually decay to zero. For a linear viscoelastic solid, the instantaneous stress will be proportional to applied strain and will always decrease with time.

The molecular causes of stress relaxation and creep can be classified to be based on five different processes.

l. Chain Scission The decrease in the measured stress over time is shown in Figure(l.8) where 3 chains initially bear the load but subsequently one of the chains degrades and breaks.

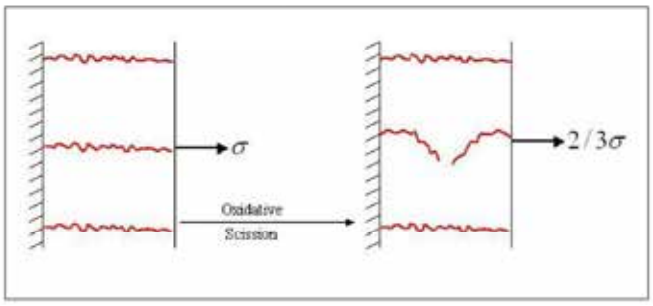

Figure 1.8: Chain Scission in an Elastomeric Material

2. Bond Interchange In this particular type of material degradation process, the chain portions reorient themselves with respect to their partners causing a decrease in stress.

3. Viscous Flow This occurs basically due to the slipping of linear chains one over the other. It is particularly responsible for viscous flow in pipes and elongation flow under stress.

4. Thirion Relaxation This is a reversible relaxation of the physical crosslinksor the entanglements in elastomeric networks. Generally an elastomeric network will instantaneously relax by about 5% through this mechanism.

5. Molecular Relaxation Molecular relaxation occurs especially near T_g (Glass Transition Temperature). The molecular chains generally tend to relax near the T_g .

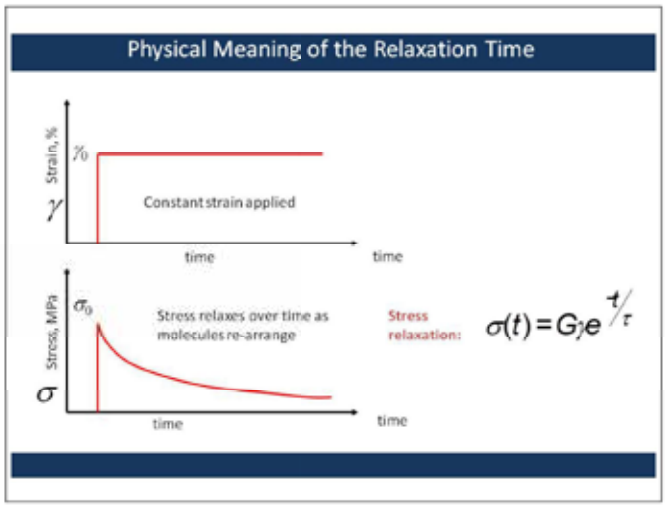

Figure 1.9: Physical Meaning of the Relaxation Time

The related effect of stress relaxation in sealing applications is the reduction in stress (i.e. sealing force) under constant strain (compression) conditions. In many applications when sealing force approaches zero, leakage is likely to occur as the seal geometry loses contact

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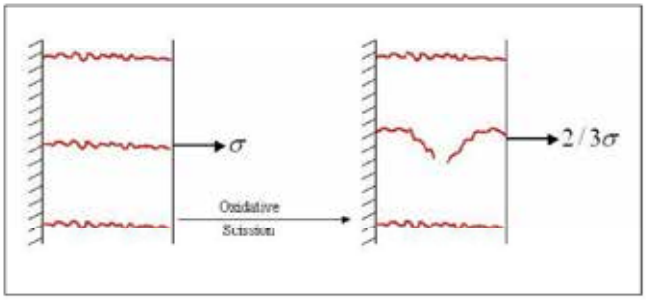

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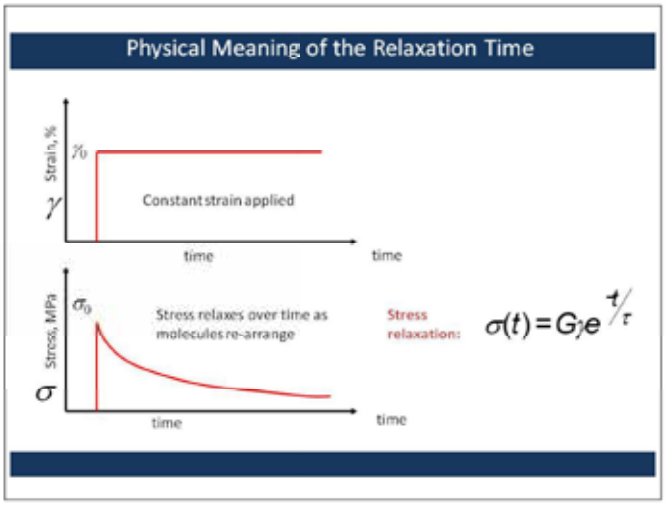

Figure 1.9: Physical Meaning of the Relaxation Time

The related effect of stress relaxation in sealing applications is the reduction in stress (i.e. sealing force) under constant strain (compression) conditions. In many applications when sealing force approaches zero, leakage is likely to occur as the seal geometry loses contact between the mating surfaces. Stress relaxation and compression set effects are undesirable and are of key importance in determining sealing performance. For amorphous linear polymers at high temperatures, the stress may eventually decay to zero. If there is no viscous flow in the material, the stress decays to a finite non-zero value.

Stress relaxation as discussed above is caused by a combination of physical relaxation, and chemical degradation. Physical relaxation is dependent on elastomer material properties. It increases with temperature, is dominant over short timescales during the initial time period of the experiment and is fully recoverable. Chemical degradation is highly dependent on temperature and on the aggressive chemical action of fluids and application environments and is applicable over longer time frames in an experiment. ASTM D6147 and ISO 3384 with methods A and B are the applicable standards for stress relaxation experiments. Method A refers to the continuous method of measuring the force over time, while method B refers to the intermittent method of measuring the force over time. Wykeham-Farrrance test apparatus is the preferred method to measure the force decay over time in method B.

1.5 Creep

Creep is an increase in plastic strain under constant stress. Creep is an increased tendency of a solid material to move slowly or deform continuously under the influence of mechanical stresses. In other words it tendes towards high strain and plastic deformation with no change in stress. Figure (1. 10) shows a the stress and strain curves for a part undergoing creep. The material is stressed with an applied force. Creep tends to occur as a result of long-term exposure to high levels of stress that are still below the yield strength of the material. Over time, the force and stress do not change, although the shape of the part continuously deforms. When unloaded, there is additional permanent set. Old PVC pipes for electrical installations sag at the center when simply supported at the ends. This is an example of creep under the constant force of gravity. Creep in polymers at low strains (1 percent) is essentially recoverable after unloading.

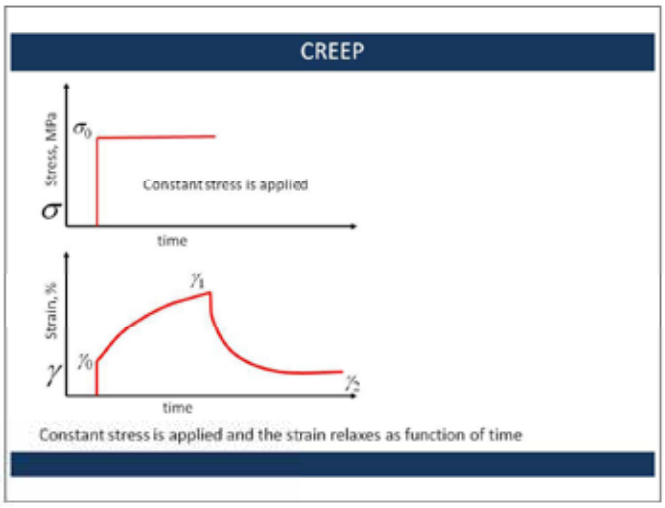

Figure 1.10: Physical Meaning of Creep

ϒ1 is the immediate elastic deformation taking place under the effect of applied load. ϒ2 is the elastic deformation that takes place over a period of time. ϒ3 is the flow of the material or the non-recoverable creep that remains once the loading on the material is removed. The creep compliance may be define as

$$C_{comp.}(t) = \varepsilon_t/\sigma(0)$$

Creep is thus a time- dependent deformation under an externally applied load. It generally occurs at high temperature (thermal creep), but can also happen at room temperature in certain materials albeit at much slower rate. As a result of Creep the material undergoes a time dependent increase in length, which could be dangerous while occuring in engineering components under service loads and boundary conditions.

ASTM F38 is the standard test method for Creep experiments on a gasket material.

1.6 Effect of Fillers on Dynamic Properties

Dynamic properties of rubbers are affected by fillers and other compound ingredients. It is found that the filler network can substantially increase the effective volume of the filler due to rubber trapped in the agglomerates, leading to a high elastic modulus. Fillers like carbon blacks increase the modulus of rubbers by forming reinforcing bonds with the polymers. The increase in modulus is due to the fact that fillers can be considered having higher rigidity as compared to the rubber. They do not participate in the deformation and increase the strain in the rubber matrix between adjacent filler particles. The strain increase because of this can be expressed by

$$X = 1 + 2.5c + 14.1c^2, \qquad (1.11)$$

where x is the strain increase ratio and c is the volume fraction of the material. The equation shows that tan8 increases linearly with x.

1.7 Application of Dynamic Material Characterization

Dynamic material characterization is a technique that measures stress as a function of strain, or force as a function of displacement and time. It also involves the application of one or more forces at various frequencies, as a means of determining how material changes in a dynamic environment where the material comes under the effect of multiple frequencies. Dynamic characterization testing normally includes components like tires, springs, dampers, biomedical implants and vibration isolation components from the automotive, aerospace and biomedical industries. These components perform under time and frequency varying conditions during their entire lifecycle making them ideal candidates for dynamic study bothfor product development and failure analysis.

1.7.1 Development and Failure Analysis of Rubber Rollers

Equation (1.11) can be particularly applied to materials where the carbon black filler size is larger (e.g. N990). In smaller sized filler particles the rubber is just in static form around the blacks and the effective volume fraction has to be suitably used. The strain increase or amplification concept due to the presence of fillers also affects the energy losses per cycle of operation. Since the presence of higher rigidity fillers magnify and increase the local strain, the dynamic losses which are proportional to local strain amplitudes also increase. During cyclic strain, while the stable filler network can reduce the hysteresis of the filled rubber, the breakdown and reformation of the high sructure filler network would cause an additional energy dissipation resulting in higher hysteresis. More information on this increase of losses can be obtained from Meinecke et al. As per studies, as compared to carbon black, silica is able to form a stronger and more developed filler network resulting in higher modulus and lower hysteresis at low and room temperature applications.

The E', E", E* or Tan Delta values are to be used as a comparative set of values from different compounds, or a single compound tested at different conditions i.e., temperature, frequency, or strain levels. When different compounds are tested, variables such as cure systems, filler types and levels and plasticizers can be evaluated and compared to provide inputs about dynamic properties.

For an example where dynamic properties testing could be helpful a filler is changed from N-762 to a N-550 black in a rubber covered pinch roller for paper applications. Some other compound adjustments were also made to maintain the same tensile, elongation and durometer values. A few weeks after the compound revision it was observed that there is a noticeable increase in failures of the roller. The operating conditions dictate that the paper roller runs at 180 rpm under 8000 Newtons resulting in the rubber warming up. A dynamic test at three Hertz and Tan Delta values is carried out to compare the compounds. The greater values of E" and Tan delta (damping coefficient) indicate a higher hysteresis in the compound. It can be inferred from the results that higher hysteresis can cause greater heat buildup in the rollers leading to failures.

1.7.2 Viscoelastic Analysis of Tires

Tires are subjected to cyclical high deformations when vehicles are running on the road. When exposed to harsh road conditions, the service lifetime of the tires is jeopardized by many factors, such as the wear of the tread, the heat generated by friction, rubber aging, and others. As a result, tires usually have composite layer structures made of carbon-filled rubber, nylon cords, and steel wires, etc. In particular, the composition of rubber at different layers of the tire architecture is optimized to provide different functional properties.The desired functionality of the different tire layers is achieved by the strategical design of specific viscoelastic properties in the different layers. Zones of high loss modulus material will absorb differently than zones of low loss modulus. The development of tires utilizing dynamic characterization allows one to develop tires for smoother and safer rides in different weather conditions.

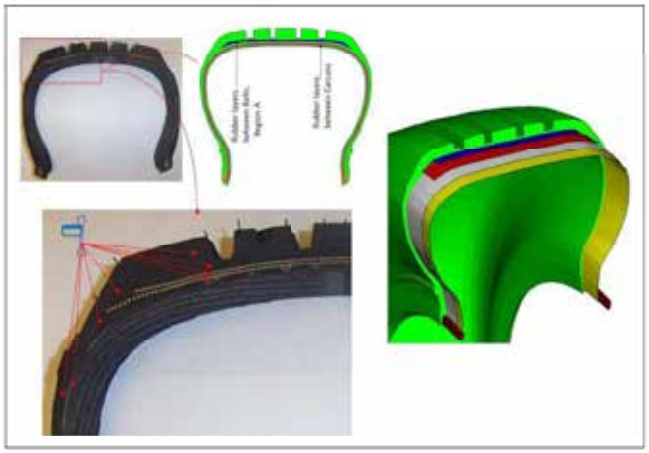

Figure 1.11: Locations of Different Materials in a Tire Design

The dynamic properties are also related to tire performance like rolling resistance, wet traction, dry traction, winter performance and wear. Evaluation of viscoelastic properties of different layers of the tire by DMA tests is necessart and essential to predict the dynamic performance. The complex modulus and mechanical behavior of the tire are mapped across the cross section of the tire comprising of the different material. A DMA frequency sweep test is performed on the tire sample to investigate the effect of the cyclic stress/strain frequency on the complex modulus and dynamic modulus of the tire, which represents the viscoelastic properties of the tire rotating at different speeds. Signigcant work on effects of dynamic properties on tire performance has been carried out by Ed Terrill et al. at Akron Rubber Development Laboratory, Inc.

1.7.3 Non-linear Viscoelastic Tire Simulation Using FEA

Non-linear Viscoelastic tire simulation is carried out using Abaqus to predict the hysteresis losses, temperature distribution and rolling resistance of a tire. The simulation includes several steps like (a) FE tire model generation, (b) Material parameter identification, (c) Material modeling and (d) Tire Rolling Simulation. The energy dissipation and rolling resistance are evaluated by using dynamic mechanical properties like storage and loss modulus, tan delta etc. The heat dissipation energy is calculated by taking the product of elastic strain energy and the loss tangent of materials. Computation of tire rolling is further carried out. The total energy loss per one tire revolution is calculated by;

$$\Psi^{diss} = \sum_{i=1}^{\infty} i2\pi\Psi_i Tan\delta_i, \qquad (1.12)$$

where Ψ is the elastic strain energy,

Ψ^{diss} is the dissipated energy in one full rotation of the tire, and
Tanδi, is the damping coefficient.

The temperature prediction in a rolling tireas shown in Fig (1.12) is calculated from the loss modulus and the strain in the element at that location. With the change in the deformation pattern, the strains are also modified in the algorithm to cause a change in the temperature distribution in the different tire regions.

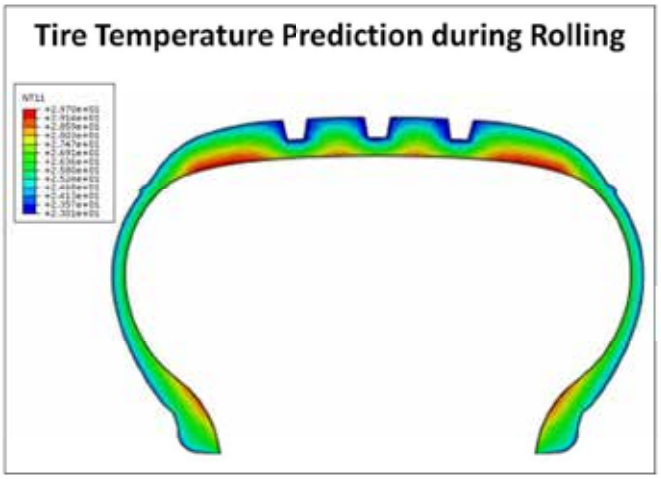

Figure 1.12: Temperature Distribution in a Tire under Rolling Conditions

Rolling resistance is now calculated from;

$$F_{RR} = \frac{-\Psi^{diss}}{2\pi R} where,$$

F_{RR} is the Rolling Resistance
$2\pi R$ is the Circumferential length.

In summary, the absolute values from dynamic tests are meaningful, but have little values as isolated data points. They do become valuable as values when compared to each other or some other known variable. A tan delta or damping coefficient value of 0.4 is poor for a natural rubber or EPDM based compound, but very good in FKM materials where the structure of the compound makes it venerable to lower than optimum dynamic properties. Most uncured rubbery compounds start on the viscous side, and as we cure the compound, we shift towards the elastic side.

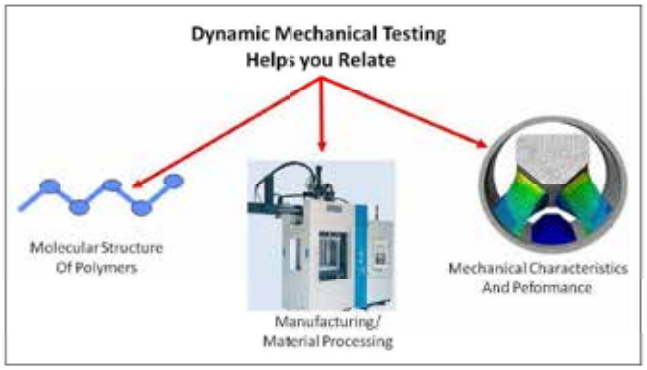

Figure 1.13: Viscoelastic Studies Correlate Molecular Structure to Manufacturing and Mechanical Properties of Engineering Components

As it stands today, the theory of dynamic properties can be applied judiciously to product development or failure analysis problems. The field of application has evolved over time with availability of highly sophisticated instruments. The problems need to be studied upfront for any time or frequency dependent loads and boundary conditions acting on the components and the theory be suitably applied. Needless to say that dynamic properties have utmost importance when rubber components show heat generation and fatigue related field failures as it relates the molecular structure of the polymer material to the manufacturing process and to the field performance of engineering products.

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Surfactants and Emulsions:

By James Fox

Dedicated to the tireless work of Dr. Paul Stamberger, Crusader Chemical Founder (circa 1950).

Surfactants are very important for coatings, cosmetics, environmental, and health care applications due to a range of surface-active properties they possess. Additionally, the global surfactant market is expected to be worth approximately US$28.83 billion by 2023 [1], further demonstrating their significance Here, we discuss some basic ideas and techniques that will aid in the selection of surfactants for formulating wetting, defoaming, or cleaning , as well as for simple cosmetics.

Surfactant theory and practice can be seen throughout many disciplines. The name surfactant refers to "surface active agents" and their use is to modify the surface tension between liquid/liquid, gases/liquid, or liquid/solid interfaces. Characteristic to surfactants are their critical micelle concentrations (CMCs) which is defined by the concentration required to promote self-assembly of the molecules into hierarchal structures called micelles (also vesicles or worm-like micelles). The CMC is illustrated in Figure 1.

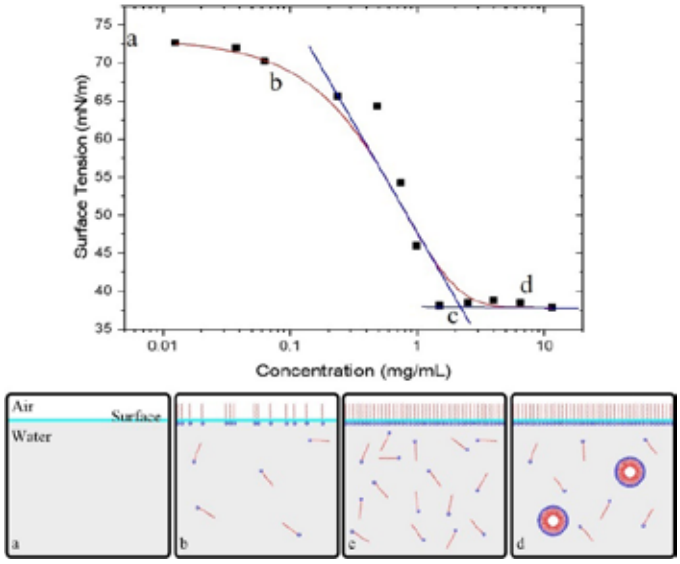

Figure 1. Illustration of critical micelle concentration and its relationship to solution surface tension as a function of surfactant concentration (c_s). a) $c_s = 0$; $0 < c_s > CMC$; $c_s = CMC$; $c_s > CMC$.

The CMC of a surfactant can be measured using a surface tensiometer. Other methods make use of light scattering or fluorescent probes to determine CMC. Figure1. demonstrates a typical surface tension measurement as a function of surfactant concentration to determine the CMC (Figure 1, c).

The branch of chemistry involving surfactants is sometimes call "soft colloids" and the earliest known use of this chemistry dates to the Neanderthal cave

paintings in Lascaux, France. The Food Industry uses a naturally occurring surfactant, phosphatidylcholine (lecithin) to make emulsions like mayonnaise (liquid/liquid) or meringues (gas/solid). The Printing Industry improves printing resolution on high energy surfaces with the addition of surface modifiers. Foam mattresses use such surface modifying agents to stabilize cells filled with entrained air.

Surfactants also have relevance in biology. In medicine, a condition called Surfactant Dysfunction, is an imbalance of phospholipids (a surfactant) and proteins around the lung alveoli causing difficulty in breathing and eventually death. [2] New surfactant drugs reduce scarring of lung tissue Cystic Fibrosis patients. Finally, surfactants in a grasshopper's regurgitate are used to ward off attacking ants. The low surface tension regurgitate covers the hydrophobic cuticles of the ants causing them to spend most of their time cleaning their cuticles. [3]

In 1949, Griffin [4] assigned a scale to describe a hydrophobic–lipophobic balance (HLB) that predicts the nature of surfactants. This scale assigns a numeric value to the ratio of polar functional group strength relative to the non-polar portion of the surfactant. Surfactants with a hydrophilic head have contributing values for water soluble segments >10 and for lipophilic tails the contributing values for oil soluble segments

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are <10 Combining these contributions produces an overall number for HLB, which is outlined for various surfactant behaviors in Figure 2. For example, given the same hydrophilic head group, a surfactant with a higher molecular weight (MW) alkyd tail length would be more hydrophobic, and thus, lower on the HLB scale.

To calculate HLB of ethoxylated, nonionic surfactants from physical data, one uses the formula, HLB = E / 5, where E is the percentage of the ethoxylated mass in the surfactant. For example, Oleth-20 has 20 ethoxylate repeat units in its hydrophilic portion. Each ethoxylate unit is 44 g/mole. The hydrophobic portion, oleyl alcohol, has a molecular weight = 268 g/mole. The calculation for the HLB of Oleth-20 is as follows:

$$20 \times 44 = 880 \quad (1)$$

$$880 + 268 = 1148 \quad (2)$$

$$880 / 1148 = 76.6\% \quad (3)$$

$$76.6\% / 5 = 15.3 \quad (4)$$

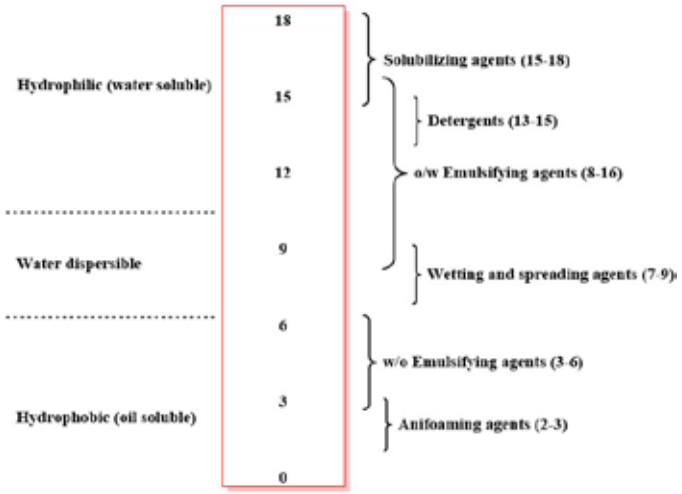

Figure 2. HLB scale showing classification of surfactants.

From Figure 2, one notes that Oleth-20 is quite water soluble (HLB= 15.3). Another method (Davies, 1957) calculates HLB based on chemical groups to assure stronger and weaker hydrophilic groups are accounted for when describing the HLB value. [5]

There are several surfactant categories: ionic, non-ionic, and amphoteric (Figure 3). Ionic surfactants have subgroups that include anionic (negative) alkyl benzyl, sulfonates, or phosphates which are utilized in the cleaning industry. Cationic-based surfactants (positive) are used as water softeners and anti-static agents. Cationic, anionic and amphoteric surfactants may be pH dependent and are often affected by added electrolytes in water, which has implications in formulating coatings when pigments are used that carry a charge.

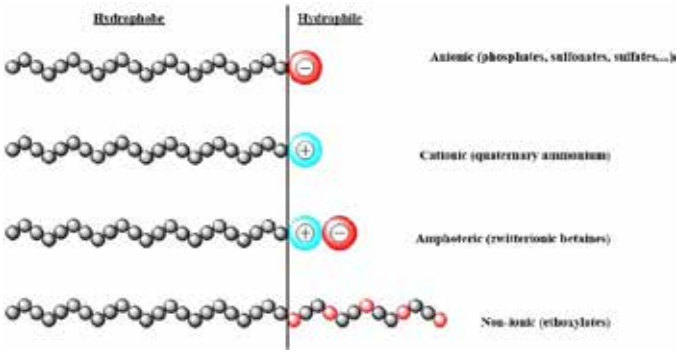

Figure 3. Types of surfactant groups and charges.

As the name infers, non-ionic surfactants are not ionized, and thus are not affected by wide pH swings or free electrolytes in solution. As a result, nonionic surfactants have good compatibility with additives like pigments and clays that may carry a charge. The synthesis of these molecules is carried out via the ring opening polymerization (ROP) of ethylene oxide monomer using an initiating species, often an alkyl alcohol. The reaction results in the formation of a polymeric ether with a degree of polymerization that is dictated by the monomer to initiator molar ratio as representing in the ring opening polymerization of ethylene oxide in Figure 4.

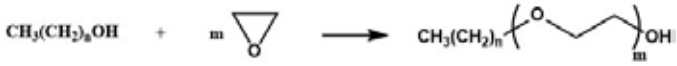

Figure 4. Ethoxylated alcohol formation from an alkyl alcohol and ethylene oxide.

The degree of ethoxylation plays a role in the properties of the final surfactant. One property is cloud point (CP), which varies with molecular weight. As the temperature increases above what is called a lower critical solution temperature (LCST), the ethoxylated chains undergo an extended-to-collapsed conformational change. This LCST behavior results in the solution becoming turbid or cloudy as the temperature increases due to a decrease in the solubility of the ethoxylated chains in water.

Another observation on cloud points is the molecule (CP) is lowered by electrolytes in solution.[6]

The decrease is due to anions weakening the hydrophobic hydration along the alkyd chain length as depicted

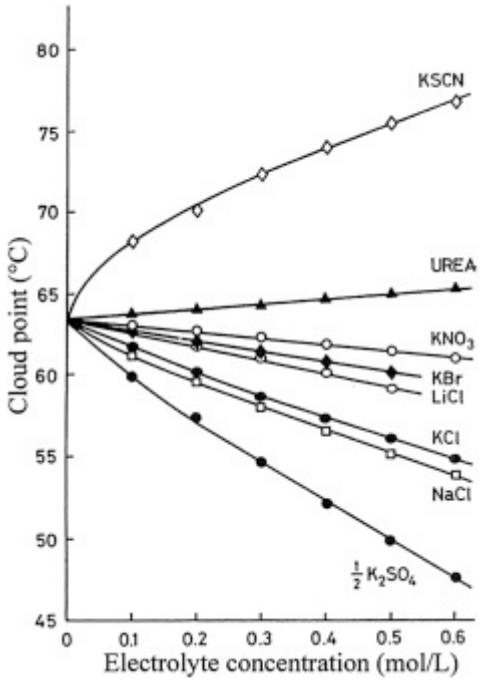

Figure 5. Effect of electrolytes on the cloud point of C12EO7 (5 mmol/L)

When selecting ethoxylated alcohol type surfactants, one should know they come with some precautions. Ethoxylated nonylphenol type (NPE) are banned in textiles by the European Union's REACH Committee. This is because NPE surfactants are removed in the washing cycle of textiles. This displaced nonylphenol molecule causes infertility due to the accumulation in aquatic life. [7]

Some nonionic surfactants are derived from sucrose-base chemistry due to their biocompatible structures. For example, polyglucosides tend to be more environmentally friendly and less toxic for skin care creams. A safer glycoside-derived surfactant, Tween 60, is a polyoxyethylene (20) sorbitan monostearate. The (20) represents the number of polyoxyethylene groups (w+x+y+z) attached to the sorbitan ring (Figure 5). The monostearate group for Tween 60, or as another example, monolaurate for Tween 20, describes the hydrocarbon chain capping a single terminus of the ethoxylate groups (Figure 7)

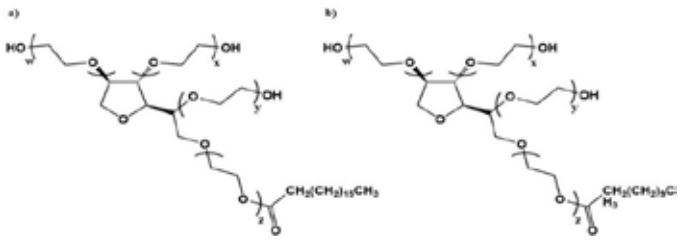

Figure 7. Chemical structure of a) Tween 60 (CAS No. 9005067-8); b) Tween 20 (CAS No. 9005-64-5).

New trends in reducing one's carbon footprint, give rise to new sustainable chemistries. Bio-based ethanol is replacing petroleum-based grades to generate ethylene oxide for surfactant syntheses. These intermediates are used to produce "green" surfactants like the above Tweens (Figure 7). Additionally, the cosmetic industry is not only promoting plant-based creams but EO free ingredients as well. Chemistries with propylene oxide are now added onto the linear alcohol chains to make Tween-type surfactants. Surfactants with both EO/PO copolymers exhibit lower CMCs, lower surface tension, and better dispersing power than the surfactants with only EO groups. Combinations of EO/PO copolymer capped systems can also be synthesized on the alkyl chain to modify HLB, and subsequently, the demulsifying properties of surfactants. (Wu, 2004). [8]

A novel surfactant group called Gemini (twin) entails two hydrophobic tails joined by two hydrophilic heads. In the special case shown in Figure 8, amino acids are used for the head portion, lending itself to a more biocompatible molecule. (Perez 2014) [9]

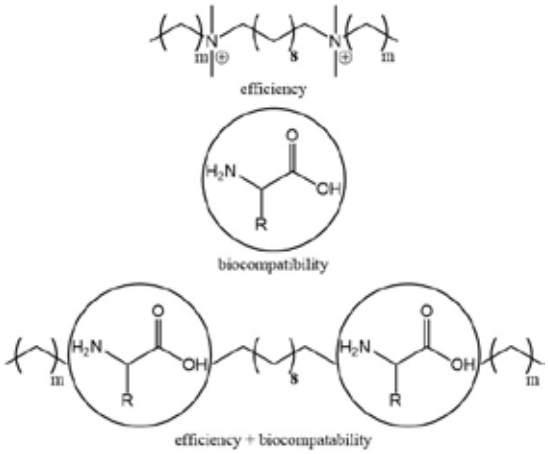

Figure 8. Gemini Surfactants based on hydrophilic amino acid head groups.

