Plastics and Rubber Sri Lanka

The Journal of the Plastics and Rubber Institute of Sri Lanka

PRI SRI LANKA

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VOLUME 20

CHALLENGE DRIVEN GROWTH

- **Unleashing the 'billion dollar' potential of Sri Lanka's rubber industry**
- **Challenge of change for manager**
- **Natural rubber – a history of challenge driven growth**
- **Smart manufacturing**
- **Future directions of R&D in tyre industry**
- **Leading conglomerate attributes resilience through pandemic to customer-centricity**
- **Carbon nanotubes as catalyst**

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Message from the President

It is with great pleasure that I convey this message for the 20th Volume of the Journal of the Plastics and Rubber Institute of Sri Lanka.

The challenges posed by the Covid-19 pandemic and the economic downturn in the country, delayed publishing of the Journal. Despite the challenges, I am very pleased to note that the Seminars, Publications & Image Building Subcommittee have worked diligently to make it a reality.

Being essentially devoted to the educational and professional development of the polymer industry in Sri Lanka, the Annual Journal serves as the vehicle to disseminate knowledge gathered from local and overseas academics and professionals in the polymer industry. The Journal also provides an opportunity for the local researchers to publish their research papers in the international arena and also help our members to gain an insight in to the latest developments in the polymer Industry.

Innovation is the key to success. Today the entrepreneurs are looking for innovative solutions to survive and sustain their businesses under the economic downturn, and it is prudent to look at the challenges that lay ahead for the polymer industry in Sri Lanka.

The industrialists, academics, researchers and technologists under the umbrella of The PRISL can revitalize the Polymer Industry, thus assist in bringing in vitality to the national economy and bring prosperity to Sri Lanka.

It is noted that, latex gloves, industrial tyres and personal protective equipment (PPE) have enjoyed an enhanced local and global demand.

Enhancing natural rubber production, to meet the growing demand, and manufacturing innovative products are considered to be the priorities.

The PRISL being the accredited institute, for providing education and training for the personnel engaged in the polymer industry, envisages playing a vital role, in providing career guidance for school leavers to encourage them to enter the polymer industry to improve the knowledge base. In addition to continuing the regular educational and Continuous Professional Development (CPD) Programmes, PRI is also focused on customized training programmes based on specific industry needs.

The institute will continue to take up the challenge of collaborating with overseas organizations for knowledge sharing, to find innovative solutions to face the challenges in these difficult times.

I am very much impressed by the efforts taken in compiling an impressive Journal and congratulate the Chairman and the members of the Seminars, Publications & Image Building Subcommittee for accomplishing this challenging task.

Kalyana Dhirasekera
President PRISL

Message from the Hon. Secretary, PRISL

The publishing and launching of the Annual Journal of the Plastics and Rubber Institute of Sri Lanka has always been a significant milestone in our achievements. It is enlightening to note that the theme of this year's journal, is "Challenge Driven Growth", which is consistent with the national effort towards industry growth.

I consider it's a pleasure and privilege, as the Hon. Secretary of the Plastics and Rubber Institute of Sri Lanka, to convey this congratulatory message for the 20th edition of the annual journal of our beloved institute.

The polymer industry in Sri Lanka, which faces unprecedented challenges, needs continuous development through sustainable growth, to be competitive globally, and our institute will continually endeavor to enhance the manufacturing and technological capabilities to the polymer industry.

The articles selected for the journal covers a wide range of topics suitable for the challenges faced by the industry today. I appreciate the editorial team and admin staff of PRISL, for their tremendous effort to make this event a great success under the prevailing adverse circumstances.

I thank Subcommittee Chairman and the team for their tireless contribution and commitment.

I am confident that the contents of the journal will provide a significant contribution to enhance the knowledge of the personnel engaged in the rubber and plastics industries in Sri Lanka and overseas

Congratulations for task well accomplished.

Prabath Jayasinghe
Hon. Secretary PRISL

Note from the Editor's Desk

"Our very survival depends on our ability to stay awake, to adjust to new ideas, to remain vigilant and to face the challenge of change." – Martin Luther King Jr.

The Plastics & Rubber Institute of Sri Lanka is entrusted with steering an industry that holds great promise for our beleaguered economy. Especially so in these challenging times. We can, however, draw some encouragement in that the Plastics & Rubber industry, through sheer grit and innovation, achieved an export income of over US$1 billion in 2021.

The Industry has demonstrated that the human spirit is much like our familiar polymer material, resilient & flexible. We have faced adversity head-on and survived with tenacity.No doubt technology's multiplying effect on progress has been experienced now more than ever before and as such, this trend dictates the language we speak and the way we think. Either we speak this language, or we remain mute. Towards this end, the journal we put forward in this volume aims to give voice to these times and their trends. However, we leave it to our readers to be the judge.

The journal's focus aims to shed light on the many instances of human capital being engineered to overcome these challenging times. With pride, we present the Annual Journal for 2021 under the theme "Challenge Driven Growth". This 20th volume contains articles and research papers contributed by professionals in Sri Lanka and overseas. It explores opportunities and the obstacles that need to be overcome in this billion-dollar industry. The publication harnesses the expertise and knowledge to overcome the present challenges while mapping a path for a resilient future. Further it also aims to provide a retrospective assessment of what was achieved.

The innovative spirit and dynamism of members of the Seminars, Publications, and Image Building Committee helped immensely in the task set out for us. I must also acknowledge the dedication of the PRISL admin staff that supported our endeavors.

Finally, our contributors deserve recognition for the excellence of their contributions, and I would like to record my deep debt of gratitude to each one of them. The PRISL also acknowledges the generous assistance of our sponsors, without whom the journal would not have come to print.

A special word of thanks to Mr.P.P. Perera, Vice President of the PRISL & Mr Prabath Jayasinghe, Secretary of PRISL, for their unstinted support. Thank you, President PRISL , Mr Kalyana Dhirasekera, for your guidance and encouragement while not forgetting the entire EXCO team for their support and encouragement that contributed to the success of this publication.

Pio Perera
Hon. Assistant Secretary, PRISL

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Mr. P. P. Perera
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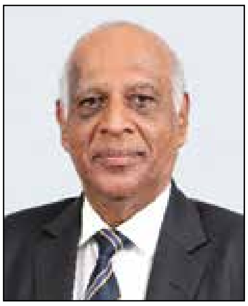

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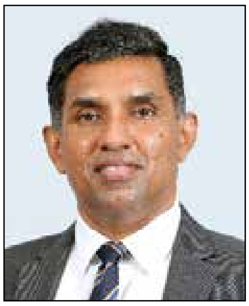

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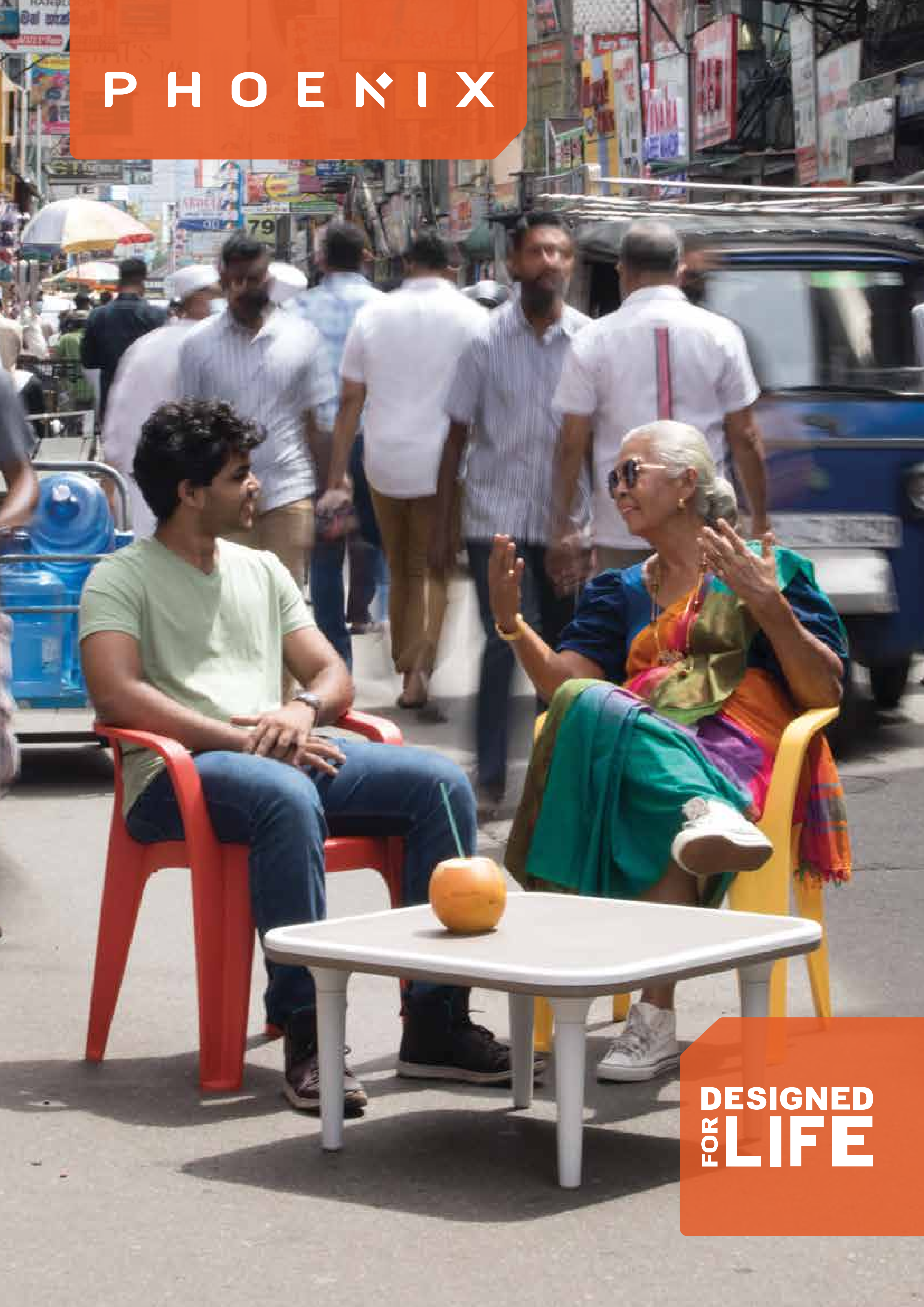
Patron Members

1.	ACL Cables PLC	Cable Insulation
2.	Sierra Cables PLC	PVC & XLPE cables
3.	Ansell Lanka (Pvt)Ltd	Dipped latex gloves
4.	Aqua Packaging Pvt Ltd.	Flexible packaging materials / plastic bags
5.	Associated Motorways Ltd.	Retreaded tyres, custom mixed rubber
6.	Associated Speciality Rubbers Ltd	Manufacturing tailor made superior processing
7.	C.W.Mackie PLC	Technically specified rubber sole crepe, moulded & extruded products
8.	Central Industries Ltd	Manufacturer of PVC pipes and fittings, PE pipes and storage tanks, electrical switches and
9.	Ceytra Ltd	Manufacturer & exporters of moulded extruded products For international & local markets
10.	Chemanex PLC,	Exporters of CNC & Knitted gloves, suppliers of raw materials to the Industry.
11.	CIC Holdings PLC	Supplier of Industrial raw materials for plastics and rubber
12.	D. Samson Industries , Ltd	Manufacturer of shoes, shoe components & rubber products
13.	Damro Plastics Products Ltd.	Plastic furniture products
14.	Dipped Products Ltd.	Dipped latex gloves for medical purposes
15.	DKW Plastics Industries	Manufacturer of polythene film & bags
16.	Elastomeric Engineering Co	Gaskets for plate heat exchangers, wheels for castors
17.	Eu-Retec (Pvt) Ltd	Manufacturing, remoulding of industrial solid tyres
18.	FABNA Indutries (Pvt) Ltd.	Manufacturing rubber compound and recycling tyre dust
19.	Falco International Trading (Pvt) Ltd	Agents for international manufacturers of plastics, rubber, elastomer, chemicals and flexible packaging films
20.	FMJ Plastics (Pvt)Ltd	Injection and blow moulders of plastic components and containers for Industrial and commercial use
21.	Hayleys Industrial Solutions Ltd	Industrial Chemicals
22.	Imperial Rubber Industries (Pvt)Ltd.	Manufacturing & exporting of high quality moulded and excluded technical rubber products and rubber compounds
23.	Interplast Asia Ltd	Manufacturing of plastics products
24.	Jafferjee Bros. Exports (Pvt)Ltd	Manufacturer & exporter of extruded & moulded rubber products.
25.	Jayes Trading Co,	Trading / Marketing
26.	Kavin Polymers (Pvt)Ltd	Footwear, footwear components & rubber chemicals
27.	Camso Loadstar (Pvt) Ltd	Manufacturer and exporter of Pneumatic tyres, solid rubber tyres, wheels & tracks
28.	M SJ Industries (Ceylon) Ltd	Manufacturer of pharmaceuticals and plastics items
29.	Microcells (Pvt.) Ltd	Manufacturer of rubber mats & matting s for domestic & Industrials applications
30.	Multiform Chemicals Ltd.	Indenting and ex-stock sales of industrial chemicals
31.	Orient Holdings Ltd	Manufacturer of electrical accessories
32.	Phoenix Industries (Pvt)Ltd	Manufacturing and distributing consumer plastics products and plastics packaging Solutions
33.	Polydime International (Pvt)Ltd	Film out of recycled materials, agricultural film – grow bags, 2layerfilm
34.	Polymer Color (Pvt)Ltd	All Types of additives and master batches for polymers
35.	Polymer Products Impex (Private) Limited	Technical rubber products
36.	Polypackaging Industries (Pvt) Ltd	Flexible Packaging manufacturer
37.	Prime Polymers	Industrial safety gloves and medical gloves
38.	Richard Pieris & Co. Ltd	Manufacturer of polyurethane foam, plastic water tanks, Rigi foam, tyre retreading, industrial and household products
39.	Rubber Research Institute of Sri Lanka	Research on rubber plantation and products
40.	Samson Manufacturers Ltd.	Manufacturer of shoes.
41.	Sinwa Rubber Industries Ltd	Manufacturing shoes, rubber products and adhesives
42.	Trelleborg Lanka (Pvt) Ltd	Manufacturer of Industrial tyres
43.	Unitrac Holdings (Pvt)Ltd	Importers of all types of plastics raw materials, metalized PET & CPP& PET films, additB34:C44ives for the plastics processing industry and adhesives for the laminating Industry
44.	S-Lon Lanka (Pvt)Ltd	Manufacturer of PVC pipe & fitting, electrical conduit, solvent cement for PVC articles
45.	Wheel Works (Pvt) Ltd	Solid rubber tyres
46.	Workwear Lanka (Pvt) Ltd	Industrial gloves and sports gloves
47.	World Polybags International (Pvt)Ltd	Manufacturer of HDPE & LDPE packaging material
48.	Textrip Ltd.	Manufacturers & Exporters of Latex rubber bands, strips & tubes
49.	BASF Lanka (Pvt) Ltd	Rubber Processing Chemicals, Polyurethane, Styropor – Expandable Polyester, Bio-degradable Plastics, High Impact & General Purpose Polyester, Construction Chemicals, Engineering Plastics
50.	Chemron Private Ltd.	Retail Services, Packaging Solutions, Industrial Equipment, Home and Garden, Chemicals, Plastic Products business activities.
51.	Kalhari Group of Companies	Manufacturer of Footwear Uppers and recycling of industrial and post consumer waste.
52.	J K Imports & Export Co. (Pvt) Ltd	Distribution and trading of wide range of raw materials, H.D.P.E., L.D.P.E., L.L.D.E., Polystyrene, Master Batch, Filler Master Batch (Caco3) & Chemicals in Sri Lanka and Globe.
53.	Global Rubber Industries (pvt) Ltd.	Manufacturer of Solid Tyres for World Market
54.	Polymet SA (s) Pte Ltd	Import and Distributors for Plastics Raw Materials
55.	Lanka Minerals and Chemicals (Pvt) Ltd	Manufacturers of Calcium Carbonate
56.	St. Anthony s Industrries Group (Pvt) Ltd	Leading Manufacturer of PVC Pipes & Fittings
57.	Penguin Industries (Pvt) Ltd	Manufacturers of Compact Discs and other Plastics products
58.	PASAN RETREADERS	Tyre Rebuilding & Flat Production
59.	Ravago Lanka (Pvt) Ltd	Distributor of PP, HDPE, LDPE, PVC, EPS
60.	National Petrochemical Industrialization Marketing Co.	Producer of Plastics Raw Materials

61.	Vaughan Chemicals (Pvt) Ltd	Indenting and Trading of Industrial Raw Materials. Specialize in The Polymer Field, Synthetic Rubber and Plastics,Colour Master Batches,Carbon Black
62.	CMC Engineering Exports GMBH	Suppliers of Food Processing and Packaging Machinery, Injection & Blow Moulding,Waste Treatment Plants,Textile & Industrial Raw Materials
63.	CRS Engineering (Pvt) Ltd	Mechanical or Industrial Engineering
64.	PET Containers (Pvt) Ltd	High Quality PET Bottles for Water / Oil
65.	Rubber Lanka	Importers, stockist and distributors of rubber to metal adhesives, mould releases, structural adhesives for planes, trains, automobiles, bridges and boats.
66.	Lord India (Pvt) Ltd	Manufacturers of world renowned LORD range of rubber to metal adhesives and structural adhesives.
67.	Samson Reclaim Rubbers Ltd	Manufacturer of reclaim rubber for the Export and local market,
68.	PE Plus (Pvt) Ltd	Manufacturer of PE Water tanks, solar hot water system and polymate plastic items. sport surface and clay fields.
69.	V S Polychem (Pvt) Ltd	Raw materials supplier and indenting agent.
70.	Natures Beauty Creations Ltd	Manufacturer of Cosmetic items, pet bottles and injection moulding.
71.	Islandwide Marketing Services (Pvt) Ltd	Supply of Raw materials
72.	Samson Trading Company (Pvt) Ltd.	local and international raw materials and accessories supplier for footwear industry.
73.	Union Chemicals Lanka PLC	Manufacturing cum trading organization for chemicals & allied products specialized in synthetic latex polymer dispersions, silicon emulsions, water based wood coatings and industrial chemicals
74.	Lankaplas Technologies	Raw materials supplier and indenting agent.
75.	TRW Lanka (Pvt) Ltd	MANUFACTURE HEAVY DUTY, INDUSTRIAL, EARTHMOVER AND CONSTRUCTION WHEELS, IN BOTH TUBE AND TUBELESS TYPES. WHEEL SIZES RUN FROM 12 TO 29 INCHES IN DIAMETER AND CARRY MOST BRANDS OF DOMESTIC AND IMPORTED TRACTOR WHEELS
76.	Lakpa Footwear (Pvt) Ltd	Manufacturers & Exporters of Rubber Slippers,Synthetic Rubber Slippers,Leather & Artificial Leather Sandals,Rubber Play Balls,Door Mats,Moulded Rubber Goods & Rubber Compounds
77.	Korean SPA Accessories (Pvt) Ltd	manufacture superior quality printed and unprinted corrugated cartons to be used mainly in food, garment and various other industries.
78.	M/S Dharmasiri Tyre House (Pvt) Ltd	Manufactures of rubber related products, importers and distributers and brand new tyers,rubber chemicals, PBR, carbon black etc
79.	Rainco (Pvt) Limited	Importer,Manufacturer,Exporter and Distributor of Umbrellas,Raincoats,Mosquito Nets,Canopies,Tents,Blinds,Curtains,Bamboos,Fabric,Venetian/Vertical,Marques,Tents,Party Tents,Bricks,Outdoor Furniture
80.	ABC Trade & Investments (Pvt) Ltd	ICT Solutions, Healthcare, Retail Marketing, Water Purification Solutions, Lighting Solutions, Consumer Electronics, Printing, Plantation, Tourism and Import Export Trading.
81.	Nellchem Associates (Pvt) Ltd.	Rubber Chemicals, Plastic Additives, Industrial Chemicals
82.	Global Vinyl Ltd	Manufactures of PVC Vinyl Flooring Leather cloth, floor carpets, vehicle carpets, roofing felts Tent Material and PVC sheeting
83.	Ceat Kelani International Tyres Pvt Ltd	Tyre Manufacturers, Distributors & Deale
84.	Poly Glass (Pvt) Ltd	Manufacturers Importers & Distributors of Aluminum Ladders & Rubber Beadings
85.	Plastics Industry Association Of Sri Lanka	
86.	Akhtari Trades (Pvt) Ltd	Manufacturing of flexible packaging materials and films
87.	Jeya Packaging (Pvt) Ltd.	Packaging - Pvc Shrink Films / Plastic Products / Polythene Materials And Products / Polythene Manufacturing & Printing
88.	Kanli Chemicals (Pvt) Ltd.	Supplier of industrial chemical and raw material to PVC, Plastic, Packaging and Coating industry.
89.	Multi Polymers (Pvt) Ltd	
90.	Liberty Polythen (Pvt) Ltd.	
91.	LPG Rubber Industries (Pvt) Limited	Manufacturing rubber and plastic products.
92.	Lalan Rubbers (Pvt) Ltd.	Manufactures and Exports Disposable Gloves, Household Gloves and Industrial Work Gloves.
93.	Evinco Plymers Pvt Ltd	Distribution Company of CaCo3 Filler and Compostable resin
94.	A P I Traders (Pvt) Ltd	Suppliers of Industrial Technologies, Plant & Machinery
95.	Clean Poly Packageing (Pvt) Ltd	Polythene manufacturing and printing
96.	Zahra International Impex (Pvt) Ltd.	Provider of Raw Materials for Plastic, Polythene, Soap, Detergent, Candle, Crayon, Rubber, Paint and PVC Industries.
97.	J. J. Feed and Pharma (Pvt) Ltd.	Importers of Food flavors,Fragrances, Fine chemicals, Pharmaceuticals and Plastics
98.	D S Industrial Souloutions	Stainless Steel , Industrial & Construction Solutions
99.	Penguin Polymers Pvt Ltd	
100.	Taplo Chem International (pvt) Ltd	Plastic Raw materials
101.	Petform Lanka Pvt Ltd	PET Based Packaging
102.	Three Star Packaging Solutions	Manufacture & Supplier of Polythene & Flexible Packaging Meterial in Bags,Pouch & Reel Form
103.	Idea Industries Limited	Exporter, Manufacturer, Supplier of Pvc Spanish Roofing Sheet , Red Splanish Roofing Sheet, Green Spanish
104.	Rubberplex Enterprises	Supplier of Moulded rubber products, rubber compounds, silicone rubber moulded products
105.	DM polypack	Packaging materials
106.	Champion Recycle(Pvt) Ltd	Retraing tres
107.	Plastechs polymer recyclers	Dealers in Recycled plastics raw materials
108.	Nethchem Colour Works Lanka Pvt Ltd	Sales and marketing of Chemicals & the Research & Development of Colorants and Curatives
109.	Rolanka Enterprises	Supplying Rubber Products
110.	Agromet Asia Pvt Ltd	Transforming Non-Ferrous metal scrap into useful Chemical and Alloys (Recycling)
111.	DSL Lanka Pvt Ltd	Natural Rubber and Soft toy Manufacturer
112.	E.B. CREASY & CO PLC	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Unleashing the 'Billion Dollar' Potential of Sri Lanka's Rubber Industry

Manoj Udugampola

At a time where Sri Lanka is in much need of increasing its foreign exchange reserves, the vast untapped potential of the country's rubber export industry requires due attention.