The Gemini structure achieves a CMC using less material, which is beneficial when used as additives in the coatings industry. Lowering the surfactant levels will result in less fisheyes, craters, and orange peel surface defects. In clear coats, less surfactant will result in less blushing of high gloss lacquers.

Cosmetic chemists attempt to formulate stable emulsions from specialty oils, surfactants, and water using predictions from a variety of methods. One method used to predict such stability is centrifugation followed by heat cycling. For example, canola oil has an HLB =7 and can be matched with a specific surfactant (HLB = 7) prior to adding water (most of the selection process can be done with a test tube that is shaken by hand).

Over time separation will occur because the dispersed particles tend to migrate towards each other to reduce their interfacial area in the continuous phase. Varying the concentration may result in a stable emulsion, however, one can improve emulsion stability by selecting surfactants with high and low HLB values (e.g. SPAN 80 = 4.3 and Tween 80 = 15.5) until the overall HLB is equal to 7. In the above case, the surfactant mixture calculation is as follows:

Tween 80	15 x 0.255	= 3.825	(5)
SPAN 80	4.3 x0.745	= 3.203	(6)
Adding HLB approx.		= 7.0	(7)

In the final formula, 2.55-part Tween 80 and 7.45 part of Span 80 are used to create a stable emulsion.

Note the chemistry of both surfactants is derived from the same sorbitan monooleate. The fact they are the same improves emulsification of water in oil. Based on Bancroft's rule, the nature of the emulsifying agent determines the emulsions stability.

Typical equipment for emulsifying water and oil mixtures include, shear mixers, Silverson mixers, or even sonication equipment. Sonication has shown that less surfactant is needed since the droplet sizes produced are very small. Homogenization factors include shearing time, shearing blade shape, and temperature. It is critical to maintain the homogenized state to reduce separation of both phases. To overcome this entropic nature, cellulosic derivatives have been added to aid in homogenization; additives like methocel lower the surface tension at the oil/water interface. Stability tests show very little oil migration on top and slight water separation at the bottom. Additionally, a conductivity test can reveal if you have an O/W emulsion (conductive) or a nonconductive W/O system.

In conclusion, most formulating is done countless trial and error. Design of Experiment Software is a useful tool for this field since it will improve product development. One aspect of formulating that should be standardized is a supplier's raw material quality.

Alternative materials used for an ISO 9000 contingency plan can lead to supply chain problems. One should not be surprised when the "so called" same raw materials show different results. There is an old adage "if it isn't broke, don't fix it" can be a useful reminder before changes are made to formulas. Finally, choose surfactants, with good product stability or shelf life in the system. Factors of hydrolysis, compatibility, long term UV stability, service temperatures and regulatory synergies all lead to the success of the product. The formulator should be detail oriented, innovative and most of all love his work.

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Can We Make Money From Rice Husk

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Rice is the world's second most important cereal crop following only to corn. The Food and Agriculture Organization's (FAO) statistics says world milled-rice production in recent years is about 750 million metric tons. According to the Department of Census and Statistics in Sri Lanka the contribution to the world's rice production from Sri Lanka in recent years is about 1.8 million metric tons per annum. Milling is a vital step in post harvest production of rice. The major objective of rice milling system is to remove the husk and the bran layers, and produce white rice kernel that is well milled and free of impurities. Scholars found that $1/5^{th}$ of the paddy represent the shell which in turn tells us that approximately 0.45 million metric tons of rice husks are produced per annum.

Disposal of rice husk is one of the major challenges faced by many rice-millers all over the world because hundreds of millions of tons entering the waste stream each year. In some countries the husks are burnt in electricity producing incinerators. However that process creates millions of tons of ash. When rice husk burns $1/4^{th}$ of the content is ash, which is still a great environmental threat but on a positive note, the rice husk ash (RHA) contains 60% to 80% amorphous silica, which has application in various industries such as rubber reinforcement as in tyre industry, plastic reinforcement industry, food, healthcare, cosmetics, catalyst, coatings, pulp and paper processing. Thus the ash generated can be stored for silica extraction.

For a moment if we assume all the rice husks produced in Sri Lanka can be collected and if the ash contains 70% of silica then we should be able to extract 78750 metric tons of Silica. In practical conditions, it is impossible to collect all the rice husks produce all over the country. However, if we have a proper mechanism we can easily collect 50% of the rice husks. That means we should be able to produce 39375 metric tons of silica per annum. The conventional silica that is exported for tire industry in Sri Lanka costs around 800 USD. If we can replace conventional-exported-silica from RHA-silica we can save around 31.5 million USD per year. If the production cost is 500 USD per metric ton still we will have net profit of 11.8 million USD per year. This saving is purely form-extracted silica. Along with silica, there are other by-products like carbon and sodium carbonate that are useful in various industries and can generate additional dollars for the country.

The extracted silica from RHA has several advantages over the conventional silica. First and foremost, it is from a bio source and is non-toxic. Secondly, this silica is extracted from waste hence nullifying the raw material cost. Further, any industry that uses rice husk as fuel for cogeneration can benefit from this technology.

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If we can't sell the silica for local industries one might think who is going to purchase this renewable silica. The good news is many industries including US based tire manufacturer, Goodyear, is producing fuel-efficient tires though the use of rice husk waste. According to the Goodyear's web page (*last access on20/10/2019*) they plan to use ash leftovers from the burning of rice husks to produce electricity as an "environmentally friendly source of silica" for use in their tires. Silica is a compound that mixed with rubber used in tire treads to increase the rubber's strength and help reduce the tire's rolling resistance. Lower rolling resistance helps improve a vehicle's fuel economy. Some of the Chinese companies have already worked with Goodyear to make more environmentally friendly tires. Further, Goodyear is negotiating with potential suppliers to purchase rice husk ash silica because sustainable supply is the challenge. According to the statistics of the Goodyear Tire and rubber company the current suppliers of this silica can satisfy only a very small percentage of Goodyear's needs. Thus, we have a potential to enter to this emerging market.

In conventional silica productions sodium silicate is manufactures by fusing pure silica sand with Soda ash in Rotary furnace at 1300 °C, using various SiO_2/ Na_2O ratios. This technique is highly energy intensive, as it requires the reactants to be heated to high temperatures. Then this sodium silicate is subjected to acid precipitation to produce precipitated silica. Sodium sulphate is a waste that is generated and this liquid effluent requires elaborate treatment to meet emission standards. In contrast preparation of conventional silica, RHA silica can be extracted in few steps. First, RHA is digested with sodium hydroxide to make sodium silicate solution.

$$NaOH + RHA \rightarrow Na_2SiO_3 + H_2O$$

Once sodium silicate solution is prepared to pH of the medium should be lowered to precipitate SiO_2. pH adjustment can be basically done using any acid. We have used hydrochloric acid, sulfuric acid and even CO_2 gas. As reported in many scholarly works use of mineral acids introduces many issues such as costly effluent treatments. Our research group has successfully used CO_2 for sol-gel process as well as in-situ powder formations by spray drying method. The formation of SiO_2 with CO_2 is shown in the following equation.

$$2Na_2SiO_3 + 2CO_2 \rightarrow 2Na_2CO_3 + 2SiO_2$$

The details of the CO_2 process can't be disclosed at this moment. In this process the chemicals used can be regenerated as shown in the following reaction thus eliminating expensive effluent treatment plant.

$$Ca(OH)_2 + Na_2CO_3 \rightarrow 2NaOH + CaCO_3$$

Then CO_2 can be prepared by thermally treating the $CaCO_3$ and resulting carbon dioxide can be used for the precipitation step.

$$CaCO_3 \rightarrow CaO + CO_2$$

One drawback of regeneration step is the use of high temperature of about 850^oC to decompose the $CaCO_3$. In an industrial process the energy requirement can be achieved by incinerating the rice husk. Calcium oxide can be reacted with water to give calcium hydroxide, which is sent to the regenerator so that sodium hydroxide and calcium carbonate is produced when sodium carbonate reacts with it.

$$CaO + H_2O \rightarrow Ca(OH)_2$$

Theoretically this process is zero cost in terms of chemicals needed for the process. The materials obtained through this method exhibit high levels of purity and homogeneity.

Our research group is extensively work on this specific project to produce silica with tunable characteristics and check the compatibility with rubber matrices to improve the mechanical properties. The microstructure, elemental compositions, functionality and porosity extracted SiO_2 powder was evaluated by using SEM-EDX technique, X-ray diffraction spectroscopy (XRD), FT-IR technique, Brunauer-Emmett-Teller (BET) surface area analysis.

The Figure 1 a shows the gel of silica formed in presence of different acids while Figure 1 b shows the purified silica.

Figure 1. Photograph of (a) silica gel and (b) Purified silica

The microstructure and elemental composition of the purified silica was evaluated by SEM-EDX technique. The Figure 2 shows the SEM images of the silica while Table 1 shows the elemental composition of the samples obtained by EDX technique. It is interesting to note that silica was found to be present in solid aggregates.

Further zoomed-in images confirm the presence of fine particles of size less than 1µm. This confirms the solid chunks are the accumulated smaller particles.

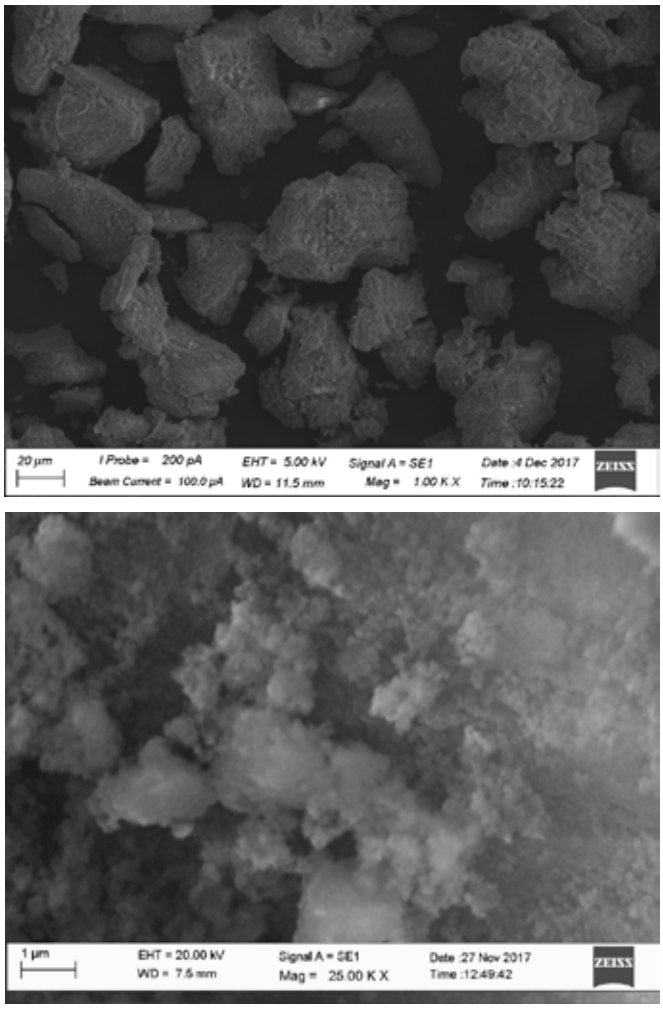


Figure 2. Scanning Electron Micrograph of purified silica extracted from RHA

An elemental composition analysis of the purified and unpurified RHA silica was carried out by energy dispersive X-ray spectroscopy (EDX). The data is given in the Table 1. The EDX spectra of both samples showed the characteristic peaks for the two elements at 0.5 keV and 1.73 keV, which correspond to the spectral lines of O and Si. In addition, several other peaks were observed for unpurified silica, which were absent in the purified silica. This is further confirmed by the XRD analysis of unpurified silica as shown in the Figure 3 a. It confirms the purification process that we followed were sufficient enough to remove the impurities present in the silica. Moreover, the EDX analysis confirmed that the synthesized materials formed in a good stoichiometric ratio.

Table 1. Elemental composition of unpurified and purified silica determined by Energy dispersive X-ray diffraction technique

Element	Weight Percentage (%)	
	Unpurified Silica	Purified silica
C	14.11	-
O	58.08	70.42
Na	3.01	-
Si	23.12	29.58
K	0.27	-
Fe	0.07	-
S	1.33	-

The XRD pattern of the extracted SiO_2 powders from RHA is shown in Figure. 3. The presence of sharp peaks with broad halo in Figure 3 a confirmed the presence of crystalline impurities in amorphous silica. After acid wash the peaks disappears. Absence of sharp peaks in the XRD pattern indicated the absence of crystalline materials while the broad halo confirms the presence of amorphous nature of the material. The Figure 3 c shows the XRD pattern of commercially used silica in tyre tread industries which is identical to the pattern of extracted silica. Therefore, the RHA silica powder confirms the characteristics of the commercially available silica.

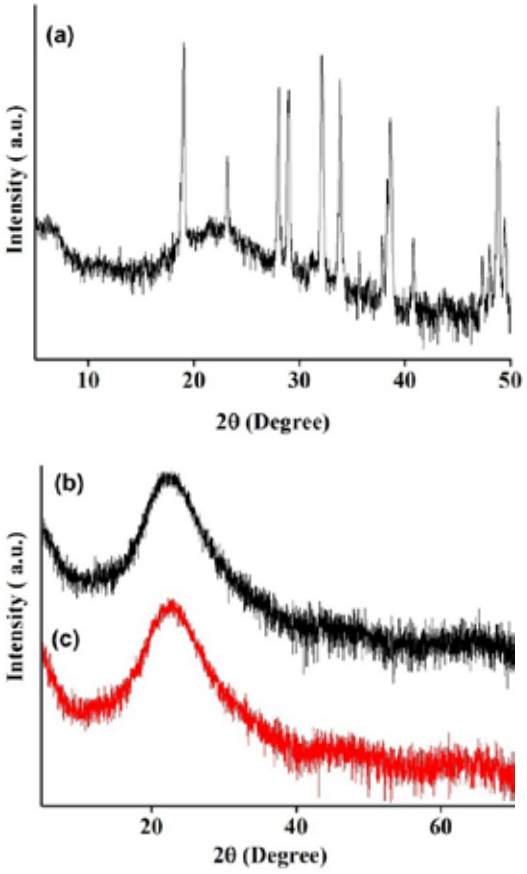


Figure 3. X-ray diffraction pattern of (a) unpurified silica (b) purified silica using acid digestion and (c) commercially used silica in local tyre tread industry

To evaluate the chemical bonding of the purified SiO_2 powder, Fourier transform infrared (FTIR) transmittance spectra were taken. The FTIR spectrum of the silica powder is shown in Figure 4. The corresponding bond vibration modes for different peaks are labeled on the spectrum.

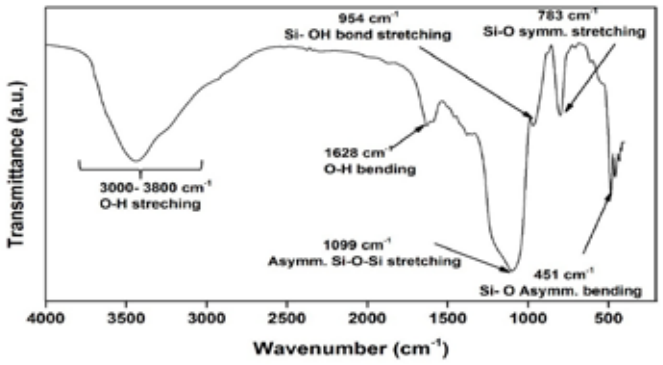
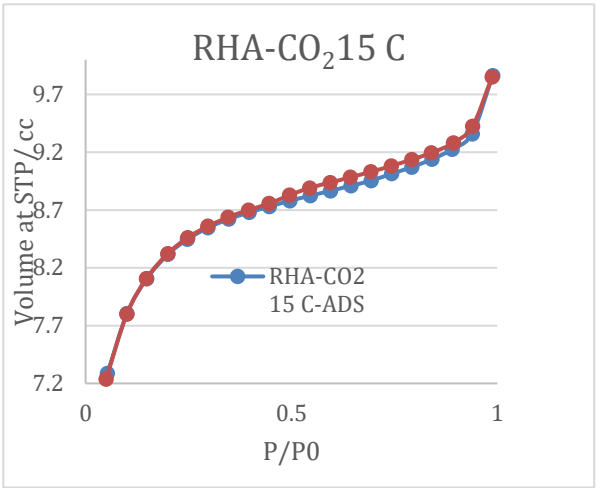


Figure 4. FTIR spectrum of purified silica extracted from rice husk ash

One of the major goals of project was to develop silica particles with tuneable surface characteristics so that the extracted silica can be applied to many different applications. The surface area and the pore characteristics of the silica particles were determined using the Brunauer-Emmett-Teller (BET) and Barret-Joyner-Halenda (BJH) methods. Representative adsorption-desorption isotherms of the porous silica are shown in Figure 5. It is clearly seen that the surface adsopption-desorption behavior is different in the same silica extracted from different methods. The surface characteristics are summarized in Table 2. The results confirms that we have synthesized silica particles with spectrum of surface characteristics compared to the commercial silica used in local tyre tread industry.



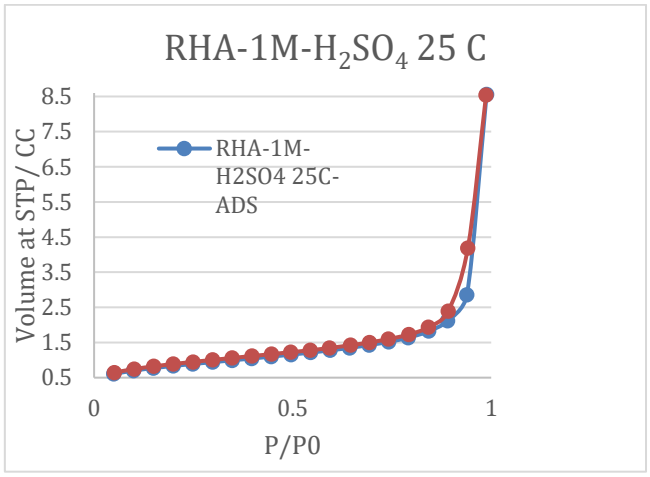


Figure 5. The nitrogen adsorption-desorption isotherm of the extracted silica

Table 2. Surface characteristics of extracted silica powders.

Sample name	Specific surface area/ m^2g^{-1}	Total pore volume/ ccg^{-1}	Average pore radius/ nm
RHA-CO2 15 °C	626.545	0.3676	1.17331
RHA-CO2 50 °C	460.788	0.3966	1.7216
RHA-CO2 80 °C	290.835	0.3205	2.20367
RHA-1M-H_2SO_4 25 °C	116.807	0.5233	8.96079
RHA-1M-HCl 25 °C	43.054	0.1726	8.01578
RHA-5M-HCl 25 °C	25.881	0.05985	4.16135
Commercial silica	150.957	0.439	0.58161

In rubber industry, silica is widely used as a non-black reinforcing filler to improve the mechanical properties particularly tensile strength, tear resistance, abrasion resistance and hardness of NR and synthetic rubber composites. However, a major problem with silica-reinforced rubber is the incompatibility between the hydrophilic silica and hydrophobic rubber molecules. A well-known method for improving the reinforcement effect is to treat the silica surface with Silane coupling agents to promote interaction between silica and polymer chains. In our work we have tried to reinforce the NR and synthetic rubber lattices with *in situ* coupling of silica with silane coupling agents. As a representative data the Figure 6 and Figure 7 shows the abrasion volume loss and percentage of equilibrium swelling in presence of toluene in NR/NBR/silica composites. We have developed this material as O-rings and oil/solvent sealers for Rotary-evaporators.

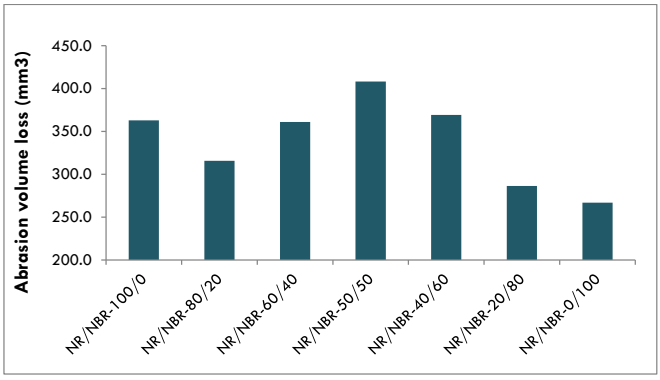


Figure 6. Abrasion volume loss of NR/NBR/silica composites with different NBR and silica loadings

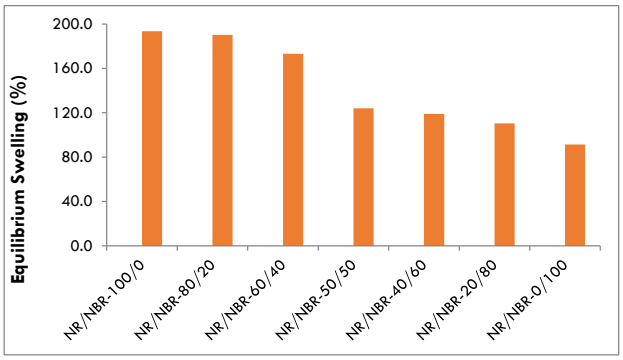


Figure 7. Equilibrium percentage of swelling of NR/NBR/silica composites with different NBR and silica loadings

We have used these oil/solvent sealers in the rotary evaporators used in our laboratory. So far these sealers are being used for approximately six months and no failures have been reported. The Figure 8 shows the sealer that we made and the instruments that the sealer was fixed. Our research group is producing many rubber-based products using this extracted silica and evaluation of their performances are undergoing.

Figure 8. Photograph or sealers made by the NR/NBR/silica composites and its uses

Last but not least, I belive our scientists must tap on the technology to extract this valuable resource from basically almost zero-cost waste at the moment in Sri Lanka. If our entrepreneurs enter to this emerging industry one day we might be able to see many rubber-based products made using RHA-silica. On top of that we can be very proud considering the impact on the environment in the sense of waste management.

Acknowledgement

The author would like to thanks following members of his research team, Dr. Dilhara Edirisinghe, Kirushanthi Thangaveil, Ishara Wijesinghe, K. P. R. I. Dilani, Pasan Manjith for their contribution to this research work. Further, the author greatly acknowledges the funding provided by USJP and UWU research grants.

Recycling of End of Life Tyres - New Developments

John Boyd Dunlop, a Scottish veterinarian was inventor of the first practical pneumatic tire in 1888, he invented it for his son's tricycle.

It took another seven years for someone to take the leap. André Michelin and his brother Edouard, who had previously patented a removable bike tire, were the first to use pneumatic tires on an automobile. Unfortunately, these did not prove durable. It wasn›t until Philip Strauss invented the combination tire and air-filled inner tube in 1911, that pneumatic tires could be used on automobile with success. As the use of tyres in trucks and other vehicles increased a new problem arose. There was hardly any use of the waste tyres.

- A few tyres were used as boat fenders, as fuel, and making distillate oil by pyrolysis.
- Re-treading of used tyres became popular.

In spite of above uses, stock piles of ELT (end of life tyres) starting mounting up.

Some of Statics on ELTs are as follows:

Advent of MRP

In 2004 after ten years of research carried out by the **Integrated Waste management Board of California** & a paper was published, in which Continental tyres, Michelin and Ford motor co were involved.

It was found that if the rubber in waste tyre is micronized to 80 mesh or finer and mixed with rubber does not deteriorate properties of the high tensile compounds. It was recommended to use 10 PHR in case of 80 mesh.

Some studies show that 120 mesh can be used up to 20 phr without loss of properties. Following is the data for the use of 120 mesh from 5 to 30 phr. The table shows the results.

Test Results – Tinna 3R – 125 (120 Mesh)

Sr. No.	Test Description	Test Method	0 PHR	10PHR	20 PHR	30 PHR
	Curing Temperature(degree celsius)		160	160	160	160
	Curing Time(min)			7	7	7
Sr. No.	Test Description	Test Method	0 PHR	10PHR	20 PHR	30 PHR
1	Hardness Shore A	IS 3400	58	64	65	65
2	Tensile Strength(kg/cm square)	IS 3400	212.37	222.24	212.48	198.99
3	Elongation at break (%)	IS 3400	518.47	529.54	519.57	523.79
4	Modulus at 300% (kg/cm square)		102.22	101.54	99.48	92.03
5	specific gravity	IS 3400	1.13	1.13	1.14	1.14
6	Abrasion Resistance	IS 3400	122	115	125	137
7	Angular Tear strength	IS 3400	97.05	87.4	83.33	83.04

KEY FINDINGS / OBSERVATION:
1. At 20 PHR Tensile, Elongation and Abrasion is similar to compound without Tinna 3R 175, resulting in substantial cost saving (Please refer next slide)
2. At 10 PHR, properties improved dramatically for tensile, Elongation and Abrasion.
3. Hardness increases. However the same can be controlled by reducing Carbon, which further helps in cost saving

Bird's eye view of a waste tyre yard in Oman

Some of Statics on ELTs are as follows:

There are over

1 BILLION

End-of-life tyres generated annually.

It is estimated that

4 BILLION

Unwanted end-of-life tyres exist in landfills and stockpiles.

Some

290 MILLION

Tyres are discarded in the United States each year.

Michelin and Lehigh Technologies

Michelin North America after using MRP for ten years bought Lehigh Technologies of USA, the largest manufacturer of MRP (Micronized Rubber Powder) who has sold 50,000 tons of MRP in the year 2018 as claimed by Lehigh.

Lehigh published their experience as follows.

"We sell to seven of the top 10 tire customers in 18 countries and 45 tire plants around the world," said Team Lehigh. "There are more than 500 million tires that have been made with our product".

Strong Upside

Even with the inroads Lehigh along with Michelin have made with MRP, there is potential for much more business, both in tire and non-tire applications. Thus far, the firm has focused on getting the material used in the tire tread, but other external components such as the sidewall are candidates for additional MRP usage.

Glenn Denstaedt, Lehigh technical director for tire and rubber.

As tire companies get more used to the product and learn how to process it, there will be opportunities to increase the amounts of MRP used in the compound itself, Denstaedt said, noting that current applications range from 2 percent of batch weight up to 10-12 percent.

Article by Bruce Meyer | Rubber and Plastic News

In 2016 the End-of-life tire (ELT) arising in Europe reached 3.9 million metric tons, which represented an increase of approximately 66,000 metric tons, Meanwhile, reuse of tires by re-treading dropped by 5 percent.

European Tyre and Rubber manufacturer's Association

After sorting, around 3.29 million metric tons of ELTs remained for further treatment. ELT granulation continued to be 'strong' with a growth rate of 9.3 percent when compared to 2015, the association points out. ELTs sent to energy recovery increased 'slightly' by 2 percent. Civil engineering uses of whole or shredded ELTs shrank by 3 percent, while reuse of tires as blasting mats and dock fenders was down 15 percent. As of 2018, 23 countries were operating under an extended producer responsibility (EPR) scheme for tires, representing around 65 percent of EU waste tyres.

NEW DEVELOPMENTS

Micronized Rubber Powder

Tinna Rubber & Infrastructure Ltd was the first company of India which realised the advantage of Micronized Rubber Powder in high quality compounds. The only technology known was Cryo-grinding which involved use of Nitrogen.

In India the cost of using Nitrogen was prohibitive at approximately Rs. 20 /- PKG of Rubber Crumb.

Tinna developed the **ambient grinding system**, where use of Nitrogen was not required. Today Tinna Rubber offers MRP of 80, 120 and 140 mesh.

Some tyre companies have their typical specification requirement, Tinna Rubber is able to meet their requirement and therefore is selling today 3500 tons per annum. This capacity can be increased at a short notice, since tyre cutting and crushing capacity is already in place to crush 72,000 Ton per annum.

Compounded Micronized Rubber Powder

CMRP is a unique idea of supplying MRP of 80 mesh and finer MRP in pre-dispersed compounded form.

Since MRP grades are very fine powder and have a tendency to fly causing fly loss and also makes work place dirty, we pre-disperse MRP in NR or SBR as required by customer.

Comparision chart of Radial Tyre Tread Compound

S. No.	Standard Recipe	Rate	Price
		Wt.	@
1	NR	100	130
2	zinc oxide	5	210
3	Stearic Acid	2	70
4	TDQ	1.5	400
5	4020	2	400
6	Carbon 220	55	120
7	0/ 10phr 80/ 10phr CMRP 80/ 12.5 CMRP 80	0	35
8	Oil 710	8	45
8	TBBS	1.5	400
9	Sulphur	1.5	25
10	PVI	0.1	400
	Total	177	

Standard Radial Truck Tyre Compound

PROPERTIES	Standard	10 phr 80 mesh Crumb	10 phr CMRP -80	12.5 phr CMRP-80
Hardness	62	64	62	63
Tensile Strength	181.84	170.28	174.41	168.51
Elongation at Break	458.25	444.9	444.43	466.26
Modulus at 100%	20.97	21.83	22.1	20.11
Modulus at 200%	54.2	56.94	57.27	50.95
Modulus at 300%	101.65	103.52	104.49	94.5
Specific Gravity	1.13	1.14	1.13	1.13
Abrasion Resistance Vol. Loss	128	154	151	151

Refrence: Attuned Lab Report No. 6228/2019-20 Dated 13/09/2019

CMRP made by using 20 parts of Polymer and 80 parts of 80 mesh crumb. Findings on standard radial tyre tread compound is as below:

Advantages

- CMRP is in sheet form. There are no fly losses.
- Containers can carry higher load as compared to crumb, saves cost.
- There is no leakage in transit due to a bag getting torn.
- No need of EVA pouches thus save cost.
- Pre-dispersed master batch gives better properties to compound
- Storage/stacking is easier.

SPECIFICATIONS:

S No	Parameter	Standard Specification
1	Volatile Matter (%)	Max 1%
2	Ash Content (%)	8.05%
3	Carbon Black Content. (%)	16.4%
4	Acetone Extract. (%)	12 %
5	RHC (By Difference) (%)	63%

Coated Rubber Crumb

The idea of joining crumb rubber particles together is very old. Many patents were taken but nothing succeeded. Tinna Rubber has successfully launched CRC under the name of TENSOFLEX. The advantage here is that it has a tensile strength of 10 MPa. And it imparts high abrasion resistance.

MATERIAL DESCRIPTION	COATED RUBBER CRUMB (C.R.C)
Material source	Recycled rubber crumb
Tensile strength	9- 10 MPA
Elongation at break	270%
Shore A Hardness	65 Shore A
Specific gravity	1.13 KG/LITER
Ash Content	Max 8 %
Physical Appearance	TACKY POWDER
Color	BLACK
Smell	MILD

Rubber Tackifier

Although Reclaim Rubber is known to Industry for last 70 to 80 years yet new uses are being found. One of these is to use Reclaim (modified) as a very low cost material, giving high tack to a rubber compound, particularly where Fabric Penetration is required.

MODIFICATION:

The reclaim rubber when made under certain processing conditions can produce a material of very low Mooney of 15 to 20 and thus it is like a dough. Just as when we make adhesive from NR, it is masticated several times to make it very soft and tacky. It is Oxidation of NR. Similarly Reclaim rubber can be softened by Oxidation, and this level of softness can be maintained by use of special chemicals. Therefore unlike Reclaim rubber where Mooney increases on storage, the Mooney of Tacky Reclaim is maintained between 20 and 30. Secondly to give it silky smoothness this Reclaim is made from finer mesh of Crumb.

USES:

It is currently used in tire Compounds for making Compounds which impregnate fabric. Because of its softness the Compound penetrates the fabric easily and after curing, it also vulcanizes with the rest of the Compound and the final product regains its elasticity. Another advantage is that lesser Oil is required for Compounding.

CALENDERING:

This Grade can also be used in calendared Products, since it is Grain less.

NR TUBES:

Automobile and Cycle tubes can be made from this Grade due to consistent Mooney and grain less structure.

SPECIFICATIONS:

S No	Parameter	Standard Specification
1	Volatile Matter (%)	Max 1%
2	Ash Content (%)	Max 10%
3	Carbon Black Content. (%)	25-29%
4	Acetone Extract. (%)	15-20 %
5	RHC (By Difference) (%)	48-52
6	Sp. Gravity	1.13-1.15
7	MooneyViscosity {ML(I+4)@100^{o}C}	15-30
10	Hardness (Shore A)	60-65
11	Appearance	Black Blocks
12	Tackiness	Highly Tacky Compound

CONCLUSION

A lot is happening in finding various uses of ELT tyres. Today TBR and PCR are designed to last long. The life of these tyres is 50 years. It can be used in building construction as part of aggregate, Sound insulation pads, Heat insulation sheets, Road speed barriers, floor tiles, and adhesives etc.

Polymer/Filler Interactions: A Critical Review

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Abstract

Development in the era, needs cost effective structural and functional materials with diverse properties. Material science is an interdisciplinary area concerned with invention of new materials and improving the already known and existing materials for their better use in present scenario. Materials form the basis of human life with more emphasis given to polymer composites. In this mini review authors describe the role of fillers in enhancing properties of polymer composites with principles governing their distribution and interaction within polymer composite materials.

Introduction

Fillers [particulate fillers and fibers] irrespective of their sources are gaining importance in manufacturing of technical goods and products for structural and functional applications. The increase in their importance is attributed to their fundamental and practical behaviour. Hence it is vital to understand the complex behaviour of fillers when they are practically used in solid [polymer], liquid or gaseous media[1]. This short review focuses on the behaviour of these fillers particularly to polymers. Behaviour of fillers with polymers requires the knowledge on physical and chemical characteristics of fillers; as these characteristics determine the enhancement level in performance of the final product[2]. In general, polymer mixed with fillers [with respect to concentration] is termed as polymer composite material. There are various classifications for polymer composite materials depending upon the source of polymers and fillers, but in this review we shall only focus on the organization of phases within polymer composite material and principles governing filler distribution and interaction.

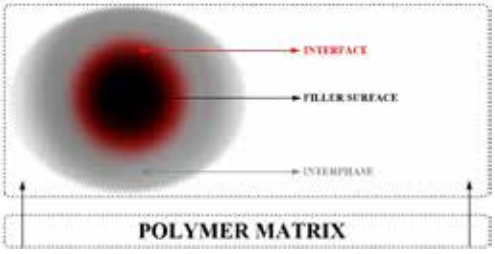

Figure 1: Schematic representation of molecular dimensions zones in filled polymer composites (Interface and Interphase)

"Interface" and "Interphase" are two molecular dimensions within the polymer composite material and are used sometimes in replacement to each other or as a synonym to each other; but rather there is a huge difference between their actual presence in the polymer composite material, as seen in **Figure 1**. The molecular dimension in the vicinity of the polymer is termed as "interface" and the dimension extending from the polymer surface which is influenced by the polymer surface is "interphase"[1]. "Interface" and "Interphase" are the two molecular dimensions within polymer composite materials responsible for properties of the final polymer composite material under stress during application.

Filling polymers with fillers is one of the most widely used methods in manufacturing of structural and functional materials with required set of mechanical, physical and functional properties for any practical application[2]. Fillers are those materials in polymer composite which are distributed near to uniformity (with isotropic and anisotropic alignments) as shown in **Figure 2**, with appropriate means of processing, after knowing the physical and chemical properties of the polymers as well as fillers.

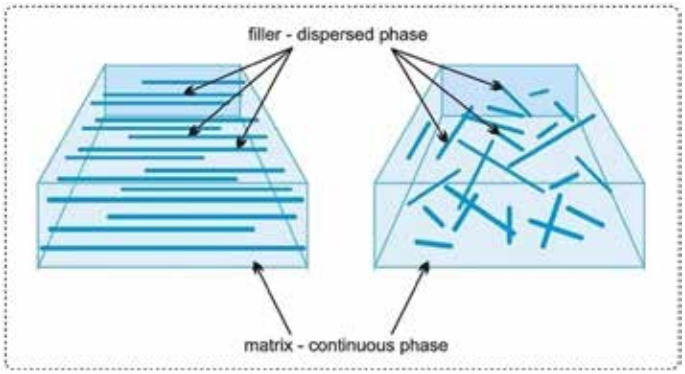

Figure 2: Schematic representation of phases in polymer composite "Macrostructure of a polymer composite"

Reinforcement of polymers with fillers is a process that indicates the compatibility of the fillers with the polymers, thereby having a distinct phases (i.e. interface and interphase) with the polymer phase[2]. As we already discussed, polymer composite materials are

"heterophasic" [two or more phases] wherein phases interact with each other. Proportion of the constituents phase is an important parameter, giving rise to different properties in polymer composite materials, but formation of two molecular dimensions (i.e. interface and interphase) cannot be neglected. Following the definition of composites, on a broader aspect the polymer composite materials may be ordered and structured into "particulate or fibrous filled polymer composite" and "long fiber reinforced polymer composite". Further on following the dimensional aspects, of fillers as we can order polymer composites into "dispersed particles", "short cut fibers" and "long fibers"[2]. Several physical characteristics of fillers influence the properties of the polymer composite materials, to name a few - shape, dimension, size distribution, orientation and composition, out of which "mean values of particle size" is considered as the important property relating to the property of polymer composite material; that contributes to the total surface of the phase border between phases[2]. Particle size along with the shape predicts the performance of the polymer composite material. Effectiveness of the filler action is determined by the "specific surface area" of the filler; specific surface is important wherein fillers are modified by utilizing any of the available chemical methodologies of modification. Packing of fillers within the polymer composite material is dependent on the shape of filler used, i.e. hybrid effect wherein smaller size fillers are used to fill in gaps between larger size fillers within polymer composites. Fillers having tendency to enhance the mechanical properties of base polymer are termed as "active fillers"[2]. "Inactive fillers"[2] intend to give a particular color or rather makes the final product cost effective. As physical properties are important, chemical characteristics of the fillers also have an important role in determining the final properties of the polymer composite material; free surface energy is one such chemical property – as interfacial interactions [between polymer and filler] within polymer composite is dependent on the ratio of "free surface energy" of polymer and filler. Fillers in polymer cannot introduce change in only one particular property[2] as addition of filler into polymer results in formation of new material, with properties completely different from the polymer, it shall be accounted to "micro and macro heterogeneities" and "physical and chemical interactions at molecular dimensions zones". Strong chemical interactions (strength of interface) within polymer composite material increases the stiffness of polymer composite material. Strong physical interactions (strength of interphase) contributes to elastic modulus within polymer composite material and enhances toughness. Having a balance between "stiffness" and "toughness" is of great importance in research area of polymer composite materials. Distribution of phases within polymer composites has a great influence on the properties of the polymer composite materials. Polymer matrix in any polymer composite material is "primary continuous phase"[2]; continuous fibers in a polymer composite material is termed as "secondary continuous phase"[2] whereas particulate fillers in polymer composites are termed as "secondary dispersed phase"[2]. As mentioned about the properties of fillers for polymer composite material, polymer material should possess properties to be used in polymer composite material out of which "good ability to wet the filler surface" is essential. "Area of application" of polymer composite material, determines the choice of polymer and fillers. Fillers activity into polymers, can be classified as "structural"[2] "kinetic"[2] and "thermodynamic"[2]. Changes in polymer structure on a molecular or sub molecular level by a filler is termed as structural activity[2]; ability to change the viscoelastic and relaxation properties of polymer chains in contact with filler (i.e. chain mobility) is kinetic activity[2] and ability of filler to influence the phase state and thermodynamic parameters (enthalpy and entropy) important for filled "polymer blend" is termed as thermodynamic activity of filler[2]. "Influence of filler"[2] can be arbitrarily determined by relating the changes in properties per unit content of filler. In the above text we described the important physical and chemical factors of fillers and polymers, formation of molecular dimension zone and their influence on properties of polymer composite materials, now in the further text we shall discuss on the principles governing filler distribution and interaction within polymer composite materials.

Factors governing the organization of fillers within the polymer composite materials are related to physical and chemical nature of the fillers and the polymers, and further determine the performance and properties of the polymer composite materials. Through this mini review we attempt to discuss interactions and the factors governing them, within a polymer composite material, for readers to consider them during their next additive formulation of polymers with fillers. First of all it is the particle size distribution[3,4] of filler within the matrix, that depends on the surface availability and potential for interaction with the polymer matrix with respect to filler; with considerations for polymer – polarity, crystallinity and viscosity are the parameters; finally processing methods also determines the filler distribution within polymer matrix. Filler distribution in polymer matrix is subjected to "area of application", polymer composite materials intended to be used in electrical conduction, adhesive may decrease in performance if uniform distribution of fillers occurs in polymer matrix. Morphological analysis for distribution of filler in polymer matrix may appear identical but may differ in their properties, this may be

attributed to the molecular motions within the polymer matrix. The "intensity"[3] and "extensity"[3] factors should be considered to have a uniform distribution of filler within polymer, intensity factor i.e. reduction to the smallest particle size determining the property; and extensity factor i.e. uniform inter particle distance[3] determining the uniformity of the properties. Then comes the orientation of fillers in a polymer matrix. Particle shape and concentration of filler and viscosity of polymer matrix are the material factors determining the orientation of fillers in a polymer matrix[3]. Orientation of fillers within polymer matrix is also determined by the processing as distribution of fillers is. Processing factors like rate of flow, characteristics of die, residence time and mold characteristics[3] also effect orientation of fillers within polymer matrix. Orientation within polymer matrix can be induced by controlling the shear forces or by simultaneous shearing and electric fields[3]. "Area of application" also determines the best orientation of fillers within the polymer composite materials. Further comes important dimension in the polymer composites "Void", void if "macro" sized would reduce the mechanical performance of the polymer composites, hence void minimization is taken care of; in some applications "micro" voids are created to enhance the toughness of the polymer composite materials[3]. "Polymer – filler interaction" forms the basis of all set of experimental observation through any means of characterization as reported in past and current literatures. Physical interaction and chemical interaction within the polymer composites are responsible factor for "polymer – filler interaction". Chemical interaction between polymer functional groups and surface groups on fillers, physical interaction through Vander Wal forces and hydrogen bonding between polymer – polymer, polymer – filler and filler – filler, mechanical interlocking between polymer chains are responsible factors for "polymer – filler interaction"[3]. Ionic interactions, acid base interactions are other interactions responsible[3]. Changes in morphology of interacting components also confirms the "polymer – matrix interaction". Molecular dimension zones (interface and interphase) formed due to molecular transformation is a static phenomenon dependent on the concentration of fillers. These molecular transformation forms molecular dimension zones which have properties different from the bulk of the polymer and hence usually improves the material properties. Chemical interactions also play a role in organization of fillers within polymer matrix. Chemical interactions are chemical reactions occurring at the surface of filler and with filler surface. Interactions within polymer composites materials are complex and their quantification is difficult; however the structural characterizations e.g. FTIR, RAMAN, NMR and ESCA are used to determine the type of interactions i.e. physical or chemical, occurring within polymer composite materials[3,FR3]. All the factors governing filler distribution and interactions are inter – related to each other. Further interfacial adhesion and interphase thickness can be roughly estimated through tensile test. Filler chain links, polymer chain dynamics and bound polymer[3] are few experiments which may give an inference on organization of fillers within the polymer matrix.

Conclusions and Outlook

This mini review address, distribution and dispersion of fillers; and interactions between polymer and filler within polymer composite material. Physical and chemical properties of the polymers and fillers should be taken into consideration depending on the potential application. Processing techniques also is an important parameter to be considered. Specific and required level of distribution and dispersion of fillers within the polymer matrix plays a vital role in the final properties imparted to the polymer composite product.

Acknowledgement

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Advanced Agriculture Solutions Enabling Richer Harvests

By Ahmed Al Mehairi, Vice President, New Business Development, Borouge
Rakesh Pandya, Agriculture Marketing Manager, Borouge

Addressing global arable land scarcity by improving farming productivity

The way that we do farming is heavily dependent on the availability of arable land and water. Based on statistics from the United Nations (UN), the world's population will balloon by an additional 57 million people to reach 9 billion in 2050[1], a marked 6% increase from today. In tandem with this population growth is an accelerated urbanisation rate that decreases the availability of cultivable land. This trend will immensely affect India and China, which have 40% of the world's population, but only 7 – 9% of the world's arable land. These countries are already experiencing or will experience rising pressure to not just ensure, but also improve food security for their respective population. Agriculture is one of the main priorities of national governments concerned about food security. In light of arable land scarcity, farmers are all the more looking for innovative and sustainable solutions to increase farming productivity and to enhance crop yield.

The adverse effects of climate change on crop cultivation

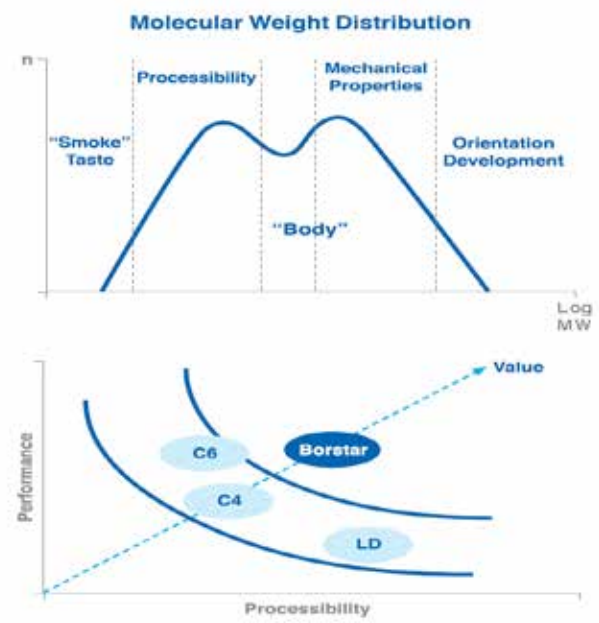
Currently, close to 80%[2] of global water resources are used for food production. With the world's population growth projected to surpass the availability of natural resources, and with the added challenge of adverse weather from climate changes severely affecting rainfall frequency and volume, growers must now find other ways to cultivate rainfed crops.

On top of requiring high volumes of water, conventional irrigation systems incur excessive water wastages through over-watering, excessive infiltration, run-off and evaporation. Consequently, only 40-50% of the water is effectively utilised. This is because current systems are open systems based on flood and furrow methods featuring a simple irrigation ditch channeling water from a well or river. These factors encouraged farmers in India and China to turn to more efficient irrigation methods, specifically sprinkler irrigation and drip irrigation. These modern techniques such as a drip irrigation system can not only attain around 100% conveyance efficiency, but also reduce water evaporation by a significant 50%.

Greater farming efficiency and crop yield with Borouge greenhouse solutions

Borouge is committed to overcoming the challenges of increasing food production through its innovative agriculture solutions that improve farming productivity and decrease water wastage. As an example, greenhouse films made of Borstar® FB2230 polyethylene possess a unique matt surface designed to increase light transmission and to minimise reflection, allowing optimal sunlight to enter the greenhouse. A natural 80% high haze diffuses sunlight that enters the greenhouse, distributing it evenly across the entire crop area for wider and higher coverage, improving both crop yield and quality.

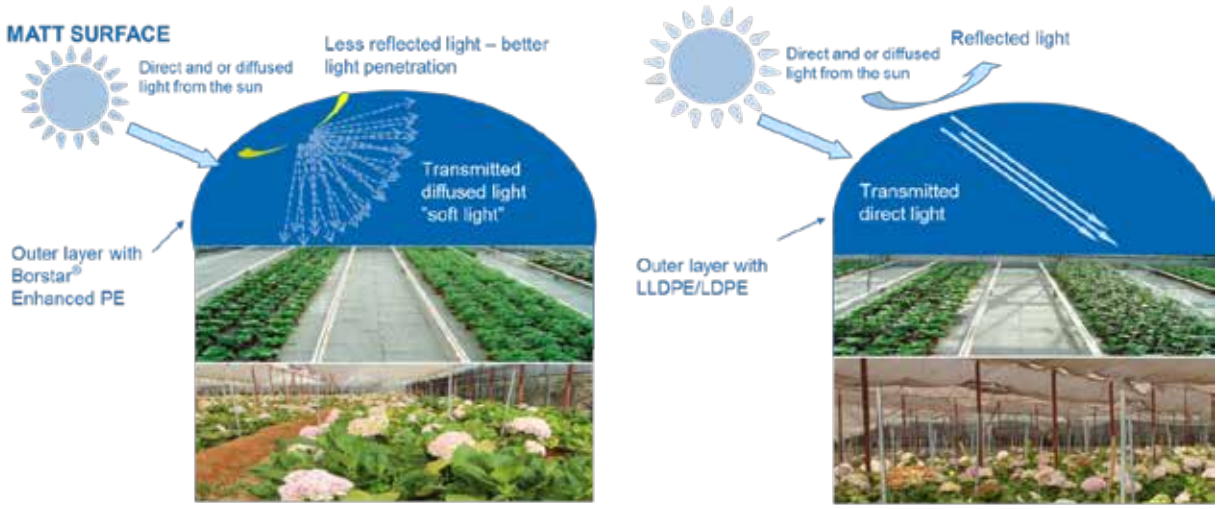
Borstar® Bimodal Technology



This is possible because the *Borstar*® technology is produced with a unique polymerisation process using multiple reactors that create a multimodal molecular weight distribution. This technology establishes a whole new level of performance in polyethylene, excellent for use in covers for growing crops such as greenhouses and small tunnels.

Leveraging on these, Borouge also works closely with partners across the value chain globally, on collaborative projects to develop best practices for the industry.

Light Transmission



Caption: To achieve the same level of diffused light transmission and haze as that of Borstar® films, non-Borstar® films would need 11-12% colour masterbatch (MB), resulting in extra cost of MB. A high percentage of MB tends to also deteriorate the quality of the film in terms of stress whitening characteristic and mechanical performance, possibly also impacting anti-dripping or anti-fogging.

Boosting rose yields from better light penetration

Inside a Borstar®-based greenhouse that provides diffused light optimal for crop yield and quality

A leading grower of roses and an expert in greenhouse construction, Shrihari Polyhouses Pvt Ltd has more than 25 years of experience in modern greenhouse, polyhouse, shade-net design and build in India and West Africa. In India, Shrihari has constructed more than 800 acres of greenhouses for farmers, corporations and the government sector. The company is known for adopting advanced agricultural technology and construction processes which are customised to the local environment and topography.

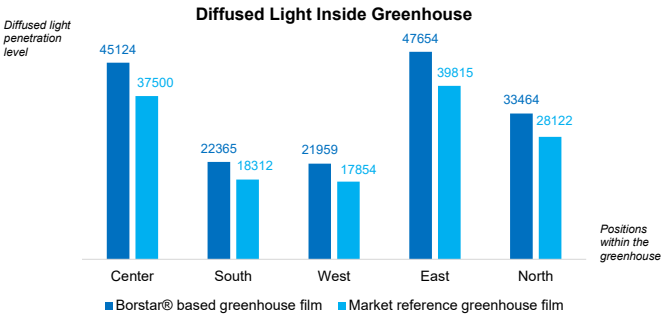
Globally, demand for roses is high during the festive period of November to mid-March. However, as these winter months tend to have less sunshine, greenhouses that use standard transparent films will have lower light penetration, and this insufficient sunlight affects the healthy growth of roses.

Borouge recommended Borstar® FB2230-based greenhouse films to Shrihari as an alternative, noting that these films have superior ability in transmitting high amounts of Photosynthetically Active Radiation/ PAR (the light that makes plants grow) through light scattering. They also have excellent mechanical properties providing strong protection for the crops. Borouge partnered Shrihari in a 3.5-year trial where we installed Borstar®-based greenhouse films in one of their greenhouses to test its performance as compared to standard transparent greenhouse films.

Results from the successful trial proved that Borstar® FB2230 film and its unique diffused surface provide the following benefits as compared to standard transparent greenhouse films:

- 18-22% higher average light penetration regardless of the crop's position within the greenhouse, even during winter months
- Increase in the number of roses at the node on each plant from 2-4 flowers with standard transparent greenhouse films to 4-7 flowers when Borstar® films were used, due to better light transmission inside Borstar® greenhouses
- 18-20% improvement in total yield of roses per one acre area coverage

The Shrihari Farm Manager also noted that Borstar®-based film enables more light penetration inside greenhouses, which allows him to achieve better crop growth and yield with quality produce. More light is especially important in the rainy season and during the winter period when demand for roses is high.



Light penetration measured by handheld Lux Meter from various positions within the greenhouse

Improving crop quality and yield even in the desert climate of UAE

Inside a Borstar®-based greenhouse, the diffused film enables higher cucumber yield.

As part of its roadmap to become the world's top ten food secured nations by year 2021, the UAE Ministry for Food Security has been actively encouraging commercial farms in the UAE to adopt innovative agriculture solutions to raise farming productivity, so as to produce even more food for local consumption as well as export.

In line with this national drive and focus on increasing food production, Al Dahra Agriculture, an Abu Dhabi-based leader in agribusiness and a major grower of vegetable crops, was keen to explore solutions that could help it increase its crop yield. As cucumbers are in high demand from consumers not just in UAE but also the Middle East, Al Dahra was particularly interested in producing more and better quality cucumbers.

UAE has an arid desert climate with low rainfall and high temperatures, especially during the dry and hot summer months. In Al Ain, a city in the Eastern Region of Abu Dhabi, mid-day temperature can reach as high as 50°C. Such harsh environmental conditions are adverse for the cultivation of commercial vegetable crops.

Borouge proposed to Al Dahra Agriculture, Borstar® FB2230 greenhouse film solution, which has superior mechanical performance and high Environmental Stress Cracking Resistance (ESCR) against wear and tear caused by scorching heat and strong sunshine. Borstar® FB2230 greenhouse film also has the ability to effectively transmit and distribute Photosynthetically Active Radiation (PAR) through diffused light scattering, promoting plant growth across the entire greenhouse and avoiding plant burn seen in crops grown with standard transparent greenhouse films.

We partnered Al Dahra in a 12-week trial where we installed a Borstar® FB2230 greenhouse film over two acres of cucumber crop, to compare the performance of Borstar® with another greenhouse covered by a standard transparent film.

Results from the successful trial proved that Borstar® FB2230 enabled the following improvements as compared to standard transparent greenhouse films:

- Higher cucumber crop yield by 16%
- 40% more buds and 73% more internodes contributing to higher crop yield. This is due to better light transmission and distribution inside Borstar®-based diffused light greenhouses
- Earlier harvesting by 2 weeks, translating into additional crop production and higher profits for Al Dahra Agriculture

All areas of the greenhouse using Borstar® FB2230 film also received an equal amount of sunlight, which is important for the growth of the cucumbers. The crops grew at a uniform rate and I needed less amount of pesticide. All these enabled more production cycles and yield.

Plasticulture-the solution for richer harvests

As evident in the above case studies, growers are adopting technologies such as controlled environment systems, greenhouse, mulching, and silage, which require large quantities of agricultural films. Across the agriculture value chain, stakeholders have also been putting in tremendous efforts to improve productivity of land by employing measures on water management that at the same time reduce carbon footprint resulting from agriculture.

The solution is a scientific way of cultivating crops through judicious use of plastics to improve productivity and optimise resources, thereby reducing overall costs, benefitting the farming community and beyond. Plasticulture, the practice of using plastic solutions in agriculture applications, is one of the key trends that will help improve food security in countries with fast urbanizing populations, and will significantly help address the global challenge of food security.

Greenhouse film properties impacting crop yield and quality	**Borstar®-based greenhouse solution**
Diffused Light (Long lasting diffusion)	Higher haze which is inherent properties of Borstar® LLDPE delivers permanent diffuse effect (close to 80% haze)
Possible negative impact on PAR light transmission while increasing haze to achieve higher diffusion	PAR transmission is equal or slightly higher than transparent or conventional diffused greenhouse film
Mechanical and Tear Strength Environmental or outdoor weather resistance	Higher Environmental Stress Cracking (ESCR) helps to increase weatherability
UV, Anti-drip and Anti-fog performance	Strong mechanical performance and good extrusion processability
Life span of minimum 3 years	Longer service life

A joint venture between ADNOC and Borealis, Borouge is a leading petrochemicals company that provides innovative plastics solutions for the energy, infrastructure, mobility, packaging, healthcare and agriculture industries. With 4.5 million tonnes of annual capacity, Borouge has the world's largest integrated polyolefin complex, with the ambition to more than double its current capacity by 2030.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Impossible, you might say.
Possible, we say

Possible because humans always strive eternally.
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To break new barriers
To conquer new challenges.
Which is Why, science changes things.
Which is Why, technology shapes tomorrow

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NSSPC is the first IATF 16949 compliant organization, having largest PP compounding facility in GCC region with installed capacity of 100,000 tons/pa.

In Sri Lanka, we along with Acteil Innovative Solutions (Pvt) Ltd started marketing our specialty PP compounds in 2019 and have been able to deliver value-based solutions to customers across the industries.

Few case studies are presented in this journal, for benefit of readers as per below:

NSSPC PP Specialty compound for Home Appliances, as a low cost substitution to Styrenics – ABS/HIPS:

PP compounds is widely considered as cost reduction solutions in appliances.

There have been many advances in the development of polypropylene compounds such as high gloss, rigidity and heat performance gained through new filler and polymer technology.

Flow and shrinkage analyses have now provided appliance designers with the freedom to use polypropylene compounds.

NSSPC offers solutions with products having good gloss, rigidity, hardness and balanced mechanical properties which can be used to replace styrenics mainly ABS, HIPS in appliances.

NSSPC PP Specialty compound for Electrical Industry to Substitution for Polyamide Compounds:

Electricity powers almost every aspect of our lives, at home and in our jobs, at work and at play and everywhere that we find electricity, we also find plastics.

In the kitchen, there are the labor-saving devices that we wouldn't be without; JMG, microwave ovens, kettles etc.

In the living room is the television, the video or the music system, while at work, we may use a computer, a fax machine or a telephone.

Plastics make progress possible, making electrical goods safer, lighter, more attractive, quieter. more environmentally friendly and more durable.

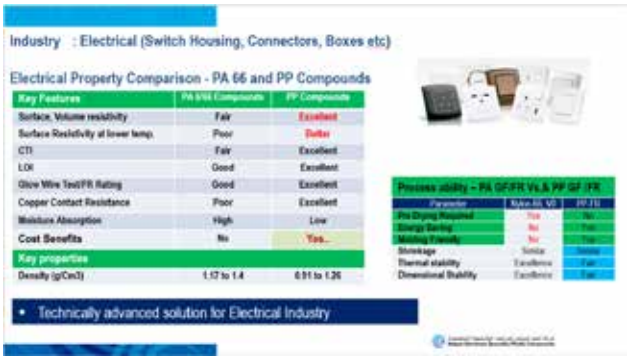
Plastics fall into two broad categories: thermoplastics such as polypropylene, which can be repeatedly melted down and remolded and thermosets such as urea formaldehyde which, once set, cannot be re-melted, making them suitable for applications where heat is encountered.

However, with advancement in design – to meet the safety as well as aesthetics, elegant looking needs of consumers, thermoplastics have found wider usage in this industry which otherwise was dominated with thermosetting plastics 10-15 years ago.

With changing needs, expectation from thermoplastics are much stiffer – supporting safety needs, environment friendly as well as design solutions.

To meet such requirements, NSSPC offers specialty PP compound for Electrical and Electronic application competing to Polyamide (Nylon 6 and 66) compounds with many advantages.

Polyflam range of PP – Flame retardant compound offers balanced properties, halogen free (environment friendly) and copper contact stabilization (to prevent the oxidation/ degradation of material when exposed to contact with copper). These unique property combinations along with cost-effectiveness attracts electrical industry to use PP compounds over conventional Halogen/Phosphorous base Nylon 6 and 66 compounds.



More details of these products and other offerings from NSSPC can be had from our business associate in Sri Lanka.

M/s Acteil Innovative Solution (PVT) LTD,
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Or you can visit our website www.natpetschulman.com

Challenges Faced by Occupational Safety and Health Managers in the Manufacturing Industry – Sri Lanka

By Shayan Appuhamy [B.Sc (Colombo), M.Sc (KL), MBA (UK)

Abstract

This write up is based on a case study design research conducted with a qualitative thematic analysis approach (purposive sampling with semi structured interviews) for the purpose of a master's thesis. Due to the word count limitations, only the key findings of the research are briefly mentioned.

This study was engaging with the challenges faced by the safety managers in the manufacturing industry. In Sri Lanka, there are no standards, guidelines or product standards for personal protective equipment. Due to the gaps in regulatory and legislative framework, safety managers are facing immense challenges in ensuring safety & health in their respective work environments. PPE is a critical element in OSH and this study was focused on PPE related challenges.

Despite regulatory gaps, there are organizations who are maintaining higher standards of occupational safety and health and winning 'national and international awards. Through a case study design with a qualitative approach, this study was focused on the challenges faced by safety managers as well as their initiatives to overcome those challenges.

It was evident during the research that there are challenges in establishing a system to select, source and use personal protective equipment due to the regulatory and legislative gaps. Also, it was evident that some safety managers were using very innovative ways to overcome those challenges.

With all the challenges faced by the safety managers, it is important for the government of Sri Lanka to establish a regulatory body, product standards and guidelines for personal protective equipment (PPE).

Key findings of the research

The study was focused on the challenges faced by safety managers as well as their initiatives to overcome those challenges.