To place this industry's foreign exchange earning potential in context, the Export Development Board (EDB) had earlier set an export earnings target of USD 4.4 billion for the export of rubber products by the year 2024.

This proven, well established industry has a great potential to increase the country's export earnings both in both short to medium term and the long-run.

In short-term, significant increase in prices of rubber offers a time-bound opportunity. During the first half of the year, the Colombo Rubber Auction saw prices more than doubling, increasing from Rs. 300 to over Rs. 700 per Kilogram.

In the long-run, Sri Lanka enjoys a competitive edge in its ability to manufacture grades of rubber which are not produced by other countries. The unique properties of rubber produced by Sri Lanka (for instance, Sri Lanka is the only producer in the world for Latex Crepe and Sole Crepe grades which are the purest form of natural rubber) further strengthens the country's value proposition. In the value addition arena, Sri Lanka is also the largest exporter of industrial solid tyres and the fifth largest exporter of surgical / examination latex gloves in the world, according to the EDB.

However, whilst the industry has enormous potential, accomplishing the ambitious ForEx earnings target is a challenging endeavour. In 2020, Sri Lanka's export earnings from raw material rubber and rubber products only amounted to USD 816 million. Hence, achieving the EDB target of earnings of USD 4.4 billion through rubber exports by 2024, or perhaps, the more feasible target of USD 3.0 billion by 2025 given in the Rubber Industry Master Plan (2017 – 2026), requires cohesive action and support by policymakers.

Immediate challenges

At present, the raw material rubber industry is being plagued by two main challenges. These are the severe scarcity of fertilizer and a fast-spreading new leaf disease affecting rubber plantations.

Given the high rubber prices at present, there is renewed interest among growers to start new and expand existing cultivation, which augurs well for both the industry and the economy. However, difficulty in obtaining suitable fertilizer due to the current import ban placed by the Government of Sri Lanka is hindering these aspirations.

Due to the fertilizer import ban, the industry expects to see a 10- 15% drop in production by next year and this adverse impact will amplify over the coming years. If this is to be the case, it would be most unfortunate, since rather than expanding, the industry would shrink, thereby reducing its contribution to the economy and to foreign exchange earnings. This would also negatively impact the livelihoods of a large number of individuals (estimated to be around 200,000) linked with the industry in Sri Lanka.

Optimum growth and yields can only be achieved by providing the nutrients required by the rubber plant. Compounding the current issue is the fact that Sri Lankan rubber plantations have gone through the cultivation of several generations which has degraded the fertility levels of the soil. This makes application of fertilizer in correct proportions essential. The rubber growers are required to obtain a site specific fertilizer

About the Author:
Manoj Udugampola has over 30 years of experience in the rubber industry. He is the current Vice President of the Rubber Traders' Association and the Chief Operating Officer – Rubber of Pussellawa Plantations Ltd. An alumni of Wayamba University, he holds a MBA and a Post Graduate Diploma in Business Management. He also possesses a Diploma in Plantation Management from National Institute of Plantation Management.

recommendation of RRISL based on soil and foliar analysis every 3 years. Accordingly, If RRISL guidelines are adhered, there will be no necessity to apply excess fertilizer to the plant.

In addition to short-term yield reduction, non-application of fertilizer as per RRI recommendations will retard the growth of the rubber plant and will extend the immature period which is approximately 6 years from planting. This would reduce total production from the tree (within its productive lifetime of around 30 years) and hence production of the overall plantation.

Besides the above, fertilizer is also required to improve the plant immunity to fight against pest and disease attacks faced by Sri Lanka's rubber plantations.

Today, the 'Circular Spot Leaf Disease' which was earlier known as 'Pestalotiopsis', a leaf disease, is having a serious negative impact on local rubber plantations across all rubber growing areas in Sri Lanka. The disease was initially seen in Ratnapura District in the year 2019 has spread over 40,000 hectares of rubber plantations across the country by the end of year 2021.

This fungus causes the leaves of rubber trees to fall prematurely. Repeated attacks of this new disease could lead to a crop drop of almost up to 40 % per annum. Unfortunately, application of certain chemicals to control the disease together with application of additional fertilizer is one of the key recommendations to address this condition. These inputs being unavailable are compounding issues further.

Having seen the adverse effects of this Circular Spot Leaf Disease, the Ministry of Plantations established a Task Force with the representatives of all stakeholders including the Rubber Research Institute, Rubber Development Department and Regional Plantation Companies.

Long-term impact

The scarcity of fertilizer could have a long-term negative impact on the industry as well, beyond the short-term implications.

Rubber replanting is a very important and costly exercise which is a key requirement in maintaining viability and sustainability of the rubber industry. It is heartening to see the enthusiasm building among the growers with the attractive rubber prices. But, other unfortunate negative factors would diminish it looking at the long term repercussions forced down on it,

To produce healthy & vigorous rubber plants required for replanting, it is important to apply a special fertilizer mixture to plants every fortnight at the nursery stage. The lack of fertilizer at nurseries could compromise the quality of the plants, thereby having a long-term negative impact on production, as these plants will be used for rubber production for the next 30 years.

Even currently, Sri Lanka lags behind its competitors in terms of yield per hectare. Sri Lanka's rubber yield per hectare is around half of that of competitors such as India, Vietnam and Thailand. This is due to factors such as the soil of being plantations being degraded by successive cycles of cultivation, low stand per hectare, lack of income due to unstable rubber prices and high costs hindering replanting and non-use of best agronomic practices. To increase the sector's competitiveness in exports, it is important to raise these yields. However, ongoing developments could instead reduce yields further, reducing the ability of our rubber exports to compete in international markets.

Alternative solutions

RRISL and rubber plantations of the country are already working on numerous initiatives to minimize fertilizer usage. For instance, experiments have been successfully conducted in immature rubber areas to introduce slow release fertilizers by using a porous tube buried around the rubber plant. Thus far it appears that this technique can potentially reduce fertilizer usage dramatically – essentially by half. Such techniques which also help maximise absorption rate of fertilizer and can save plantations money both in terms of cost of fertilizer and labour and hence would be adopted by plantations if they are viable on a commercial scale.

These alternatives would significantly lessen the impact of the use of the chemicals on the environment and hence could have a similar impact to replacement of conventional fertilizer with organic substitutes. Although there were recommendations to use organic fertilizer in immature rubber areas to improve the physical, chemical and biological properties of soil, in most rubber growing areas have shown increase incidence of pest and fungal attacks when organic fertilizer / compost is used.

Further, there was no substitute organic fertiliser at present recommended by the RRI for use in place of conventional fertilizer in the mature rubber estates. With recent fertilizer import restrictions, RRI has proposed new such recommendation which have been now practiced on experimental basis. It must also be noted that application of entirely organic material could potentially increase certain diseases which affect rubber trees.

'White root disease' (a fungal disease) and cockchafer grub can have a devastating impact on rubber plantations. Adding organic compost provides nourishment for the grub, causing it to grow rapidly. Hence, within the first three years it can kill the rubber tree and it affects the growth of the plant as well. White root disease is even more dangerous and can kill the plant at any stage within a very short time.

Non-availability of pesticides and fungicides due to current import restrictions may discourage the estates from using organic / compost materials.

Industry open to cooperation

While there are many challenges facing the rubber industry, it deserves greater attention, considering both its massive potential as a foreign exchange earner and in uplifting the livelihoods of a significant part of the country's population.

Superior natural properties of locally produced rubber and Sri Lanka's ability to manufacture grades of rubber not produced by other countries have given the country a competitive advantage. However, this opportunity cannot be fully realized if the short-term and long-term industry challenges, most critically those related to fertilizer, are not addressed.

Industry stakeholders are eager to engage with the authorities and find viable solutions. We are confident that with dialogue, collaboration and cooperation, we can find a solution amenable to all parties, which will elevate the industry to its true potential.

Challenge of Change: The Manager's Balancing Act

P.P. Perera

Vice President, PRISL

At the onset, I must admit that that my objective is not to go on to a review of the pros and cons of recent business strategies, some of which happen to be forced options adopted during the recent past due to the unprecedented and unmapped scenarios created by the Covid -19 pandemic. As a person who has been actively engaged in the rubber and tyre industry for the past 53 years, I would rather like to share some of my thoughts and interpretations on what I have witnessed in the industry. As typical of my generation of professionals. I cannot refrain from drawing inspiration from traditional wisdom and, some of the trend setting management thoughts of the past few decades.

Change and impermanency is the common denominator of all phenomena and processes in nature, which include human activities as well. Heraclitus, the 5th Century BC, Greek philosopher has said that no man can step in to the same river twice which means that the world constantly changes and that no two situations are exactly the same. Just as water flows in a river, one cannot touch the exact same water twice when one steps into a river. This view has been affirmed by the Lord Buddha around the same period.

In fact, the challenge of change, can be considered as the key driver in all the human endeavors across history, and the main motivating factor of business strategies that have evolved through the four industrial revolutions spanning form the mid-18th century to the present day of mass digitalization. The four principles of change management at any level be it personal, family, work place, company or a country are

- Understand the change
- Plan the change
- Implement the change
- Communicate the change

As a young executive at the Bata Shoe Company of Ceylon Ltd, I remember how the global Bata organization, started planning in the late 70s, to face the challenges of the new millennium. The catch word" globalization" was not much in the limelight in those days However, such long term planning has become a luxury of the past, due to the rapidly changing technologies, and the turbulent economic conditions, and politico-social instability. Planning horizons have shrunk drastically over the recent years.

Corporate change has always been associated with leadership, and Jack Welch, the master of transformational leadership has once quoted that "good business leaders create a vision, articulate the vision, passionately own the vision and relentlessly drive it to completion".

Notwithstanding the tremendous utility value of these approaches, I have witnessed the beginning, growth, decline and final exit of some great business empires in Sri Lanka, which could not survive up to the third generation. Similarly, there are exemplary business organizations, the roots of which can be traced back in history to a single person who started with a few rupees, and later developed in to corporate giants that are thriving through the third generation. It is therefore apparent that there are no hard and fast norms or standard ground rules but an emerging factor is the importance of the people at all levels, despite the benefits of automation and digitalization. Success and failure episodes are abundant, throughout the world and corporate grave yards are cluttered with casualties.

Change and business strategy are always closely interlinked without clear boundaries. The "Art of War", which is attributed to the ancient Chinese military strategist Sun Tzu (around 5th century BC), remains the most influential strategy text in East Asian warfare and has influenced both Eastern and Western military thinking, business tactics, legal strategy, lifestyles and beyond.

The Covid-19 outbreak which started around two years ago and developed in to a devastating pandemic has brought about years of change in the way companies in all sectors and regions do business. The entire world scenario which we currently witness is reminiscent of the opening paragraph of "A Tale of Two Cities", an

1859 historical novel of Charles Dickens, which has the period of the French Revolution as its backdrop

"It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity, it was the season of Light, it was the season of Darkness, it was the spring of hope, it was the winter of despair, we had everything before us, we had nothing before us, we were all going direct to Heaven, we were all going direct the other way – in short, the period was so far like the present period, that some of its noisiest authorities insisted on its being received, for good or for evil, in the superlative degree of comparison only."

The Coronavirus has rapidly made "business as usual" a phrase from the distant past. There is no "usual" in this uncertain time. But organizations who outmaneuver uncertainty create a resilience they can count on, no matter the changes that come. We've all changed the way we operate during the COVID-19 crisis. Some changes were forced on us; others represent the height of innovation in a crisis. There's been a reset of the workforce and work itself, a reset of the employer/employee relationship and a reset of the business ecosystem. For most, the business impact of the pandemic has been negative; and for some, positive.

The pandemic may have wiped our strategy slate clean (or at least it feels that way), but we have also garnered invaluable experience. Now it's time to bring together our executive teams and use those lessons to reconfigure the business and operating models for a new reality. It appears that in addition to the conventional **3Rs** (reduce, reuse, recycle**),** with respect to resource consumption and sustainability, a set of new **3Rs**, namely respond, recover and renew has emerged during the Covid-19 crisis. As we shift from response to recovery, the key for senior leaders is to make strategic decisions that will lead them to a renewed future state, however paralyzing the uncertain outlook may seem. We can burrow a leaf from the strategy and tactics by the Covid-19 virus itself in learning how to adapt for survival by adopting new paradigms, namely producing more virulent strains such as the Delta, and the latest Omikron varieties.

In the absence of a 100% effective vaccine or cure for COVID-19, any rebound in business activity could easily be followed by another round of response, recover, renew, so the imperative is to absorb lessons learned quickly and build sustainable changes into business and operating models.

But first, we need to determine exactly where and how the crisis has stretched and broken your existing models, and where the risks and opportunities lie as a result. When talking about risks and opportunities, I cannot help going back to the basics of ISO 9001:2015 Quality Management System (QMS) requirements which expects a company to evaluate the external and internal issues (Clause 4.1), expectations of interested parties (4.2), determining the risks and opportunities (6.1) and planning for change (6.2).In some of the companies, I happen to audit, the priority given to these is at a minimum or no priority given at all apart from stagnant records which do not show any objective evidence of monitoring and review.

However, one important factor we have to consider is, that everyone, irrespective whether it is an individual, family unit, organization, or a country, are on various stages of their unique learning curves, and the strategic horizons have drastically become shorter. Business and strategy planning is no longer an elite task shrouded with mystery and confined to the corporate managers only in their air conditioned rooms, but a task to be accomplished in consultation with those who are finally going to implement the strategies and plans. While the Japanese Genba (the actual place), approach is more than fifty years old, it is mostly confined to operational levels, which is rather unfortunate. This crisis has created an opportunity to reset some of our goals and ambitions; it's time to ask: "As we recover from this crisis, do we want to be different, and if so, how?"

One can see that many companies are in the recovery mode at the moment, and trying to do damage control based on profit motive which is understandable. The entire social. cultural and ethical models and paradigms have changed drastically, and the entrepreneurs need to realize that they are no longer operating in the pre Covid era. Drastic changes have occurred in the entire supply and value chains, with changing customer preferences.

The daunting challenge for the modern manager is how best to cope up with the challenge of change. Considering the heavy performance expectations placed on them, by the corporate management, which are understandably skewed, towards profit generation. the manager is often impeded in gaining a holistic view of the circumstances. This situation is further complicated by the social, family and peer demands. It is also a growing trend that the boundaries between the various disciplines are overlapping and the manager need to develop the skill of identifying the inter-relationships between the functional areas and the activities. A manager in modern times has to be "jack of all trades" if he is to cope up with change successfully.

Furthermore, unlike in the old days of "life- long" employment, the job mobility is high, which has resulted in a diminished sense of loyalty to the place of work, and the erosion of the ethical values essential for life, such as honesty, integrity and commitment. More often than not people seem to operate in their comfort zones and are too complacent to face the challenge of change.

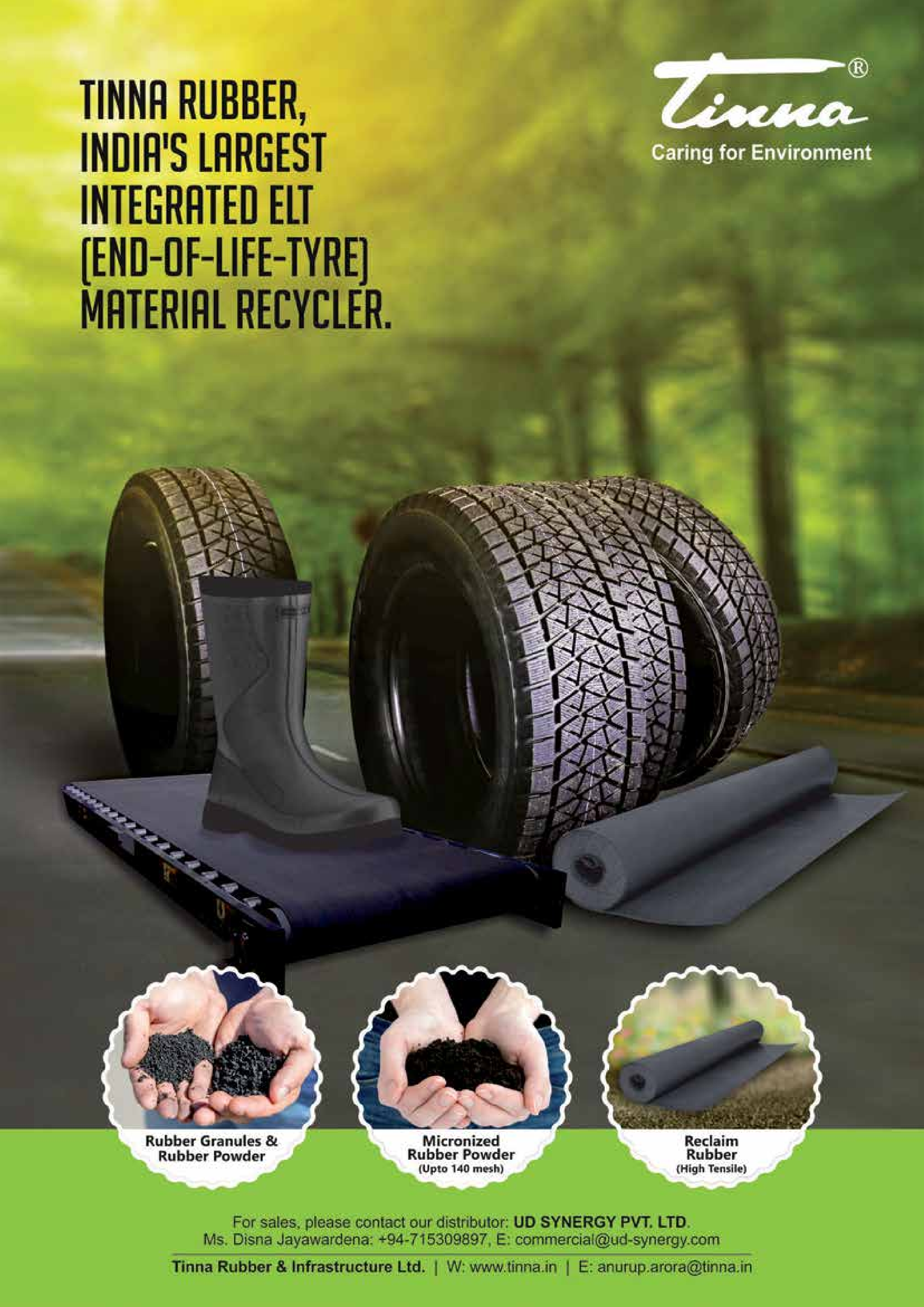
The following quote attributed to many including Eleanor Roosevelt, a former First Lady of United States, is appropriate to be sited here:

There are people who make things happen, there are people who watch things happen, and there are people who wonder what happened.

On the other side of the coin, there is the growing trend of over reliance on information systems digitalization at the expense of eroding the basic human values, which form the bed rock foundation of any society. The short and medium term gain in monetary terms can be substantial but at the cost of long-term sustainability, which ultimately boils down to understanding human values and interrelationships. Change should not be for the sake of change, but for the purpose of personal, organizational and social value addition. Despite remarkable and enviable breakthroughs technology and the information. the modern day manager has to understand the vital importance of the "balancing act" of finding the correct blend of technology and the traditional wisdom.

It was Mahatma Gandhi who once quoted:

I do not want my house to be walled in on all sides and my windows to be stuffed. I want the cultures of all lands to be blown about my house as freely as possible. But I refuse to be blown off my feet by any.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Natural Rubber – A History of Challenge Driven Growth

Dr R.K. Matthan, PhD

1. Introduction and Perspective

Natural Rubber from its induction as a material of interest into industry has changed the course of the rubber history. The chronology of the upstream production history indicates it as known as far back as 3500BC. The Mesoamerican civilizations of Central and South America (The Mayans, The Aztecs and the Incas) have recorded its presence and use especially in the ball game which had significant socio-cultural implications. Introduction to the Western came with the voyages of Christopher Columbus and the Spanish conquistador Cortez who through colonization in the 15^{th} century saw the impoverishment and destruction of the Mesoamerican civilizations. The voyages of Christopher Columbus and the movement of natural rubber to Asia are captured in Figure 2.1 and 2.2 Rubber as a material of scientific curiosity found its way to Europe where useful applications emerged. The first scientific paper was to the French Academy of Sciences in 1751

Figure 1.1 Christopher Columbus (1492-1504)

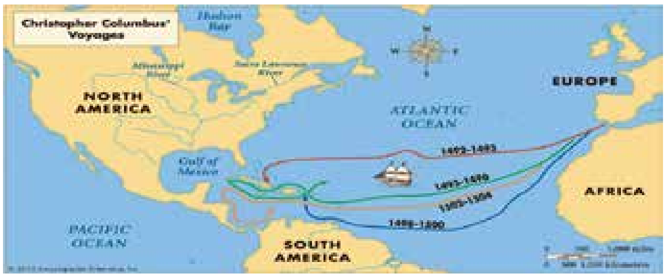
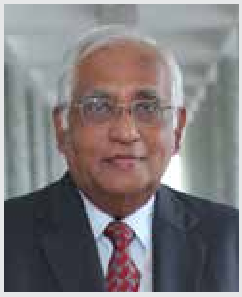


Figure 1.2 Brazil/Britain/Southasia (1877-1888) – RIDLEY

The panoply of now famous names who played a role in the midstream and downstream rubber economy in the 19^{th} and 20^{th} century include Wickham, Cross, Ridley, Macintosh, Hancock, Goodyear, Dunlop and Michelin.

More recently in the second half of the 20^{th} century the key role of Bateman, Mullins and Sekhar standout for Natural Rubber Research which enabled the emerging challenges to Natural Rubber be countered. The

Brief profile of Dr R K Matthan



Dr Matthan {PhD, (U.K.), FIOM3 (UK)} is a fifty year veteran of the Indian and International rubber industry. He has been providing comprehensive technology consultancy from plantations to products to the global rubber industry under the flagship Polymer Consultancy Services P Ltd established in 1975.Additionally he was associated with the Malaysian Rubber Research and Development Board (MRRDB) from 1975-1993, MARDEC (Malaysian Rubber Development Corporation) from 1980-2000, including as Director of MARDEC Indian subsidiary Plaat Bhadra P Ltd (1995-2000). He was Adviser to Revertex Malaysia Sdn Bhd (2000-2014) and Managing Director of its Indian subsidiary KA Revertex India P Ltd (2004-2011).

He is a Director of Vystar Corporation USA with oversight of its R&D operations. Vystar patents licensed products of Ultra Low Protein Latex (ULPL) are commercially produced in India, Thailand, Vietnam and Guatemala. Corrie MacColl(EU)I have acquired the global marketing and distribution rights for Vystar products, which now include the latex and solid forms of ULP and new variants including ULP TMTD/Nitrosamine free, Ammonia Free, Ultra Low Ammonia ULPL and ULP Nitrosamine-free PV Latex.

In 2019 he was appointed President of Indian Rubber Manufacturers Research Association (IRMRA) which is an autonomous Research Institute under the Ministry of Commerce and Industry engaged in Rubber R&D, tyre and non tyre testing, education and training, and certification of tyre and non tyre products.

Dr Matthan was awarded the prestigious K.M.Philip award in 2008 for his services to the Indian Rubber Industry and in 2014 the Hancock Medal of the Institute of Materials, Minerals and Mining(IOM3) U.K. He is a member of the Board and Executive Committee of the Schieffelin Institute of Health-Research and Leprosy Centre, Karigiri,Tamil Nadu which includes a special microcellular footwear manufacturing unit for the physically challenged.

He is a regular golfer, inveterate traveler (pre Covid) and a reader of an eclectic range of historical literature and fiction.

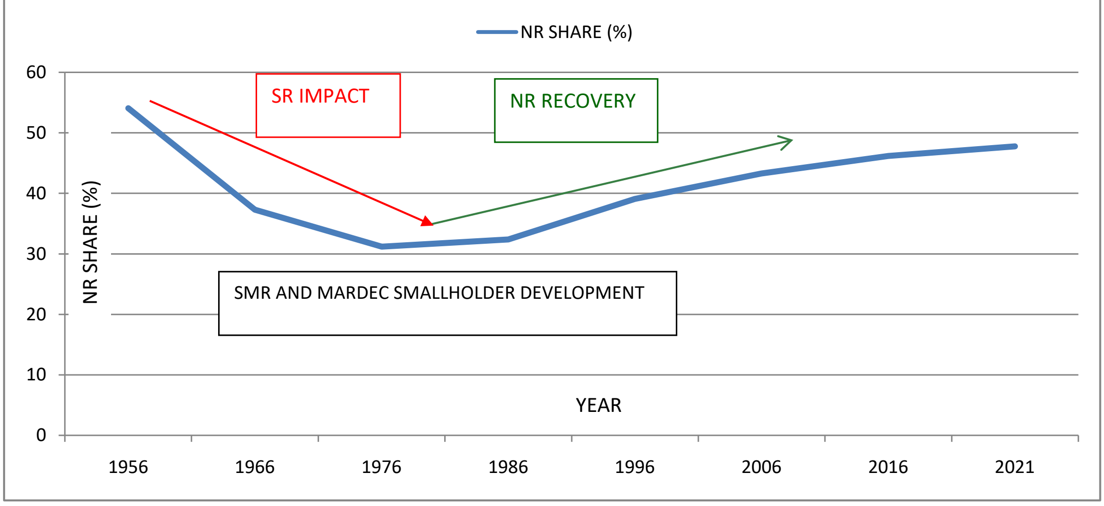
pneumatic tyre and the rise of the personal automotive era pioneered by Ford put the rubber industry on a strategic footing. Natural rubbers emergence as a high performance material has few parallels.[1]

2. Overview of Natural Rubber Transformational Journey

The 20th century saw the rise of synthetic Rubber especially post World War II with the era of cheap oil and advances in polymerization chemistry which yield Synthetic rubbers of significant properties and challenging the dominance of natural rubber. These challenges to NR are reflected in Figure 2 which shows the downturn in relative share of Natural Rubber in a growing Rubber consumption market in the 1960's and 1970's.

The principal factors which enable Natural Rubber to recover was the pioneering introduction of the standard

FIGURE 2 CHALLENGE TO NR



Malaysian rubber (SMR) scheme in the mid 1960's, wherein natural Rubber was technically specified as an alternative to the visual grading system in place. The adoption of this scheme by the other Natural rubber producers especially Indonesia and later Thailand , India, Sri Lanka, Vietnam and in Africa enable its continuous evolution over the years to meet the performance requirements of the manufacturing industry . The simultaneous empowerment of smallholders in Malaysia with the formation of MARDEC enable the worldwide marketing of these new forms of Natural Rubber with the smallholder participation and is well documented.[2]

The current specifications for 9 Grades that evolved from the initial 4 (SMR 5.10, 20, 50) which evolved over the period is well laid out in ISO2000:2019 Table 1.

Table 1. Current ISO 2004:2019 TSR Specifications

Table 2 — Typical properties of TSR

Properties	Grade [a]									Test method
	LoV	*CV*	*L*	*WF*	5	10	20	10CV	20CV	
Colour coding, marker	Green	Green	Green	Green	Green	Brown	Red	Brown	Red	
Dirt retained on 45 µm sieve maximum % (by mass	0,05	0,05	0,05	0,05	0,05	0,10	0,20	0,10	0,20	ISO 249
Ash maximum % (by mass)	0,5	0,5	0,5	0,5	0,6	0,75	1,0	0,75	1,0	ISO 247
Nitrogen content maximum % (by mass)	0,3	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	ISO 1656
Volatile-matter content maximum % (by mass)	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	ISO 248-1 (oven method at 100 °C ± 5 °C)
Initial plasticity (P_o) minimum	N/A	N/A	30	30	30	30	30	N/A	N/A	ISO 2007
Plasticity retention index (PRI) minimum	N/A	60	60	60	60	50	40	50	40	ISO 2930
Lovibond colour index maximum	N/A	N/A	6	N/A	N/A	N/A	N/A	N/A	N/A	ISO 4660
Mooney viscosity, ML(1+4) at 100 °C	55 ± 10 [b]	60 ± 5 [b]	N/A	N/A	N/A	N/A	N/A	65^{+7}_{-5} [c]	65^{+7}_{-5} [c]	ISO 289-1
Gel content maximum % (by mass)	4,0 [d]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Annex A

[a] The raw material is given in Table 1.

[b] Other viscosity levels may be agreed between the interested parties.

[c] The viscosity of these grades is not specified as it can change with, for example, age and handling. However, the viscosity will typically be controlled at the producer's end to a value of 65^{+7}_{-5}. Other viscosity levels may be agreed between the interested parties.

[d] Other gel content levels may be agreed between the interested parties.

3. NR in the Total Rubber Mix

The current global share of various grades is seen in Figure 3 and the predominance of the Technically Specified Grades is evident.

The global transition of pneumatic tyre design from the conventional bias ply to the radial ply (pioneered by Michelin-France) played an important role. Europe transitioned rapidly in the 1970-80 period, but the USA moved through the intermediate phase of the bias belted radial but succumbed to the superiority of the pure radial tyre design with its enhanced road grip and mileage.

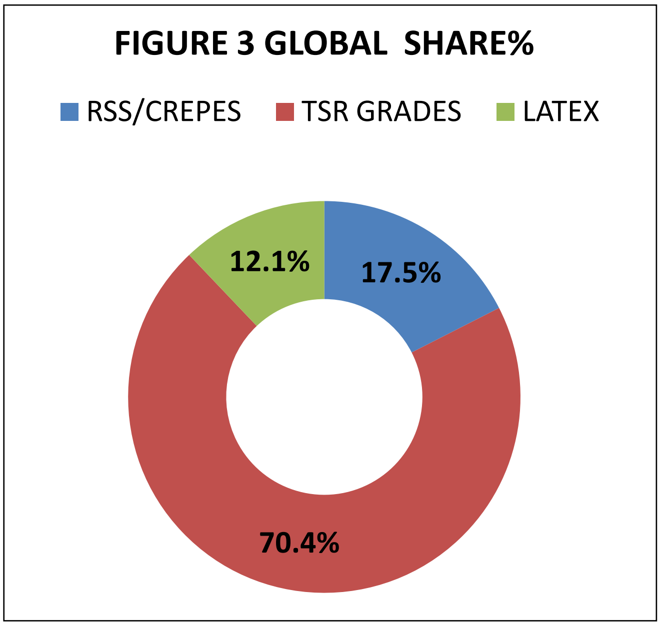
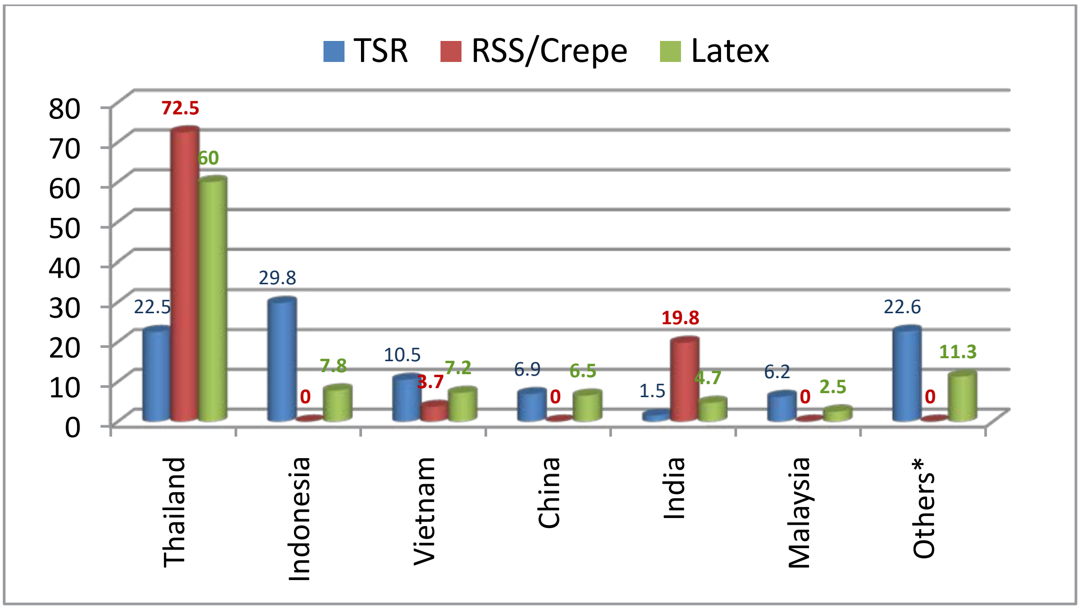
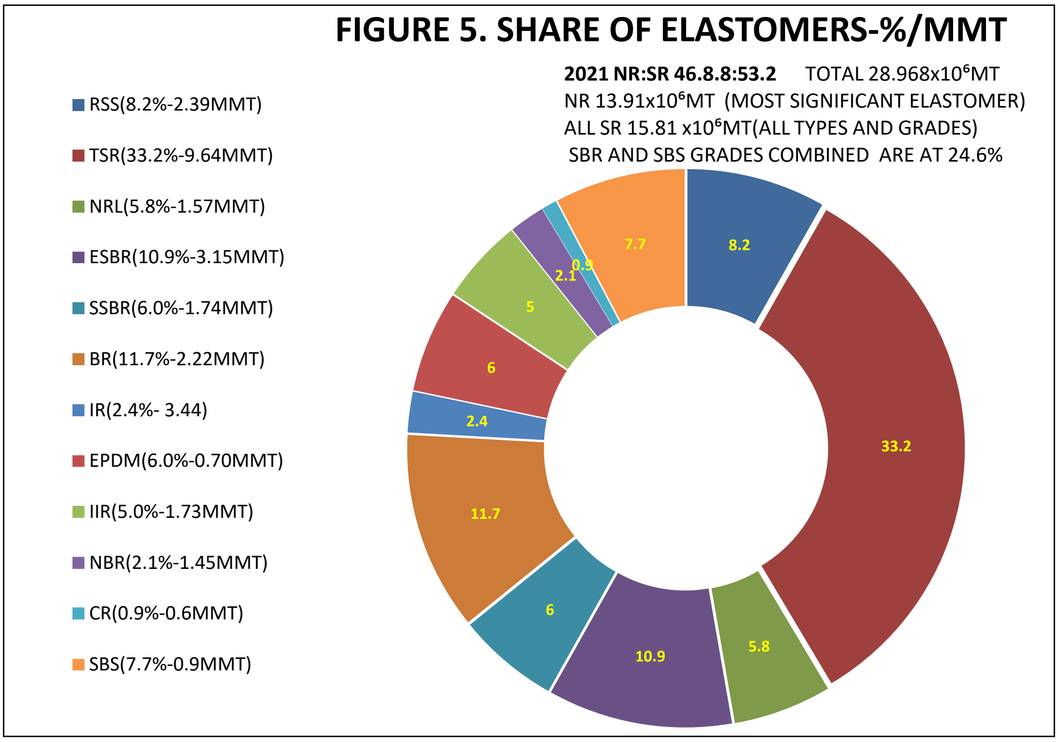


Figure 4: Country Specific Grade Output





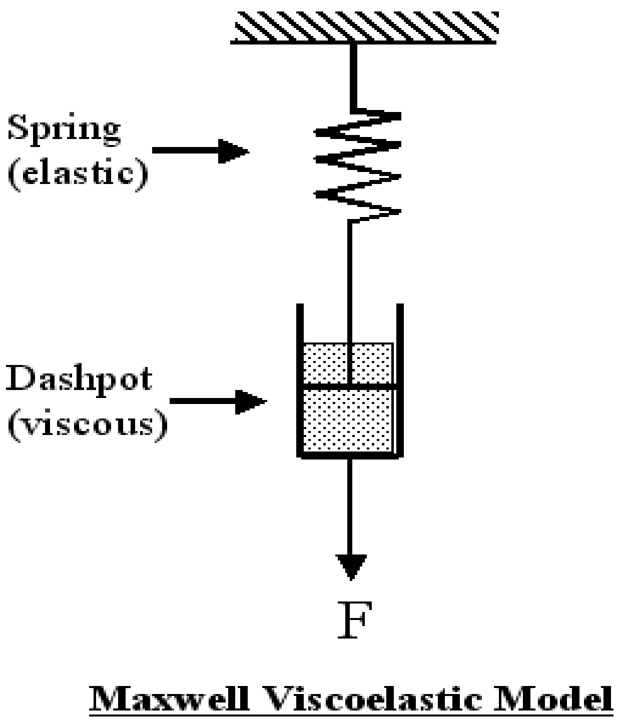
Therefore as a single CIS1,4 Polyisoprene elastomer Natural Rubber accounts for 47.2 and SBR and PBR combined in its two principal dry rubber forms (Emulsion and Solution) are at 28%. With the tyre industry being the single major consumer of both Natural and Synthetic Rubbers, it accounts for about 60% of total rubber consumption i.e. around 18 million MTA.

4. Diversification Through Modification

Synthetic Rubber will continue to push the envelope for greater share the Challenge for NR is to offer matching Synthetic Rubber Grades.

Fundamentally and simplistically changing the behavior of the elastic and viscous components as shown in Figure 5 of the through mechano-chemical actions will alter various base characteristics and properties of Natural Rubber. This is found to be effective especially when the starting material is a low Non Rubber Solid Latex and the reactions can be carried out in the colloidal state.

Figure 6. The Basic Maxwell Viscoelastic Model



More sophisticated modeling is now available including the application of FEA.

The Table 2 provides the various prominent alternatives that are available in the Natural Rubber stable, which will be released into the market building up market share

Table 2. Natural Rubber as a Bioelastoplastic Material

1. **Deproteinised Ultra Low Protein (ULP) (latex and dry rubber grades)** denatured residual proteins
2. **Ultra Low Gel Content** latices from ULPL latex –ultra low gel content solid rubber for better dispersion in tyre applications
3. **Epoxidation** (10, 25, 50%) **of** the deproteinised field latex pre concentration latex and dry rubber as a polar rubber and also as an alternative to Butyl, Nitrile
4. **Depolymerised and homogenised** deproteinised latex and dry rubber for uniform particle size and molecular weight distribution for replacing synthetic binders and adhesives
5. **Halogenation, hydrogenation, cyclisation** of field or centrifuged ULPL latex alternatives to Polychloroprene, EPDM and Bioresins
6. **Custom grafted latices from ULPL** with various monomers in the range of 15-50% (molar ratio) Methyl Methacrylate, Vinyl Acetate, Vinyl Pyridine, Caprolactam, Carboxylation and Maleation
7. **Thermoplastic Natural Rubber and Thermoplastic ENR** offer alternatives to the Thermoplastic Block Synthetic Rubbers such as SBS and SIS
8. **Custom compounded DPNR and ENR block rubbers** with Carbon Black, Silica/ENR/SWCNT/ Compounding Chemicals (S/Act/Accelerator/AO/ ZnO/FA Soap/Oil Ext) incorporated in the post modified latex stage
The base platform is Ultra Low Protein Nitrosamine Free Field Latex
There are other customized derivatives of the above.

One of the more interesting modifications under study is the controlled hydrogenation of Natural Rubber. Advances in Hydrogen manufacture offer avenues for the "in situ" hydrogenation of the ethylene-propylene components within the isoprene molecules. This leads to a partially unsaturated Ethylene –Propylene Natural Rubber where relatively low unsaturation levels are possible.