Hence the study attempted to address following research questions,

- What are the challenges faced by safety managers due to the lack of regulations and guidelines for personal protective equipment?
- What are the initiatives made by safety managers in their respective organizations to overcome challenges faced due to lack of regulations and guidelines on personal protective equipment?

1. Procedure for hazard identification and risk assessment

Most safety managers were using their own system for hazard identification and risk assessment. It is identified that those systems are in two directions. Safety managers who are working for multinational companies are following their mother company/ head office provided guidelines in hazard identification. Other have developed guidelines locally (for their organizations) using published international guidelines.

Safety managers of the local companies had to prepare

Shayan Appuhamy [B.Sc (Colombo), M.Sc (KL), MBA (UK)

- Senior Manager at McLarens Lubricants Limited
- Visiting lecturer at Ministry of Industry & Commerce, CIDA, EFC & CIPM on Occupational Safety Subjects.
- Former Professional Services Engineer at 3M

guidelines by their own as they did not have locally published guidelines by the government authorities.

S9 mentioned that,

"*We have adopted US-OSHA guidelines. We made some changes to it so that it will suit both local conditions and food industry*"

S11 mentioned that,

"*We developed a local system using Canadian guidelines. It is in line with 5 step method and it is a very simplified guide*".

Also, S18 mentioned that,

"*We asses hazards through a team following a locally developed guideline. It is an internal process headed by safety manager*"

Safety managers who are working for multinational organizations are facing different challenges. Following are examples of the findings confirming use of the guidelines given by respective head offices which was the case in most multinational organizations.

S1 mentioned that,

"*We are using the guidelines provided by our US safety team, as there are no clear guidelines published by local authorities."*

Also, S7 mentioned that,

"*No guidelines in Sri Lanka hence we use our company guidelines provided by USA office*".

It was evident that some multinational companies had the support and compliance requirement from their head office to develop occupational safety and health through providing their guidelines.

2. Hazard control methods used by safety managers

OSHA guideline has become a universal guidelines for hazard control. During this study it was evident that safety managers of the sample were aware of the OSHA control methods.

S9 mentioned that,

"*Elimination is the key as we are in food industry. We buy everything in food grade. Even materials like a paints and organic solvents used in construction and maintenance work. Even our brackets in fire extinguishers are made of stainless steel. Even though there are no hazard control methods published by local government, we follow the best practices in the industry*".

It was evident that safety managers are having challenges due to lack of locally published guide lines.

S11 mentioned that,

"*As we are engineering company and having plenty of engineering staff, we focus more on engineering controls when it comes to hazard control techniques*".

It was evident that most safety managers were aware of the hierarchy of hazard controls techniques published by OSHA. And they were facing challenges in selecting the most effective method for their respective organization as there were no published guidelines locally.

Also, it was evident that some of the best control techniques such as elimination, substitution and engineering controls were difficult to introduce as it is very expensive to justify.

3. Method of identifying the requirement of personal protective equipment

Sri Lanka has no published guidelines related to identifying personal protective equipment. Having a guideline is utmost important as it covers the safety measures, justifications and requirement of such method. As per the findings most safety managers are depending on the supplier and workers on identifying the requirements of personal protective equipment.

S9 mentioned that,

"*Depending on the safety committee requirement we decide requirement of PPE. We do not have a procedure as OSHA – walk through survey. But once we understand the requirement of personal protective equipment, we request potential suppliers to recommend the correct equipment through a walk-through survey process*".

Also, S11 mentioned that,

"*We do not have a formal method to identify the requirement of personal protective equipment. But after the risk assessment, safety committee and workers get together and decide suitable personal protective equipment types*".

It is evident that most safety managers are depending on the gut feeling or workers ideas or supplier

recommendation to identify the requirement for personal protective equipment. The challenge in depending on the workers idea is that sometimes workers may not feel comfortable to wear personal protective equipment. Also, there will be a resistant to change if they are used to a certain working pattern.

4. Challenges faced when identifying suitable personal protective equipment

Once the personal protective equipment requirement is identified, the next responsibility of the safety manager to define the standards to select the right equipment. As there are no local product standards and guidelines, it is very challenging for safety managers to complete this task.

S11 mentioned that,

"We have a selection committee. Depending on the risk assessment we select suitable personal protective equipment. It is an informal method".

In this scenario, ideas of the committee which comprise of workers and other administrative staff are considered even if they do not have an in-depth knowledge on safety. This could lead to purchase of inferior quality products which will not provide adequate protection. This challenge is mainly faced by safety managers working for local organizations.

Some safety managers have taken important steps to avoid possible errors in selection of personal protective equipment due to the lack of product standards and guidelines.

S1 stated that,

"We have got the top management approval for international product standards when selecting personal protective equipment. And also we have developed the purchasing guide lines based on those US standards".

This is a very useful method used by safety managers to counter previously mentioned challenge.

5. Challenges in ensuring the standards of the purchased personal protective equipment

Once the personal protective equipment if identified, safety manager has the responsibility of sourcing the suitable safety equipment which will provide adequate protection. Lack of locally published product standards and a regulatory body was creating a challenging environment for safety managers in selecting or purchasing right personal protective equipment.

S1 mentioned that,

"*There are many counterfeited and duplicate personal protective equipment in the market. And sometimes there are factory-rejects flooding the local market as there is no regulatory body to control imports and production. Even when we are selecting we do not know whether those claimed products are really complying to standards. The local government should establish a licensing system*".

S12 mentioned that,

"*Lack of regulations on top of lack of products standards are making our job difficult. And on top of all this, government is not verifying whatever the personal protective equipment manufactured or imported*"

When selecting the product from the suppliers, they had no proper mechanism to verify the authenticity of the claim on product compliance and performances. Many safety managers had the experience of buying counterfeited products and duplicate products. As there is a decision-making unit involved in purchasing of personal protective equipment in most organizations, safety managers were sometimes pushed to select inferior quality products, since there was no proper mechanism to identify authenticity.

Despite these critical challenges some safety managers were using very effective methods to select right personal protective equipment.

S7 mentioned that,

"We have developed a purchasing policy stating the required standards for personal protective equipment even though government has not published standards. We register all PPE suppliers and purchase only from the registered suppliers who offer products with international standards. Also we sign warranty agreements with suppliers to avoid potential counterfeits and fake products".

Having such policies in place safety managers assure the receiving of personal protective equipment with international standards. This is a very effective mechanism to justify their proposals and to get the other department members to comply with the safety requirements.

6. Challenges facing during the justification of the proposal for personal protective equipment

Top management of most companies tends to consider safety as a cost rather than an investment. S4 mentioned that,

"Purchasing team always wants to reduce the cost hence try to purchase cheapest product. But we as the safety committee always try show the importance of comfort and performance of the respective personal protective equipment to justify the investment"

It is a very challenging situation for safety managers when there are no standards, and inferior quality products are compared against quality products. Also, it will not be a level field to justify certain costs. When the purchasing team is stressing on cost reduction and if the safety manager doesn't have strong backing to support justifying his investments it is always a very challenging situation for the safety manager.

To counter above challenging situation, some of the safety managers have taken very effective initiatives.

S14 mentioned that,

"When we have to introduce new personal protective equipment, once the product standard is selected, we always carry out sampling process. We issue samples to set of people including management and worker level, and we do not mention the price. We allow them to use those personal protective equipment samples for a while and collect their feedback and ask them to select the best product. In this method, they always select the product which provides them more comfort. As the product is selected by them, it is very difficult to challenge on the price perspective".

Most safety managers were using 'sampling method' to justify their investment on personal protective equipment.

7. Challenges faced during making the users compliance with the use of required personal protective equipment

Sometimes, even when a company is having proper policy, quality products and other resources available with regards to personal protective equipment, users tend to avoid wearing that equipment. It is a big challenge for the safety manager.

S18 mentioned the fact that,

"Union is sometimes not supporting certain occupational safety related initiatives. Especially when we introduce personal protective equipment, sometimes workers counter through union, by demanding unfeasible solutions. And when the union is involved, the top management too are not supportive as it could affect negatively on production".

It was evident during the research that unionization in manufacturing organizations, sometimes affecting negatively on occupational safety and health development.

To counter those challenges, some safety managers are using very innovative method to make workers compliance to the use of personal protective equipment. These initiatives are in two directions.

S11 mentioned the fact that,

"*We always create awareness on the importance of use of PPE. We use training materials such as videos to visualize the negative impacts of not using personal protective equipment*"

Also S14 mentioned the fact that,

"We create awareness on PPE and as most workers are having access to internet, we share web links and web sites so that they can watch and understand. Creating awareness is more effective than a penalty system"

It was evident in the research that an effective way of creating awareness among people was to get them visualize among people on the negative consequences of not using personal protective equipment. Some safety managers mentioned that they are using posters with 'safety messages' using family members of respective workers as characters. And they believe it is a very effective method to encourage workers to use personal protective equipment.

Also it was evident the fact that some set ups were using very effective penalty systems to encourage people to use personal protective equipment.

S7 mentioned the fact that,

"*We use a behavioral disciplinary procedure at our organization. It comprises of 5 steps and it is a tagging system which collects person wise records on unsafe behaviors. The 4th step is issuing a warning letter and last step is dismissal of the employment"*

It was evident that 'tagging system was a very effective

system and it makes the management also responsible to monitor the behaviors of workers. Tagging system could be a very useful technique in organizations where awareness creation takes time to change people.

S9 mentioned the fact that,

"We monitor workers through CCTV cameras on the compliance of personal protective equipment"

It was evident that some workers tend to comply with best practices when they are properly monitored or fine system in place. Depending on the work environment and working culture, safety managers should select suitable methods to encourage the use of personal protective equipment.

8. Challenges in establishing a management structure to control and provide personal protective equipment.

It was evident during the research that some safety managers are having a management structure to produce and share knowledge related to occupational safety.

S11 mentioned that,

"We do not have a proper mechanism to produce and share knowledge. People are too busy including safety managers"

Also S18 mentioned that,

"We do not have a system; we follow accident registry. We keep accident records to analyze history and take preventive actions for future"

It was evident due to the lack of regulatory mechanisms; safety managers were facing a challenge in developing a mechanism to produce and share knowledge which is a very important component in continues development of occupational safety and health.

S14 mentioned the fact that,

"We are learning through failure events of the other plants located in different countries. We share alerts which include root course analysis of the incident and required proactive measures".

It was evident that most multinational organizations were following this method to produce and share knowledge.

S9 mentioned the fact that,

"*Near missed and accidents are shred through picture format with the rout course analysis. We display each in the canteen area so that everyone notices it."*

It was evident in this research that use of visual effects to communicate occupational safety messages to be very effective.

9. Management challenge of responsibility and level of authority

It is a known leadership fact that, the managers should be given authority to hold their responsibilities in an organization. In a manufacturing set up, the organization is focused on production and KPIs are set on production efficiency, cost and over heads which in return on organizational P&L account performances.

S11 mentioned the fact that,

"Plan director's requirement is priority. Production comes first. Factories ordinance is also not properly updated"

It is evident that reporting line of the safety manager has a direct impact on his level of authority. If the safety manager is reporting to the managing director of the company, he is having adequate level of authority. But if it is not, safety manager is responsible for the overall safety of the organization but has no adequate level of authority to perform his or her duty.

S14 mentioned the fact that,

"All depends on the attitude of the top management. We always sit face to face with the top management and present our safety plan and objectives at the beginning of the year. And clarify all the doubts and agreeing for the commitments and expectations to develop safety and health of the employees".

It was evident that this initiative was very effective even if a safety manager faces a challenge in authority level.

10. Challenges in establishing a self-regulatory mechanism within the industry.

It was evident that, some safety managers were facing challenges during the effort of establishing a self-regulatory mechanism.

S11 mentioned the fact that,

"*We tried to develop a self-regulatory mechanism through our safety committee, but we failed as we couldn't keep the momentum of it. And we realize safety should be in the value system of the employees of an*

organization. We should have focused on behavioral safety".

It is important have resources and support to establish and sustain a self-regulatory mechanism to improve safety within the organization.

S18 mentioned the fact that,

"We conduct monthly meetings with safety committee with presence of top management to continue assurance of safe working environment"

It is evident that periodic meetings with the safety committee can assure the sustainability of the self-regulatory mechanism model.

4.1.11. Challenges in finding qualified professionals for the safety team

During the research, it was evident that, safety managers are facing difficulties in finding qualified people for their safety teams despite the presence of many organizations offering OSH study courses.

S13 mentioned the fact that,

"There is a knowledge gap in different safety managers. There is no uniformity in the educational structure. In other countries, safety manager is a very important role and government has strict mechanisms to ensure the competency and knowledge of safety managers. Available study courses in Sri Lanka are not enough to build really competent safety officers. All diplomas and study courses should be controlled and monitored by the government and should issue a licensing system for safety officers just like in developed countries".

Also S1 mentioned the fact that,

"Lack of grading system for occupational safety and health competency levels is a challenge and it should be fulfilled by the government".

It was evident during the study that the requirement of standardizing occupational safety education in Sri Lanka. There is a problem with finding right talent and required competencies.

S9 mentioned the fact that,

"We select people who have relatively higher education level within departments and absorb them to the safety committee and educate them and train them to become competent safety officers".

Also, S11 mentioned the fact that,

"We have adequate resources to train and develop competent safety officers within the organization"

Even some organizations had the other resources, they were lacking people with the right attitude to join occupational safety.

S14 mentioned the fact that,

"Occupational safety is a practical subject. Safety officers should know the grass root level of this subject. Safety officers produced from local institutes may be knowledgeable but not competent. It is very difficult to find a person with the right attitude. Everyone wants to become safety managers, not safety officers. Safety officer should be a role model. They should try to do the work by themselves rather than passing orders. Should have the right attitude to learn practicality of this subject. A fresh graduate who becomes a safety manager will not be able to perform a good job unless they have the right attitude to learn the grass root level"

It was evident that safety is a practical subject and has to have very strong educational methods to produce qualified safety managers. And it was evident that, current educational system is having gaps in producing quality safety officers.

Rubber technology is nothing but art and science when thought process comes to shape rubber into some parts/ article (Substrate) through injection, compression and transfer molding. Traditionally objective was to release parts from molds applying ever round/ every cure otherwise substrate would become fused to the mold.

Hence, Release agent provide the chemically critical barrier between a molding surface and the substrate, facilitating separation of the cured part from the mold make operators job easy and avoids sticking to mold resulting loss in production efficiency and increase in scrap.

Before a decade most of users were preferring to adopt traditional approach of solvent base Releasing agent or sacrificial release agent with a approach of avoiding fusing of substrate with mold surface.

Upgraded technology with environment friendly requirement from users in the industry, water base release agent either sacrificial, semi permanent has been evolved with a view of reducing solvent in usage as well as by considering impact on safety wherein factories have sophisticated nature of working, awareness on hazardous chemicals which have been ban by local authorities etc.

With the nature of rubber compounds, when a release agent is used, factors such as irregular applications or improper release agent choice may have a dramatic effect on the quality and consistency of the finished product.

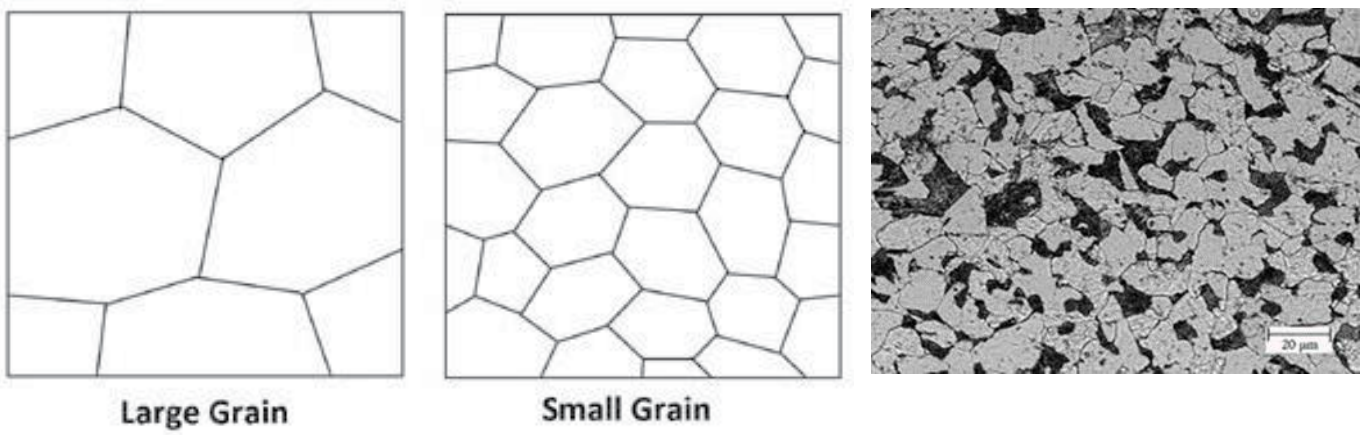
Applications of semi-permanent mold release vary from every cycle to once daily applications depending on the compound being molded and the design, surface of mold and quality of the mold.

Importance of usage of mold release is due to Mold surface which have imperfections due to :

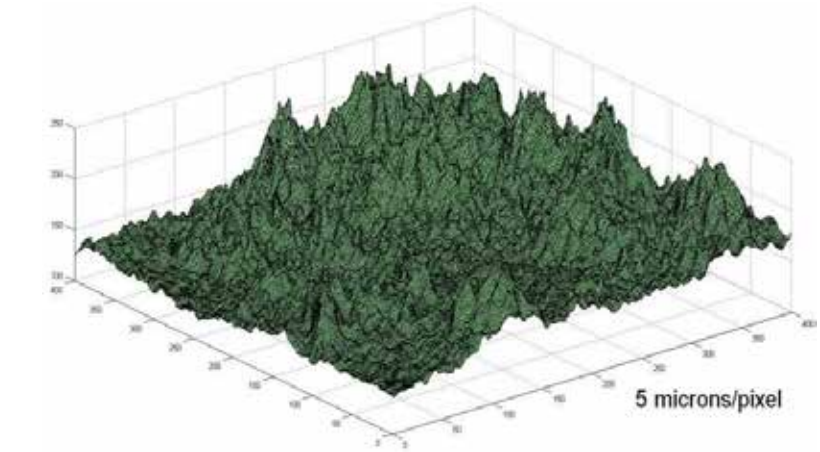
1. The grain structure as a result of Metal forming, casting and Heat treating

2. Cleaning Methods- Such as sand blasting

All these peaks and valley can fill with rubber causing parts to stick and residue to build on mold.



Computer generated 3D Image of surface roughness



All these peaks and valley can fill with rubber causing parts to stick and residue to build on mold.

PURPOSE OF MOLD RELEASE

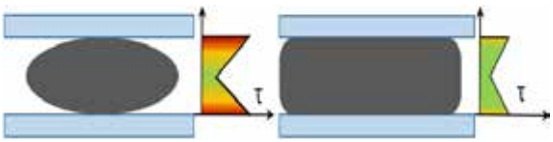
1. Help fill crevasses
2. Form a thin film barrier to reduce mold fouling
3. Add lubrication for part release and rubber flow

Apply to hot mold surface

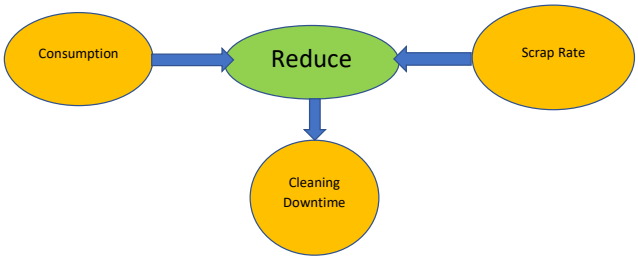
Reactive polymer forms a chemical bond to the surface

Hard, protective layer when cured

4. Increases Rubber flow due to reducing Shear stress while dragging rubber in mold.



A right selection of Mold releases helps to



Benefits of Franklynn DiamondKote Release Agents are

- Semi-permanent – Get more molding cycles per application
- Water based – Safe for both the operators and the environment
- Non-flammable – Contains no flammable liquids or solvents
- Odor free
- APE free – Does not contain Alky Phenol Ethoxylates
- Uniform appearance – Consistent tire appearance every cycle
- Minimal transfer for a non-greasy feel
- Reduced mold fouling
- Increase productivity and profitability
- Meeting customer specific needs

Non-marking solid tires with graphene nanotubes: high mechanical strength and conductivity in compliance with international standards

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Abstract

New safety regulations related to electrostatic protection are being developed to keep pace with the increasing automation of industrial facilities and the growing automotive industry. Single wall carbon nanotubes (SWCNTs) were studied as a prospective additive to improve electrical conductive properties of rubber compounds used for non-marking anti-static solid tires. A ready-to-use masterbatch containing primary SWCNTs dispersed in a polymer-based carrier was used. The study was conducted with a standard non-marking solid tire NR/BR-based formulation filled with mineral filler by introducing the SWCNT-based masterbatch at different stages in the production sequence to see which would achieve the best performance. Another anti-static additive widely used in industrial applications was used as a reference to define the performance differences. The main finding of the study is that 0.22 wt.% of SWCNTs in a rubber compound can maintain tensile properties before and after heat aging, improve tear resistance, and provide electrical onductivity at the required anti-static level, without a negative influence on other properties, while also retaining the color and the non-marking effect.

Introduction

There are number of standards related to regulations on tires in the field of electrical properties – International Standard ISO 16392 Electrical Resistance — Test Methods to Measure the Electrical Resistance of Tyres on a Test Rig, Wirtschaftsverband der deutschen Kautschukindustrie e.V. (W.d.K) 110 Measurement of the Electrical Resistance of Tyres, ASTM F 1971 – Standard Test Method for Electrical Resistance of Tires Under Load On the Test Bench, etc. These requirements regulate and ensure ESD protection to remove static electricity from the surface of a tire when it occurs at high speed and to prevent its accumulation in the long run. In some application areas, a normal tires that are required to be anti-static are considered to be capable of safely dissipating electrical charge if the resistance measured does not exceed 1010 Ω But there are a number of specific cases, such as when the tire used in potentially explosive areas, that are strictly regulated by the ATEX Products Directive 2014/34/EU and EN 1755 – Industrial trucks – safety requirements and verification – Supplementary requirements for operation in potentially explosive atmospheres. According to EN 1755, the outer material of castors and wheels should have a maximum surface resistance of 109 Ω It is a well-known fact that most tire formulations contain carbon black and can easily achieve the requirements for being anti-static, but this is not the case with non-marking solid tires. The current article is dedicated to the study of using graphene nanotubes (also referred as single wall carbon nanotubes) as an alternative solution to provide the required conductive properties as well as maintain color and basic formulation properties of non-marking solid tires. It has been acknowledged by both scientists and manufacturer communities that graphene nanotubes are one of the most advanced additives for improving almost all materials used in our daily life. When applied in rubber compounds, they enhance mechanical performance while also imparting conductivity. The key to achieving this previously unobtainable combination of properties is graphene nanotubes' extremely low working dosage.

Conductive additives: balancing of consistent conductivity with mechanical performance Various types of inorganic nanofillers has proven to be an efficient way to enhance the mechanical and electrical properties of rubbers. Carbon black and silica are widely used in commercially produced rubbers, including rubbers for tires.

It is well known that the shape of the nanofiller affects the critical concentration required to create a connected network of filler (the percolation threshold): the higher the aspect ratio of the nanoparticle, the lower the percolation threshold. That is why using 2D and 1D carbon nanofillers (i.e. graphene sheets and carbon nanotubes) in rubbers has attracted the attention of numerous research groups in academic institutions and in industrial companies. Single wall carbon nanotubes (SWCNTs) are characterized by the smallest possible diameter of less than 2 nm and are of particular interest [3].

One fairly new conductive additive that has recently entered the polymer market is multi wall carbon nanotubes (MWCNTs). However, MWCNTs are not able to fully meet manufacturers' needs for stable levels of conductivity and easier compounding, as well as for suitable mechanical properties and softness requirements. To be effective in the host material, the required concentration of thick and short MWCNTs is tens or even hundreds of times higher than that of long and thin SWCNTs.

Despite the similarity in names, multi wall carbon nanotubes and single wall carbon nanotubes – two allotropes of carbon – have hardly anything in common, and thus they impart a number of very different properties. While MWCNTs feature many tubes with decreasing diameter that are coiled inside each other, SWCNTs can be thought of as an extremely thin rolled up sheet of graphene, and thus they are widely referred to as graphene nanotubes. Being an excellent conductor similar to copper and 100 times stronger than steel, graphene nanotubes gain traction starting from a loading of just 0.01%. Even such an ultra-low concentration is enough to enable conductivity without a negative effect on the material's mechanical properties or viscosity.

Currently, graphene nanotubes are the most innovative additive that facilitates efficiency, durability, and affordability in solid tires, particularly for colored or non-marking applications where anti-static or conductive properties are required for tires to dissipate the static charge.

To impart conductive properties to white filler-based rubbers, conductive fillers need to be added during the compounding process. There are not many additives which can reach the desired level of electrical conductivity without affecting the color. Depending on the particular application, it could be copper powder, silver- and nickel-coated graphite, copper or aluminum – while these do provide the required conductive properties, adding them also leads to a number of negative trade-offs in flexibility, elasticity and high price.

For conventional polymer-based additives which are more commonly used due to their low price, the high working dosages required result in a number of drawbacks in the rubber's mechanical properties and a reduced cycle life of the final products. These shortcomings severely restrict the potential range of non-marking solid tire applications. Furthermore, conventional polymer-based additives are normally humidity-dependent and subject to migration, so the rubber's properties are not stable because of migration of the additive to the surface and release during the cycle life.

Historically, there have been several technical barriers that have prevented the mass application of graphene nanotubes in various industries, including elastomers. The main challenge was related to the difficulty in achieving uniform and homogeneous dispersion of nanotubes in the material matrix and in preventing further agglomeration. However, recent materials technology advances have enabled easy-handling nanotube concentrates that are compatible with industry-standard formulations and manufacturing processes, without requiring any specific changes or additional tools.

This article investigates the effect of graphene nanotubes on the electrical and mechanical properties of a non-marking solid tire compound in comparison with a conventional commercially available additive that is widely used in industrial applications to implement electrical conductive properties to rubber compounds without discoloration.

Experimental part

Materials

The current study investigates rubber mixtures based on a standard solid tire formulation – a blend of NR/BR and mineral filler (silica). Commercially available TUBALL™ graphene nanotubes (OCSiAl), with a diameter of 1.6±0.4 nm, were used. The Raman spectroscopy (532 nm laser) G/D ratio peaks varied in the range 70–100, indicating a very low concentration of defects. The type of TUBALL™ applied contains 14–15% of catalyst impurities (metallic iron and iron carbides), which are covered by graphite-like shells. The contents of nanotubes in the material is above 85% by weight (on a dry basis). The TEM micrographs in Figure 1 show that the untreated nanotubes form the entangled mesh of bundles with thickness varying from 10 to 50 nm [4].

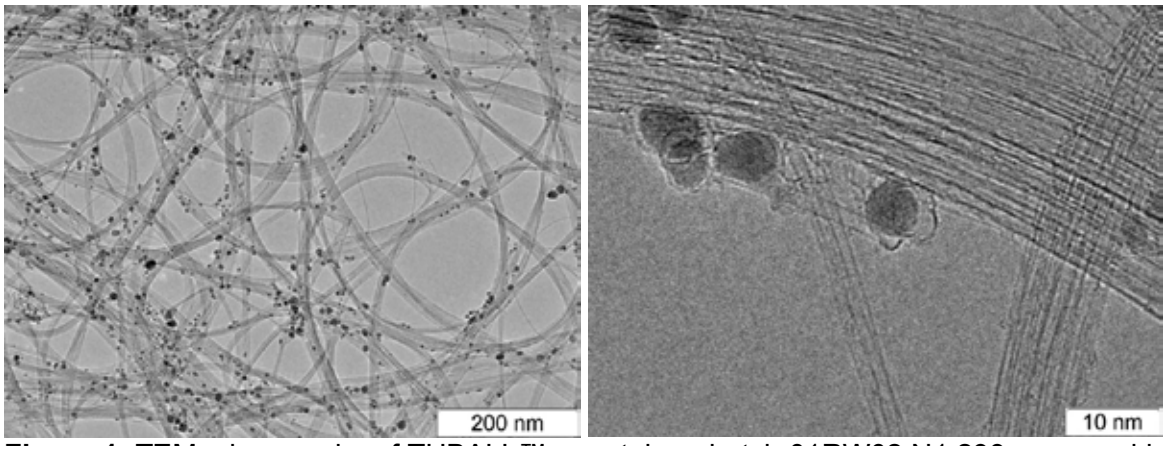

Figure 1. TEM micrographs of TUBALL™ nanotubes; batch 01RW02.N1.299 was used in the study.

Dispersing the graphene nanotubes requires the bundles to be split. Therefore TUBALL™ MATRIX 618 beta, a predispersed concentrate containing 10% of nanotubes in an ether-based plasticizer [5], was used in this study. As an additional comparison, a commercially available anti-static plasticizer based on fatty alkyl ether of polyethylene glycol, Rhenosin® RC 200 (LANXESS Deutschland GmbH), was used.

Formulation and mixing

A Banbury 1.6L internal mixer and a two-roll rubber mill (10 inch roll diameter) were used for compounding

Several ways of introducing the TUBALL™ MATRIX 618 beta were tested: at the 1st stage together with the second part of filler; at the 2nd stage into the internal mixer; into the two-roll mill together with curing agents after compounding at internal mixer. The best performance was achieved with the latter two mixing options – introducing the TUBALL™ MATRIX 618 beta into the two-roll mill at the end of compounding, and into internal mixer at the end of the mixing stage.

Testing procedures and data

Electrical properties were tested by the four-point method according to ASTM D991 and ASTM D257. Mechanical properties were studied according to ASTM

Table 1. Examples of the recipes of rubber compounds.

Composition and feeding stages			Reference compound	6.9 wt.% RC 200	2 wt.% TUBALL™ MATRIX 618 beta
Feeding stage	Raw material	Brand	phr	phr	phr
Stage 1	Natural rubber	CV 60	85.0	85.0	85.0
	Butadiene rubber	BR9000	15.0	15.0	15.0
	Naphthenic oil	KN4010	5.0	5.0	5.0
	Silica	Z-155	50.0	50.0	50.0
	Silane TESPT	SI-69	4.0	4.0	4.0
	Stearic acid	SA1801	2.0	2.0	2.0
	Zinc oxide	Active ZnO	5.0	5.0	5.0
Stage 2	Plasticizer	RC 200		12.5	–
	Sulfur	S-80	1.0	1.0	1.0
	TBzTD		0.5	0.5	0.5
	CBS		2.0	2.0	2.0
	TUBALL™ MATRIX 618 beta				3.9
Total, phr			169.5	182.0	173.4

standards D412, D624, D5963 and D2240. Heat aging was performed according to ASTM D573 (5 days, at 85°C).

Results

Electrical resistivity

Electrical resistivity measurement results are shown in Table 2. Before testing the resistivity, the surface of the unaged samples was treated with ethanol to remove the plasticizer which could bleed out to surface.

Table 2. Electrical resistivity of the compounds.

Sample	ASTM D 991		ASTM D 257		Surface resistivity meter
	Volume resistivity, Ω·cm	Deviation	Volume resistivity, Ω·cm	Deviation	Resistivity, Ω/sq
Before heat aging					
Reference compound	R out of range (too high)	–	1×10^{14}	4×10^{10}	10^{13}
RC 200	R out of range (too high)	–	2×10^{11}	3×10^{10}	10^{10}
TUBALL™ MATRIX 618 beta	**2×10^{2}**	1×10^{1}	**R out of range (too low)**	–	**10^{6}**
After heat aging (non treated sample)					
RC 200	R out of range (too high)	–	1×10^{12}	7×10^{10}	10^{13}
TUBALL™ MATRIX 618 beta	**5×10^{2}**	3×10^{2}	**R out of range (too low)**	–	**10^{6}**
After heat aging (sample surface treated with ethanol)					
RC 200	R out of range (too high)	–	1×10^{12}	7×10^{10}	10^{13}
TUBALL™ MATRIX 618 beta	**4×10^{3}**	2×10^{2}	**4×10^{7}**	**3×10^{7}**	**10^{7}**
Electrical resistivity (four-probe method) – ASTM D 991					
Electrical resistivity (two-probe method) – ASTM D 257					
Heat aging – ASTM D573					

It was noticed that all samples containing Rhenosin® RC 200 had oil bleeding onto the surface after curing and heat aging. This probably occurred due to the high dosage of material (6.9% used, with the recommended maximum according to the technical datasheet being 10%).

Figure 1. A sample of rubber containing TUBALL™ MATRIX 618 beta having its volume resistivity measured according to ASTM D257.

Mechanical properties

Tensile and tear properties are shown in Table 3.

The mixtures, containing 0.22 wt.% graphene nanotubes (2.2 wt.% TUBALL™ MATRIX 618 beta), were prepared by the mixing sequences as briefly mentioned above. The current study found that the best performance was obtained when the nanotube concentrate was introduced at the 2nd stage into the internal mixer.

Table 3. Mechanical properties of the compounds.

Sample	M50, MPa	M100, MPa	M200, MPa	M300, MPa	M500, MPa	Tensile strength, MPa	Elongation at break, %	Tear strength, kN/m
Before heat aging								
Reference compound	1.0	1.9	5.1	10.1	21.3	22.1	502	44.7
RC 200	0.9	1.5	3.8	7.3	17.0	21.0	571	52.2
TUBALL™ MATRIX 618 beta	1.5	2.2	4.7	8.7	19.0	19.9	516	49.2
After heat aging								
RC 200	0.8	1.4	3.4	6.5	14.7	15.6	521	24.8
TUBALL™ MATRIX 618 beta	1.5	2.4	5.0	9.0	–	15.7	446	30.6
Tensile parameters – ASTM D412								
Tear parameters – ASTM D624								
Heat aging – ASTM D573								

It should be noted that, despite the tensile strength remaining unchanged with either additive, at small deformations graphene nanotubes increase the moduli at 50% and 100% and RC 200 has the opposite effect. At higher elongations, nanotubes showed slightly better results compared with RC 200, probably due to higher plasticizer content in the samples containing RC 200, which is evident on elongation data. Both of the additives have a positive effect on the tear strength of unaged samples.

After heat aging, a reinforcement effect from graphene nanotubes and a strong degradation effect on tensile modulus from RC 200 was evident (a performance difference ranging from 87% to 38% for M50–M300). Tear strength was maintained to at least 20% more with TUBALL™ MATRIX 618 beta than with RC 200.

Conclusions

This study has shown that even a minor amount (0.22 wt.%) of TUBALL™ graphene nanotubes can strongly increase electrical conductivity without the negative effects on mechanical properties which normally occurs with conventional conductive fillers. The effect on electrical conductive properties of 6.9 wt.% of the anti-static plasticizer is negligible and can not meet the requirements for dissipative tire properties. Higher dosages of plasticizer would result in an even worse effect on mechanical properties.

Introduction of 2.2 wt.% of TUBALL™ MATRIX 618 beta into a standard NR/BR and silica-filled solid tire formulation improves the moduli of the rubber, increases its tear strength and improves the stability of properties after heat aging compared with a conventional anti-static additive used as a reference.

Good dispersion and distribution of graphene nanotubes in rubber is crucial for achieving the desired enhancement. For two-stage, internal-mixer rubber compounding, introducing the TUBALL™ MATRIX 618 beta at the 2nd mixing stage was found to be optimal to achieve the targeted resistivity level and the best balance of mechanical improvements.

Adding the properly dispersed graphene nanotubes in TUBALL™ MATRIX 618 beta into rubber material provides consistent electrical conductive properties without migration of carrier onto the surface and that remain stable after heat aging. The low required dosage of the graphene nanotubes allows the color of the rubber to be maintained, without any carbon release, which is crucial for non-marking solid tires.

References

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Innovation in Polyethylene Pipes for water transport, recycle and reuse

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According to data from the World Bank, India's 2015 population stands at 1.29 billion. This forms 17.2% of the world population at a growing rate of almost 1.8% p.a according to the World Development Report, with India predicted to overtake China as the worlds most populous country by 2025.

The continued rapid growth of India's population will significantly impact its economy and urban resources, especially with regard to water and sanitation. Today, an estimated 600 million Indians have no access to modern sanitation, and only a fifth of the country's collected sewage is treated. A study conducted by the Water and Sanitation program (2006) showed that the annual economic impact of inadequate sanitation in India amounted to an estimated USD 53.8 billion.

The running water supply of most Indian cities with populations exceeding 1 million is highly intermittent and under very low pressures due to the shortage of treated water and high water losses within underground pipe systems. Water supply planning, operations and maintenance operations are also not managed by a central authority, leading to low financial investments and a strong dependence on low capital subsidies from state governments.

The water scarcity is further aggravated by the huge amount of water needed for irrigation for production of foodgrains and vegetables to feed the huge population.

Therefore innovations are needed to mitigate the following issues :

- ✓ Reduction of leakages in the existing water networks and implementing use of leak proof, long life piping materials in new networks.
- ✓ Use efficient piping materials in sewage networks which are easy to install, join and tested for lifetime service with low maintenance.
- ✓ Efficient systems for rainwater harvesting and charging of ground water.
- ✓ Use of large diameter pressure pipes instead of open channel transportation of water and protecting them from corrosion

Borouge with its vision of "value creation thro' innovation" is continuously working in this direction, innovating new materials and promoting them to end users.

Best practices - materials and technology selection for drinking water networks

If we look at the water distribution systems it is clear that plastics and in particular polyethylene (PE) pipe systems provide the lowest cost and most durable system. PE pipes are being used for most critical Gas distribution networks since late 60's in UK and since early 70's in

Chanchal Dasgupta

A Chemical Engineer from Jadavpur University, Calcutta, Chanchal started his career at Indian Petrochemicals Corporation Limited, the first mega Petrochemicals Company in India, in Tech service and Application development for Polyolefins. He worked in IPCL for 14 years.

For past 19 years, he is working for Borouge for market development of Borstar PE grades for specialty applications. Borouge is a joint venture of Abu Dhabi National Oil co (UAE) and Borealis (Austria) with nameplate capacity of 4.5 Million TPA of Polyethylene and polypropylene.

Currently, as Application Marketing Manager (Pipe) he is in charge of marketing of Borouge PE and PP pipe products in Indian subcontinent. He leads the market development for Steel Pipe coating for whole Borouge territory. He is the winner of Borouge innovation award on 4 occasions and have 3 application patents.

India and have proved its reliability if quality materials and high standards are adopted. However, the question comes in the mind that if the same HDPE PE100/PE80 pipes are working so well for gas distribution for so many years, why do we often see failure of water pipes ?

The underlying reasons are that while for gas pipes in India pre compounded materials are specified following international standard ISO4437, for water, pipes made from a physical blend of of natural PE + carbon black masterbatch are allowed. Also the Indian standard for PE pipes is much more lenient compared to International standard ISO4427, which allows non standard material pass the requirements of standard.

In Europe over 70% of all new water mains are made of polyethylene material with the increasing use of PE100 compounds. In India also most of the 24X7 projects currently are using PE100 black HDPE and fittings pipes for network and house service connections to reduce the Unaccounted for Water (UFW) from over 40% to less than 5%. Malkapur in Maharashtra is an example of first 24X7 water supply in rural India where this has been demonstrated for past 10 years. The project has used pipes made from Precompound black PE100, Electrofusion fittings, Bentley's wáter network tool and many other best practices in the first 24X7 project in a village.

Fig. 1. Installation of PE100 pipes in progress at Malkapur

It is also heartening to note that the state of Andhra Pradesh, which had banned HDPE as a brittle material in early 80's due to widespread failure owing to poor quality material has over past 3 years executed the largest ever water supply project in India – Bhagiratha Project or Telengana state Water grid, where PE has been used for the distribution network. Over 50% of the HDPE pipes used in the project are made of precompounded black PE100. Hence having a strong specification in place and using high quality compounded PE materials can certainly bring in the reliability of gas pipe network in water distribution network also.

This preference for PE in water distribution is primarily due to the material's high resistance to corrosion, its flexibility and the ability to weld sections together to make a continuous "leak free" pipeline with joints always stronger than the pipe. These characteristics enable PE pipes to be pulled through old leaking iron pipes to renovate them without having to dig up the street or for new systems to be installed by ploughing or directional drilling. These "No Dig" techniques significantly reduce the installation cost of the system. As the installation cost is significantly higher than the pipe and fitting cost and as most of these techniques can only be used with PE, it becomes the automatic choice on the basis of "Whole Life Costs". Nagpur is an example of first full city 24X7 water project on PPP basis, where compounded black PE100 pipes have been used for open cut as well as many HDD installations by Veolia Water and Orange City for a 25-year operation and maintenance contract. Subsequently Veolia also followed the same practices in 24X7 water distribution projects in Hubli-Dharwad, Bijapur, Ilkal and parts of Delhi, the National Capital.

The toughness of the material also enables the welded PE pipes to withstand the stresses due to ground movements which arise due to seasonal weather patterns and even the more severe ground movements due to earthquakes. This was clearly demonstrated by the Osaka Gas investigation following the "Great Earthquake of Kobe" in Japan in 1995 where many failures were observed in their iron and steel networks but none in their PE systems.

The development of PE pipes are taking place since 1955. From HDPE PE63 and PE80, MDPE PE80, HDPE PE100 and PE100+, the latest innovation is HSCR (high stress crack resistant) PE100. These materials have 5 to

Fig. 2. Installation of PE100 pipes by HDD technique at Nagpur Veolia project

10 times resistance to slow crack growth compared to a good PE100. Therefore they can provide 50-100 years lifetime despite notches and scratches imparted on them during tough installation techniques like horizontal directional drilling, pipe bursting etc.

To have a long maintenance free service life, it is a must to specify a precompounded material and follow an international standard like ISO 4427 for raw material, pipe and fittings. The welding and installation practices should also follow international standards.

Modern plastic systems replace concrete and asbestos cement sewerage systems

The continued urbanization throughout many parts of India places increasing demands on the infrastructure, including the buried sewage systems many of which are already old and in poor condition. Failures in the sewage systems can be extremely distressing to any community as these pipelines are vital in separating waste materials from fresh water which protects us all from many diseases. Failures are also extremely expensive to repair or replace as they are usually large diameter and deeply buried – the construction costs being many times the cost of the new pipes and fittings. Therefore it is very important to select systems that are going to provide a very long operational life without requiring maintenance.

Moreover the new plastic pipe systems are much lighter in weight. Typically a 12 meter PP double wall corrugated pipe length of 600 mm diameter will be 75% lower in weight compared to a 3 meter RCC pipe of same diameter. In addition, the pipe systems are lightweight, need a lower number of joints and are much faster and easier to install which will reduce the costs of construction, cut the installation time to half and reduce the hiring charges for heavy equipment. The lower level of disruption from using a light weight system will also have a lower impact on the environment and the lives of the local community.

One of their major concerns is the corrosion and erosion of concrete and asbestos cement sewage pipes due to the action of sulphuric acid developed inside the sewers. Corrosion occurs due to the formation of sulphuric acid (H_2SO_4) on the pipe wall from the oxidation of hydrogen sulphide (H_2S) in the atmosphere inside the sewer pipe. While metals are fully susceptible to Sulphuric acid, Polyethylene and Polypropylene pipes have hardly any impact.

In the 1990's there was an important project carried out in Virginia, South Africa which provided considerable insight into the performance of different sewer pipe materials under these conditions. They investigated the corrosion rates for nine different pipe materials in a section of 900mm diameter gravity sewer linking the town's main sewage pumping station and the treatment works over a five year period. After 5 years in operation the pipes were thoroughly examined and the polyethylene pipes and the concrete pipes lined with polyethylene were in the best condition followed in order by coated asbestos cement, uncoated asbestos cement, uncoated high alumina cement and the uncoated Portland cement sections.

For flexible plastic pipes, as the traffic load or ground loading from buildings and construction are transmitted

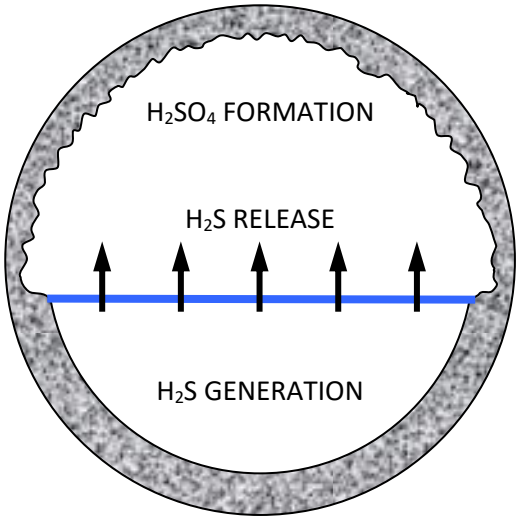

Fig. 3. Corrosion mechanism for concrete and asbestos cement pipes

A. Goynes 2005

Fig. 4. Installation of PP DWC waste water pipes at the chemical park in China.

by the soil to the pipe the plastic pipe will slowly deform. As it deforms it transfers the load to the soil surrounding the pipe, until the pipe and the soil are in equilibrium and the load has been redistributed. Therefore the stresses in the pipe wall are much lower and can easily be sustained by the pipe without any damage or further deformation. However a rigid pipe cannot deform and the stress just builds up until the pipe cracks and eventually the sewer collapses. This process will be accelerated in concrete sewers by any erosion that takes place inside the crown of the pipe due to the build up of acid in the sewer.

The smooth bore of Double wall corrugated pipes also mean lower friction and less chance of blockages in the system. As the material surface does not corrode or deteriorate with time this low coefficient of friction is maintained through the life of the system.

Double wall corrugated pipes are made both from PE and PP. However High Modulus PP grades have 50% higher stiffness than HDPE which is the most important property for sewage pipes. At the same time PP has extremely high ESCR, whereas HDPE loses it ESCR property as the stiffness goes up. Therefore High modulus PP DWC pipes are the optimum choice for modern sewage systems.

Stormwater boxes - a solution for climate change impact on water management

Due to the combination of climate change impact, resulting in many regions of the world having a heavier and unpredictable rainfall, together with increased urbanization, the possibility for lower natural infiltration of the water into the soil has created a real challenge for storm water management systems. Forecast scenarios for both the short- and long-term future are also indicating that these trends will continue to develop.

The plastic pipe industry has successfully faced this challenge over the last few years, through the development and use of "rainwater boxes" or "infiltration boxes", mainly made from polypropylene. These boxes are designed to create a buffer below ground for temporary storage of this excessive water.

The products are intended to be installed for long periods, up to 50 years and are subject to specific constraints that are somewhat different from pipes .To ensure the long-term structural integrity and fitness for purpose of the installed boxes, the proper combination of material properties and manufacturing design is essential, without compromising on the processing performance.

The advantages of infiltration box systems over conventional rainwater management systems (crushed rock systems, concrete structures and drainage pipes) are easy handling and installation due to the comparatively small weight of the individual parts, high flexibility and high efficiency due to the high void ratio and easy maintenance due to integrated inspection channels.

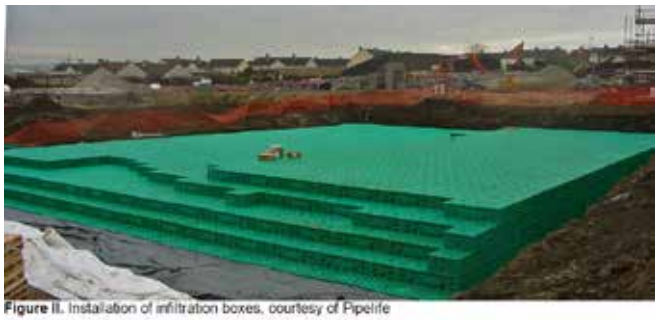

Figure II. Installation of infiltration boxes, courtesy of Pipelife

Products for waste water discharge especially infiltration boxes are part of a growing market. Product requirements have been translated into the corresponding material requirements and defined as target setting for a dedicated material development. Tailor made materials for infiltration boxes combine excellent processability for the injection molding of large parts with superior load bearing resistance and long term thermal stability. It was demonstrated that creep testing and subsequent modelling are valuable tools during product development in order to compare the long term performance of different materials under load, similar to real life operation conditions.

Storm water boxes are installed in a high demanding application. Therefore the need for qualified materials in combination with proper product design is essential to ensure the long-term performance. Ideally these requirements and characteristics should be implemented in an international standard, which is currently not yet available for this application.

Polyethylene coating for Protecting High pressure large diameter Steel water mains

The current government has presented ambitious plans for India's development and is highlighting water security as a priority. These plans will place a strong focus on the greater use of water efficient irrigation systems to increase food production whilst reducing groundwater withdrawals.

In India, the open channel transportation of water is increasingly being replaced by buried pipeline transport and that too at a high pressure in order to increase the volume flow. For large dia and high pressure pipes,

steel is the best option. However these pipes are subjected to corrosion and needs to be protected. The earlier practice of Guniting which was a time consuming, manual and inconsistent method, is being increasingly replaced by 3 layer PE (3LPE coating), where the coating weight gets reduced to only 5% of Guniting, there is no curing time and has excellent oxygen and moisture barrier contributed by Epoxy and PE layers respectively and can easily deliver 30-50 years' service life. Such pipes are being used for Oil and gas transportation in India and abroad for many years and is the most reliable method for steel pipeline protection. In 3LPE coating, the steel surface is blast cleaned to get the desired roughness profile, followed by Induction heating to 200^{o}C, spray application of Fusion Bonded Epoxy (FBE) powder, side wrapping of grafted MDPE adhesive and the final layer of Black HDPE Top coat. The total coating is of over 3.5 mm thickness to give complete protection from mechanical damage, outdoor weathering, and moisture and oxygen permeation.

Fig. 6. Installation of 3LPE coated steel pipes in GWIL project.

Fig. 7. 3LPE coating of steel pipes in progress.

To improve water security in Gujarat the State Government since 2011 launched the GWIL Project (Gujarat Water Infrastructure Ltd) where 434 kms of large diameter steel pipelines, ranging between 1.8 meters to 2.4 meters dia with 3LPE anticorrosion coating were installed for transportation of drinking water to the seven districts of Saurashtra, Kutch region and parts of Ahmedabad, Sabarakantha, Mehsana districts of North Gujarat and Panchmahals.

Later in 2013, Gujarat Govt launched SAUNI (Saurashtra Narmada Avtaran Irrigation) Yojana water conservation scheme. This huge project involves charging 115 reservoirs in the Saurashtra district with water from the Narmada River and linking them with 464km of large steel pipelines up to 3 m in diameter and 640 kms of smaller pipelines. In order to ensure the highest level of protection against corrosion, once again 3LPE coating system was selected over Guniting used in previous water projects. Borouge's HDPE top coat was used for major part of the project.

All these demanding project and environmental requirements in India and the many other "hot spots" in the Asia-Pacific region will create an increasing demand for PE and PP pipes to transport water and domestic and industrial wastewater and rainwater harvesting for recycle and reuse. Whilst this is great news for the plastic pipe industry it is essential that pipe suppliers and end users maintain a high quality in order to ensure that the engineer's expectations are achieved – news of premature failures quickly spreads and will undermine confidence in the materials. The key precursor to producing high quality products is to use a high level standard, high quality raw material from a recognized supplier such as Borouge and using good jointing and installation techniques by certified workmen.

Conclusion :

For long life and sustainable infrastructure, it is of utmost importance to use a strong project specification and specify pre compounded material, so that use of low quality material and mixing of material at converter premises are avoided. There are new generation HDPE materials available which are suitable for demanding installation techniques like Horizontal Directional drilling, where the pipe can deliver over 50 years lifetime, despite notches and scratches during installation process. It is also essential to have good specification in place for welding and installation as faulty welding and improper installation may render a good quality pipe useless. Proper enforcement of the specification through stringent inspection will ensure success of each project and give peace of mind to the utility owner and consumers.

NBR molded parts for oil seals in the automotive industry Replacement of carbon black N990 with Neuburg Siliceous Earth

K. Müller, H. Oggermüller

Carbon blacks are frequently selected as (functional) fillers when dealing with oil-resistant NBR mixtures for sealing parts – whether in mechanical engineering or in the automobile. If you look at the mixture composition, then an inactive carbon black such as the thermal black N990 often serves to fine tune the mixture in order to be able to better or even simply meet the requirements for these kinds of sealing parts, e.g. as found in ASTM D2000. Because the price of carbon black is subject to considerable fluctuations depending on the fossil raw materials and the long-term price indicates an upward trend, an alternative – one more cost-effective as possible – would be preferable. For this reason, this article deals with the replacement of N990 by Neuburg Siliceous Earth variants and examines to what extent they are suitable as a replacement material without having to make compromises with regards to the fulfillment of standard requirements. In particular, this article will touch upon the changes to mechanical properties and those of the media resistance. To summarize, it can be stated that thermal black N990 can be replaced with various siliceous earth products and that this may even also allow further adaptation and/or cost optimization.

Carbon blacks are often selected as (functional) fillers, when it comes to oil resistant NBR compounds for sealing parts be it in mechanical engineering or automotive. When considering the compound composition, an inactive carbon black, such as the thermal black N990, often is responsible for the fine tuning of the mixture and to better meet or meet at all the requirements for such sealing parts, as they are stated exemplarily in the ASTM D2000. Since the price for carbon black strongly fluctuates depending on fossil raw materials and in the long term the price is expected to rise, a possible cost-effective alternative would be desirable. Therefore, this article focuses on replacing N990 with Neuburg Siliceous Earth variants and examines to what extent these substances are suitable as a replacement material without impeding to fulfil the standard requirements. In particular, changes of mechanical properties and of chemical resistance are discussed. In summary it can be noted that thermal black N990 can be exchanged with various siliceous earth products, and the latter even allow further customisation and/or cost optimisation.

1 Introduction

NBR seals are used in a variety of mechanical engineering and automotive industry applications. Corresponding requirements are listed in ASTM D2000. For this purpose, carbon black N990 is often used along with carbon black N550 for rationalizing the property profile inclusive of costs. Depending on the price of the fossil raw materials, carbon black prices are subjected to considerable fluctuations. The long-term trend is clearly going up. The price of mineral fillers is only slightly influenced by fossil raw materials, but rather is only rising marginally without showing fluctuations. There are also temporary supply bottlenecks for carbon black N990, which can be circumvented through the use of fillers based on siliceous earth. In addition, reliable delivery times and high availability can also be ensured for Neuburg Siliceous Earth products. The objective of this study was to replace carbon black N990 available in a typical NBR formulation for oil seals with Neuburg Siliceous Earth, maintain a constant property level and contribute to cost reduction.

2 Experimental

The studies to replace N990 took place using a base formulation in which the available thermal black N990 was replaced with various siliceous earths – both untreated as well as surface treated – in order to be able to determine the resulting property profiles compared to the N990 standard. All details regarding this can be found in the following sections.

2.1 Mixture composition

The formulation used for the tests is listed in **Table 1**. This base formulation represents a molded part formulation for oil seals as they are used in many cases in the automotive industry. The nitrile rubber used has an average content of ACN and is thus suitable for common standard oils. Its Mooney viscosity is also in the middle range. The total carbon black share is 110 phr and consists of 60 phr Corax N550 and 50 phr carbon black N990. The plasticizer content is only 10

phr, which results in a hardness of 70 Shore A with a 1:1 replacement ratio for the thermal back. Aktisil PF 216, Aktifit AM, Silfit Z 91, Sillitin Z 86 and Sillitin N 82 were used as the replacement fillers. Aktisil PF 216 and Aktifit AM are surface treated siliceous earths – PF 216 treated with tetrasulfane silane for functionalization of the filler surface, AM treated with an aminosilane coated Silfit Z 91. Silfit Z 91 is derived from Sillitin Z 86 via a special calcination process and is characterized by low moisture absorption, excellent dispersion behavior and a generally lower compression set than the base product. The other Sillitins being tested were also so-called standard siliceous earths.

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If you look at the characteristic values of the carbon black N990 compared to one of the various siliceous earths, you will find that there are only relatively minor differences apart from the density. The difference in density of 1.8 (N990) to 2.6 g/cm3 (siliceous earths) is naturally considerable and is caused by the origin and composition of the materials. For example, if you look at the sizes of sieve residue, oil absorption and BET/CTAB surface that are normally used to evaluate the deviations to each other, the deviations are minor to each other in comparison.

An EV system (low sulfur quantities in combination with a high accelerator ratio) was used as the cure system. These kinds of systems improve the thermal stability of the cured rubber material, among other things.

2.2 Compound mixing and curing

All compounds were mixed on a laboratory mill (Schwabenthan Polymix 150 L, Ø 150 x 300 mm) at 20 rpm and a batch size of approx. 500 cm3. The rollers were tempered to 40 °C. The mixing times were adjusted according to the incorporation properties of the fillers and registered, and took approx. 20 min.

Curing was done in an electrically heated press at 170 °C. The cure time was always 5 min, both for the 2 mm sheets as well as the rebound and compression set test samples.

2.3 Testing

As already mentioned, ASTM D2000-08, Material type/class CH was used as a guideline for the individual tests. ASTM D2000 frequently serves as a classification standard for the specification of rubber parts and O-rings that are used in many cases as sealing elements in contact with oils as well as other media. The polymers most frequently used for the specified requirements are assigned to the material type/class. The identifier “CH” stands for nitrile and epichlorohydrin polymers. Specific base requirements must be maintained depending on the classification/specification. If Grade > 1 is listed, then additional requirements must be fulfilled. Here Grade 2 and Grade 3 were selected with additional requirements for the media resistance (IRM 901, IRM 903, Liquid C), temperature resistance and behavior for heat aging. Table 2 provides an overview of this.

In individual cases, the following test procedures/standards were used for determining the rheological and mechanical properties of the test mixtures.

- Mooney viscosity ML(1+4) 100 °C as per DIN 53 523, Part 3
- Mooney scorch time ML(+5) 120 °C as per DIN 53523, Part 4
- Maximum cure rate, time of maximum cure rate, loss angle tan d, conversion time t_{90} on the Göttfert elastograph at 170 °C, 0.2° deflection as per DIN 53529-A3
- Hardness Shore A as per DIN 53505
- Tensile strength, elongation at break, modulus 50 % as per DIN 53504, S2 bar
- Tear resistance as per DIN ISO 34-1, strip specimen
- Compression set 22 h / 100 °C as per DIN 53517

3 Results

Only the most important results of the testing will be presented in the following because, nearly as expected, there were no significant deviations in some properties due to the filler replacement – e.g. initial hardness (in the range of 70 ± 5 Shore A), rebound elasticity (identical for all mixtures) or volume change due to immersion in oil IRM 901 after 70 h at 125 °C (only unimportant differences of approx. 1 %).

3.1 Mooney viscosity and Mooney scorch time

If you replace the carbon black N990 with the named siliceous earths, the Mooney viscosity hardly changes and fluctuates between approx. 75 and 82 MU. Carbon black N990 and Aktifit PF 216 were side by side, Aktifit AM and Silfit Z 91 measured a somewhat lower Mooney viscosity compared to thermal black, and Sillitin Z 86 and Sillitin N 82 had a slightly higher viscosity. Therefore, a slightly positive impact on the processing

of the mixture is to be expected for AM and Z 91.

Table 1: Tested NBR base formulation 70 Shore A

Ingredient	Description	Quantity in phr
Krynac 2950 F	NBR, 30 % ACN, ML (1+4) 100 °C 53 MU	100
Zinkoxyd aktiv	Zinc oxide	5
Stearic acid	Processing aid	0.5
Agerite Resin D pastilles	Antioxidant	2
Corax N550	FEF carbon black	60
Carbon black N990	MT carbon black	50
Mediaplast NB-4	Ester plasticizer	10
Vulkacit Thiuram/C	Accelerator, TMTD	2.5
Vulkacit CZ/C	Accelerator, CBS	2
Ground sulfur	Curing agent	0.2
Total		232.2

Table 2: Requirements and testing conditions for the test formulation as per ASTM D2000-08, Type CH

Base requirement:
Hardness: 70 ± 5 Shore A
Tensile strength: >10 MPa and/or >14 MPa
Elongation at break: > 250 %
Compression set: < 25 % at 100 °C and 22 h
Grade 2:
Reference liquid IRM 901 70 h / 125 °C
Reference liquid IRM 903 70 h / 125 °C
Reference liquid, Liquid C 70 h / 23 °C
Hot air 70 h / 125 °C
Grade 3:
Reference liquid IRM 901 70 h / 150 °C
Reference liquid IRM 903 70 h / 150 °C
Hot air 70 h / 125 °C

Replacement of carbon black N990

The resulting Mooney scorch times, which represent a measure for the scorching behavior of a mixture during processing, were 12 to 17 min. The reference mixture with N990 was approx. 15 min. With Aktifit AM, Silfit Z 91 and Sillitin Z 86, the scorch times were shorter compared to N990 by 2 – 3 min, but remained in the acceptable range. Aktisil PF 216 and Sillitin N 82 had longer times by 1 – 2 min compared to carbon black and thus delayed the scorching. On the whole, the effects of the filler replacement can be considered to be low.

3.2 Cure characteristics

As **figure 1** makes clear, the maximum cure rate increases considerably with Aktisil PF 216 compared to the mixture with carbon black N990, while the highest value of the cure rate with the remaining siliceous earths drops slightly. The cause for the effect occurring with PF 216 may be due to the surface treatment of this filler with tetrasulfane silane.

In addition, the time of maximum cure rate – compared to the N990 mixture – is also reached significantly more quickly in the mixture with Aktisil PF 216 (**fig. 2**). Here we must also assume that this acceleration effect is due to the silaneization of the filler. In contrast, there was only a modest acceleration with Sillitin Z 86 and Sillitin N 82. The mixtures with Aktifit AM, Silfit Z 91 and carbon black N990 reach their maximum cure rate at the same time and thus do not differ from each other in this property.