5. The Future Persepctive

With the relative consumption ratios having stabiles d for the present and with prospects of new forms of Natural Rubber emerging commercially from current R&D and field evaluations the evolving journey of Natural Rubber can be summarized in Figure 6.

Table No 3. Natural Rubber- The Evolution *

NR STATUS		INDUSTRY ACCEPTANCE
NR SUPERIORITY <1950's	→	NR PREDOMINATES SHARE >50%
SURVIVABILITY 1960-1980'Ss	→	NR:SR IN BLENDS SHARE <40%
SYMBIOSIS 1980-2010	→	NR SHARE ~40%
NR SUSTAINABILITY 2010-2025	→	NR REJUVENATION SHARE>43-48%
NR SECURITY >2025	→	NR STABILISES POSITION SHARE 48-52%

*See Figure 2

The search for innovative solutions to improve NR productivity is drawing increasing attention from the production Sector. Applying AI and Technology can throw up new approaches such as the pipeline collection system (Chinese announcement).

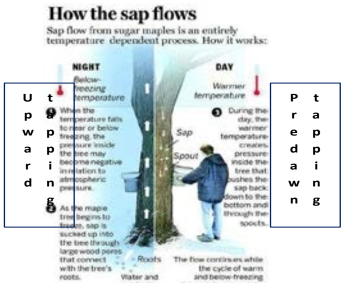
Another approach is adapting the maple syrup collection system from the USA into Latin American Plantations.

Figure7. Pipeline and Cluster Collection

Traditional method

Cluster Collection

Pipeline system



Sap/Latex Movement

Puncture tapping

Line Vacuum Monitoring

Multi acre Centralised collection

6. Concluding Remarks

From a latex platform we can produce based on a 100% natural entirely biogenic rubber polymer, and increasingly with a fully traceable FSC certified supply chain.

(A) *NOT ONLY* LIQUID LATEX CONCENTRATE WITH

- Ultra low protein content
- Reduced NRS
- Safe/compliant preservation systems (TMTD/ nitrosamine-free)
- Ammonia-free (if required)
- Pre-vulcanised (if required)
- Grafted (if required)

(B) *BUT ALSO* DRY RUBBER SPECIALITY GRADES

- DPNR based and compatibilized to compete with solution SBR in low rolling resistance / high wet grip tyre formulations
- A Natural rubber equivalent to EPDM
- A range of other grades with bioelastoplastic properties including the TPNR/TPENR challenging Plastics

(C) *AND* CUSTOM COMPOUNDED MASTERBATCHES (LIQUID HIGH PRESSURE HOMOGENISED PROCESS)

- Latex - Carbon Black
- Latex –Silica-ENR-15/MG15,
- Latex – Prevulcanisate-Filler Masterbatch

Natural Rubber Research still has immense possibilities with greater emphasis on rapid scale up through incubation opportunities as a bioelastoplastic material across rubber and plastics applications.

References

1. Tears of the Tree –Mr. J H Loadman Oxford University Press 2005

2. The Legacy of MARDEC – Mr. J.C.Rajarao, University of Malaya Press 2013

The evolution of a Technocrat
Dr Sisira Ranatunga: A Trek of 47 years

Complied by P.P. Perera

When I requested Sisira , to explain clearly in a few words," who he is", his instantaneous response was "a person who has courage to face challenges". This prompted me to do an exploration, to in to his distant pass and background to understand what made him what he is today.

A village boy, six years old, walking over the village roads and paddy fields to go to Wethalawa Primary School, in Uva- Paranagama, and a boy used to play cricket in the paddy fields, are scenarios, which are very close to my heart, reminding me of my own rural childhood, albeit a generation gap of about 23 years. He is the 10th in a family of 11 children, as per our own cultural and social traditions, which began to erode, in the early 70s with the forced introduction of the Western driven concept of the "small family". He is from a fairly affluent village family, his father being a higher up in the village administration and a farmer. He was brought up amidst traditional values of hospitality and community cooperation and harmony, which were the hallmarks of the rural society, a couple of decades ago

Sisira reverently honors his late eldest brother, whom he considers as the guiding beacon of his life, a by-product of Maspanna MV, in Welimada, who served as an Additional Secretary to three Prime Ministers of Sri Lanka.

The foundations for the gradual unfolding of his scholarly life was laid first at Wethalawa and later at Maspanna MV. He had a flair for mathematics from his early school days. He remembers with gratitude the devotion of some teachers such as Ms Rathnasiri, Lesley and Swarnalatha,who guided him in mathematics, English and Sinhala respectively. Having completed the OLs with very good results, he was admitted to St. Anthony's College Kandy. The boarding life at the college hostel, provided valuable experience to develop independency and interdependency. Although he was elected to the engineering faculty of the University of Peradeniya, after his ALs in 1989, he had to await three years to commence his studies, due to disturbances during the period 1988 -1991. He made use of this time to improve his knowledge of English. He excelled in his studies at the university and passed the BSc in Engineering in 1996,

His field of studies was manufacturing and industrial engineering and the elective subject was control, and automation. I keep wondering, whether the selection of this field was by default or by design, as this was an area of high demand in the merging industry needs. Nevertheless, this seem to have a significant bearing on his entire career path. He joined Loadstar of the Jinasena Group as a Trainee engineer in 1995. This appears as the move that glued him to the rubber and polymer industry for the ensuing period of 47 years.

Loadstar proved to be the platform for gaining valuable knowledge and experience as well as for the application of the academic knowledge he gained at the university. His career at Loadstar as Operations Engineer, involved integrated production and engineering systems. In 1998, he joined He joined Arpitalion Compact Soles (Pvt.) Ltd, as Engineering Manager and continued as Factory Manager ,till 2006 during which he made significant contributions to new product developments for creating new markets. If my memory serves me right, I think it was during his career at Arpitalion, that I first met him, at Associated Motorways, where I was working. It was on doing some compounding using the latter company's mixing facility. I found him to be cheerful and dynamic person. He played a key role in arranging the annual cricket matches between the two companies, which were always enjoyable get-togethers.

He is strongly convinced that the turning point in his career was the successful completion of the MSc in Polymer Technology from the University of Moratuwa, which 2003. This paved way to widen his knowledge and perspectives on the diversity of polymer technology.

Subsequently he had a distinguished career of 15 years, at Elastomeric Engineering co: Ltd as General Manager from 2006. His devotion, hard work and committeemen enabled him to serve as a Steering Group Member of three Hexpol Companies and as Global Head of Hexpol Engineered Production system (Lean Management).

The following can been listed as the remarkable milestones he achieved at Elastomerics:

- ✓ A 15-year journey towards business excellence - Transforming of a conventionally managed loss-making business to a profit making and a professionally managed sustainable organization and driving towards meeting the 4th industry revolution challenges.
- ✓ Regaining and expansion of solid tyre business by organization re-structuring, product reverse engineering and introducing new products range
- ✓ Implementation of lean concept at Hexpol 9 plants in USA, Sweden and China
- ✓ Team leader of Hexpol global production team
- ✓ Commercialization of economical composites caster wheels using greener materials.
- ✓ Initiation and implementation of Hexpol advanced technical and design centre in Sri Lanka.

While heavily engaged in his working life, he continued his education and further knowledge acquisition.

By completing his PhD in Polymer Technology, in 2015 at the University of Sri Jayawardenapura His field of speciality was polymer composites and simulation. He is very grateful to Prof: Lalin Karunanayaka for encouraging him to do the doctorate .

During 2021 he joined Global Rubber Industries (PVt) Ltd as Director Manufacturing and he cites the rationale as serving the local company with the wide knowledge he gained over his career, which he feels is a national obligation of any professional groomed through the free education system in Sri Lanka. It is timely decision as this is the opportune time for the local rubber and tyre industry, to forge ahead as world leader in industrial tyre manufacture.

The contributions, he has made to the companies he has worked are innumerable and list is very exhaustive to be published in a short review. During his career he also got valuable opportunity to participate in overseas training programmes, in Ahmedabad, Cochin. Singapore, Japan, Malaysia, Thailand and UK, which further enabled him to widen his knowledge and perspectives.

He is also a Fellow of the Plastics and Rubber Institute of Sri Lanka, and has served diligently in the capacity as Assistant Secretary and Secretary to the Education Advisory Committee. He also served as the Secretary of the Sri Lanka Association of Manufacturers and Exporters of Rubber Products and during his tenure accomplished organizing two very successful workshops for the tyr industry with the financial assistance from the EDB.

Sisira has many scholarly and technical publications to his credit, and continues to synergize scholarly knowledge with industry practice for the benefit of the industry.

Finite element analysis and simulation happens to be his forte and presenting the proposal to establish the FEAS Centre to the Ministry of Plantation Industries through the PRI to the Govt of SL to establish the above centre as the collaboration of Ministry of Plantation Industries,

PRI and SLAMERP at the RRI Ratmalana 2018, can be considered as one of his key innovative endeavors.

Sisira is married to Priyadarshini, who is teacher, and they are blessed with three wonderful boys, Dumindu, Sevindu and Yevindu, who seem to have inherited the attitude for mechanical innovations and the love for musical instruments from their father.

Sisira's Personal Statement is ***To be a catalyst in the field of Polymer Technology by continuous learning and innovation, providing synergy and leadership to the organization to transform to next paradigm by adapting Triple Helix Business Model and worlds best Practices.***

His *leadership philosophy is to be an example and personnel involvement in fostering my personnel values of trust, respect, openness, teamwork and intelligence. Decisions are based on analytical thinking, facts, figures and substantive argument. Long-term strategic planning to align my vision with organization by inspiring a shaved vision and challenging any process in such a way that enhances working as a good team player.*

From my long experience of the rubber and polymer industry for 53 years, I would consider Sisira in the fast expanding category of Technocrats, which has a vital role to play in developing the national economy.

The journey from a remote village in Uva Paranagama, to come to the position he enjoys is remarkably is great achievement accomplished through his own determination and perseverance

In his work Twelfth Night, infamous playwright, wordsmith, William **Shakespeare** tells us not to fear greatness: "Some are born great, some achieve greatness, and some have greatness thrust upon them. I consider Sisisra in the second category. The first is for the royalty, while the third is for the politicians.

The Product Accelerator Model of Engagement of Researchers with the Manufacturing Industry

An effective model of engagement to penetrate niche export markets with innovative products

Dr Karnika De Silva

Industrial Materials Specialist / Lead Technologist
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Newmarket innovation Precinct
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Abstract

The Product Accelerator model is an effective way to collaborate with the industry by engaging researchers and academics with a deep understanding of science knowledge to identify the missing science and technology gaps, through interacting and accessing new science and technology. This leads to rapid evolution and application of new technology.

The Product Accelerator is a New Zealand government funded programme hosted by the University of Auckland established to support the manufacturing industry in New Zealand. The model of engagement across sectors and the value chain involving technology and industry partners and the service providers in Sri Lanka with the Product Accelerator capabilities in the R&D development in the manufacturing environment, has made it possible to commercialise some unique rubber products from Sri Lanka in the overseas markets.

Introduction

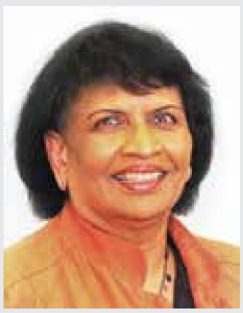
The Product Accelerator (PA) programme, hosted by the University of Auckland, evolved at eight Universities and Crown Research Institutes (CRIs) through the last decade to provide capability for NZ companies with opportunities to innovate in materials science initially, and it has progressively expanded its reach to all economically important manufacturing areas, engaging with all regions throughout the country.

Although each University now has a science commercialisation programme to connect entrepreneurial researchers with expertise in various technologies, who are focused in their area of research, it is now clear that in R&D driven economy a great deal of effort and money is wasted by the academics' in trying to promote their new findings or innovations and push them into manufacturing environment. This model has now been replaced with an industry pull process that the Product Accelerator has adopted, where the companies with R&D culture and people with deep industry knowledge can identify the technology gaps, and access new science and technological capabilities available from the government institutions. This has led to rapid evolution and application of new technology at minimum risks to the companies.

The connects businesses seeking specialist expertise, to talent within the universities and the wider R&D ecosystem, to solve real and diverse challenges in our market. It operates a 'best team' approach nationally for each unique challenge, bringing specialists and industry experts from government funded R&D institutions and the universities so that the research functions make it the only partnership of this nature in NZ. The Product Accelerator, supports the manufacturing industries

Karnika contributes to NZ Product Accelerator as the Senior Industrial Materials Specialist and a Project Lead. She has a background in rubber, plastics, composites and coatings and interests in sustainable manufacturing. Currently, she is engaged in several industry-funded projects in multidisciplinary technology platforms. Karnika has worked in the industry and has academic experience at the University of Auckland. She is co-supervising postgraduate students and has several publications in her credit.

Karnika has her PhD from University of Aston, UK. Before migrating to New Zealand in 2001, she was the Deputy Director Research (Technology) at the Rubber Research Institute of Sri Lanka. She has won numerous awards including Commonwealth scholarship and worked on several projects on funding from NSF, NSERC, CIDA, UNIDO, CFC and Malaysian and Australian government funded assignments on rubber related projects.



to increase export revenues and create new market opportunities through the development of commercially driven technology platforms and our mission is to connect NZ Industries with the best science and technology teams from across our network and assist companies with new product development, problem-solving, and embedding technology innovation through the "missing science" in the NZ research and development ecosystem. Every country should altleast have one strong group funded by the government working on R&D on this effective "Industry Pull" model.

The Product Accelerator has developed high value potential technology platforms across 6 distinct Research Portfolios; Design Innovation, Energy & Emissions, Manufacturing Systems, Materials & Surfaces, Sensing & Automation, Soft Materials, Recycling & Bioprocessing, extending and integrating the The Product Accelerator network and enterprise engagement model to foster collaboration with NZ enterprises and researchers through a pull Science mechanism, and it involves four stages, Engage, Define, Connect and Deliver as shown in the Figure 1 below.

In brief, in the Engage stage, the Product Accelerator team explores the business opportunity with the client. Once the technology definition and translation are complete in the Define stage the team moves in to the most important third stage which is the Connect stage where the missing science to articulate the science and design capabilities are finalized and the "Missing Science" to take the innovation forward is identified. Once this is done the industry-funded project is managed under an experienced Project Manager to achieve the milestones defined in the proposal.

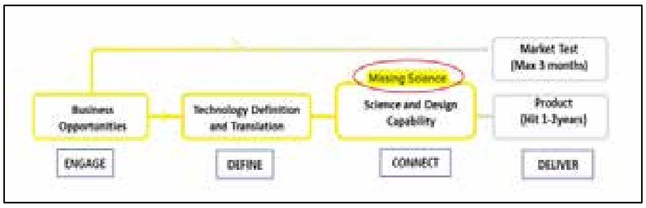


Figure 1 - NZ Product Accelerator Model of Engagement with the Industry

The Product Accelerator has a broad range of capabilities from practical business skills and technology development and application, as well as deep capability in materials and manufacturing areas. The Business Development team supported by an Advisory Board with most experienced and connected company CEOs in New Zealand. The technological capability cantered in six portfolios: Materials & Surfaces; Manufacturing Systems; Bioprocessing & Recycling; Design Innovation; Energy & Emissions; Sensing, Monitoring & Automation are shown in Figure 2 below.

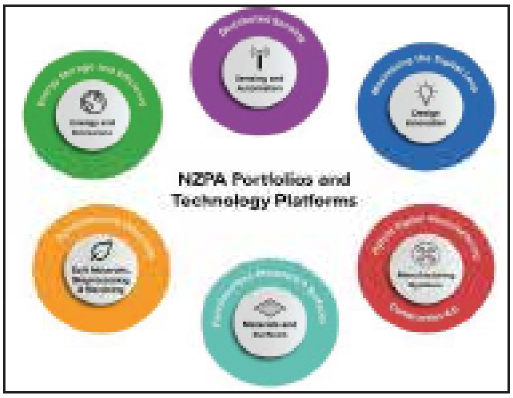


Figure 2 – The Product Accelerator Portfolios and Technology Platforms

The National Testing Register hosted by the Product Accelerator covers a wide range of product performance testing materials analysis and characterisation, materials processing and manufacturing facilities is widely used by the New Zealand manufacturing industry for various reasons, not only for testing but also to get engaged with us to do short and long-term R&D projects and innovations.

A Case Study involving the Product Accelerator with Overseas Industry and Technology The partners –

This case study is based on a strategy to get lead companies in NZ involved in the Product Accelerator model of supply chain engagement to facilitate rapid commercialization.

The project involved developing and commercialization of a unique product, requested by the company EPI Group supplying pylons to the harness horse racing tracks as a safety measure in Australia and New Zealand. This mainly required the replacement of highly plasticized poly(vinyl chloride) (PVC) pylons failing in service with UV durable rubber-based pylons.

It is known that wrong material selection is one of the most common causes of failures experienced in product manufacture and successful material selection requires a judicious scientific approach in order to evaluate the requirements of the application.

The old PVC pylons failed in service within 6 months due to the low molecular weight plasticizer leaching from the highly plasticized rigid PVC. The addition of plasticizers that are by design not covalently bound to the polymer matrix, makes them highly susceptible to leaching. The potential risks related to some phthalates such as such as Di(2-ethylhexyl)phthalate (DEHP), a widely used plasticizer to render PVC soft and malleable, include degradation of the polymer during service causing surface embrittlement and micro-cracking, yielding micro-particles that persist in the environment. It is known that the use of phthalates, into plastics as plasticizers comprise ~70% of the U.S. plasticizer market, and It is becoming under increasing pressure in Europe in several applications. A report by the US Green Building Council [1] has concluded that the risk of dioxin emissions from PVC puts it consistently among the worst materials interns of human health impacts [2].

On the other hand, the combination of unique morphology, excellent physical and mechanical properties make rubber, an appealing raw material for many industrial applications including tyres, rubber springs and vibration mounts. Rubber has high structural regularity, providing it with unique characteristics such as high tensile and tear strength, good resilience, high elasticity, excellent impact resistance, good low temperature performance and excellent overall performance and durability in service conditions. The case study discussed here show the development of a speciality product based on rubber with the supply chain engagement to meet the requirements of pylons exposed to harsh environment conditions in some the Product Accelerator rts of New Zealand and Australia.

The case study discussed here clearly shows that the model adapted by the Product Accelerator to create new market opportunities through the development and accelerate commercialization of innovative products for New Zealand companies have been successfully achieved. This unique working model administered by the Product Accelerator has enabled the local lead company to work closely with technology providers and service providers in developing new customized products needed by demanding customers. This model also allowed the lead company to access a manufacturing technology that was not readily available in the manufacturing industry in New Zealand and offer the global end users a high quality better performing product meeting all the requirements.

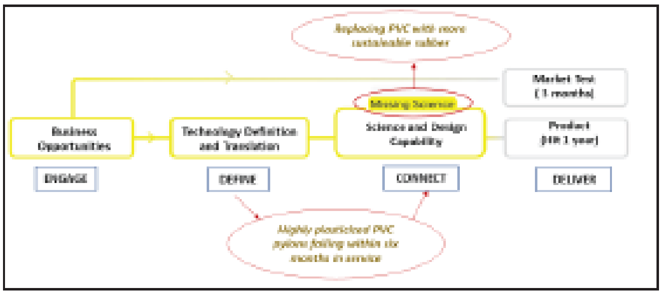


Figure 2 - Explore materials solutions for a sustainable product manufacture

The Product Accelerator model of engagement through technology the partners, industry the partners and service providers to commercialize new products into local and international markets has prompted undertake this project to improve performance of pylons in service. The rubber-based pylons have been developed at an international technology partner institution, with some advice and technical inputs from the Product Accelerator network expertise.

Figure 3 shows the Product Accelerator model adopted for the project on the development of rubber pylon to get international technology the partners and service providers that enable the commercialization of the product within a short time frame. This approach constitutes another aspect of the Product Accelerator multidisciplinary research contribution [3-14] engaging the expertise in its network the partners in various fields. Testing of rubber pylons was done at the international service provider, Rubber Research Institute of Sri Lanka, RRISL. The manufacturing of prototypes and commercial scale production were done by Samson International Plc for the client, EPI Group in New Zealand.

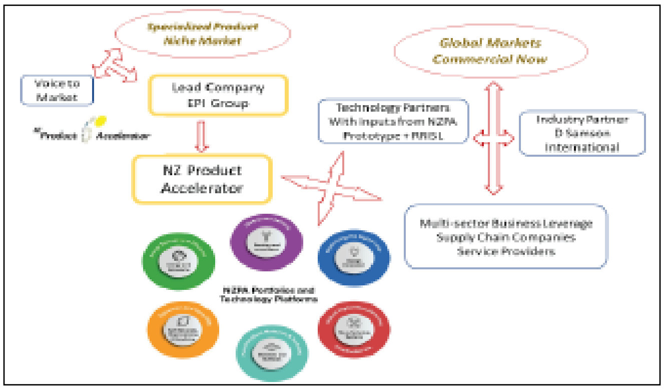


Figure 3 - Case Study on the commercialization of Rubber Pylons
The Product Accelerator Model of Engagement with the Supply Chain Partners

Rapid development of robust rubber pylon acceptable to the client in New Zealand was possible with the collaboration with a dedicated R&D at the leading rubber products manufacturer, Samson International Plc in Sri Lanka. A tax incentive given by the Sri Lankan government allowing to deduct double the expenditure incurred in R&D has been a great incentive to manufacturing companies because the finance sections always reject most of the R&D projects on evaluation of Return of Investment (ROI). These strategies and connections demonstrate alignment in more fundamental values – such as contributions to community, to support the developing countries to open new markets in develop countries and the global connections drastically support any kind of "Challenge Driven Growth"

A case study on a success story from a spun out from the Product Accelerator funded project focusing on missing science to solve an industry pull problem -

Out of several successful project outcomes, one of the projects created from the Product Accelerator funded research, the start-up company, Inhibit Coatings has successfully developed proprietary highly effective coatings to prevent the spread of the Product Accelerator pathogens and superbugs in hospitals, food processing facilities, workplaces, and health risk-prone environments with a technology partner, The Polymer Group Ltd in New Zealand, Inhibit Coatings is now an established antimicrobial and antiviral coatings company. Now working with large US and European resin and coatings companies and progressing international the patent protections and product approval. Inhibit floor and wall coatings are available through the partner The Polymer Group is another good success story of a challenge driven growth that the Product Accelerator is proud of.

Other products from Sri Lanka that penetrated the market and some pipeline product development through the Product Accelerator collaboration

Development and commercialization of high-impact resistant rubber electric plugs for construction sites and halogen-free fire-retardant rubber liners and mudflaps for Fire trucks fabricated in New Zealand for two industry partners through the Product Accelerator have also found markets in New Zealand. They are also manufactured at Samson International Plc in Sri Lanka as the supply chain industry partners for the Product Accelerator and commercialized in New Zealand.

There are few products in the development stage, and these include rubber sheets as trunk protectors in vineyards for a client in the agritech sector and a non-slippery, textured rubber tiles and nosing for the construction sector. If the trials are successful, these two products could fetch high volumes in the New Zealand market and the trend was again to approach Samson International Plc in Sri Lanka due to their track record in achieving the requirements of the clients and the milestones of the Product Accelerator contracted projects in shortest possible time frame. Following the recent audit held in November 2021 by amfori - BSCI at the Samson International Plc, the highest-grade compliance certification on global sourcing strategy on transparency and reliability and resilience and sustainability, has been offered to D. Samson International. amfori - BSCI, is a company with a mission to enhance human prosperity, use natural resources responsibly and drive open trade globally, working towards the fulfilment of the UN Sustainable Development Goals (SDGs) and this Grade A compliance certification will help the company to attract more local and overseas customers promoting sustainable manufacturing principles and to capitalize more Challenge Driven Growth opportunities in the future.

Arpico, Richard Pieris Natural Foams Ltd is another company in Sri Lanka, developed a specially designed pillow for a start-up company in New Zealand through the Product Accelerator. The company has successfully commercialized the product out of natural rubber latex foam.

A project on value addition to geothermal waste, Colloidal Silica in sustainable tyre manufacture being led by the Product Accelerator and carried out in collaboration with the Rubber Research Institute of Sri Lanka and two industry the partners in Sri Lanka, GRI Tyres and Dipped Products collaborating and supporting sustainability. The Product Accelerator highly acknowledges the service extended by the RRISL towards fulfilling the lab scale trials on the Product Accelerator sub-contracted project to get engaged in this project. The industry the partners are actively participating at discussions with the client in New Zealand and carryout in-house research and run pilot scale trials. The client is intending to visit Sri Lanka in 2022 to negotiate the terms and conditions based on the techno-economic of the project outcomes.

Another challenging project that the Product Accelerator has undertaken involves developing sustainable wool carpets for the New Zealand and export markets. Currently used toxic carboxylated Styrene Butadiene (SBR) Latex to bind the wool fibres is neither environmentally friendly nor sustainable. The initial trials will be conducted at the RRISL as the potential technology the partners on this project to see the value for natural rubber latex from Sri Lanka as a suitable binder to replace C-SBR latex. There are various other opportunities that the Product Accelerator is exploring currently focusing on sustainable manufacturing as the Product Accelerator has the potential to turbo-charge the development of in the manufacturing technology platforms and identify quick action needed to facilitate any challenge driven commercialization efforts.

Acknowledgments -

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The Product Accelerator appreciate and acknowledge the technical knowhow extended by the Senior staff at the Technology Departments of the Rubber Research Institute, Faculty of Technology at the University of Sri Jayawardnapura, and the Engineering Faculty of University of Moratuwa in Sri Lanka on various projects and the pilot scale and commercial scale manufacturing done by the private sector rubber products manufacturing companies as a part of our international collaboration.

References -

1. PVC Task Group, Assessment of the Technical Basis for a PVC-Related Materials Credit for LEED – Report authorised by the LEED Technical and Scientific Advisory Committee (TSAC) - K. Altshuler, S. Horst, N. Malin, G. Norris, Y. Nishioka- Feb 2007.

2. Health effects of dioxin exposure: a 20- year mortality study", P. A. Bertazzi, D. Consonni, S. Bachetti, M. Rubagotti, A. Baccarelli, C. Zocchetti, A. C. Pesatori, Am. J. Epidemicol, 153 (11), 1031-1044, 2001.

3. The Materials Accelerator: A new working model to promote commercialization of multi-materials through a national network in manufacturing materials - K. de Silva, R.P. Cooney, & M.P. Taylor, Proceedings of the TMS Conference 2011. San Diego, California 2011

4. NZ Industry – Research the Partnership: The Materials Accelerator Model; R. Cooney, M.P. Taylor Proceedings of 34APS 7-10th July 2013

5. A national innovation network in New Zealand: the Materials Accelerator; R. Blache, C. Nguyen, K. De Silva, R. Cooney and M. Taylor; Proceedings of XXIV ISPIM Conference, Helsinki 2013

6. A Culture Shift in Materials and Manufacturing Research for NZ Businesses; M. P. Taylor, C. Nguyen, K. De Silva, R. Blache, B. McMath and R. P. Cooney; Chemeca 2013 : Challenging tomorrow: A culture shift in materials and manufacturing research for NZ businesses, Published: Barton, ACT: Engineers Australia, ISBN: 9781922107077 (2013).

7. Towards improving the biocompatibility of prosthetic eyes. Pine K R, De Silva K, Zhang F, Yeoman J, Jacobs R, Heliyon, 7(2):1-8, 2021. DOI: doi.org/10.1016/j.heliyon.2021.e06234

8. Effects of In-Process Temperatures and Blending Polymers on Acrylonitrile Butadiene Styrene Blends. Muhammad Harris, Johan Potgieter, Hammad Mohsin, Karnika De Silva and Marie-Joo Le Guen, Inventions 2021, 6, 93. https://doi.org/10.3390/inventions6040093

9. Selective laser melting of aluminium metal-matrix composites and the challenges. Behera MP, Dougherty T, Singamneni S, De Silva K, Materials Today Proceedings, 2020.

10. Interfacial adhesion: improving the mechanical properties of silicon nitride fibre - epoxy polymer composites. Hayward M, Johnston J, Dougherty T, De Silva K, Composite Interfaces, 26(3):263-273, 2019. DOI: doi.org/10.1080/09276440.2018.1499328

11. A Sustained Release Anchored Biocide System Utilising the Honeycomb Cellular Structure of Expanded Perlite. Matthew R, Cooney, R, Zujovic Z, Doyle C, Wheelwright W and De Silva, K. ACS Applied Biomaterials, 1 (6), 1959-1971, 2018. DOI: doi.org/10.1021/acsabm.8b00495

12. Ultra-lightweight Concrete Containing Expanded Poly-lactic Acid as Lightweight Aggregate. Sayadi A, Neitzert T, Clifton G., Han M, and De Silva, K, KSCE Journal of Civil Engineering, 22 (10):4083-4094, 2018. DOI: doi.org/10.1007/s12205-018-1976-4

13. Ultra-high surface area nano-porous silica from expanded perlite: Formation and characterization. Wheelwright W, Cooney R, Ray S, De Silva K. Ceramics International, 43(14):11495-11504, 2017

14. Evaluation of fire performance of organic fire retardant free acrylic based coatings applied on various building materials by cone calorimetric method. De Silva K, Ray S, Blache R, Taylor M, Fire and Materials; 41:169–179, 2016

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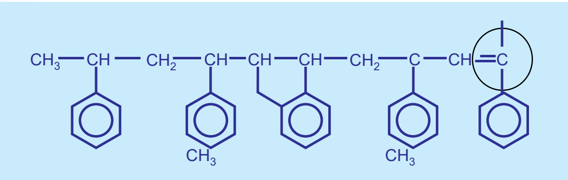
- **Improved tensile strength as a result of stiffening at room temperature and Sulphur dispersion.**
- **Increased fatigue resistance as a result of improved dispersion of the fillers and wetting of the filler surface.**
- **Retardation of cut growth by dissipation of stress at the crack tip (as a result of a decrease in compound viscosity).**
- **Can replace expensive Phenol Formaldehyde(PF) Resin.**
- Enhance Grip Performance
- Showed equivalent performance to AMS Resin in TPR/TPV Compound

Structure of the Hybrid Polymerized Structure



Technical Specifications

Parameter	Test Method	Value/Observation
Appearance	Visual	Pale Yellow / Transparent Beads
Softening Point °C	JIS-K-2207 Ring&Ball	95°C
Colour-Gardener	ASTM D-1544	6
Bromine No Br_2 g/100g		35
C-5 Content %	H-NMR	30

Application

- Fabric coating
- Silica filled Tyre tread for better dry grip performance
- Solid Tyre
- Tackifier in hot melt Pressure Sensitive Adhesive
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S-lon attributes resilience through pandemic to customer-centricity

S-lon, Sri Lanka's pioneering water management solutions supplier and a subsidiary of the Capital Maharaja-owned S-Lon Lanka (Pvt) Ltd, escaped unscathed and even prospered from the pandemic that ravaged the country's economy. Apart from compassionate leadership and foresight, 'customer centricity' may be attributable to this success. Customer centricity is at the heart of S-lon's ethos, with the guiding premise "if it's not good enough for your family, it's not good enough for the customer!"

While contemporary marketing continues to preach the cliche that "the customer is king," S-lon ascribes to the belief that 'the customer is GOD.'

Commenting on S-lon's journey through the past two years, Group Director of The Capital Maharaja Group, Mr. S C Weerasekara opined: "S-lon treats and considers all stakeholders down the line – be it the merchant, the plumbing professional, or even our own staff – as customers. This mindset of according importance to every link of the supply chain has helped us stay resilient & ahead of the curve."

"S-lon has a simple philosophy: The brand believes in offering a quality product and an unparalleled service so the customers will do the 'marketing' by becoming 'Brand Evangelists'. S-lon relies on 'earned reputation' through passion, compassion & unwavering integrity over publicity that is bought through exuberant marketing campaigns," he added.

This enthusiasm and mentality based on 'customer centricity' has helped S-lon to emerge fairly triumphant from the pandemic's various waves. While the initial wave of the epidemic was handled rather effectively in terms of particular businesses and the country as a whole, later waves had numerous effects across industries and communities.

From the outset, Mr. Weerasekara led the team from the front working hands-on with every link of the supply chain. Perhaps it was the market intelligence coupled with 'people skills' he gained as a young Sales Representative at S-lon that fueled this unique yet high-yield approach.

"Navigating Covid 19 became a humanitarian mission when many of our sales representatives lost lodgings at the height of it due to landlords fearing executives out on the field might be getting exposed, and exposing others, to the deadly pandemic. Not only did we find these team members alternative accommodation, we also provided them food and medication to boost immunity. I was able to understand their plight better, and take swift action, given my own experience as a sales representative," Mr. Weerasekara noted.

When most manufacturing was halted due to the pandemic, the S-lon facility was kept operational since it was deemed necessary to be able to meet the 'accumulated demand' once the lockdown was lifted. All of this, however, was done in accordance with strict health & safety guidelines outlined by health authorities, which included a 20-item exhaustive checklist. To reduce the spread of infection, all staff were vaccinated and transported in private vehicles to & from work.

At the beginning of the pandemic, S-lon insisted on collecting dues from distributors which was met with criticism from the industry. Although this course of

Group Director of The Capital Maharaja Group Mr. S. C. Weerasekara attributed S-lon's success to customer-centricity and taking bold, strategic decisions – pertaining to the long-term – where necessary. He also said that S-lon has managed to emerge resilient in the aftermath of back-to-back lockdowns given the organization's preparedness in the face of adversity. Instead of halting production, S-Lon forged ahead in keeping with health & safety guidelines to ensure the accumulated demand would be catered to sans shortages, delays or unprecedented price fluctuations. S-lon did not compromise on its Corporate Social Responsibility initiatives during the pandemic and did not have to down-scale, but, instead, generated more occupational opportunities for local youth. Mr. Weerasekara urged investors & industrialists to remain hopeful & asserted that recovery was possible if everyone worked towards the single-minded mission of accomplishing progress through minimizing wastage in all aspects, professional & personal. In terms of the way forward, S-lon intends to expand to newer markets in 2022 empowering Sri Lanka's aspirations of economic recovery & growth.

action was then perceived as being “greedy”, many soon agreed that it was the right thing to do pertaining to the long-term sustainability of the company’s operations. This measure enabled S-lon to supply continuously ensuring no shortages or unprecedented price hikes.

At the height of the pandemic, 1100 fully vaccinated staff members were working adhering to safety guidelines stipulated by the Government. This in turn enabled S-lon to pay full salaries as well as acquire new talent in the immediate aftermath instead of laying off staff - or downsizing - which was the common, expected scenario.

Mr. Weerasekara was optimistic that Sri Lanka could recover in the next year granted everybody commits conserve resources and endeavor to be more efficient in their job roles: “We can overcome this catastrophic period if we all commit to reducing wastage whether its in the production line or our own personal lives; sacrifices would be inevitable but I am confident Sri Lanka would regain momentum and stability over the next 2-3 years.”

S-lon did not compromise on any aspect of the business during the pandemic including Corporate Social Responsibility initiatives such as “Gamai Pansalai” & “Thuru Kepakaru” – the former is a campaign to restore & renovate religious places around the country in an effort to empower communities through spiritual enrichment while the latter is a re-forestation initiative that focuses on long-term, consistent nurturing of our precious planet.

Future Directions Of R&D In Tyre Industry With Specific Reference To Automotive Industry's Needs And Applications

By courtesy of Tyre Trends

Dr R Mukhopadhyay

Director & CE – HASETRI and Chairman – Indian Rubber Institute

Increasingly exponential all-round growth of technology added with the advent of disruptive technologies simultaneously has drastically changed every conceivable aspect of human life including automotive industry in the 21st century, more so in the last decade. The prevailing cut-throat competition amongst leading automotive brands to allure customers with unique and exciting features coupled with statutory compulsion and drive for green sustainable circular economy has culminated into a never-ending ambitious wishlist for the ancillary and subsystem suppliers including tyre industry.

It would be pertinent to remember that tyre is the only contact interface between vehicle and road which generates all the controlling, stabilising and guiding forces and moments to convert control commands of driving unit (because not only human drivers but driverless driving has become quite common and an intended feature) to successfully complete desired manoeuvres ensuring safety, stability and comfort alike. Hitherto aloof and simultaneously excluding branches of professional expertise, both intra and inter industry, are forced to collaborate and jointly undertake development programmes to successfully meet the challenging expectations both from OEMs as well as secondary market customers who have enhanced their awareness multi-fold owing to ongoing information explosion and its easy access.

But it would be unwise and far removed from the realities if we ignore or scrap those historically conflicting yet confirming to natural science demands which, in addition to newly emerging wishlist that tyre development teams have to still continue to grapple with, are enumerated below:

1. Continuous lowering of rolling resistance while improving tyre wear and traction properties.

2. Improving the entire domain of manoeuvrability encompassing handling while not sacrificing the ride quality.

3. Improving noise performance along with enhancing snow performance.

And the beauty of the approach lies in the fact that it still requires accomplishing the aforementioned with enhancement in tyre uniformity levels and continual weight reduction.

We all will agree that capital intensive conventional (Internal Combustion Engine-based automobiles largely consuming fossil-based fuel) automotive industry has faced the brunt of technology advancements like increasing acceptance of electric vehicles (EVs), sensor development etc. and innovative approaches spanning from ADAS (Advanced Driver Assistance Systems) to driverless driving and autonomous vehicles to approaches in manufacturing like 3D printing which has potential of changing or even replacing conventional understanding and landscape of manufacturing, and at the same time unleashing umpteenth opportunity to simultaneously achieve supra-industrial aspects of economy like green and sustainable economy, circular economy, traffic safety and management while maximising the positive aspects such as fun, delight, excitement, as well as comfort for customers. **The unique challenge is to adapt, survive and prosper**. Future mobility and tyre development trend are given below.

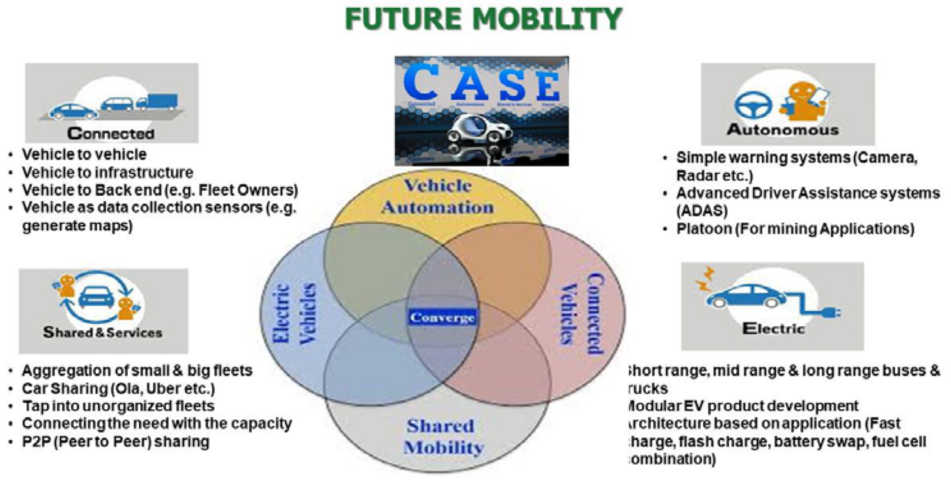

Figure - 1

Figure - 2

With average travelling speed increasing, the importance of improved ride comfort becomes a critical expectation and demand from the OEM's point of view. This requirement primarily revolves around NVH (noise, vibration and harshness) aspects where tyre now has gained even increased focus owing to other contributors like engine, aerodynamics, intake and exhaust noises coming much below their hitherto contributory values and proportions. Even pass-by noise levels are continuously being targeted for reduction through statutory route owing to its impact on public health. The approach to address it still revolves around traditional aspects like tread pattern and carcass construction (including material, contour and layout). While advances in technological tools in measurement and mitigation like simulation, active ride control/noise cancellation have helped, some new challenges like increased annoyance due to tonal components, more so in case of EVs, have actually emerged as new problem areas to be tackled on priority. Now OEMs are inclined to appreciate its importance and grant NVH performance its due respect by not only treating it as their design/target parameters but also involving tyre experts in their teams from very early phases of design cycle time. For design cycle time reduction, simulation in tyre development is playing a very important role (Figure-3). Approaches like bringing the road to lab , hardware-in-loop etc. have helped testing and simulation competitors to cooperate more realistically in optimising NVH performance as well as reducing development cycle time and at the same time drastically avoiding many costly manufacturing fixes later in product life cycle time. Increased access to testing facilities like NVH Chassis Dyno has proved to be very helpful for tyre designers to understand the ride mechanics and help to improve it.