The changes in the loss angle tan d resulting from the filler replacement are illustrated in **figure 3** for the various mixtures. Aktifit AM, Silfit Z 91 and Sillitin Z 86 match each other with regards to the tan d. Generally speaking, it is lower than the N990 mixture. For the mixture with Aktisil PF 216, it is even significantly lower and Sillitin N 82 remains on the same level as the pure carbon black mixture. Since the tan d is an indicator for the filler-filler interaction in the compound, it can be assumed that this interaction in the Aktisil mixture is the lowest, followed by Aktifit, Silfit and Z 86, followed by N990 and N 82. The cross connection to the filler structure and the surface treatment is obvious.

Figure 1: Maximum cure rate – Comparing carbon black N990 with siliceous earths

Carbon black N990

Aktisil PF 216

Aktifit AM

Silfit Z 91

Sillitin Z 86

Sillitin N 82

Nm/min

Figure 2: Time of maximum cure rate – Comparing carbon black N990 with siliceous earths

Carbon black N990

Aktisil PF 216

Aktifit AM

Silfit Z 91

Sillitin Z 86

Sillitin N 82

min

Figure 3: Loss angle tan δ – Comparing carbon black N990 with siliceous earths

Carbon black N990

Aktisil PF 216

Aktifit AM

Silfit Z 91

Sillitin Z 86

Sillitin N 82

rad

Figure 4: Tensile strength initial values – Comparing carbon black N990 with siliceous earths

Carbon black N990

Aktisil PF 216

Aktifit AM

Silfit Z 91

Sillitin Z 86

Sillitin N 82

Requirement: > 10 / > 14

MPa

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The conversion time t_{90} is used as a standard, mixture-typical benchmark for the required full cure time of a rubber article – depending on other ancillary conditions such as the wall thickness of the respective part. It is shorted by approx. 0.5 min by all siliceous earth types listed here compared to thermal black N990, the least by Aktisil PF 216 (approx. 0.4 min) and the most by Sillitin N 82 (approx. 0.5 min). The reduction of the conversion time t_{90} should also enable a reduction of the respective cycle times for regular article production compared to N990.

3.3 Mechanical properties – Initial values

For material type/class CH, there are various requirements for the tensile strength at a hardness level of 70 ± 5 Shore A depending on the application. The tensile strength requirement of >10 MPa is sufficient for a number of applications. This specification is met perfectly in this study by all tested siliceous earth products. However, the mixture containing carbon black N990, as the data show in **figure 4**, is at a significantly higher level at approx. 15.5 MPa. There is a reason why thermal black N990 or similar are frequently used for improving the tensile strength. The N990 mixture thus meets the requirements of the next highest performance level of >14 MPa tensile strength. This performance level should also be met by Aktisil PF 216 because the 14 MPa value is also exceeded with PF 216 and the resulting tensile strength with N990 is nearly reached with approx. 15 MPa. Silfit Z 91 barely clears the 14 MPa hurdle, Sillitin Z 86 remains slightly below it.

The elongation at break increases with all siliceous earth variants and they significantly exceed the performance profile of the standard by a min. of 250 % (**fig. 5**). While the elongation at break of the N990 mixture is exceeded with Aktisil PF 216 by approx. 30 percentage points, it is higher by approx. 100 percentage points for all other products.

As can be seen in **figure 6**, the modulus 50 % is somewhat higher with Aktisil PF 216 than with carbon black N990. You get a slightly less modulus 50 % with the remaining siliceous earth variants and this with a decreasing tendency in the direction of Sillitin N 82.

Figure 5: Elongation at break initial values – Comparing carbon black N990 with siliceous earths

Carbon black N990

Aktisil PF 216

Aktifit AM

Silfit Z 91

Sillitin Z 86

Sillitin N 82

Requirement: > min. 250

Figure 6: Modulus 50 % initial values – Comparing carbon black N990 with siliceous earths

Carbon black N990

Aktisil PF 216

Aktifit AM

Silfit Z 91

Sillitin Z 86

Sillitin N 82

MPa

Figure 7: Tear resistance initial values – Comparing carbon black N990 with siliceous earths

Carbon black N990

Aktisil PF 216

Aktifit AM

Silfit Z 91

Sillitin Z 86

Sillitin N 82

N/mm

Figure 8: Compression set initial values – Comparing carbon black N990 with siliceous earths

Carbon black N990

Aktisil PF 216

Aktifit AM

Silfit Z 91

Sillitin Z 86

Sillitin N 82

Requirement: max. 25

Replacement of carbon black N990

The tear resistance increases slightly with the replacement of carbon black N990 with Aktisil PF 216. It increases significantly with the remaining siliceous earth products and the highest with Sillitin type N 82. The individual details can be seen in **figure 7**.

When looking at the compression set, Aktifit AM is again at the same level as the pure carbon black mixture and achieves the best result of all tested siliceous earths variants together with Silfit Z 91. With Sillitin Z 86, Sillitin N 82 and Aktisil PF 216, the compression set increases noticeable, but all results lie safely within the selected performance level of ASTM D2000 and thus under the maximum permitted 25 % compression set (**fig. 8**).

3.4 Grade 2 – Immersion in oil IRM 903 at 125 °C

Oil resistance was tested at 125 °C with the aggressive standard oil IRM 903 as a further property. The hardness decreases in all cases. This hardness drop, however, remains within the limits, reaches a maximum of 5 points Shore A (for Silfit Z 91) and thus remains within the tolerance of ±10 Shore A. Aktisil PF 216 leads to the lowest reduction in hardness and thus the best result. The hardness drop for the remaining mixtures is to the same degree and thus remains exactly on the level of the pure carbon black mixture (**fig. 9**).

3.5 Grade 2 – Immersion in reference liquid C at 23 °C

In addition to the immersion in oils IRM 901 and IRM 903, the resistance against automotive fuel was also tested for the various mixtures. Liquid C served as the reference as per ASTM D471. The testing took place according to ISO 1817:2011 for 70 h at 23 °C. The individual results for the hardness change are summarized in **figure 10**. On an overall basis, the hardness reduction did not exceed 20 points Shore A (Sillitin Z 86 and Sillitin N 82) and thus remained significantly within the tolerance ranges of 0/-30 Shore A required for a decrease in hardness. Once again, the hardness with Aktisil PF 216 decreases significantly less here than with carbon black N990. The mixture with Aktifit AM also decreased less than the N990 mixture. Silfit Z 91 was on the same level with the thermal black.

3.6 Grade 3 – Immersion in oil IRM 903 at 150 °C

The testing as per Grade 3 requirements represents an additional tightening of the requirements because the immersion is conducted at an increased temperature. The data for oil resistance to – as already stated – the

well known aggressively reacting standard oil IRM 903 at 150 °C are thus presented here. The mixture with Aktisil PF 216 again leads to a significantly lower hardness changes as the one with carbon black N990. Sillitin N 82 is also lower than thermal black, Aktifit AM and Sillitin Z 86 are on the same level, Silfit Z 91 results in the greatest hardness change. However, all mixtures easily fulfill the requirements of the standard that tolerates ±10 Shore A (**fig. 11**).

Figure 9:

Hardness change after 70 h immersion in oil IRM 903 at 125 °C – Comparing carbon black N990 with siliceous earths

Carbon black N990

Aktisil PF 216

Aktifit AM

Silfit Z 91

Sillitin Z 86

Sillitin N 82

Requirement: ±10

Shore A

Figure 10: Hardness change after 70 h immersion in liquid C at 23 °C – Comparing carbon black N990 with siliceous earths

Carbon black N990

Aktisil PF 216

Aktifit AM

Silfit Z 91

Sillitin Z 86

Sillitin N 82

Requirement: 0/-30

Shore A

Figure 11: Hardness change after 70 h immersion in oil IRM 903 at 150 °C – Comparing carbon black N990 with siliceous earths

Carbon black N990

Aktisil PF 216

Aktifit AM

Silfit Z 91

Sillitin Z 86

Sillitin N 82

Requirement: ±10

Shore A

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In addition to the hardness, the results of the swelling behavior of the mixtures can also be discussed. The data are shown graphically in **figure 12**. Generally speaking, Aktisil PF 216 triggers a lower volume increase than carbon black N990. The volume changes with the remaining siliceous earths are only marginally higher than the increase for the pure carbon black mixture, showing no significant differences between the products. With regards to the fulfillment of standard requirements, all tested mixtures are easily in the permitted tolerance range of 0/+25 % because 11 % of swelling is not exceeded for all.

3.7 Cost aspects

As is shown in figure 13, the use of siliceous earth products results in a significant reduction in mixture raw material costs. This is all the more remarkable because the different mixture densities compared to the mixture with carbon black N990 have already been taken into account in the volume-related mixture price indices listed. Thus, there is a cost savings of approx. 4 or 6 % with Aktifit AM and Silfit Z 91. Even more pronounced, you can achieve a cost savings of up to 9 % with Sillitin Z 86 and Sillitin N 82. Even Aktisil PF 216 results in a small price advantage.

4 Conclusion

Aktisil PF 216 results in a lower hardness change along with improved cure characteristics (t_{90}, loss angle tan d) and the same high tensile strength after immersion in oil IRM 903 and fuel Liquid C when compared to carbon black N990.

A good compression set and no mold fouling characterize the effect of Aktifit AM and Silfit Z 91 at a cost savings

of approx. 4 or 6 %.

Both Sillitin Z 86 and Sillitin N 82 can achieve a cost reduction of up to 9 % with minimum value changes.

A combination of Sillitin and Aktisil PF 216 offers a way to balance out the physical properties and the cost situation. Thus a 50:50 combination, for example, achieves a property profile that tends to be more like that of Aktisil PF 216.

High availability and a reliable supply of siliceous earth products are additional important arguments in favor of this.

The end result is that carbon black N990 can be replaced with Aktisil PF 216 with technical advantages and in particular, replaced with other siliceous earth products with a cost reduction.

Figure 12: Volume change after 70 h immersion in oil IRM 903 at 150 °C – Comparing carbon black N990 with siliceous earths

Carbon black N990

Aktisil PF 216

Aktifit AM

Silfit Z 91

Sillitin Z 86

Sillitin N 82

Requirement: 0/+25

Figure 13: Cost aspects – Comparing carbon black N990 with siliceous earths based on the mixture liter price (as of: Price situation Germany 01/2015)

Carbon black N990

Aktisil PF 216

Aktifit AM

Silfit Z 91

Sillitin Z 86

Sillitin N 82

High Fidelity Numerical Simulation of Non-Pneumatic Tire

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Abstract

This study is focused on, developing a high fidelity three dimensional (3D) finite element model of solid resilient tire for the static numerical simulation. To develop the model and describe the mechanical behavior of filled vulcanized rubber in the tire a suitable hyper-elastic material model is required. The best fitted hyper-elastic material model is obtained by using curve fitting approach. Numerical and laboratory experimental data are compared together to validate the developed model. The validation results show that the minimum values of the three measures (MAPE, MAD, and MSD) of accuracy obtained from best fitted numerical model with experimental model deviation values are very smaller and less than permissible limits (5%). Further, stress distribution in tire reinforcements are investigated using numerical model. Moreover, this study can be further extended to investigate the dynamic behavior of the solid tire.

Keywords: High Fidelity Static Simulation, Hyper-Elastic Material Models, Non – Linear Finite Element Simulation, Solid Tires.

1. Introduction

Solid tires more popular in heavy duty vehicles due to its ability to operate in harsh environments with bearing excessive loads. In the solid tire, base section, cushion section and tread section are the main three rubber sections. Moreover, few bead bundles (reinforcements) are embedded into the base layer as the structural reinforcements. These three rubber sections are made by using three different rubber compounds and properties are different to each other. The reinforcements with base can define as foundation of the tire. It gives better contact with tire and rim while aids to sustain under heavy loads. Arise heat is mainly dissipated through the cushion. Tread section controls the rolling resistance, traction, tire service life and its durability.

Mostly, the analysis of these tires are often done in industry using laboratory experimental methods. These methods are time consuming, costly and usually do not help to explain the mechanical behavior and tire attributes properly.

In the literature, the majority of FE studies on the tires have been conducted for pneumatic tires (Marais, 2018; Hofstetter *et al.*, 2006; Cho *et al.*, 2004; Lin, 2004). For solid tires, Suripa (2008), developed a general FE model to study distribution of strain energy density and deflection of a solid tire under different loading conditions. Moreover, Phromjan (2018), developed 3D FE tire model to analyze the tire behavior on static conditions. Here, tread section was modeled using tetrahedral elements while the other sections of the tire were modeled using hexahedron elements. Dechwayukul *et al.* (2010), proposed an experimental method to evaluate tire service life, life time of the tire at different loading conditions and speeds of selected industrial solid tires. Further, Rukkur *et al.* (2013), conducted a laboratory experimental study to improve and reduce heat buildup at the tread layer of a solid

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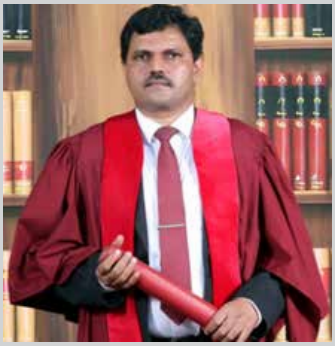


industrial tire. Moreover, to acquire more realistic tire analysis results it is necessity to having a detailed tire model which includes all tire elements (Cho *et al.*, 2004; Cho *et al.*, 2006). Considering these factors, the main focus of this study is to develop high fidelity Finite Element (FE) model for a solid resilient tire to analyze its static conditions with numerical simulation.

2. Methodology

This study is focused on learning the importance of driving simulator tire static model and a mathematical representation of solid tires in three dimensions (3D). Figure 1 shows the flow diagram of the methodology of this study which is used to develop a suitable numerical simulation model for solid tires.

The 3D hexahedron (brick) element type has been used to model all sections in the solid tire. To develop the FE model, the required best fitted constitutive model/s and material properties of the rubber and other reinforcements of the tire are gathered through conducting relevant laboratory experiments. Here, the Yeoh hyper-elastic material model is selected to describe the mechanical behavior of the filled rubber. Moreover, the properly validated FE model is then used to analyze the static behavior of an actual solid tire under different load conditions.

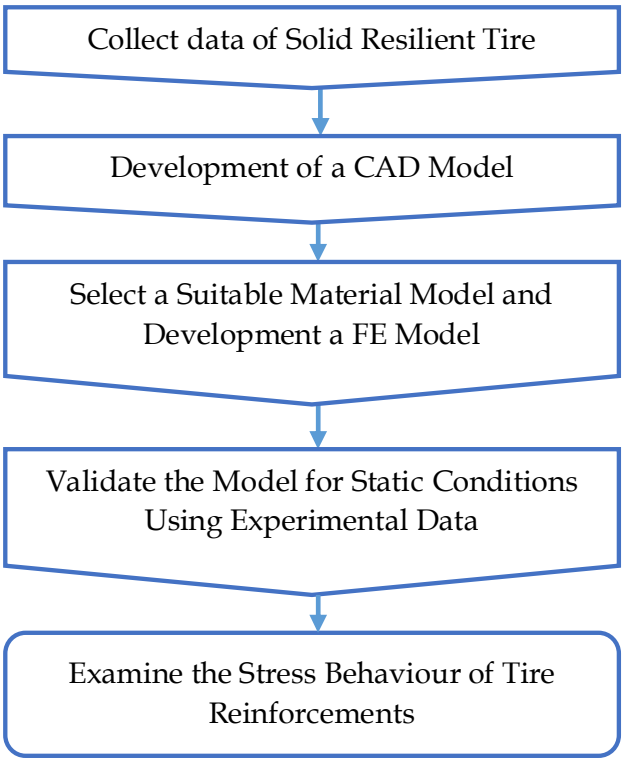


Figure 1: Flow Chart of the Methodology

3. Validation of the FE Model

Figure 2 and Figure 3 present, that the numerical simulation results of the tire vertical and horizontal deflections are in good agreement with the physical experiments conducted in this study. Statistical analysis has been used to compare and select the best fit FE model with physical experimental data. Table 1 shows the minimum values of the three measures (MAPE, MAD, and MSD) of accuracy obtained from best fitted numerical model with experimental model. Since, all three measures values are very smaller and less than the permissible limits (5%), it can be concluded that the model is on acceptable level of the validation process.

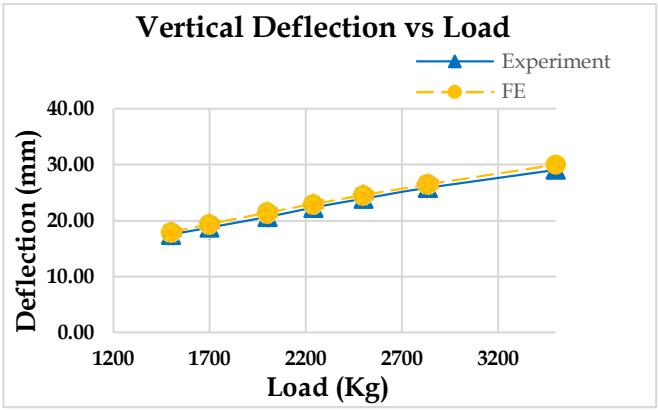


Figure 2: Tire Vertical Deflections

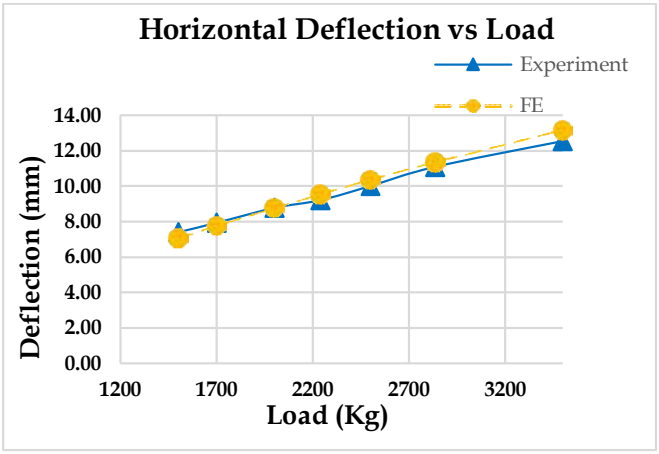


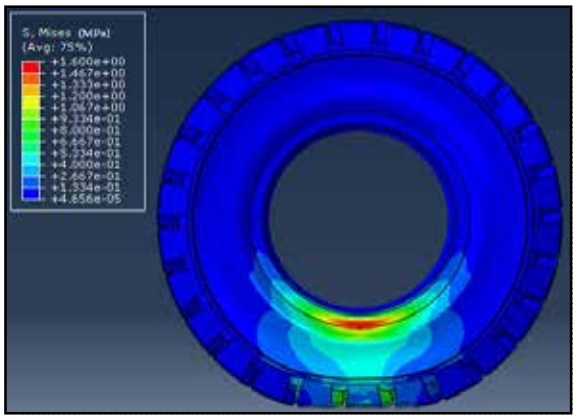
Figure 3: Tire Horizontal Deflections

Table 1: Measures of Accuracy

ERROR	MAPE (Mean Absolute Percentage Error)	MAD (Mean Absolute Deviation)	MSD (Mean Squared Deviation)
Vertical	2.91	0.66	0.46
Horizontal	3.00	0.29	0.12

4. Results and Discussion

Figure 4 shows the solid tire 3D FE model and Max Von Mises stress distribution of the developed 3D FE model using *ABAQUS CAE* application. Based on the results the high stresses accumulate in the region of base. This may leads to occur the issues on gripping contacts with tire rim when it reaches to its maximum bearing load capacity. Figure 5 presents the numerical simulation view of stress distribution in reinforcements. In addition, Figure 6 represents, that the stress in reinforcements increase when the applied load on the tire increase.



(a)

(b)

Figure 4: Max Von Mises Stress Distribution in Rubber Components of Deformed Tire Model (Load: 2240 kg): (a) Tire Side View, (b) Tire Profile View

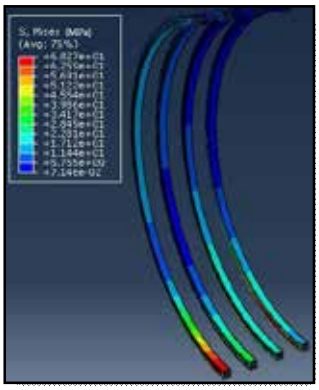


Figure 5: Max Von Mises Stress distribution in reinforcements of deformed tire model (load: 2240 kg)

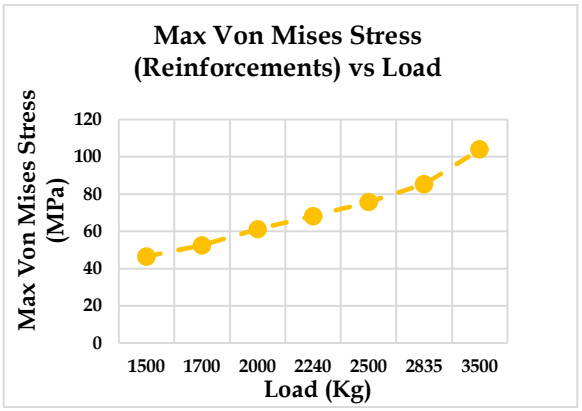


Figure 6: Numerical Values of Max Von Mises Stress Distribution in Reinforcements

5. Conclusion

The study presents the usage of modeling and static analyzing techniques of FE method on solid resilient tire. In the study the validated model is used to analyze the vertical and horizontal deflections of solid tire under different loads. In addition, Max Von Mises stress in reinforcements are obtained through the model. Here, localized high stresses are mainly distributed in base section and reinforcements. In addition, asymmetrical stress distribution in the reinforcements are observed. Further, such observations can be effectively identified using FE simulation and it can be used to optimize the tire design.

6. Acknowledgement

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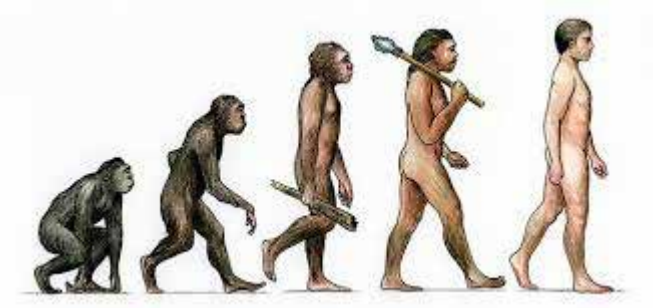
Technology Revolution for Industry Growth

By N.C Narayanan
SSA Business Solutions India

Evolution of Mankind

Science discovered the evolution of human brain since last 6 million years from a mere emotional Limbic brain of an animal to a thinking gadget with the growth of Cortex and Neo cortex. Ever since human species got the rational & imagination faculties, they have never stopped challenging the status quo to move away from stone age to iron age to digital age now. Constantly human brain is seeking to discover the secrets of mother's nature, convert science to technology and then engineer new products for human comfort and happiness. Those of us living in the current era are the luckiest in terms of scientific inventions that made our life most comfortable. Although human beings are the weakest creation physically, learned to fly without wings, sail in the ocean and even reach the farthest planets through innovation. This quest for knowing & conquering nature will continue till the imagination exist as faculty of human beings.



Industrial Revolution

In the last 3 centuries mankind witnessed many inventions that revolutionised the way civilisation moved forward. To site a few the first one is Gutenburg's invetion of printing press in 1468, which provided the breakthrough of recording and dissimination of knowledge. The second one was locomotive by George Stephension in 1825 which reduced the human slavery. The invention of IC engines by Nikolaus Otto in 1876 revolutionised transportation. The birth of digital age commenced by the invention of electronic computers in 1943 by Max Newman which revolutionised the way human beings

Mr. NC Narayanan

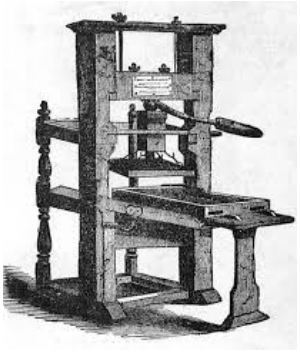
Founder Chairman of SSA Group

NC Narayanan, fondly known as 'NC', is the Founder Chairman of SSA Group. His personal mission when he founded SSA back in 1999 was to help industries achieve "Prosperity through Quality" – a goal that he has pursued with passion throughout his career spanning almost five decades.

As a CEO coach and mentor for leadership teams across geographies, NC has made significant contribution to hundreds of organisations and thousands of people across multiple countries spanning South Asia, Middle East and Africa where he has earned the reputation of a 'Transformation catalyst'. He specialises in Envisioning, Strategy Formulation and Change Management with an emphasis on leadership and people development. NC is also very passionate about developing young leaders by mentoring and coaching them. He is an avid blogger and writes on myriad topics such as "Parenting", "How to make marriage work?", "Psychic equity" and many other self-development topics.

NC has authored many books on the topics of Lean and Statistical Problem Solving. Some of his popular books are "Enigma of Lean", "Lean Six sigma in a Nutshell" and "Statistical Guide for six sigma". McGraw Hill Education has published his latest book "Pragmatic Leadership" in which he deals with a systematic approach to mastering leadership through personal leadership, team leadership and organisational leadership. He has been conferred with several awards in recognitions of his contributions to the field of Quality & Business Excellence. NC is a revered speaker and regularly chairs international conferences on Lean Management, Six Sigma and Operational Excellence. NC is a Gold Medallist in Mechanical Engineering from Anna University, and holds an MS in Computer Aided Design from the prestigious Indian Institute of Technology, Madras.

live today. The digital age pervaded into every aspects of our life today with the advent of smartfones which has become an indispensable gadget of our daily life. This will continue to unearth all unknown territories of nature.

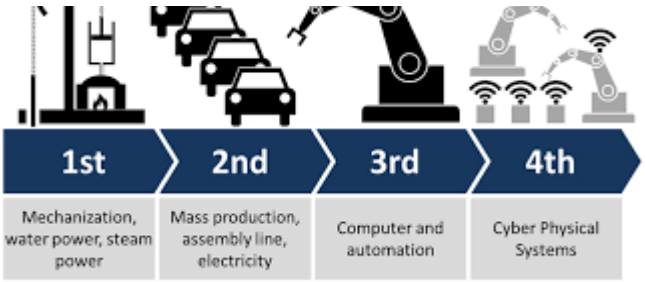


Change vs Transformation

There are many emerging concepts and technology that improves efficiency and effectiveness of the enterprises which are small incremental changes and some of them are breakthrough transformations. There is a subtle difference between 'Change' and 'Transformation'.

- The change is incremental but transformation is significant
- Change needs acceptance but transformation needs a paradigm shift
- Change gives a marginal improvement in results by transformation leads to huge benefits
- Change is reversible but transformation is irreversible.

Technology revolution in manufacturing



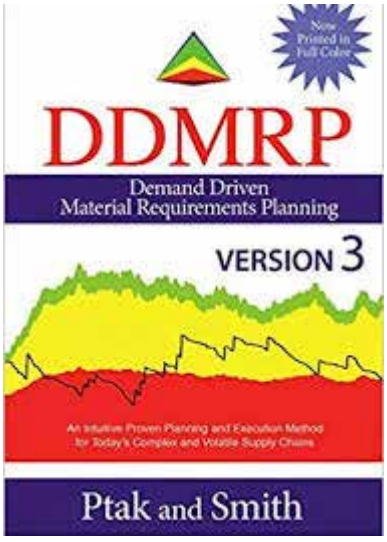
The **Industry 4.0** is the buzz word for leaders who are looking for the next step to lead transformation in their industry. Let us look at what is this buzz word really mean. There are 4 major steps in which the manufacturing technology transformed in the last 3 centuries. The first one is the invention of steam power which is called **Industry 1.0** that gave birth to usage of energy for many industrial work.

In 1906 Henry Ford established the mass production based on the concept interchangeability proposed Eli Whitney in 1798 which is the major step forward in manufacturing complex gadget like automobile in large quantities. Mass production technology applying electrical energy is referred to as **Industry 2.0**. So, the current manufacturing systems adopted by vast majority of the manufacturing companies are based on Ford manufacturing systems.

During 1950s, Taichi Ohno from Toyota car manufacturing introduced the concept of Lean manufacturing challenging the ford manufacturing system by eliminating the waste from a manufacturing system which are referred as 7 Muda (Japanese word for Waste). The invention of computers and application of digital systems in manufacturing technology through CNC machines significantly improved the accuracy and change over times leading to flexible manufacturing systems called FMS. This step forward is called **Industry 3.0.**

The next major transformation happened when **Tim Berners Lee** invented the Internet by networking of computers and developing a common language through which the computers worldwide can talk to each other. No one knew that Internet will lead to cloud and all digital information age. IOT (Internet of things) pervaded into manufacturing creating all machines as intelligent machines leading to 'Cyber physical systems' combining human beings and robots together which is called **Industry 4.0**

MRP to DDMRP (Material Requirement Planning to Demand Driven MRP)



On of the major concerns of a manufacturing and trading companies is increasing inventory consuming working capital which eats away the profit. The companies borrow funds from banks for augmenting the demand in working capital leading to incapability to service the debts. One fine morning a heavy cash crunch happen and the industry declares insolvency. The CEOs have night mare to manage working capital and hence scared of facing the stakeholders in the board rooms.

More the complex the organisation becomes, greater is the inventory management issues There are many external factors changed over the last few decades. Many decades ago the product variety was low and customer waiting time was high. As we move into 21st century the customer expectations have gone up with increased obsolescence of products demanding more frequent new products. As the product life cycle come down the non-moving stock piles up. The regulatory norms are increasing day by day with new & stringent norms for safety and performance of the products to meet environmental norms. In addition to the above industries face stiff competition constantly differentiating to have customer stickiness. The digital technologies and IOT changed the way commerce works. The e-commerce and mall culture changed the way outbound logistics works. Hence what concepts and paradigms worked decades ago are falling apart to meet the changing environments discussed above.

The concept of material requirements planning (MRP) introduced in early 1960s has given leverage for planning and execution through computerised planning system. MRP is based on the forecasting which has its own inaccuracies. The recent research shows that the highest forecasting accuracy is 61% which means the planning, procurement and manufacturing of goods are based on 40% inaccurate information. More over the variation in product design, supplies, quality issues etc introduces many variability that affects inventory. This is one of the reason for the piling up of inventory. The MRP is called "PUSH system" as it assumes a sale and pushes material across the value stream.

In order to sole this problem Ptak and Smith introduced a new concept called "DDMRP" based on a scientific demand driven planning system as a natural extension of Lean manufacturing (Refer the book DDMRP for more details). DDMRP works on Customer pull instead of pure forecasting. The engine that drives DDMRP is called de-coupling through strategic buffers and strategic locations which reduces inventory substantially and increases sales with right materials available at the right place. DDMRP is supported by computerised applications that works seamlessly with the ERP systems. The results achieved through DDMRP is 30% reduction in inventory with over 99% on time delivery.

Change Management

The human beings always have a resistance to change to adopt to the new environment. The main reason for resistance to change is due to the fear of obsolescence, Lack of knowledge and the need for learning the new skills. So, the resistance starts from the leadership level and percolates up to lower most level of the organization. The major challenge for adopting the new technologies needs an open-minded approach considering the benefits and also recognizing the possible obsolescence that threatens the very existence of the organization. The paradox is:

- Prosperity is the result of improvement
- Improvement is the result of change / transformation
- Human beings want prosperity but resist change!!