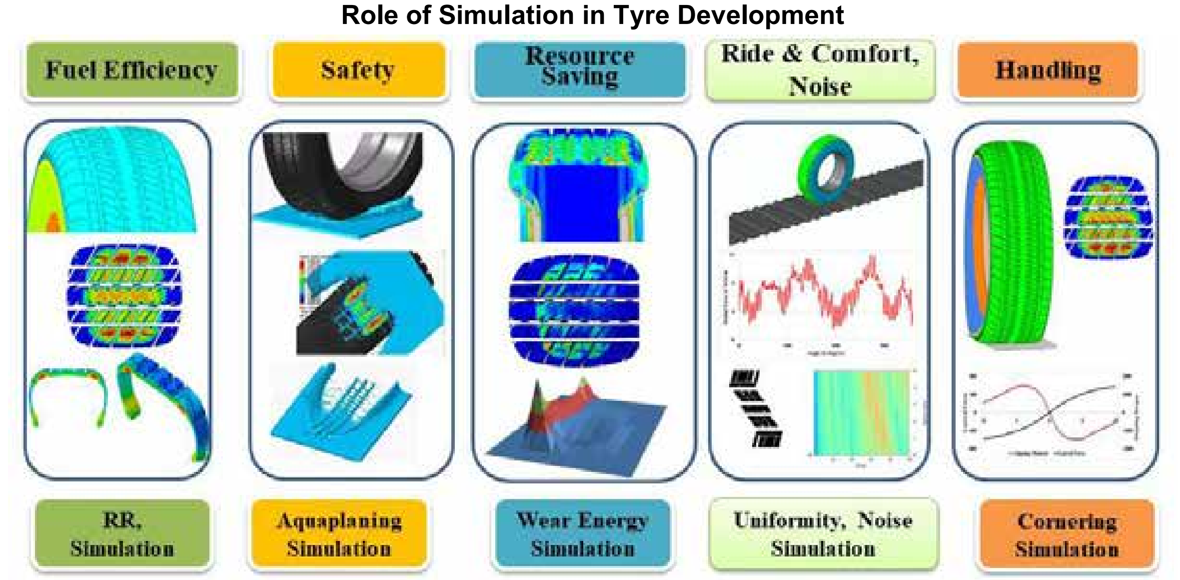

Figure-3

Tyre traction, both dry and wet (including snow traction), is a property crucial for OEMs from controlling driving dynamics point of view. While conventionally it was an exclusive domain of compounding experts with some useful assistance in casing design optimisation, now it has significant scope for sensor-assisted traction control devices as well as for 'adaptive tyre (capable of changing contact patch best suited to operating conditions)'. This property gains additional priority in case of driverless/autonomous driving where collision avoidance ensuring the traffic and pedestrian safety in all driving conditions need to be sensor monitored and controlled. It is important to work continuously for further reduction in stopping distance and maintaining directional stability while braking. We may also witness increased inclusion of sensor-assisted systems like lane/trajectory departure warning system with autonomous control loop giving customer higher confidence about safety.

OEMs will continue to accord highest priority for continuous weight reduction as it helps them in their evolving target of improving fuel efficiency by reduction in rolling resistance. Apart from new material development as well as development in allied areas to preserve ride and handling at similar level are current as well as future focal points.

For tubeless radial tyres which are now omnipresent on all new vehicles being introduced, the work to improve air retention property still happens to be the core concern in which newer concepts are being tried. Tyre technology may be inching close to attaining the goal of 'Puncture-proof' equivalent to non-pneumatic counterpart which is discussed in next paragraph.

Historically, the concept of 'airless/non-pneumatic/run flat technology' has one thing common. The focal intent is that the mobility's dependence on tyre state could be decoupled and customer should neither be left stranded mid-way in his travel nor be bothered by the thought of uncontrollable loss of the vehicle's directional stability and roll control at any moment of travel. Such an objective can either be met by incorporating suitable mechanisms in present tubeless tyres so that loss of carcass shape and bead unseating due to sudden loss of air can be prevented, or another novelty could be to convert tyre to its non-pneumatic sibling. Some breakthrough in such direction like TWEEL or UPTIS (Unique Puncture Proof Tyre System) or honeycomb spoke structure have been tested and also being tried out commercially to selected segments, but its widespread commercial introduction is still little distant in near future. It is important that the current level of ride comfort and handling ease needs to be retained in all operational modes before it can be offered as a viable alternative and tyre development & research teams continue to keep it as high priority focus area. This will also help by completely eliminating the need of keeping spare tyre on vehicle as well as bringing the need to remove tyre for repair to bare minimum. This may help in achieving customer delight from travel as an exciting experience and fun every time one ventures on road, more so with autonomous electric vehicles.

Tyre Pressure Monitoring System (TPMS), which is in vogue for quite some time now, is also witnessing significant advancements in terms of making tyre inflation as a continuously monitored and recorded data by vehicle ECU, attaching all the tyre-related information through usage of RFID chips, and above all, tyre companies spear-heading the drive of development with a desire to monitor product life cycle management through IOT (Internet of Things). This may also culminate into continuous monitoring and controlling of tyre performance parameters including its force and moment properties either through embedded or otherwise sensor usage, achieving the desire to evolve a cybernetic smart tyre.

Now the earlier scope of tyre having ‘Adaptive material’ has been enhanced to encompass many other performance criteria to make tyre shape pattern and behaviour also adapting to requirements of operation including road condition and driving needs. Such concepts are further getting fuelled by technological advancement in areas like 3D printing, which may not only help in making custom built tyres but may also change the landscape of tyre manufacturing forever. Some out of the box concepts like introduction of spherical tyre may revolutionise the way not only traffic moves but also parking philosophies. Such moves may help in reducing parking lots from current size by more than 60 percent. Therefore, both OEMs and tyre developers have initiated concept development in such arena.

‘Material & Compounding Research’ will have to take equal lead with other branches in Tyre Design & Development to achieve goals of green mobility, sustainability and simultaneously that of meeting the growing and changing demands from OEM as well as replacement market, more so in wake of increasing share of EVs as well as emergence of autonomous driving.

Rapid urbanization, with an estimate that about 60 percent of population may be residing in cities by 2030, may accelerate problems like climate change, traffic congestion, travel safety etc. Therefore, focus will move towards reducing fossil fuel consumption, noise, rolling resistance and energy loss while improving durability, air retention, heat dissipation as well as dry/ wet traction at the same time. Limiting consumption of non-renewable resources, e-mobility, adaption of eco-friendly materials and compound will become core focal points of R&D in tyre industry. It should not be a surprise if greater available resources are allocated to such ambitious projects as replacing fossil fuel-based raw materials with bio-sourced and recycled material as early as in next 30 years and concurrently achieving 50 percent weight reduction without compromising performance parameters of tyres.

New matrerial usage trend may include items like modified NR, bio-source SR, functionalised solution SBR modified with different coupling agent , rubber containing functional groups over the entire length of back bone , latex-carbon black/Silica master batch as well as rapid development in the area of magneto-rheological materials. The other significant trend may involve materials based on the principle of bionics, natural materials like Nano Clay, Natural Silica, Nano Calcium Carbonate, Montmorillonite ClayS (MMT), Carbon Nano Fibers (CNF), Polyhedral Oligomeric Silsesoquioxanes (POSS), Carbon Nano Tubes (SWNT & MWNT) and Graphene. Alternative natural rubber sources like Russian Dandelion & Guayule may also contribute to a degree. Similarly synthetic rubber manufacturers may venture into using monomer from bio-source, eco-friendly processing-aid; Solvents may be replaced by water based lubes and sulphur by peroxides. Another objective of complete elimination of zinc oxide usage seems attainable in near future. Current materials trends and future potential in tyre industry, industrial biotechnology and renewable resources and rubber material development trend are shown in Fig-4, 5 and 6, respectively.

In the area of filler, materials like silica (based on bio mass, rice husks & fly ash), Starch, treated Corn powder, Graphene & Carbon nano tubes may arrive in a significant proportion. For reinforcement, newer materials (primarily having property of equal or high strength at similar or lesser weight) – such as Aramid, Hybrid cords (Nylon-Aramid), Ultra high tensile steel cords including ternary alloy (Cu-Sn-Zn/Co-Cu-

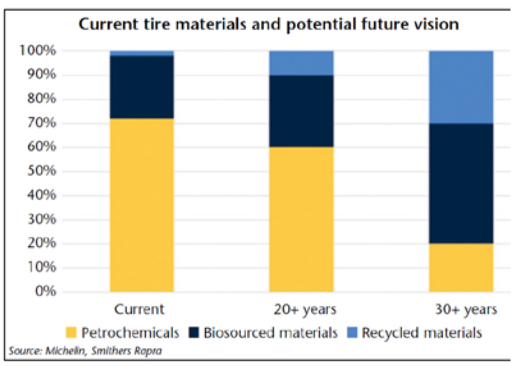

Fig-4

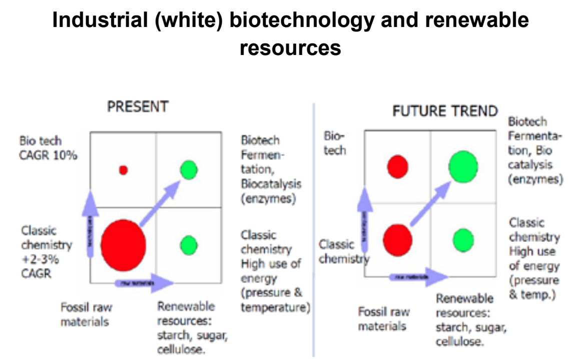

Fig -5

Figure-6

Zn) coated steel cord – may start dominating in next 30 years, yielding improved fatigue and corrosion resistance. In a nutshell, materials and compound research may contribute significantly in achieving grand vision of making tyres meeting all performance and durability criteria at optimal cost through sustainability and promoting green mobility.

It would be worthwhile to take a look of some other important parameters and have a sense about how and to what extent these could impact the tyre technology development. It is estimated that global vehicle population may swell to 2.4 billion in 2050 from a reported level of 1.1 billion in 2019. The world human population may touch a mark of 10 billion by 2050 and population of people in the age bracket of 65+ years may increase to 16 percent from current the level of 9 percent. Another significant factor could be that car sharing/ pooling may fast overtake today's tendency of owing a car. Work to reduce ecological footprint of cars/vehicles and tyres will gain relevance and prominence. While developed nations may totally shift away from fossil-based fuel, other nations will also achieve significant reduction in such fuel consumption and thus help in carbon dioxide emission control. Increase in share of EV as well as emergence of autonomous driving may prove to be catalyst in bringing more people on road, increase in running kilometres and connected vehicles through wide spread implementation of IoT (Internet of Things). So, future may demand to get a tyre which is extremely safe and reliable, giving desired level of performance all through the product's life cycle time with increase in mileage through wear control while being lowest possible in cost. Global electrical vehicle production trend and future potential is shown in Fig.7.

Emergence and increased usage of non-conventional automobiles like EV (Electric Vehicles)/FCEV (Fuel Cell

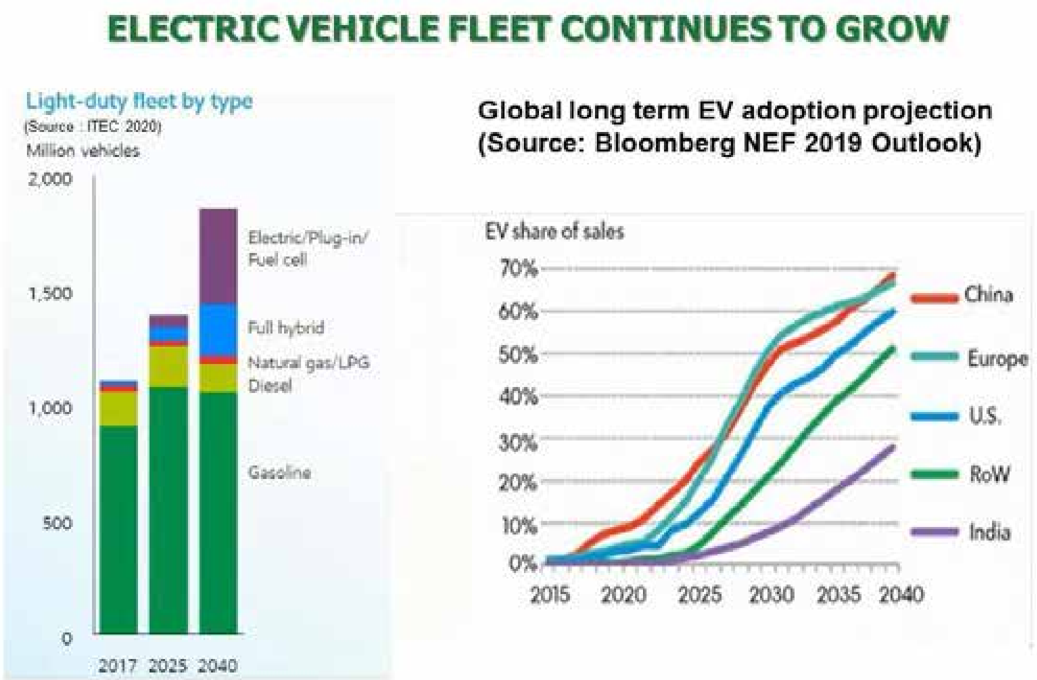

Fig-7

Electric Vehicles) threatens the market of conventional ICE (Internal Combustion Engine) based automobiles. It is estimated that by 2040, in developed countries such vehicles may touch a market share of 70 percent plus (refer figure below). In Indian scenario, owing to charging infrastructure issue becoming a constraint, this figure may reach to only 30 percent by that time. While EV has its distinct advantages in terms of green economy, environment protection and sustainable development, it has got its fair share of challenges also. Cost of buying currently lies in a margin of 20-40 percent more with respect to equivalent conventional ICE based automobile; however, experts estimate it to bridge that gap quite fast and comprehensively. But other challenges, more technical in nature, will keep the OEMs as well as tyre developers busy for many more years to come. It is easy to understand that 25-30 percent higher overall vehicle weight of EV, owing to its battery weight, will help in enhancing vehicle stability owing to lower CG (Centre of Gravity) height but would also require tyres to become larger and thinner with higher load carrying capacity (refer Figure below). The demand for reducing rolling resistance further will be coupled with increasing grip and reducing wear, which may get challenges from high initial torque generated by electric motor. More focus will be required to keep noise also under control and equally larger effort will have to be devoted to achieve overall property balance. Issues like air retention and extended mobility on existing radial tubeless tyres will gain further prominence. In a nutshell, tyre development teams will have enough challenges for decades to come. A glimpse of property requirement for EV tyres is listed in Table 1.

Table 1: Property requirement for EV tyres

Property	Enhancement expected
Fuel efficiency	Required ultra low rolling resistance tyre
Grip	Superior grip property
Load bearing	Higher load carrying capacity
Wear	Higher wear resistance
Torque	Resistance to high torque
Noise	Less noisy tyre
Bead area design	Better contact pressure distribution at tyre bead-rim interface to improve slip resistance.
Air retention	Superior air resistance property
Extended mobility/puncture resistance	Self-sealing ability
Overall property balance	More balanced requirement

Even before the arrival of wide scale usage of disruptive technologies like 3D printing, the manufacturing technology of present times will also move towards more sophistication by usage and integration of complex electronic control systems and automation to ensure efficiency, constancy and quality of manufacturing to scale newer heights. The products will show better uniformity and more consistency in performance. This will also help in keeping manufacturing costs within control which is so essential in today's fiercely cut-throat competitive market. The objective of development in tyre manufacturing process will be aimed at enhancing productivity, quality and performance while reducing the cost, waste and scrap and also move towards better sustainability and environment friendliness through conserving resources.

- Continuous degradation of environment is threatening the existence of human life on mother earth planet. It is estimated that by 2100, the average temperature may rise by 3 degrees Celsius, which may prove to be catastrophic and play havoc. Economy impact due to climate change and environmental impact on climate change are shown in Fig 8 and 9.

- Climate change could directly cost the world economy USD 7.9 trillion by mid-century as increased drought, flooding and crop failures hamper growth and threaten infrastructure.

- Rising temperatures meant the global economy was projected to hit USD 250 trillion by 2050, as opposed to USD 258 trillion with no climate impact.

Sustainability has to be the key focus and 5R Strategy (Reduce/Reuse/Recycle/Regenerate/Renew) of circular economy needs to be the guiding principles in such an effort. Design for Environment and 5R Strategy for tyre & rubber Industry are shown in Fig-10 and 11. Apart from depleting natural resources, the greater threat to sustainability may emerge from significant employment loss owing to increased automation and emergence of disruptive technologies, which may even become more challenging for fragile economies of developing countries like India. Increased requirement of technical literacy for emerging scenario in all aspects of business may render people currently in the age bracket of 40+ as literally non-employable.

Economic Impact due to Climate Change

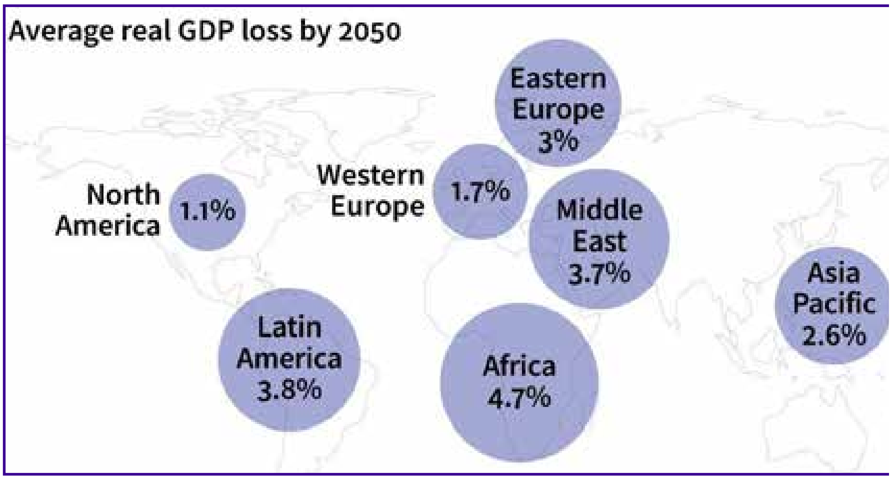

Fig-8

Environmental impact on Climate Change

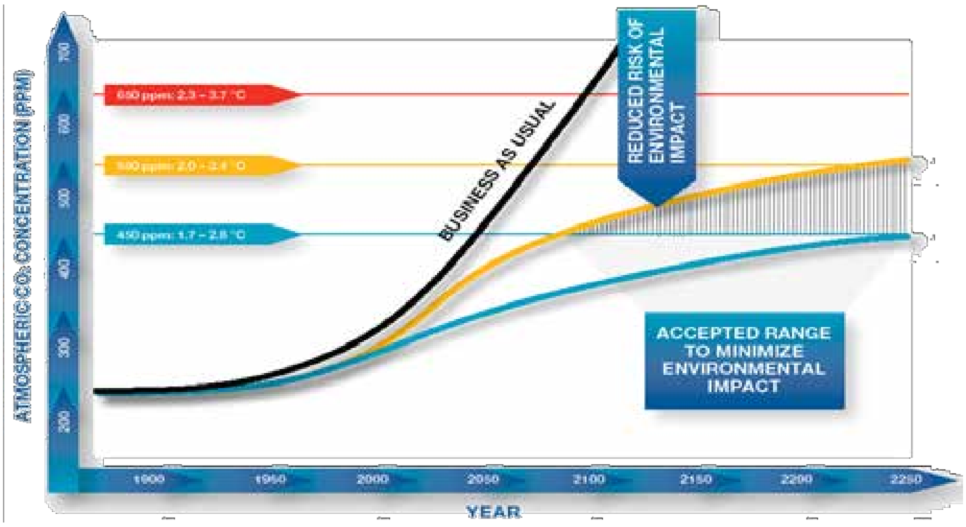

Fig-9

Design for Environment for Tyre & Rubber Industry

Fig-10

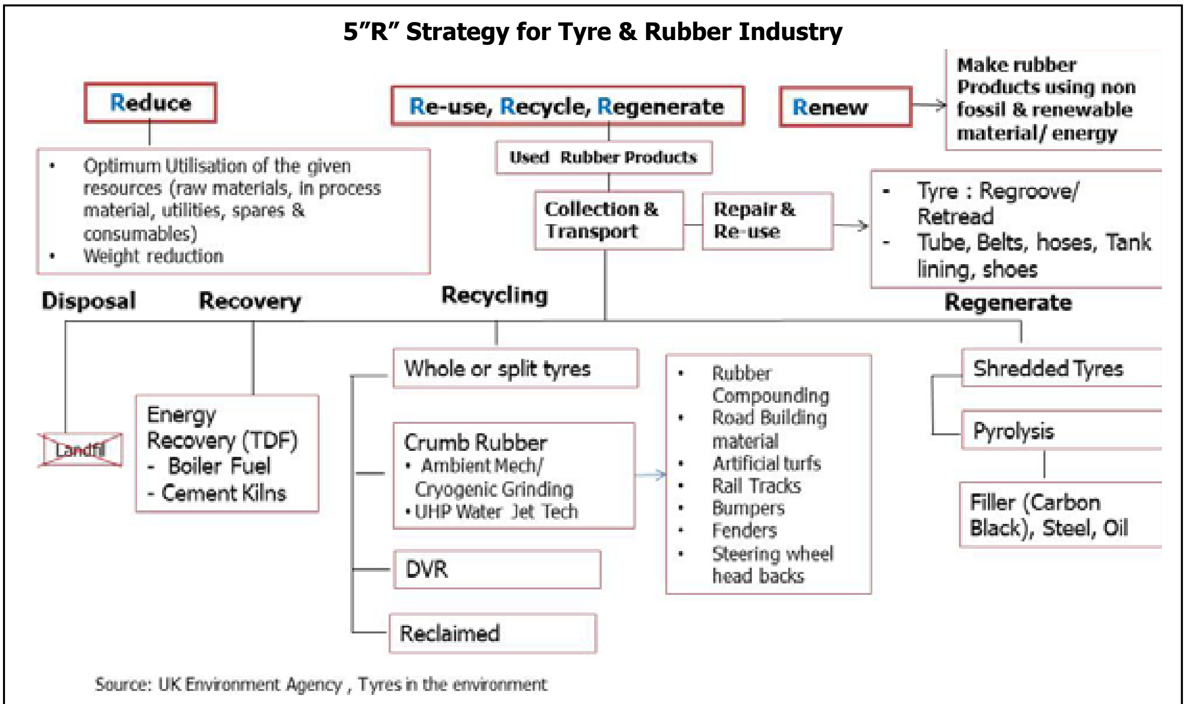

Fig-11

So, all, including the industry, will have to shoulder the responsibility of conserving the environment as well as resources. We understand well that population increase (estimated world population in 2050 to touch 10 billion mark) has negative impact on economic growth, whereas continuous mindless resource consumption has adverse environmental impact. These causative factors coupled may result in GDP growth drying up, presenting hitherto unknown challenges for policy makers. Therefore, all sectors of society will have to put their knowledge and intellectual resources together to find an optimal way out ensuring continuance of survival with growth orientation. Technology teams at tyre industry may have to devise newer ways to adapt design and material for recyclability and reusability really faster and to a higher constituent level. This may well necessitate innovating newer technologies.

Such a scenario may put tremendous pressure on available resources and may constrain the path of growth or even survival to many existing leaders. It will not only force them to find innovative ways to generate necessary financial funds but may also pave way for increased collaborations and partnerships amongst current competitors. This may even be mandated by prohibitively high cost and expert resource crunch with any single player in any given domain, so the same may also become essential for global leaders in tyre industry of today.

In summary, it is evident that the already endless wish list of the automotive industry (particularly OEMs) will continue to grow in size, increasing burden of tyre research and development teams. It may also open unique opportunities for tyre teams to get more resources and increased involvement with OEM teams to develop custom built unique products optimally, which OEMs in turn will require for their own survival and competitive growth. Future is going to be interesting and fiercely competitive with a long cherished dictum of '**survival by collaboration**' getting realised.

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3rd	JSR HPR350, JSR HPR355 JSR HPR355H, JSR HPR355A	Basic grade for CB/Silica compounds. Chain end modifier enables excellent Silica dispersion
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JSR 1502	52	0.94	NS	Salt/Acid	23.5		Sidewall, Footwear, Rubberized Fabric, other light-colored products, non-staining type black products
High Cis BR Grades 1,4 Cis Containt 96%	**Mooney Viscosity (ML_{1+4}(100°C))**	**SP Gravity (g/cm³)**	**Catalyst**	**Oil**	**Functional Modification**		**Application**
JSR BR01	45	0.90	Ni	–	No		PCR / TBR tread, sidewall
JSR T0700	43	0.90	Nd	–	No		PCR / TBR tread, sidewall
JSR BR730	55	0.90	Nd	–	No		PCR / TBR tread
JSR BR54	50	0.90	Nd	–	Y(CB / Silica)		PCR tread
JSR BR740	55	0.90	Nd	–	Y(Silica)		PCR tread
Low Cis BR Grades 1,4 Cis Containt 32%	**Mooney Viscosity (ML_{1+4}(100°C))**	**SP Gravity (g/cm³)**	**Catalyst**	**Tg (°C)**	**Functional Modification**	**Vinyl Content (%)**	**Application**
JSR BR500	61	0.90	Li	-88	Y(CB)	20.0	TBR tread, sidewall

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3	**Synergism on mechanical properties :** Improve tensile properties such as Elongation at Break Enhance Cut and Tear resistance (Toughness and Durability) Silane treated talc improves Compression Resistance
4	**Extend service life** : Very good Retention of Tensile properties
5	**Superior weathering and UV stability** : No gloss variation after weathering, Limited discoloration after weathering

Market	Applications
Electric Vehicles	Lower CO_2 emissions Increased performance of lithium ion batteries for electric cars
Car Tires	Weight reduction is one of the key drivers for decreasing CO_2 emission in Cars

Physical characteristics :

CHARACTERISTICS		Specific area BET m²/ g	Sedigraph $D_{50}(\mu)$	Laser granulo $D_{50}(\mu)$	Aspect Ratio
Jet Mill Process	Mistron Vapor	13	2.2	4.8	23
Wet Milled Process	Mistron HAR®	20	1.1	6.7	143

Application :

A. HAR® Talc in **Tyre Inner liner** Partical CB Replacement

Advantages :

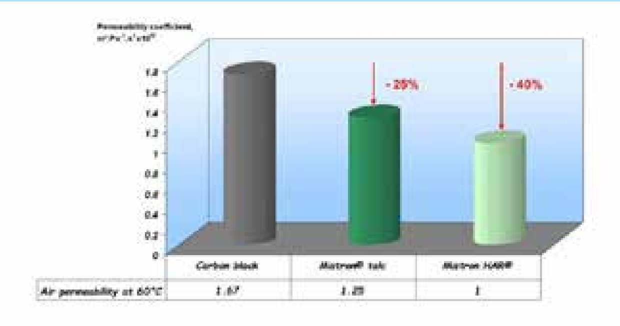
1. Retention of properties after Air Ageing also maintained
2. Further Permeability reduction possible without Carbon Black

B. HAR® talc in **Tyre Side Wall Partial** CB Replacement

Advantages :

1. HAR® talc enhance cut growth resistance of SW compound & Thermal Resistance is also improved Vs Pure CB Compound enabling possible extension of Service life
2. No negative effect observed on Rebound, Ozone Resistance

Permeability Performance



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Advantages of Manufacturing and Using Natural Rubber Gloves[1]

By courtesy of PRI, Malaysia

A.H. Eng[2]

It is easier to manufacture rubber gloves using natural rubber (NR) latex than 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, manufacturer, user

Introduction

Materials for rubber glove applications must be able to form thin and flexible barrier films to provide the users with 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 sufficient stabilisers 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 phosphate and fatty acids. Phosphate is known to precipitate the magnesium ion in the latex to form magnesium phosphate. Magnesium ion is one of the ions that is known to reduce the latex stability.[1] The free fatty acids released from the phospholipids could form fatty acid soap with ammonium ion which imparts stability to the latex.[2] However, during the long term storage of the 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 agent is 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. Continual vulcanisation during production of latex products would eventually render the latex over-vulcanised or over-cured with poor mechanical properties. As the prevulcanised latex is optimally vulcanised, the mechanical properties are less susceptible to the fluctuation of drying 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 ozones for gradual drying and curing to prevent cracks.

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1 A paper presented at International Rubber Conference 2018, Kuala Lumpur.

2 K&W Training & Consulting, Malaysia
e-mail: engaikhwee@gmail.com; engaikhwee@outlook.com

Good Wet Gel Strength

NR latex is known to have much better wet gel strength than synthetic latexes.[3] 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 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 surfactants such as proteins and phospholipids. 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 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.

Low shrinkage

Due to the broad particle size distribution 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. A high shrinkage glove is expected to pose a higher risk in cracks formation during drying. In addition, the low surfactant level of natural rubber latex also leads to a lower shrinkage. This is because when the surfactant is removed out during leaching, it is replaced by water or latex particles via reorientation. All this leads to the film shrinkage. The higher surfactant therefore is expected to cause higher shrinkage in the dry film. A low shrinkage will have a lower risk of film cracks.

Simple Procedure

NR latex has been used to produce latex products for a long time. As such, the formulation, machine design, processing conditions are simple and have been well studied and published. On the other hand, the information on synthetic rubber gloves manufacturing is less readily available in the literature as synthetic rubber gloves, particularly the thin products were only started to manufacture 20-30 years ago, which is relatively short compared to NR gloves.

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.[4]

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.[5,6] 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.[7] 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 studies showing that unlike synthetic gloves such as vinyl, chloroprene and nitrile gloves which showed significant viral and bacterial leaks 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.[6,8]

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.[9] 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 pathogen 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 latex 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.

References

1. Malahom N., Jarujamrus P., Meelapsom R., Siripinyanond A., Amatatongchai M., Chairam S. (2017) Simple test kit based on colorimetry for quantification of magnesium content in natural rubber latex by miniaturized complexometric titration without using masking agent. Polym. Test., 59 , 160-167

2. Chen S.F., S.S. Ng (1984) The Natural Higher Fatty Acid Soaps in Natural Rubber Latex and Their Effect on the Mechanical Stability of the Latex. Rubb. Chem. Technol., 57, 243-253.

3. Dik L., Krutzer B., and van Dijk N. (2013) Wet-Gel Strength Improvement.
Kraton Innovation Center Amsterdam.
http://www.kraton.com/products/pdf/Cariflex%20IR%20latex%20-%20Wet%20Gel%20Strength.pdf

4. MYLON P., LEWIS R., CARRÉ M.J., MARTIN N., BROWN S. (2014) A study of clinicians' views on medical gloves and their effect on manual performance. Am. J. Infect. Control, 42, 48-54.

5. Walsh D.L., Schwerin M.R., Kisielewski R.W., Kotz R.M., Chaput M.P., Varney G.W., To T.M. (2004) Abrasion Resistance of Medical Glove Materials. J. Biomed. Mater. Res. Part B: Appl. Biomater., 68B, 81–87.

6. HASMA H., OTHMAN A.B. AND FAUZI M.S. (2003) Barrier Integrity of Punctured Gloves: NR Superior to Vinyl and Nitrile. J. Rubb. Res., 6, 231-240.

7. Yoshiyuki Nakamura Y., Ishizu O., Aihara S. (2017) Latex for molding use, composition for dip molding use, and dip-molded article. US Patent 9546239.

8. Bardorf M.H., Jäger B., Boeckmans E., Kramer A., Assadian O. (2016)

Influence of material properties on gloves' bacterial barrier efficacy in the presence of microperforation. Am J Infect Control., 44, 1645-1649.

9. Centers for Disease Control and Prevention (2015) Guidance on Personal Protective Equipment (PPE) To Be Used By Healthcare Workers during Management of Patients with Confirmed Ebola or Persons under Investigation (PUIs) for Ebola who are Clinically Unstable or Have Bleeding, Vomiting, or Diarrhea in U.S. Hospitals, Including Procedures for Donning and Doffing PPE.

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

Luxury Vinyl Tile Changes the Path of Tile Industry

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Dawn of a "New Tile"...

A new era begins in the floor tile industry with LVT (Luxury Vinyl Tile) flooring. This tile is made using Limestone and Polyvinyl Chloride as key raw materials. As an eco-friendly product, these tiles are 100% recyclable, making it an ideal, sustainable product for the environment conscious consumer. LVT is made in full compliance with international REACH and ROSH regulations. The product range is offered in two thickness ranges (2 mm & 3 mm), while offering the consumer a wide array of design choices to choose from. Whilst offering a superior value proposition, the tiles are priced at an attractive range, highlighting their excellent value-for-money prospects.

Figure 1: Product Range

What is LVT

LVT (Luxury Vinyl Tile) is the latest development and most eco-friendly product in the tile industry. That is widely used in European countries. LVT floor appears as real wood / stone and has a wide range of designs embossed. It is manufactured in several shapes of planks and tiles. Though LVT is still a relatively new product, it has been gaining notable market share in many Asian and European countries.

Construction Of LVT

LVT is commonly made from multiple layers of PVC vinyl and other protective coatings.

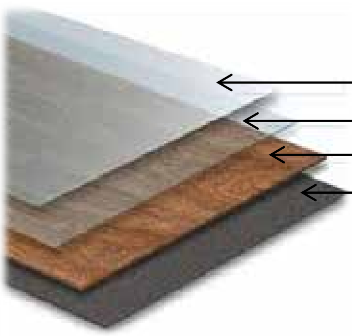

Figure 2: Layers of LVT

These layers have special properties for improve the product quality.

UV Curing Layer

This is the topmost layer of the LVT. It acts as a protecting coat to minimize wear of the product. Matte/ Gloss finishing availability, scratch resistance, low volatility and anti-slip properties are other key benefits from this layer.

Wear Layer

The Wear Layer is simply an extra layer of protection placed between the printed design of the vinyl plank or tile flooring material and the UV Curing Layer at the top. This is the layer that is subject to wear when the tile is being used. 20 – 28 mil ratings are typically suited for higher foot traffic and commercial areas. The UV Curing Layer is applied on this Wear Layer.

Design Layer

The Design Layer is the printed decorative film that allows the LVT to look luxurious! With several years of technological advancements and R&D breakthroughs, LVT tiles are made to be ever more realistic, thanks to enhanced technologies in printing and embossing.

Bottom Layer

This is the fundamental layer of the product. This layer is made up of harder materials as this is the part which maintains the structural stability of the LVT. Glue is applied to bottom of the layer for adhesion purposes. Furthermore, the bottom layer features a diamond pattern to increase the surface area for better bonding with the installed floor, also for ease of laying. The product thickness is dependent on the thickness of this layer.

Benefits of LVT

- 100% Recyclable
- Eco-friendly
- Cost efficient
- Waterproof
- Durable
- Softer than tiles
- Provides warmth than tiles
- Wide range of designs
- Easy to clean
- Easy to lay

- Rich look – LVT, by popular demand, is mostly available in natural wood and stone designs. The designs are endless and there is as large variety of vivid, photo realistic natural timber textures to choose from. LVT designs carry a sharper finish and a richer look compared to a porcelain tile with a similar print on it. The aesthetic appeal is what makes LVT top choice for homes, offices and commercial premises.

- Affordable Luxury – The Vinyl plank costs less than the porcelain ceramic tile of similar standards and dimensions. The installation costs are significantly less as most of the vinyl tiles can be glued down or interlocked, making the installation fast and easy in addition to being cost effective.

- Durability – While both LVT and floor tiles are durable, what makes LVT stand out is the fact that it doesn't break when heavy objects fall on it. LVT doesn't chip, break or form cracks, unlike the porcelain tile. The thick Wear Layer (usually 0.50 mm and above) as well as UV Curing Layer will ensure that the wearing of the product occurs at a very low rate. The icing on the cake when it comes to LVT is that, even scratch marks are almost non visible.

- Hygiene – LVT floors do not have grout lines, unlike porcelain tiled floors. Grout lines are where dirt accumulates and bacteria / fungus start to grow. Due to machine cut, high precision LVT tiles, the tight-fitting LVT floor overcomes this issue and stands out as the most hygienic solution. It's one of the main reasons most hospitals and healthcare facilities mandate the usage of Vinyl flooring. In most hospitals, sheet Vinyl is used with seam welding to ensure that there are no joints present. In addition to this plethora of benefits, Vinyl flooring is waterproof as well. The floor could be mopped any number of times per day and spills could be cleaned rapidly. In contract, Porcelain tiles are generally not waterproof and have varying degrees of porosity. They are also not stain proof unlike the vinyl counterpart due to this reason.

- Comfort – LVT is a very comfortable solution, as it is not as hard as the Porcelain tile. Due to this reason, LVT floors have the ability to mute footstep noise when walking over, unlike the Porcelain floors. There is also the comfort of knowing that Vinyl has less environmental impact. LVT flooring products could be completely recycled into new Vinyl floor products. In contrast, end-of-life Porcelain flooring products end up in landfills most of the time.

Our Product specification (LVT)

Characteristics	Standards	Specification	
Total Thickness	EN ISO 24346	2.00 mm	3.00 mm
Wear Layer Thickness	EN ISO 24340	0.50 mm	0.50 mm
Dimension of Plank	EN ISO 24342	6" x 36" | 152.4mm X 914.4mm	6" x 36" | 152.4mm X 914.4mm
Weight of Plank	g/sq.ft	300	450
Gloss Value (Matt)	ISO 2813:2014	5	5
Dimensional Stability	ASTM F2199	Pass	Pass
Pass Hardness Shore D	ISO 7619:2010	>55	>55
Abrasion Resistance	EN 660-2	Group T	Group T
Resistance to Chemicals	EN ISO 26987	1	1
Reaction to Fire	EN ISO 11925-2	Class Bf1-s1	Class Bf1-s1
Castor Chair Test	ISO 4918	OK	OK
Thermal Conductivity	EN ISO 10456	0.25 W/(m.K)	0.25 W/(m.K)

Table 1: Product Specification

Trending of LVT

LVT could be laid on any surface. It is installed on to the floor by the use of a special adhesive. Glue must be applied on the top of the surface and back side of the LVT and leave for 20 minutes to dry. Then it is installed on to the floor by pressing on the surface. A special advantage of LVT is that it can be laid on ceramic tiles directly. This product could also be used for Bathrooms as LVT product is waterproof.

LVT is a great choice for Office Rooms, Restaurants, hotels, Bed Rooms, Kitchen etc… Being a chemical resistant product, LVT does not degrade / fade upon getting into contact with oils and detergents.

Figure 3: LVT in Marble Tile

Figure 4: Mix LVT

Figure 5 : LVT forBath Room

Figure 6: Wall Decorate With LVT

Figure 7: Kitchen with LVT

Research and Development side of the LVT

This product is produced as per international ROSH and REACH regulations in order to acquire export access to Europe countries. In REACH regulation, it restricts nominated chemicals that is hazardous to human health therefore, we implement strict monitoring of our raw material selection / usage.

There are several properties we constantly monitor while manufacturing LVT.

- Dimensional stability

  As a product that could be used in different environments, it never subjected to shrinking or expand with the variations of temperature.

- Deformation

  Deformation can be long term and short term. LVT have ability for recover from a certain degree of deformation after the deforming force is released from the product.

- Bonding strength

  Bonding between LVT layers is a critical factor. We use several techniques to increase the bond between layers. We have pioneered our production process to ensure that these is no layer separation after the manufacturing is completed.

  LVT could be installed on a floor in any condition (wet environment, dry environment, smooth surface and rough surface) because of the excellent bonding properties of the glue.

- Thickness

  Punch resistant, Dimensional stability, wear resistant can be increase with the thickness. The thickness will vary with the area of LVT laying. If the area has higher foot traffic it is better to lay high thickness LVT. We have skilled technicians who are well capable of inspecting the customer's floor and offer customized, specialist advice as per your requirement.

- Chemical resistant

  LVT is a chemical resistant product. Detergents, soap, lime, vinegar, grease and oil are the some of chemicals that we use frequently. LVT has the special ability to be non-reactive with these substances, and as a result, is not subject to fading or degradation.

Recyclable product

Figure 84: Recycle Logo

LVT is a 100% recyclable product. Any type of PVC scrap material could be utilized to manufacture LVT. With Global Vinyl's scrap recycling capabilities, the process waste that is generated from the manufacture of LVT and other PVC scrap shall be recycled in-house. We are delighted to declare that Global Vinyl is an environment friendly PVC base product manufacturer in Sri Lanka.

About Global Vinyl:

Global Vinyl (PVT) LTD has 30 years of proud history as the leading manufacturer of Vinyl flooring and synthetic leather in Sri Lanka. The company manufactures a wide variety of products such as Tarpaulin, roofing felt, Homogeneous vinyl flooring, Synthetic leather and car matting.

Figure 9: LVT

Figure 10: Tarpaulin

Figure 11: Homogenous vinyl flooring

Figure 12: Car matting

Figure 13: Synthetic leather


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Requirement of Environmental Friendly Plant Protection approaches for a Sustainable Rubber Plantation Industry in Sri Lanka

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Introduction

Natural Rubber is very significant in our economy. It makes export earning, provides livelihood for thousands of people, supplements thousands of hectares to the forest cover and provides many socio-economical and ecological benefits. In terms of ecological benefits, rubber plantations contribute thousands of hectares as a forest crop that ultimately results in environmental sustainability. Furthermore the cultivation is being expanded in to nontraditional areas and therefore future expectations are much more.

Over the next two decades, the increase in crop production will be essential to meet the rising needs of the world. Measures should be adopted without causing much harm to the environment. The government of Sri Lanka is encouraging towards a green agriculture and therefore needs to identify alternative methods to manage harmful disease conditions of economically important agricultural crops. Hence plant protection approaches should be developed to suit the future prospects making the processes more environmental friendly. Integrated pest management (IPM) is the ideal concept for sustainable disease management. For this chemical, biological, and agronomic controlling systems play equally important roles. For the development of IPM systems for rubber plantations, biopesticides play an important role.

Generally biopesticides are found in nature and are made of living things. Biopesticides make less risk to the environment than the chemical pesticides (Villasenor *et al*., 2012). Currently, biopesticides fulfill approx. 5% share of the global chemical pesticide market. The use of biopesticides is hindered mainly by the high cost, slow action and short supply. Their biodegradable nature and low toxicity levels make them important. They are also specific in action, causing less pest resistance issues. Use of biopesticides in sustainable agriculture provides social acceptability, sustainable economic productivity fascilitating environmental stewardship. At the same time, sudden changes in the protection products from chemical pesticides to biopesticides may have implications short-term or long-term. Intensive agricultural programmes that have been conducted for long periods have influenced the naturally inhabiting microbe populations especially in agricultural soils. Most of our agricultural soils are “sick” in nature due to the prevailing intensive agricultural practices. Hence the rehabilitation process should be undertaken slowly reducing the chemical usage and promoting the application of biological agents. In biological agricultural systems, the short-term benefits are always less but there are long-term benefits.