Conclusion:

The industries of the world acknowledge the fact that adopting the available technology is a must, however, their major challenge comes in adopting the right technology that would suit their business. Adopting technology is not enough but adopting the right technology is the key to utilise the benefits that the technology has to offer for an organization to grow.

Approach to Develop an Integrated Management System (IMS)

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An integrated management system (IMS) combines all related components of a business into one system for easier management and operations. Before introduction of ANNEX SL by ISO, Quality, Environmental, and Safety management systems are often implemented as isolated management systems as there were lot of dissimilarities in the structures of those standards than the similarities.

Integrated Management Systems allows your company to manage and execute similar processes without duplication, to conduct integrated audits and assessments, as well as optimize processes and resources. When you can integrate these systems it can help reduce the time it takes to do certain activities, eliminate the amount of time interrupted and therefore reduce costs.

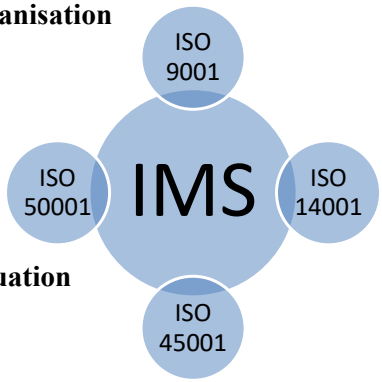
What are the most popular management system standards that can be integrated in line with ANNEX SL?

Annex SL solves the problem of potential redundancy in basic structure for companies wishing to deploy multiple standards. Following standards are the most popular standards in line with ANNEX SL and those are being implemented all over the world as well as in Sri Lankan rubber related products manufacturing industry.

- ISO 9001:2015 Quality Management Systems — Requirements
- ISO 14001:2015 Environmental Management Systems — Requirements
- ISO 50001:2018 Energy Management Systems — Requirements
- ISO 45001:2018 Occupational Health And Safety Management Systems — Requirements

High level structure of ANNEX SL (formerly called Annex SL but renamed “The Annex L” with the 2019th edition)

1. Scope
2. Normative references
3. Terms and definitions
4. **Context of the organisation**
5. **Leadership**
6. **Planning**
7. **Support**
8. **Operation**
9. **Performance evaluation**
10. **Improvement**



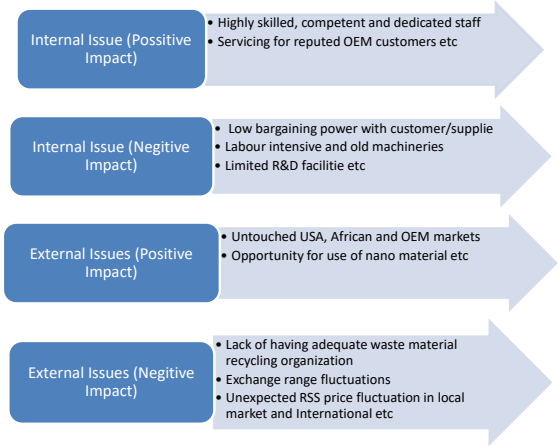
Critical areas to be considered when developing an integrated management system

01. Integrated context review for quality, safety, environment and energy

context of the Organization is “*business environment*“, “*combination of internal and external factors and conditions that can have an effect on an organization’s approach to its products, services and investments and interested Parties*“. The following two areas are very important under the context review.

i. Internal and External Issues

Identification of internal and external issues that are having an impact on **quality, safety, environment and energy management system** are highly important when developing integrated management system and some examples which are relevant to solid tyre manufacturing are as follows

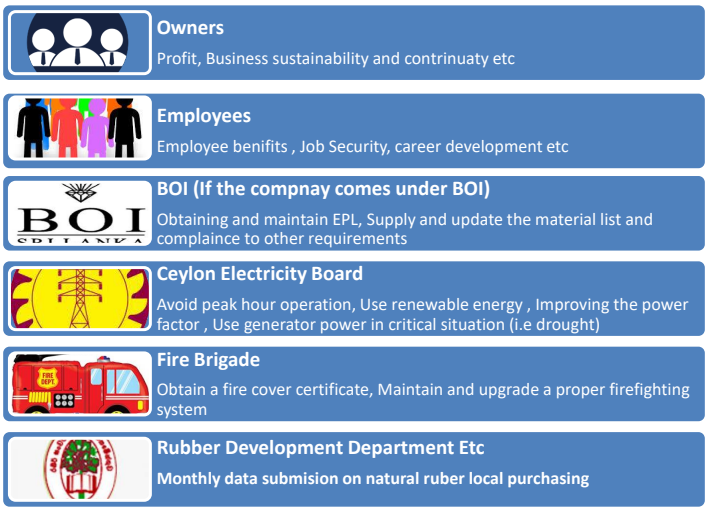


(Issues can have both positive and negative impacts for the organization and those can be vary company to company)

ii. **Need and Expectation of Interested parties on quality, safety, environment and energy management system**

Nonfulfillment of the need and expectations of the interested parties are also significantly affect to any business and it is a pre-requisite to identify those needs and expectations and any risks/opportunity that can have an impact to the organization from them.

I.e



(These needs and expectations may have both positive and negative impacts for the organization and those can be vary company to company)

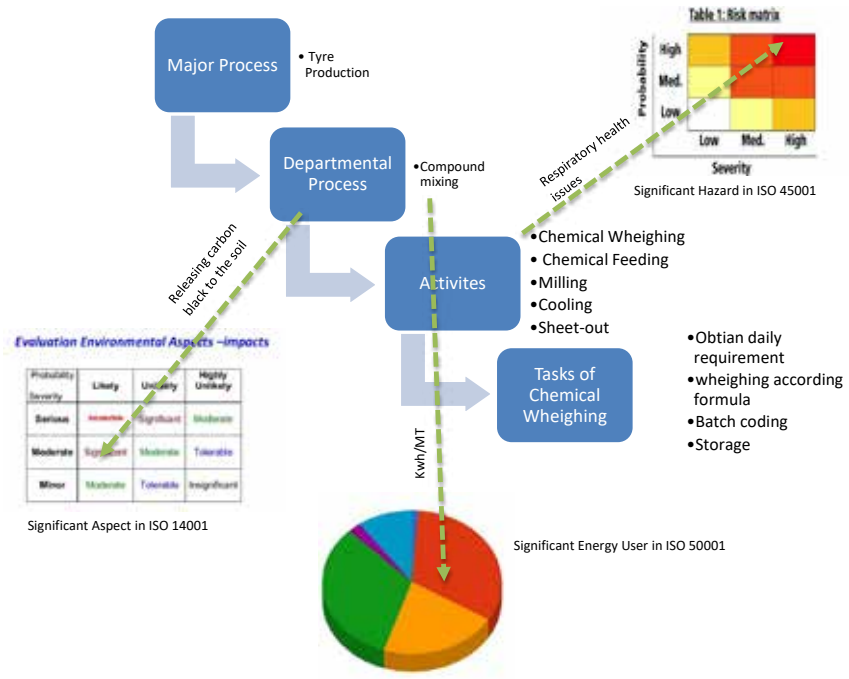
iii. **Quality, safety, environment and energy management systems and its process**

When developing an integrated management system it is necessary to determine the processes needed for the quality, environment, safety and energy management systems and their application throughout the organization. It includes

Decompose major process in to sub process activities and tasks and

- Determine the inputs required and the outputs expected from these processes;
- Address the risks and opportunities including significant environmental aspects and impacts, high risk OHS hazards, significant energy users etc
- Determine and apply the criteria and methods (including monitoring, measurements and related performance indicators) needed to ensure the effective operation and control of these processes;
- Determine the resources needed for these processes and ensure their availability;
- Assign the responsibilities and authorities for these processes;
- Improve the processes and the integrated management system etc

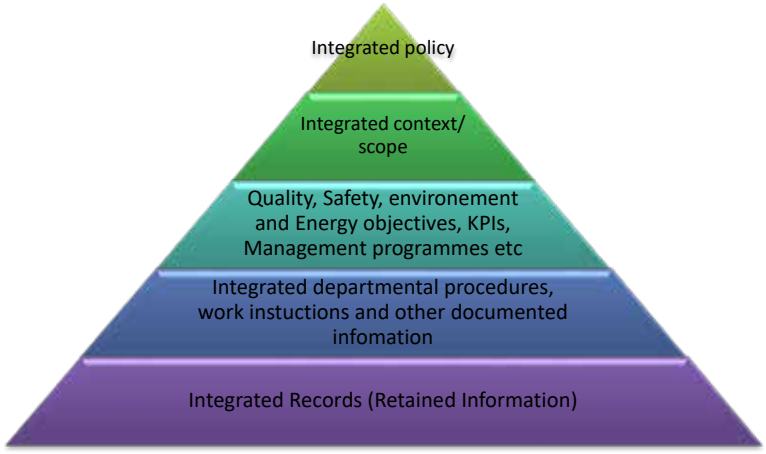
It is highly important to map all the process and activities by focusing on **quality, safety, environment and energy** management system requirements and the following example illustrate how to integrate all management systems in the process mapping



02. **Integrated management system policy for quality, safety, environment and energy**

An integrated management system (IMS) combines all related components of a business into one system for easier management and operations. Quality, Environmental, and Safety management systems are often combined and managed as an IMS

03. **Integrated documented information and retained information management system for quality, safety, environment and energy**



Note: Some are not mandatory documented information and those may be highly contribute to effective integrated management system.

04. **Integrated Internal Audits and Management Reviews**

As has already been mentioned, there are many common processes that exist in all management systems. In fact, these processes contain the same requirements in all ISO management system standards. This will include determining the context of the organization, identifying interested parties, management of documented information, handling competence requirements, performing internal audits and management review, and many others. With this long list, it is easy to see that if the process is the same, there is no requirement for extra resources to maintain more than one management system for these common processes.

Additionally, many of the benefits of all management systems are the same. Therefore integrated management system enables better decisions based on facts, increase process efficiency, improve organization's image, and make improving the processes a habit among employees. These benefits can be gained by focusing on one management system, or by looking further to several management systems integrated together.

Rubber Economy Outlook in the 2020S

Pong Kai See, FPRIM

With just 2 months to go (at time of writing) to beginning of the next decade, it is timely to look back at state of the rubber economy in the last few years and look forward to what the next few years will likely bring.

There is nothing new in what I am going to say looking back but it is worthwhile to set the stage for what is to come. A number of points are relevant to the current discussion.

Firstly, there was an orgy of new planting during the period of high prices in 2006-2012 that was in excess of demand to 2020 and depending on the rate of future growth of demand this situation of supply overhang will likely go beyond the mid-2020s. As recent as middle of 2003, price of TSR20 was below US 1.00 per kilo. The period of low NR prices before that discouraged planting of new areas of rubber which ultimately led to the tight supply situation beginning from mid-2000s as developing nations grew at a rapid rate. In particular, China led the charge to buy more rubber fuelled by rapid growth of infra-structure and urban construction and a new-found appetite for car ownership. Egged on by speculative trading NR prices reached a historical high of over US 5.50 per kilo. This period of high prices is over as the trade returns to long term trend which is a decrease of 2% in real terms since 1950.

Secondly, traditional producers are divided into low cost producers, i.e. Thailand, Indonesia and Vietnam, that can take the low prices of recent years, and high cost producers like Malaysia and India and to a lesser extent China, that stop production when prices are low. In the opinion of many analysts, these high cost producers act as "marginal producers", making up the volume when prices spike due to periodic shortage (e.g. during winter of 2016/2017) and thus stabilise prices at this low new level. China, as the dominant consumer of NR (it accounts for approximately one-third of total consumption) has emerged as the new "big brother" in terms of keeper of buffer stock as well as sponsors of newer producers in CLMV countries as well as West Africa, notably Cote d'Ivoire and Sierra Leone, in order to secure supply of NR (China does not have enough land to be self-sufficient) and to keep prices low. Meanwhile, governments of producer countries

Mr. Pong Kai See

Mr. Pong obtained his First Class (Honours) in Polymer Science & Technology from the National College of Rubber Technology, London before returning to the Rubber Research Institute Malaysia (RRIM). He subsequently obtained his Masters in Techno Economics from Stirling University (Scotland). After several years providing regional technical services for RRIM, he became the general manager of Plaat (Rubber) in Penang and successfully turned around the failing company. With the advent of the AIDS epidemic in the '80s he worked in several consultancy capacities with prophylactics and gloves. His expertise lies in analysing technical problems in rubber product manufacturing companies and finding adequate solutions for them.

He received the FPRI from UK in 1986,, the youngest person to to get it as previously there was a minimum age limit of 40.

In 1995, he took over the helm of CY Handee , a major producer of rubber bathmats and swim fins and remains as group Managing Director till today.

For the Plastics and Rubber Institute Malaysia (PRIM), he served in various capacities and established the Diploma in Rubber Technology course for the people in Penang and the Northern Region for many years. For this effort, he was awarded a Fellowship status.

like Thailand, Indonesia, Malaysia and Vietnam are taking measures to subsidise income of rubber farmers and restrict supply, which has the effect of subsidising the tyre companies of the West that are making record profits due to low rubber prices.

The capacity to produce, known as NORMAL PRODUCTION, therefore remains high, and short of cutting down rubber to plant another crop – not yet happening though some governments, e.g. Thailand, encourages this – small rubber farmers, who are the majority, are able to regulate supply due to multi-cropping and availability of other forms of income. This supply overhang will keep prices low. David Shaw, a UK tyre consultant, in his November 2018 blog, estimates this will drag on to 2027-2028 because of low growth rate of new consumption of natural rubber in coming years. Other analysts noted there is a production overhang of 15% or so. Thailand, for example, has a normal production of close to 6 million tonnes but actual production is only about 5 million tonnes or an overhang of about 17%.

Third, low prices of NR and relatively higher prices of SR (and also threats of higher oil prices due to Middle East, North Africa and Venezuela situations) are motivating countries to move in different directions in recent years. In India, low price of local rubber caused Indian tappers to slow production leading to higher imports which attracted punitive duties. This encouraged rise of new SR producers (part commercial, part government driven) which reduced percentage of NR use in India from 80% to about 60% in recent years and this ratio will continue to drop. Part of this trend toward higher SR usage in India is due to radialisation of passenger tyre manufacture. It was reported only 44% of tyres are radial tyres compared to above 90% worldwide. Radials are more fuel efficient compared to cross-ply tyres. In China, other forces are at work, including new tyre regulations, labelling of tyre performance characteristics like rolling resistance, wet grip and noise levels and domestic laws like higher load bearing properties and ability to be retreaded multiple times for MCV and HCV tyres. This moved manufacturers to use more NR compared to SR. NR usage ratio has increased from 46% in 2015 to 52% in 2018 though there are some analysts who argued this is indication of ready substitutability of SR with NR due to lower prices. The two different approaches reflect fundamental shifts in product requirements and of country strategy to produce its own raw material rather than rely on imports.

A fourth point to note is the restocking of NR and that a big part of the stocks is held by governments. Stock-to-use ratio increased from about 15% during the high prices in 2010/11 to above 25% in recent years. China is one of the major holder of NR stocks, much more than producer countries like Thailand, and this may have the effect of stabilising prices in times of a demand spike, so avoiding future price spike crises. This may be China's strategy to neutralise the "cartel-like" behaviour of ITR0 and ANRPC, a perception also raised by Cinalpa of the ETRMA. More of that later.

Another reason why rubber prices in general will stay low in next few years is over-capacity of SR production, especially ESBR, SSBR, even BR because of building of new capacity by China, recently also by India, for various reasons including nationalistic ones. According to Petrovic of the IISRP, SR demand is only 60% of world capacity with new capacity in China still under-utilised. This is because of observed trend that NR and SR prices generally track each other. The writer wishes to underplay the role of substitutability of SR vs. NR, often invoked by non-technical analysts to explain movements of ratio of NR vs SR usage. It is generally agreed by experts that there is little scope of substitution in developed countries of tyre and technical rubber products because these products are usually produced to tight technical specification that offer little scope of rubber formulation change. In developing countries, where there is less control of technical quality, there may be possibility of substitution of NR by SR or vice-versa. For non-technical products, and also in gloves, substitution is possible. Worldwide, substitutability is limited to a few percentage points either way.

Future Trends

So what will change in the new decade?

A major trend is the relentless drift of major producer countries towards high GDP and wages. History teaches the example of Malaysia, the one-time number one producer of NR. As income levels grew, Malaysian plantations moved from rubber to less labour-intensive oil palm. The mantel of top producer was taken over by lower cost Thailand and Indonesia. Now Thailand and Indonesia are facing a similar problem and face competition from lower cost countries in ASEAN and West Africa (see text box). These are long term shifts.

A second trend is that of consumer company or country, e.g. the tyre companies, China, etc. investing upstream into rubber production. China in particular has acquired rubber companies in Thailand and Singapore (e.g. Sinochem Group, a Chinese listed company, bought Halcyon, a Singapore-based rubber grower and service

integrator, and Guangken Rubber of Hainan, China took over Thai Hua, a Thai rubber grower, processor and trading company) as well as spearheading investment in rubber growing in Africa and CLMV countries. Rubber companies like Goodyear, Michelin, Bridgestone and Trelleborg, are also doing same. From limited data available, it would appear that new planting by such activities is enough to cater to projected growth in rubber demand. This will have effect of prolonging the surplus supply situation into the late 2020s.

A third trend as I see it, is the ability in recent years of producer countries to adjust production output to balance demand, as seen by recent production vs. consumption data for NR. There are those who questioned the effectiveness of export restriction policy pursued by Thailand and other member countries of the International Tripartite Agreement, arguing that the rubber should be left in the tree. This is what many small rubber farmers had done. In the old days most rubber smallholders planted only rubber and they had no other source of income. They must tap whatever the price. Most rubber farmers now planted other crops and so had other income. Or they can work in neighbouring factories. This allows farmers to tap rubber when price is high and seek employment elsewhere when prices are low. A most effective way of balancing supply and demand.

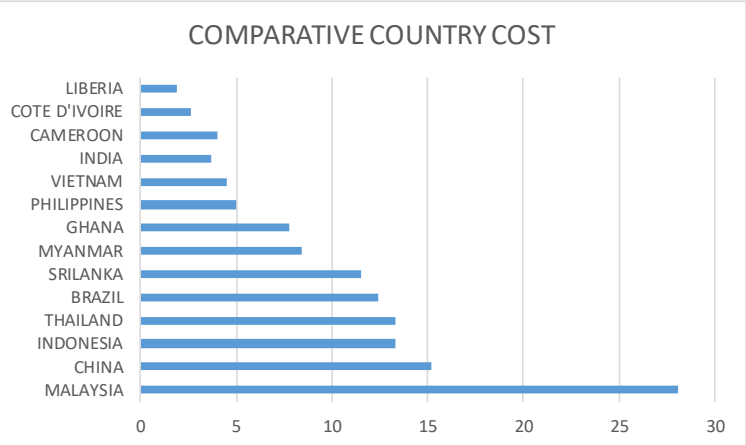
A fourth factor is the role consumer and social responsibility advocate groups play in development of the NR supply chain. A recent video by DW Documentary of Germany, went viral. The video highlighted how foreign rubber tappers were exploited by farm owners. These tappers were paid low wages, in many cases much below the country's mandatory minimum wage. They lived in sub-standard housing. During the non-tapping season, they were left to fend for themselves, sometimes going hungry. Other advocacy groups revealed indiscriminate clearing of jungle and traditional tribal land to plant rubber, often displacing the original inhabitants and causing loss of bio-diversity. The Tire Industry Partnership (TIP) and Sustainable Rubber Initiative (SRI) by the International Rubber Study Group (IRSG) are global forums that emerged as a result. Social and ecological forms of sustainable management of rubber planting are now important issues.

AFRICA GROWS & GROWS

In 2018, according to World Bank data, Cote d'Ivoire overtook Malaysia as the sixth producer of rubber with Malaysia seventh. Jom Jacobs of ANRPC in his June 22 presentation at the MRPMA Rubber Conference projected Cote d'Ivoire will produce close to one million tonnes of rubber by 2022. This may perhaps be an understatement. In October 22, 2018 the Cote d'Ivoire Minister of Agriculture announced output of rubber will reach two million tonnes by 2023 as rubber plantations spread to new parts of the country.

In 2014 West Africa produced about 725,000 tonnes of rubber or close to 6% of world production. It is projected by 2020 total African production will reach 1.5 million tonnes or 10% of world total. The rush to Africa (and other lower cost ASEAN countries like Laos, Cambodia and Myanmar) was prompted as much by increasing costs of production in traditional producer countries like Thailand, Indonesia and Malaysia as these countries developed and their GDP and wages increased, as by the wish to spread the risk of disease which infects rubber from time to time, often with disastrous effects.

Data comparing cost of rubber production for different countries are not generally available. A proxy for this is to use FAO data on area under rubber and production to calculate average yield. Dividing country GDP per capita (or average income if available) by average yield provides a useful indicator of country competitiveness (see chart). Not surprisingly, Malaysia is least competitive, even adjusted for known yield of average active smallholder, confirming popular wisdom. African countries are most competitive and looked good prospects to replace ASEAN as the next rubber power.



What comes first? Pay a fair price so that workers can be paid properly or provide fair wages and living conditions and the price can be negotiated later. Arguments like this are not new. This will be a point of contention between producers and consumers for a long time to come.

Flagging Demand

Worldwide, about 70% of all rubber, NR and SR, are used in the transportation industry, either as tyres or auto vehicle parts. A large part of the demand debate therefore centres around growth of new vehicle market in the next decade. Historically, new car market grows at around 2% worldwide, slower in EU, NAFTA and around 6% in China as its economy slows (previously 12-20%). This gives a 2% growth rate for new OEM tyres.

Growth in the replacement tyre market is proportional to distance travelled x growth in total number of cars. This is traditionally 2-3% but may be 3-4% due to tyre labelling and other new regulations. This change-over cycle should be complete in 2-3 years, leading to "back-to-normal' growth.

The conventional demand growth model is therefore based on little or no growth in developed countries, and quite rapid growth in "new" markets, i.e., the developing countries. Recent developments have raised uncertainty and many possibilities. The optimistic view is the car market will continue to grow but latest trends put doubts to that view. A contrarian view is gaining traction: new car sales will be affected by shared mobility and new model of transport/mobility. An extreme view, shared by, for example, Tony Seba, a Harvard professor, is car market will shrink by as much as 70% by 2030. Is this possible?

Impact of new transport economy

Hiccups in new car sales for 2018 in North America, Europe and China, have created lots of confusion to the simple conventional picture. This trend continues in 2019 with little or no growth in EU and NAFTA and more than 16 months of continuous decline in China. One interpretation is that government-led initiatives to limit growth of car ownership to combat environmental pollution has resulted in change of travel habits. In one poll in China, more than 60% of young adults indicated they had no intention to buy a car. The China transport model of high speed train for inter-city travel, mass transit and electric buses and taxis for inner-city, and walking or bike-sharing for the last mile has interesting ramifications. Rubber consumption for new cars may show no or negative growth and may or may not be filled by increase in replacement tyres, depending on whether total kilometres travelled increase, remain static or reduce. Is growth of non-tyre sector able to compensate?

For specialty rubber consumption, there will be major impact due to demise of ICE in cars. SBR, EPDM, NBR and CR will be impacted, maybe by as much as 50-60% in oil-resistant components and maybe by 50% in engine (heat) related applications. 10% of total rubber is used in auto component applications; as much as 30-50% of this 10% is related to ICE vehicles.

Impact of New Tyre Technology

Major tyre companies target reduced use of material in tyres by as much as 20% in the next 5 years by techniques such as stronger material (tyre cord), thinner walls, thinner tread, and better abrasion compounds, etc. For some applications, normal pneumatic tyres will be replaced by "airless" tyres that require less rubber, e.g. in off-road, agriculture and some solid tyre applications.

Consider the following: in the 1970s life of a set of tyres was 20,000 KM. Fast forward to 2018, this is now close to 100,000 KM, almost to the extent no replacement tyre will be needed over life time of a vehicle (PCs) but different situation for CVs and heavy vehicles.

Impact of EVs

Two opposite directions.

Conventional or high performance EVs have higher acceleration, torque and are heavier to take extra weight of batteries, and this will lead to extra wear.

Trend towards LSEV ad mini-EVs with lower top speed and lower range means less rubber.

Also in NEW MOBILITY MODEL replacing urban car travel with public transport and last mile of travel modes (walking or 2-wheeler, Mobike, etc.) will reduce rubber use.

Autonomous Driving

There is consensus among experts that autonomous vehicles will hit our roads in the coming decade. In combination with ride sharing this will have major impact on car ownership and how the automobile will be used. Experts cannot agree on likely impact and whether this will lead to greater or lesser demand for cars in general and rubber use in particular. Data and poll results indicate car ownership and new car sales will reduce. There are those who argue total kilometres driven will increase even as privately owned cars will be driven less.

Conclusion

In conclusion, it would appear that there is enough interest to continue investment in the planting side, albeit in low-cost non-traditional 6 areas. Whether actual production is adequate to meet expected demand will depend on price being high enough to enthuse higher cost producers in the traditional 6 countries to continue tapping. This will be helped in some way by what would appear to be a reduced rate of growth in rubber demand as new technologies and disruption in transport/mobility model impact the tyre as well as non-tyre sectors.

Precipitated Silica for Rubber Products

Dr. Bijan Kumar Roy Ph.D (Chemistry)
Head - R&D and Technical Services Madhu Silica Pvt. Ltd.

Typical rubber compounds used to anufacture industrial rubber products such as tyres, hoses and conveyor belts contain up to 8 classes of additives. They include curing agents, accelerators, activators, processing aids, antidegradans and fillers. Fillers improve the physical and mechanical properties such as tear, abrasion resistance, hardness and tensile strength. Choice of filler thus has a major influence on the service life, performance and durability of rubber products. Particulate fillers used in rubber industry in general can be classified as “Black” and “Non black” , depending on their origin, the former being produced from petroleum feedstock and the latter from mineral sources. The most important particulate reinforcing fillers being used in rubber industry are carbon black and precipitated silica. Carbon Black historically was the first reinforcing filler used in the tire industry. Since the early nineteen forties, carbon blacks have been complemented by the group of highly active silicas. Technological reasons have long prevented silicas from being used in tyre compounds. Conventionally, carbon black is considered to be more effective reinforcing filler for rubber tyre treads than silica if the silica is used without a coupling agent. Precipitated silicas are traditionally used in shoe soles of athletic footwear, where these white reinorcing fillers give an improved resistance to wear and tear with the option of using all possible colours. The great advantages of light-colored reinforcement vis-a-vis carbon black is the possibility of satisfying practical requirement, whether they be that of shoe soles be non-marking, transparent, or a particular color or whether it be necessary for applications in rubber rice rollers, conveyor belts, transmission belts, hoses, footwear, rubber sheets, railway pads etc. The addition of 20 - 100 parts by weight of precipitated silica to 100 parts by weight of natural or synthetic rubber improves the tensile strength, hardness, tear strength, and abrasion resistance of the vulcanized material. Precipitated silicas are also used as reinforcing agent in silicone rubber, where they replace the more expensive pyrogenic silicas in certain formulations. Precipitated silicas have been used in tire compounds for many years, typically as a minor portion of the filler owing to its hydrophilic nature, in combination with carbon black as the major filler. In the tread area the primary usage of silica has been in large off-the-road tires to promote high tear, cut growth, and chunking resistance. In tire wire compounds silica promotes good brass coated wire to rubber adhesion. Silica is also reported to be used in tire sidewall for increasing tear strength, cut growth resistance and resistance to ozone ageing.

The major breakthrough in silica technology came with the discovery of silane coupling agents. Sulfur functional organosilanes are utilized as coupling agents that modify the surface chemistry of silica and enhance its compatibility and reinforcement capabilities. The fillersystem based on silica and the silane coupling agent in winter tire tread compounds which led to an improvement in winter performance never seen before. Compounds using silica are more elastic and flexible at lower temperatures, allowing better grip and braking during wintry weather. Silanes turned silica into an active chemical reactant in the rubber compound. Another major improvement of the precipitated silica came with development of highly dispersible silica, an innovation that has proven to be a breakthrough for the tire industry. On account of its excellent dispersion capacity, the newgeneration silica has permitted to develop the green tires (replacing carbon black by silica in car tire tread compound) which have a low rolling resistance, improved wet grip and maintained longevity.

Demands for lower rolling resistance, with its resultant reduction in fuel consumption and lowering of combustion gas emissions, created the need for a new balance of tire tread properties that were beyond the capabilities of traditional carbon black !ill er approaches.

Precipitated silicas are manufactured using a wet process that involves chemical reactions and precipitation, achieved by neutralizing a solution of sodium silicate (water glass). The process steps

include precipitation, filtration, washing, drying, milling and granulation, followed by packing and shipping

of the product. The size of the primary particles and the amount of aggregation and agglomeration are determined by the manufacturing processes, reaction conditions, e.g. pH, temperature, concentration and amount of agitation. Precipitated silica thus produced has its use in manifold applications. Among all, the use of precipitated silica as a reinforcing agent in rubber & tires is the largest single application. At present, precipitated silica manufacturers supply products that can be divided into three groups 1.
Products that can be described as first-generation, standard, or conventional (CV) silica.

2. Products belonging to the second generation of silica. Today, such products are frequently termed easily dispersible silica or semi-highly dispersible (SD)silica. 3.The third and latest generation of silica comprises a productgroupcharacterizedbyexcellentdispersion.These products are described as highly dispersible (HD) silica. An easy incorporation of the silica into the rubber mixture and its good dispersion are crucial because they have a considerable effect on the processing costs and on the rubber product's performance. Table 1 indicates some of the rubber grade silicas available from Madhu Silica.

Table 1 : Rubber Grade Precipitated Silica offered by MSPL in Granular Form\

Silica Grade	BET Surface Area, $m^2/_g$	CTAB Surface Area, $m^2/_g$	pH (5% in Water	Loss on Drying,%	Bulk Density, g/l	Type
MFIL-150(G)	125	115	6.9	5.5	333	CV
MFIL-200(G) LG	160	145	6.5	5.5	330	CV
MFIL-200 (G) RG	180	170	6.5	5.5	330	CV
MFIL-200 (G) HG	220	200	6.5	5.5	330	CV
MFIL-210(G)	205	155	6.2	5.5	312	SD
MFIL-125(G)	125	120	6.9	5.5	300	SD
MFIL-100 (G)	115	110	6.5	6.0	300	HD
MFIL-200(HDS-G)	175	170	6.5	6.0	300	HD
MFIL-210(HDS-G)	210	200	6.5	6.0	300	HD

*All corresponding grades are also available in pow:ier and micro-pearl forms.

Highly dispersible silica (HDS) has become the worldwide benchmark, enhancing low rolling resistance and high wet-grip properties when compared to carbon black compounds. HDS, compared to conventional (CV) silica, provides substantially better dispersibility and higher loadability in rubber compounds due to its specific structure. Proper understanding of silica's morphology and surface chemistry is necessary to understand the behaviour of silica in rubber. Characterizing silica morphology include the ratio between the inner and outer surfaces, the size and shape of pores, the absorption capacity, the surface roughness, the primary particle size, the formation of aggregates from these primary particles with the development of siloxane bonds, and the combination of aggregates to form agglomerates held together by van der Waals forces.

However, in recent times synthetic precipitated silicas have also proved to be beneficial to rubber properties, and are replacing blacks in many applications. Partial replacement of carbon black by precipitated silica in rubber formulation (e.g. tread, footwear, conveyer / transmission belt, seal and hoses compounds) is one such example, wherein it has been reported to have reduced rubber compound cost, optimised process-ability and achieved desired end application properties. Table 2 gives an example of such a guideline compound formulation which is commonly used for partial replacement of carbon black by low surface area silica grade, MFIL-1oo(G) in combination with regular surface area grade, MFIL-2oo(G) and where the silica/ black ratio varies from 5/55 to 25/ 35; as seen in the table compound costs decrease in proportion to silica content.

Table 2 : Compound Formulation

SI. No.	Ingredients	PHR				
		C1	C2	C3	C4	C5
1	Natural Rubber	49.50	49.50	49.50	49.50	49.50
2	Poly Butadiene Rubber	50.5050	50.50	50.50	50.50	50
3	Peptiser	0.07	0.07	0.07	0.07	0.07
4	Process Oil	12.00	12.00	13.00	13.00	14.00
5	**Carbon Black**	**55.00**	**50.00**	**45.00**	**40.00**	**35.00**
6	**Precipitated Silica, MFIL-200(G)**	**5.00**	**5.00**	**5.00**	**5.00**	**5.00**
	Precipitated Silica, MFIL-l00(G)		**5.00**	**10.00**	**15.00**	**20.00**
7	Anti-oxidant	2.25	2.25	2.25	2.25	2.25
8	Stearic Acid	2.50	2.50	2.50	2.50	2.50
9	Microcrystalline Wax	1.75	1.75	1.75	1.75	
10	Zinc Oxide	2.60	2.60	2.60	2.60	2.60
11	Soluble Sulphur	1.64	1.64	1.64	1.65	1.70
12	Accelerator	1.03	1.03	1.03	1.05	1.10
	Compound Cost/ Kg {Rs)	**X**	**X_**	**X--**	**X---**	**X----**

A detailed rubber compound properties evaluation based on this partial replacement of carbon black by low surface area silica, in Table 3, also shows its superiority as far as hysteresis, reinforcement and processing characteristics are considered.

Table 3 : Compound Properties

Compound Properties		C1	C2	C3	C4	C5
A	**Cure Characteristics (150 deg C / 30 Min) MOR**					
	ML(lb-in)	2.46	2.47	2.24	2.12	2.33
	MH(lb-in)	15.59	15.91	14.41	13.11	12.72
	MH - ML(lb-in)	13.13	13.44	12.17	10.99	10.39
	TSl (min)	4.6	4.75	5.23	5.8	5.52
	TS2 (min)	5.52	5.2	6.3	7.02	6.82
	Tel0 (min)	4.98	4.75	5.57	5.98	5.55
	Tel5 (min)	5.5	5.73	6.17	6.7	6.35
	Tc25 (min)	6.02	6.25	6.77	7.48	7.23
	TcS0 (min)	7.07	7.22	7.87	8.77	8.63
	Tc90 (min)	11.65	11.47	12.45	13.77	13.47
B	**Mooney & Mooney Scorch**					
	Mooney@ 135	51.66	52.24	49.06	49.13	53.29
	MS@135					
	ts	12.34	12.75	13.79	1457	13.99
	t10	13.2	13.66	14.87	15.9	15.31
	t35	14.6	15.08	16.57	18.04	17.54
C	**Dispersion Rating of Cured Sample, lOOX Magnification, G Scale**					
	x	10	10	10	10	9.5
	y	9.5	9.5	9.5	9	9

D	Unaged Physical Properties (cure 150c/30m)					
	M100 (Mpa)	1.91	1.84	1.73	1.53	1.31
	M200 (Mpa)	4.54	4.2	4.19	3.26	2.67
	M300 (Mpa)8.61	8.13	8.13	6.16	5.01	
	TS (Mpa)	21.7	21.04	22.4	20.95	20.98
	EB(%)	592	580	608	678	754
	Abrasion loss (mm3)	122	116	118	128	131
	Hardness (Sh-A)	61	61	61	57	56
	Work up to break (J/mm2)	1.38	1.27	1.42	1.46	1.6
	Tear Strength (N/mm)	85	78	84	80	79
	Tear Energy (J)	21.35	19.73	19.04	19.77	22.66
E	De-Mattia Cut Growth Resistance: Samples Cured at 141.7 deg C for 60 min					
	Crack Length after SK Cycles	11.7	11.9	10.5	10.3	9
	Crack Length after 10K Cycles	17.5	18.4	16.3	17.1	13.3
	Crack Length after 25K Cycles	21.9	22.6	21.5	22.1	20.3
F	Dynamic Mechanical Properties (cure 150 C / 30 m) : 10 hertz, 0.25%, dynamic strain					
	Storage Modulus at 60 degC (Mpa) rr-	14.9	13.3	14	11.1	10.3
	Loss Modulus at 60 degC (Mpa) E”	2.44	2.1	2.13	1.77	1.7
	Tan delta at 60 degC 0.164	0.159	0.152	0.159	0.165	
	Loss Compliance at 60 degC (Mpa-1)	0.0108	0.0115	0.0106	0.0139	0.0156

This highly dispersible, low surface are silica grade, MFIL-10o(G), is specially introduced for higher load-ability, partial replacement of carbon black in the formulation to prove its feature in mechanical rubber goods. As demonstrated, around 10 to 12 phr replacement of carbon black by silica in compound formulation woks well and thus reducing compound cost is gaining considerable attention in rubber industries.

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Product Design and Development through Numerical Simulation Technology: Sri Lanka Perspective

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Mr V S C Weragoda

Introduction

The global society as at now is at the pinnacle of development in many different fields including science, engineering and technology. However the ambitious nature of the human being has never been fulfilled though they have been able to send satellites to stars, thousands of miles away from the earth. Aforementioned statement depicts, we have been able to explore the *macro and mega* scale of the universe in parallel with never ending cycles of design / development of machineries and equipments. Jumbo jets, space rockets / shuttles and satellites portray the apex in this scale. Besides, man has never introduced barriers to explore micro / nano, and even quantum level of the matter, extended the technology of the equipments and machineries to scrutinize the miniature world. The motivation in this has probably triggered due to the need to alleviate human/animal diseases in medical and biological sciences through the development of micro/ nano imaging. Later, the trend shifted towards in the development of miniaturized machines, novel materials through the introduction of Electron / Scanning Electron Microscope. Though the development has widened bi-directionally (towards mega and pico level) in size scale, human thirst in exploration of nature will never be quenched.

In this journey of experimentation, application of computers has always been a key factor in the advancement of science and technology. Though the contribution of computers in various aspects is widely known within global community, a question still remains whether the general public with science background, operational level managers in industries and some academics in certain universities in Sri Lanka are aware of this regard. In Sri Lanka, the affiliation of computers in science and engineering is always broadly referred to as *Computer Aided Design and Drafting* or *CADD*. Nevertheless there are other alternatives that this can be used in a much broader sense. The country has appealed to various investors of different leading industries (semiconductor, automotive, aerospace and materials processing) that it is vital to become aware of

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this regard. The aim of this article is to make the readers aware on the other alternatives in using computers, so that Sri Lanka can utilize this in the growth of her economy in a much broader sense, in engineering design and development.

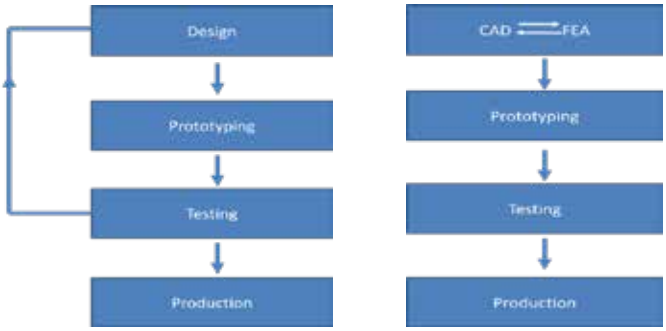
Engineers and scientists have been playing the most important roles along this long journey and they mainly involve in modeling of physical phenomenon in nature. Engineering and scientific modeling is essential in predicting the outcome of certain phenomenon that is useful to human existence, such as finding concentration of pollutants in lakes and sea water, prediction of the weather in an attempt to understand the formation of thunderstorm and tornadoes, to determine of stress/strain distribution of structures subjected to mechanical, thermal and aerodynamic loads, in countless other engineering applications. These processes and anomalies can be described with the aid of the laws of physics or other fields in terms of algebraic, differential and /or integral equations; that relates variables of interests. Most of these expressions are analytical descriptions of physical phenomena and processes and are called *mathematical models*. The complexity of these mathematical models can range from Newton's second law of motion to Navier – Stokes equations in fluid dynamics. The increased complexity of the solution process itself restrict the scientist or the engineer in achieve their intended task. However, computer technology has enabled an immense relief in this respect with the use of *Numerical Simulation*. The main intend of this article is to aware the readers on the impact of numerical simulation on the technology and improvement of product life cycle.

Numerical Simulation

The use of numerical method and a computer to evaluate the mathematical model of a process and estimate its characteristics is called *Numerical Simulation*. In computer industry jargon, numerical simulation lies in CAE or Computer Aided Engineering domain; is the use of computer software tools to engineering analysis tasks. Numerical Simulation is implemented on systems comprised solely on solids, liquids and systems that have interaction between solid and fluids. Following techniques are used to perform numerical solutions in problems exclusively consisted on

1. Solids – Finite Element Analysis (FEA)
2. Fluids – Computational Fluid Dynamics (CFD)
3. Solid Fluid Interaction – Multi Physics Simulation Techniques.

The influence of these techniques to traditional engineering design has been tremendous since it was evolving around 70s. The article is mainly focused on Finite Element Analysis.



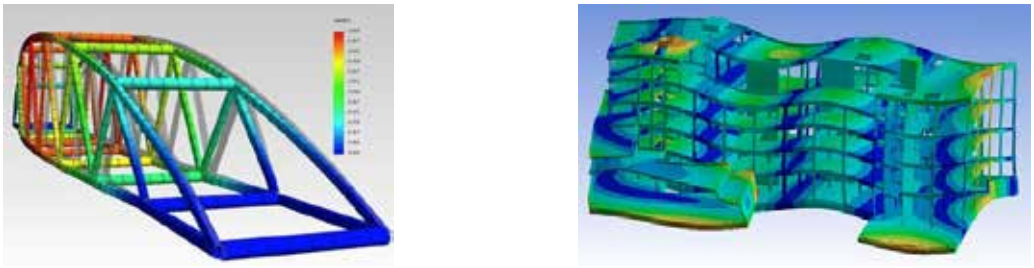
(a) (b)

Figure 1: (a) Traditional driven design process (b) FEA/CFD driven design process

According to figure 1(a) traditional design process consist of an iterative loop between "design" and "testing" stages. It is widely known that engineering design is a repetitive operation and generally incur considerable amount of financial and time commitment to obtain a successful efficient product. The financial and time commitment incurring in this process is mainly due to the construction of physical prototype of the design and validating it with the actual environmental or factory conditions. It is indeed in this step that designer identifies the weak localities of his/her design and requires performing another trial with the modified design. This process need to be done several times and acquire significant amount of time and money.

This can range from petty hundred dollars per days to millions of dollars per year, depending on the scale of the industry. The remedy for this issue lies in numerical simulations. With respect to figure 1(b), it is clear that the recurring loop has departed. The key reason is that once the numerical simulation is introduced, the production of physical prototype will be omitted and instead, the equivalent will be represented by computer aided design (CAD). The numerical simulation will be performed on the CAD model, such that the actual working conditions and the behavior of the material / fluid of the proposed design are described accurately by mathematical model. Hence the need for actual run of the prototype of the design through costly facilities is no longer required. If there is a need of a physical CAD can also be easily modified and promptly rectified based on the requirement of the product performance. This approach can significantly reduce the product development cost and will incur profits. Some of the areas that we can apply the said technology are elucidated by the following figures.

1. Civil Engineering (Building and Structural Engineering Design)



(a) (b)

Figure 2: (a) Bridge Design (b) Building / Structural Engineering

2. Mechanical Engineering (Automobile / Engine related component design)

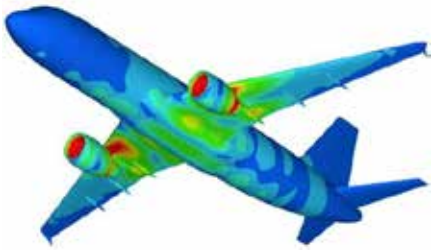


Figure 3: Automobile and engine development

3. Electrical Engineering (Design of electrical machines with the consideration of heat dissipation and electromagnetic flux distribution)

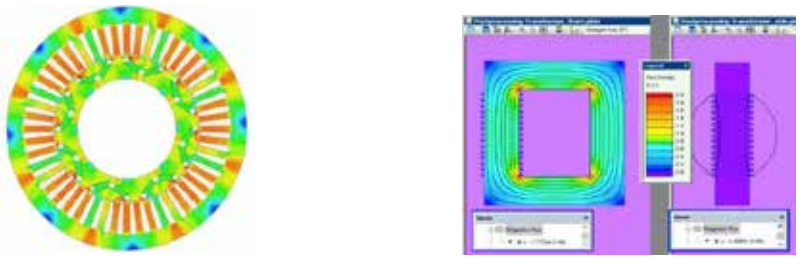
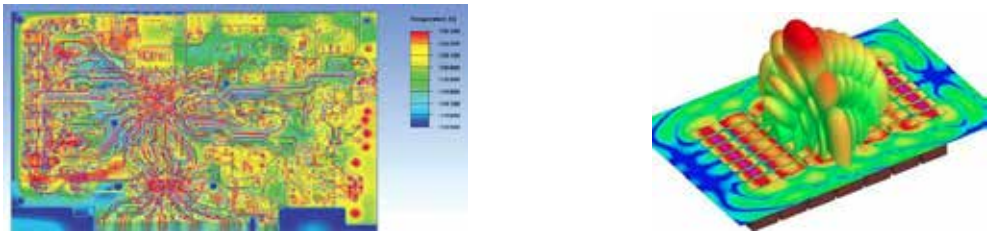


Figure 4: (a) Electrical motor magnetic flux analysis (b) Electrical transformer flux density analysis

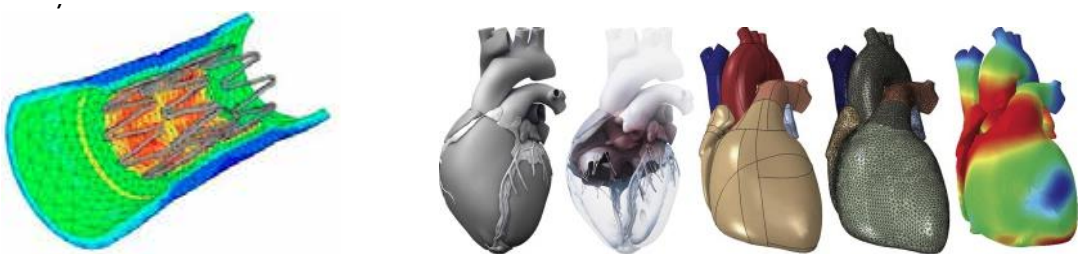
4. Electronic and Telecommunication Engineering (Analyse the heat dissipation of circuit board with the intention of the application of heat sink)



(a) (b)

Figure 5: (a) Electronic circuit temperature analysis (b) Flux density analysis of antennas

5. Bio Medical Engineering (Analyse the stress strain behavior of biological tissues to develop bio materials and to design bio medical and surgical instruments in the medical field)



(a) (b)

Figure 6: (a) Design of Stent geometries for the solution of coronary heart diseases (b) Heart modeling for stress and strain analysis under different conditions.

6. Textile and Clothing Engineering (Analyse stress – strain behavior of technical textiles to be used in aggressive environment to specific purposes)

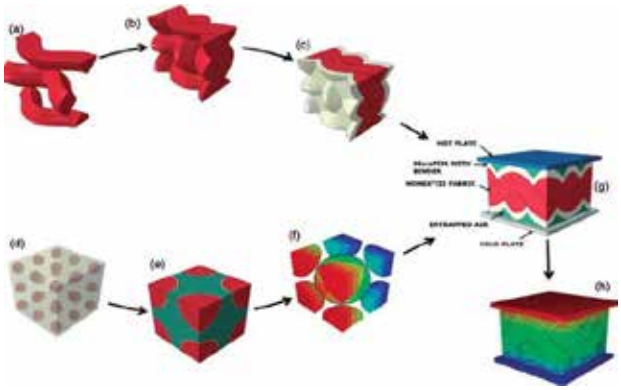


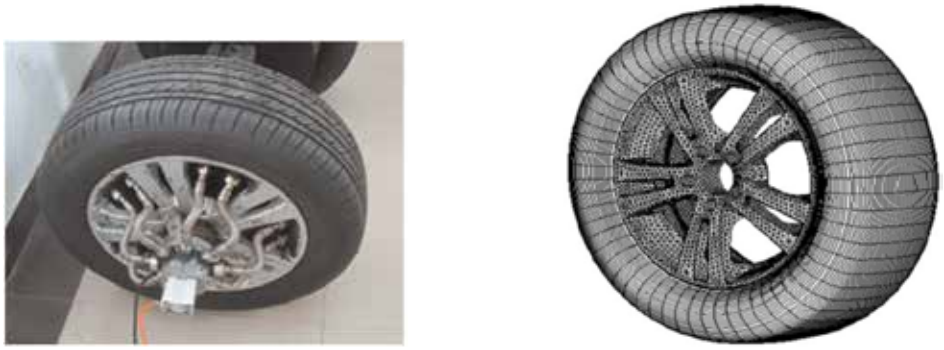
Figure 7: Design of weaving patterns and application of different materials for better performance of the intended textile.

Following are the Benefits of Numerical Solutions.

1. Reduction of the number of prototype used.
2. Reduce design and analysis cycle time.
3. Optimize design for weight or cost.
4. Identification of design errors at initial stage of design.
5. Ability to handle complexity. (Material, Loads, Boundary Conditions)
6. Visualized Stress distribution and deformed shapes of the design.

Finite Element Analysis (FEA)

A rigorous mathematical explanation of FEA is not the intent but a brief introduction on the method. Critical and in-detail explanations are available in various text books available in literature [1], [2]. FEA acts by the method called *Finite Element Method* or *FEM*. In *FEM*, a given solid domain is viewed as a collection of sub domains, and over each sub domain the governing equation is approximated by a traditional mathematical techniques. Product designs with complex shapes are not possible to analyze using traditional analytical frame work. However with FEM, one can subdivide the complex design into simple geometrical domains (squares, triangles) and the numerical method typically transform differential equations that govern the full domain of the design into set of algebraic equations of a discrete model. Following figure illustrate FEA mesh of a vulcanized tire model in studying the performance at different rolling conditions.



(a) (b)

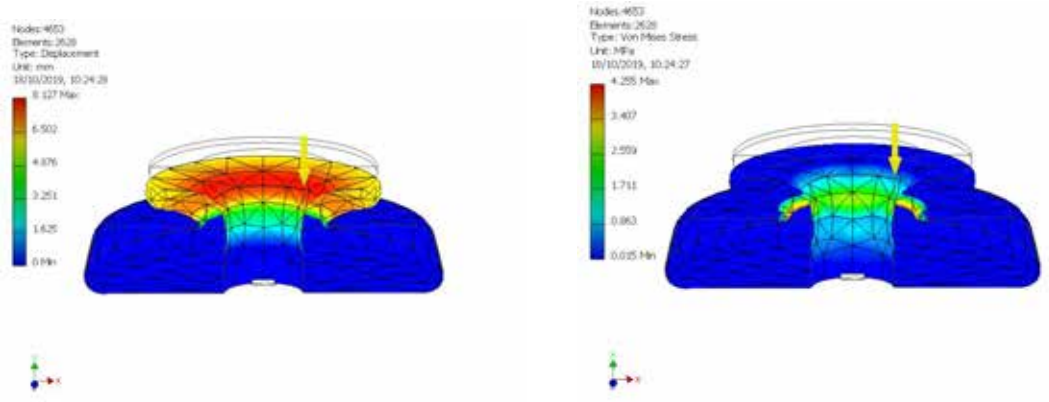
Figure 8: (a) Physical tire to be developed/analyzed (b) FE mesh of the CAD model of the tire [3]

Subsequent to the action of the discretisation, each domain is considered as an individual *element*. Loading or boundary conditions applied to the considered geometry are also distributed along each domain according to a formulation, such that the total effect would be the same. Once the boundary conditions or the loading conditions are determined for each domain; material behavior; contact conditions will be taken into consideration. Once these inputs are satisfied, it is the role of the computer to calculate stiffness of each element of the complete domain. In the event of completion of the elemental level calculation, the computer requires to assemble all the elements that consist the original geometry or model. It is in this process that computer needs to represent the total solution of the complete domain, in order that the analyst can consider the requirement, whether to change the selected material, boundary condition or the original geometry.

A summary of a comprehensive case study, conducted in the Department of Materials Science and Engineering of University of Moratuwa will elucidate the use of FEA in engineering product design. In this scenario, it is a polymer based rubber strut mount design modification.

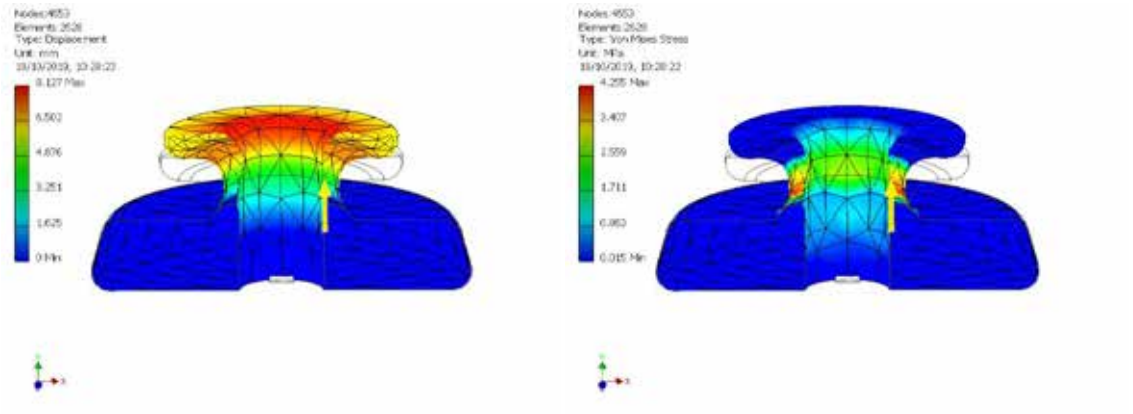
The primary function of a rubber strut mount is to isolate the vibrations transmitted from the wheel to the vehicle body. The rubber component of the strut mount absorbs the vibration energy and dissipates it as heat within. In addition the strut mount also bears the weight of the suspension components when the vehicle wheels drop to a road depression or when the wheel is lifted off the ground. Therefore the strut mount has to be strong enough to support the sprung mass of suspension as well as soft enough to dissipate the vibration. The particular design of the spring in this study had a high rate of premature failure when in use after 25000km-30000km.

The figures 9(a) and 9(b) shows a half sectional view of the rubber spring when subjected to the maximum estimated compressive load.



(a) (b)

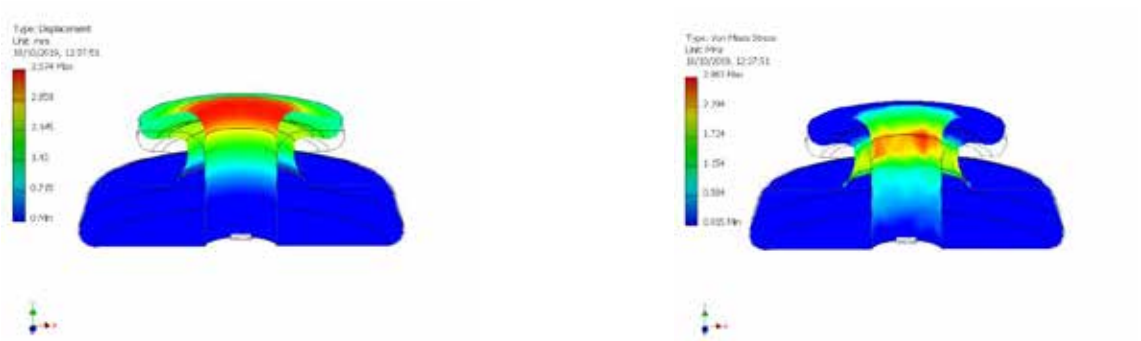
Figure 9: (a) Displacement on compression (b) Stress distribution on compression



(a) (b)

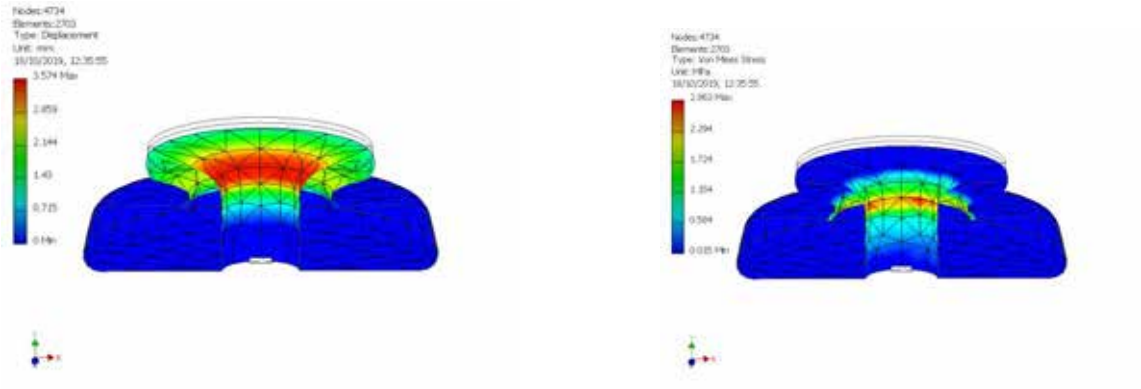
Figure 10: (a) Displacement on tension (b) Stress distribution on tension

Similarly, the figures 10(a) and 10(b) shows a half sectional view of the rubber spring when subjected to a similar tensile load. It has been clearly apparent that the neck region of the spring has a high localized stress concentration which eventually leads to excessive permanent deformation and subsequent play. One approach correct this situation is to alter the cross sectional area of the critical region slightly and excessive deformation in the top region can be reduced by hardening the compound in the given region.



(a) (b)

Figure 11: (a) Displacement on tension (b) Stress distribution on tension



(a) (b)

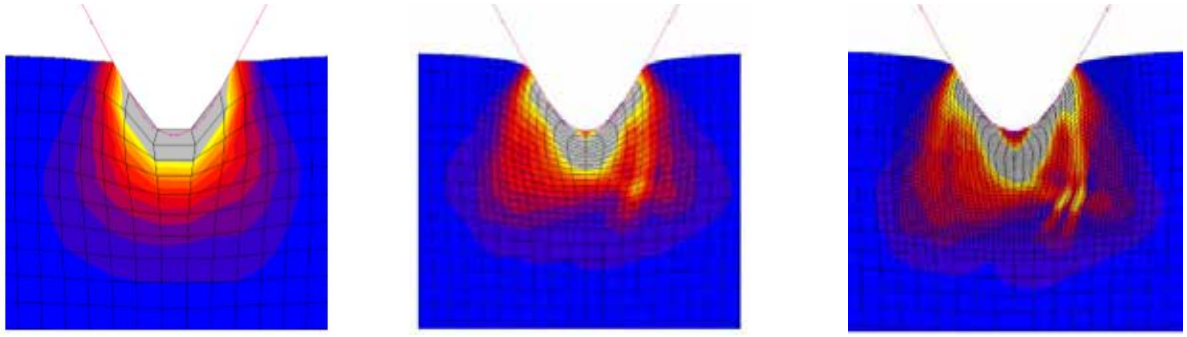
Figure 12: (a) Displacement on Compression (b) Stress distribution on Compression

Figures 11 and 12 shows that subsequent to the given modification of increasing the minimum thickness in the neck region by 30% and increasing the hardness of the compound by 5 IRHD units in the top region, the maximum stress and the displacement have reduced by almost 50%. On road testing, the component was still in service after 45600km. This product improvement was obtained with the efficient use of FEA with less number of prototypes and hence low design cost and cycle time.

Though the case study is for the polymer based product, FEA is not limited for certain material category. This numerical solution strategy can be applied for any engineering material ranging from soft/bio material to

super alloy aerospace material and the geometry lies in the span from nano to macro level.

It is evident in this scenario that higher the number of elements of a domain, number of calculations (stiffness and other mechanical, thermal variables of the domain) raises proportionately. This increases the computational cost in terms of computational resources and solution time. In FEA, contrarily; the accuracy of the solution increases correspondingly along with the number of elements. The illustration shown below elucidates the dependence of the solution accuracy with the number of elements.



(a) (b) (c)

Figure 13: Plastic Strain Contours as depicted by FEA, under the deformation of an spherical nano indenter on a Metallic Glass with different mesh sizes (a) L=10µm (b) L=4.54µm (c) L=2.84µm [4]

Figure 13 illustrates propagation shear bands within the material volume of a bulk metallic glass sample under spherical nano-indentation. It is evident from the above representation that shear bands are clearly visible with the reduction of element size (hence elevated number of elements). Mechanical, thermal or any physical variable to be studied with the FEA should be carried out, along with "FE Mesh Convergence Study". Mesh convergence study let the FEA personal to aware the minimum size of the element to be divided in par with balanced solution accuracy and computational time.

However, with the development of information and communication technology, in par with the numerical techniques, "Super Computers" are available to study complex problems. Super computer [5] is a computer that has high level of performance compared to a general purpose computer. Currently they are widely used in Molecular Dynamic Studies and Weather Modeling and Computational Fluid Dynamics studies in multi disciplinary areas. As of 2018, the fastest super computer is with Oak Ridge National Laboratory of the United States that can perform 122.3 peta floating point operations per second.

Sri Lanka is still yet to embark to this level and we believe that Sri Lankan government should have proper plan to deploy this technology within the existing industry. The plan should include number of training opportunities on FEA for local engineers to enhance their vision on this. These trainings can be done in local universities or with joint collaboration of foreign institutions. In Sri Lanka, certain number of experts in the field do employ in state universities. But the lack of interest and less exposure about these technologies within the local industries has led the local experts either to conceal with the theoretical knowledge or to develop foreign industries. However there are some positive signs on the development in this aspect with the establishment of Finite Element Analysis and Simulation Center (FEAS Center) at the Sri Lanka Rubber Research Institute premises. Local industries can get the benefit of numerical simulation much easier with the facility.

In conclusion, it is crucial for the government, to formulate some strategies to deploy these international trends in the local industries and move the country towards prosperity.

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