Biopesticides consists of naturally occurring organisms or compounds that suppress the growth of pests. They are classified into three main groups;

- Microbial biopesticides
- Biochemical biopesticides
- Plant incorporated protectants (PIPs)

Microbial biopestices

Micro-organisms such as bacteria, fungi, viruses and protozoa are generally used as biopesticides. They are more targeted in action. Some common microbial biopesticides are entamopathogenic fungi, *Beauveria bassiana* or *Trichoderma species*. These biopesticides are targeted for plant pathogenic bacteria, fungi, insects and weeds. One of the most widely used microbial biopesticide is the insect pathogenic bacteria - *Bacillus thuringiensis* (Bt). There are other entamopathogenic Baculoviruses and fungi. At least 170 different biopesticide products based on entomopathogenic fungi like *Beauveria bassiana* or *Metarhizium anisopliae* have been developed. Microbial biopesticides based on different *Trichoderma* spp. are active against *Rhizoctonia*, *Pythium*, *Fusarium*, *Rigidoporus* and other soil-borne pathogens while specific strains of *Bacillus subtilis*, *Pseudomonas fluorescens* and *Pseudomonas aureofaciens* are being used against a range of plant pathogens including damping-off and soft rots. Microbial antagonists, including yeasts, filamentous fungi and bacteria are also used as control agents of post-harvest diseases. On the other hand, plant pathogens are being used as microbial herbicides. Two products, 'Collego' (*Colletotrichum gloeosporioides*) and 'DeVine' (*Phytophthora palmivora*) are already used in the USA (Onilude & Seyi-Amole, 2018).

Biochemical biopesticides

Biochemical biopesticides include plant materials like essential oils, semiochemicals, plant growth promoting regulators, insect growth regulators. They tend to control pests without killing them. For example, they may repel pests, disturb their mating or growth of secondary metabolites or natural minerals. Plants produce a wide variety of secondary metabolites that prevent herbivores from feeding on them. Some have been identified to be used as biopesticides. The most widely used botanical compound is neem oil, an insecticidal chemical extracted from seeds of *Azadirachta indica.* A semiochemical is a chemical signal produced by one organism that causes a behavioural change in an individual of the same or a different species. The most widely used semiochemical for crop protection are insect sex pheromones, some of which can now be synthesized and are used for monitoring or pest control by mass trapping

Plant incorporated protectants (PIPs)

PIPs are transgenic plants. The genes are introduced into plants by genetic engineering so that they are capable in protecting themselves from pests.

Advantages of biopesticides

Biopesticides have a range of attractive properties that make them good components of disease controlling (Mitchell & Dix, 1975; Singh *et al*., 2012). Most are selective, produce little or no toxic residue, and development costs are significantly lower than those of conventional synthetic chemical pesticides. Biopesticides can be applied with spray equipment and many biopesticides are suitable for local scale production.

- Chances of developing resistance is less compared to the chemical pesticides since they show multiple modes of actions against targeted pests
- The environmental negative impacts like pesticide related pollutions, bioaccumulation of chemicals, biodiversity losses, insurgence of secondary pests and elimination of natural beneficial enemies are less with the use of biopesticides
- With the prohibitive restrictions towards the synthetic pesticides, biopesticides have become beneficial
- Low toxicity properties
- Slight negative impacts on non-target organisms or humans
- Biodegradable
- No postharvest contaminations
- Stability against abiotic stresses
- Compatibility in integrated pest management (IPM)

Limitations of Biopesticides

The disadvantages of biopesticides include a slower rate of controlling compared with the conventional chemical pesticides, shorter persistence in the environment and susceptibility to unfavourable environmental conditions. Because most of the biopesticides are not as effective as conventional chemical pesticides and also they are not suited for use as stand-alone treatments.

- High cost
- Inability to meet market demand
- High specificity which may require an exact identification of the pest/pathogen and the use of multiple products to be used
- Susceptibility towards environmental factors
- Slow action
- Some biopesticides showing effects on beneficial organsisms
- Users need more knowledge to use biopesticides effectively.

Prospects of Biopesticides

IPM is a pest-control option, equivalent to an effective multi-faceted approach involving the combination of cultural, chemical and biological practices and other suitable control tactics into one management program to achieve a long-lasting reduction of pest population. The limitations are to be addressed through research breakthroughs in the coming years as research and developmental activities related to biopesticides have received more attention during the past.

Challenges and opportunities for Integrated Pest Management (IPM)

Integrated pest management tool is the most efficient disease controlling strategy in the world.

The chemical controlling methods are very popular among the growers and the other agronomic practices and physical methods are too familiar among the growers. Use of biopesticides in the management of diseases have been restricted only to laboratory or protected house conditions in many countries. Improvement of productivity levels is of importance for the sustainability of the agriculture and one way to increase is to effective management of pests. There are around 67,000 different crop pest species in the world and it has been estimated that together they cause about 40% reduction in the world's crop yields, even though improved plant varieties, plant protection, plant nutrition, and other stimulants have increased the yields by nearly 70%. The use of synthetic pesticides has increased significantly during the recent past owing to, injudicious use of broad spectrum pesticides affecting human and environment health, prophylactic use of pesticides excessively poses the development of heritable resistance

There is an urgent requirement for alternative methods for the sustainability of crop protection. Hence IPM is promoted as the best way forward as different crop protection practices are combined with careful monitoring. Therefore the shortcomings of individual methods are reduced. The overall aim would be to not to eradicate pest problems but managing them below levels that cause economic damage. Some of the approaches are given below;

- Use of synthetic chemical pesticides
- Use of resistant cultivars
- Crop practices such as crop rotation , intercropping
- Physical methods
- Natural products like plant extracts
- Biological control measures

Economically important diseases of rubber plantations

Today, the rubber tree is susceptible to many foliar diseases. Powdery mildew, Colletotrichum leaf disease, Corynespora leaf fall disease and Phytophthora leaf disease are the economically important diseases. A new leaf fall disease is also spreading in many rubber growing countries posing a threat to the rubber plantation industry. Most of the rubber clones show resistance towards the stem and panel diseases and hence currently they do not play an economic factor for the industry. Three root diseases such as white, brown and black root diseases play a major role in the rubber plantations. White root disease is more prevalent in the wet rubber growing areas and shows a rapid spread resulting poor tree stand leading to reduced yield levels in rubber plantations. This pathogen shows a wide host range as well fascilitating the spread in agricultural lands (Fernando and Madushani, 2013). Brown root disease is found more in non-traditional rubber growing areas of the country since the disease is associated with forestry crops. Black root disease is present in the district of Kegalle and incidence is very rare. In spite of the fact that the correct land clearing techniques play a main role in the prevention of the root diseases, chemical controlling methods are very popular among the growers. As a result of extensive research programmes, the use of chemicals against diseases has been reduced to a minimum. Growers are requested to adopt integrated disease management systems as much as possible. Disease resistant clones have been introduced for almost all the economically-important leaf diseases as the most long-term and effective strategy in managing diseases.

Table :- 1 Economically important diseases of rubber plantations and their causative agents

Plant Part	Disease	Causative agent
LEAF DISEASES	Powdery mildew	*Oidium heveae*
	Colletotichum leaf disease	*Colletotichum* spp.
	Corynespora leaf fall disease	*Corynespora cassiicola*
	Phytopthora Leaf Fall disease	*Phytophthoro* spp.
STEM DISEASES	Phytopthora bark rot	*Phytophthoro* spp.
	Ustulina stem rot	*Ustulina deusta*
	Pink disease	*Corticium salmonicolar*
ROOT DISEASES	White root disease	*Rigidoporus microporus*
	Brown root disease	*Phellinus noxius*
	Black root disease	*Xylaria thwatsii*
	Patch canker disease	*Pythium spp. & Fusarium spp.*

Recent developments to introduce native biopesticides

Antagonistic fungi isolated from rubber growing soils showed effectiveness in biological controlling the most destructive root disease in Sri Lankan rubber plantations, white root disease caused by the fungus of *Rigidoporus microporus*, the causative agent of the white root disease (Jayasuriya and Thennakoon, 2007; Kaewchai & Soytong, 2010). Among the twenty three antagonistic fungi isolated for biological controlling the pathogen, three fungal species were identified as most effective. *Trichoderma* spp. was proven to effective in controlling the pathogenic fungus and mode of actions have also been identified. The diffusible metabolites and fungal cell wall degrading enzymes, volatile metabolites also contributed to control the pathogen. Increase of available phosphorus level is an additional benefit that can be gained by these antagonistic fungi to overcome the phosphorus deficiency in the soil. Combinations of these isolates may increase the effectiveness. Indole Acetic Acid is an important phytohormone which has significant impacts to stimulate and facilitate plant growth. The selected fungi show the production of IAA also.

According to the results from the trials, the highest effectiveness was recorded by two native fungi; *Trichoderma koningi* and *H. lixii* (teleomorph of *Trichoderma harzianum*). *Trichoderma* isolates form symbioses with plant parts especially the roots, playing an important role in plant growth, yield, nutrient cycling and energy conversion in soil (Halifu *et al.*, 2019). Moreover, several mechanisms of *Trichoderma* include root colonization, solubilization of the minerals, increasing the availability of insoluble nutrients and therefore plant nutrient uptake, secretion of plant growth regulatory materials, vitamins and enzymes. The two biopesticides after conducting the trials to show the effectiveness have been forwarded to the Registrar of Pesticides for registration. The use will reduce the chemical pesticide usage in the country.

References

Villasenor N.C., Arreguint J.A.S. & Estrella A.H.H. (2012). *Trichoderma*: sensing the environment for survival and dispersal. Microbiology Research 158: 3–16.

Jayasuriya K.E. & Thennakon B.I. (2007). Biological control of *Rigidoporus microporus*, The cause of white root disease in rubber. Ceylon Journal of Biological Science 36(1): 9-16.

Kaewchai S.& Soytong K. (2010). Application of biofungicides against *Rigidoporus microporus* causing white root disease of rubber trees. Journal of Agricultural Technology 6(2): 349-363.

Mitchell C.P. & Dix N.J. (1975). Growth and germination of *Trichoderma* spp. under the influence of soil fungistasis. Transactions of the British Mycological Society 64(2): 235-241.

Singh A., Shahid M., Pandey N.K., Sharwan K., Mukesh S. & Biswas S.K. (2012). Influence of temperature, pH and media for growth and sporulation of *Trichoderma atroviride* and its shelf life study in different carrier based formulation. Journal of Plant Disease Sciences 6(1): 32-34.

Onilude A.A. & Seyi-Amole D.O. (2018). Mycelia Growth and Spore Yield of *Trichoderma harzianum* in Batch and Fed-Batch Cultures: Influence of pH and Temperature. International Journal of Current Microbiology and Applied Sciences 7(4): 627-635.

Computer aided rubber compound formulation using design of experiments

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Abstract:

The article explains how the technique of design of experiments (DOE) can be used to formulate rubber compounds with the aid of commercial software. Some background information in theory followed by advantages of the factorial method over conventional methods that are practised in the industry are discussed. Then an example of a two-level factorial study related to rubber compounding is explained. Finally the best combination of the ingredients in the formulation for a set of desired properties are determined using an optimization method available in the software.

Introduction

In the rubber industry the products are made by using different elastomers, compounding chemicals and processing methods. In the rubber product manufacture it involves an accurate combination of all of these factors. These are generally practised in the rubber industry using trial and error methods or with the knowledge from previous experience. Sometimes traditional scientific method which dictates changing one factor at a time (OFAT) is also used. Most of the time these techniques can take many man hours to produce a product. Unfortunately, at the end very little is learned about how these factors (ingredients and processing conditions) related to a selected response (property) of the manufactured item which is important in product development. These drawbacks can be overcome through taking a systematic design of experiments[1,2] multifactor approach.

Design of experiments is an established and proven technique for product and process development in all sectors of the industry[3]. Design of experiment is an invaluable method to identify critical parameters in optimization of chemical processes and identify robust operational regions for processors. It will have the advantage of getting the product's knowledge early in the development cycle and reduce the time to market the product.

Using design of Experiments protocol[3] product and process development are done by making a series of controlled intervention according to a specified plan. A well designed experiment will use the smallest number of experimental runs to get the maximum amount of information. These experiments should be able to clearly separate the effective parameters from the noise (experimental error) of the system. This way it is possible to screen out the important few parameters from the trivial many.

The experimental design process involves three stages i.e. planning, implementation and analysis. Planning involves some knowledge on the system that is being investigated when it comes to the selection of factors and responses. This means for such action can only be done by persons with previous experience related to the similar systems. Implementation involves carrying out experiments by changing factors in a systematic fashion and minimising the effects of uncontrollable factors (noise). The changes in the factors should cover the entire design space. Once the experiments are carried

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out, mathematical modelling is used to find the relation between the input factors and the response for further analysis.

Planning of experiments

The first step in any experiment is to have a clear objective. The objectives should be translated into precise questions that the experiments can answer. It is important to find the factors that will affect the performance of the final product. As a general rule is to include in the design any borderline factors, since to eliminate them early in the process is much cheaper than to identify and introduce them further down the line.

Implementation

Next is to identify the factors and response and check the levels of the factors that give the best response. If the responses are linear the factor levels can be two. If there are nonlinear factors more than two levels are selected.

Scientific learning is iterative, the results from each stage of investigation generate questions to be answered during the next stage. It may even turn out a different factor, not initially suspected of being important, will dominate future investigations. Therefore never spend more than 25% of your experimental resources on the initial experiments[2].

Mathematical modelling of factors- response relation

The relation between the recipe ingredients and process conditions on selected properties of a product can be investigated using mathematical modelling methods. The aim of mathematical modelling is to derive a function or a formula that closely reproduces the behaviour of the system under investigation. This mathematical function when presented with input values, it predicts the output values of a property close to what is observed experimentally. Modern day software that is used for such applications also has the ability to visualise such data in graphical form when subject to various analyses. One of the graphical outputs is the response surface[4] which is a surface that is generated in a 3D coordinate space using values of a property that are calculated by varying the values of two factors (ingredients or process conditions). Use of such visual aid enhances the identification of critical ingredients and process conditions. Through this method it will be possible to design products with optimum performance efficiently.

Statistical[5], neural network[6] and multiple linear iterative[3] are three mathematical modelling techniques that are used in the above mentioned investigations. All give very promising results but each has its own advantages. In statistical methods the data points (factor levels) in the design space are selected using theory to minimise experimental errors. Thereafter with experimental results a mathematical model is built using regression techniques. In neural network methods the model building is data driven. Therefore more and more data is needed to build an accurate model. However, this method can detect very complex interactions of the factors (ingredients or process conditions) to a selected property. Neural network methods also have the capability of optimising a higher number of factors more effectively compared to statistical methods. One of the advantages of this method over statistical methods is that it can use data that is already available in a manufacturing environment. This becomes very handy for rubber companies since they have thousands of formulas with evaluated properties in their databases. Both statistical and neural network modelling can produce recipes after optimization of selected desired properties. Mathematical modelling based on multiple linear iteration techniques has been recently implemented[7] and it is getting popular in the rubber industry for recipe development. This is similar to neural networks where historical data can be used to generate new recipes. In this paper application of statistical methods in design of experiment will be discussed.

Statistical method

Design of experiments using statistical methods generally follow two steps[8]. Initially a screening test is done on factors that are not sensitive to a selected response to eliminate them. This is done using a two level factorial method. The advantage of the screening process will reduce the number of experiments to generate the response surface by limiting the number of factors to a lower number. Once the sensitive factors are identified additional levels for the factors are introduced to generate response surfaces. The additional data points will help in mapping the curvature of the response surface accurately for optimization.

Design of experiments -Two level factorial

Two level factorial analysis based on F-test was developed by Sir Ronald Fisher, a geneticist[1]. He developed this theory to compare treatments that are used in agricultural experiments. F-test compares the variance among the treatment means versus the variance of individuals within specific treatments. High values of F-test indicates that one or more of the means differ from another. This is a valuable information to find factors that are sensitive to a selected property.

In design of experiments each factor value is changed and the response of a selected property is determined. In a set of experiments where the factors are varied between two levels can be done by two methods. One method is to change one factor at a time. Here only one factor is change while keeping all other factors at one level. This is called the OFAT (one factor at a time) method. Many people in industry are familiar with this technique. In the second method, factors are changed simultaneously. This is called factorial study. If the change is between two levels it is called a two-level factorial study. This method has an advantage over the OFAT method, where complete design space is covered during experimentation. Therefore factorial study is more effective than the traditional OFTA method. In OFAT replicate runs must be done to get the equivalent power as factorial study. The result for a two factor two level study is that to get the same equivalent power, OFAT required six runs versus only four for the two-level factorial design.

The advantage of factorial design becomes more pronounced as more factors are added. In a three factorial study, the factorial design requires only eight runs versus 16 for an OFAT experiment with equivalent power[9]. In both designs, the effect estimates are based on an average of four runs each: right to left, top to bottom and back to front design is now twice for OFAT for equivalent power. In this case the OFAT design covers twice as many data points compared to factorial design to gain the same power. The relative efficiency of the factorial method increases with every additional factor. The factorial design has another two advantages; it covers a broader volume of design space, and it reveals interaction between factors. Figure 1 shows a summary of the technique. When carrying out experiments, it is important to minimise the effect from uncontrolled factors by randomization. The only downside of this method is that the experimenter as mentioned earlier should have a basic understanding of the behaviour of the system i.e. to select the factors and corresponding response for the experimentation. This method becomes important in screening of factors in optimization of a set of properties. This is done by a response surface method which will be discussed subsequently.

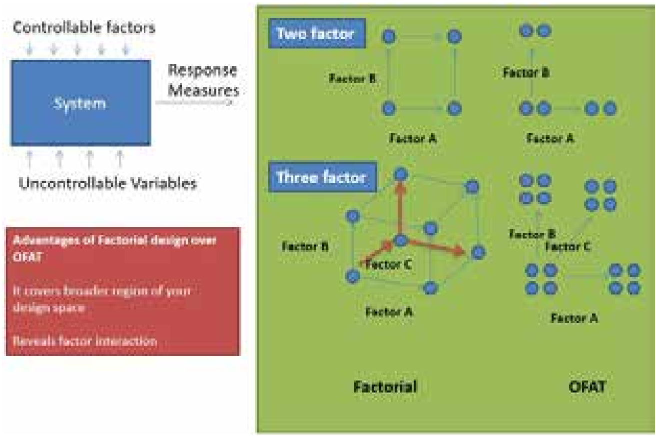

Figure 1 Two level factorial method. Number of experiments comparison between OFAT and two level factorial method[5]

Example of a two level factorial study

In this example a set of data obtained for rubber compounds[10] consist of five ingredients were investigated. The five ingredients are CBS (cyclohexyl benzothiozyl sulphenamide), thiuram disulfide, silica, naphthenic oil and sulphur. In these compounds silica, naphthenic oil and sulphur had been varied and CBS and thiuram disulfide had been kept at 1.2 and 0.6 phr respectively. The final vulcanised films had been tested for range of properties but only tensile strength and 300% modulus are used for the purpose of this example. Table 1 summarises the experimental changes. The overall object of this exercise is to identify factors that are sensitive to a selected property.

Table 1: Factor changes

Factor	Name	Units	Low level (-1)	High level (+1)
A	Sulphur	phr	2	3
B	Silica	phr	30	50
C	Naphthenic oil	phr	6	18

As mentioned previously, full factorial experiments are conducted using all combinations of factors at all levels. Since this is a two level factorial 2^3 experiments are carried out. The following Table 2 shows the results for experiments carried out. Standard order gives how the experiments are performed to minimise noise.

Table 2: Results from the experiment

Standard Order	Run	A: Sulphur (phr)	B: Silica (phr)	C: Naphthenic oil (phr)	Y1: Tensile Strength (MPa)	Y2: 300% Modulus (MPa)
2	1	3	30	6	9.41	2.44
6	2	3	30	18	8.13	1.64
8	3	3	50	18	13.68	1.73
1	4	2	30	6	14.14	2.84
5	5	2	30	18	11.48	1.23
3	6	2	50	6	14.8	2.38
7	7	2	50	18	14.41	1.22
4	8	3	50	6	17.13	2.7

In the first investigation let us analyse the factors that contribute to tensile strength. Using the results from the experiments full factorial main effects and interaction effects are arranged for each response. The following Table 3 gives all effects on Tensile Strength for each type of factor. Since a log transformation is used the tensile is converted to its log values.

Table 3 Effects for each type of factors

Standard	Main Effects			Interaction Effects				Response
	A	B	C	AB	AC	BC	ABC	Ln(Y1)
1	-	-	-	+	+	+	-	2.65
2	+	-	-	-	-	+	+	2.24
3	-	+	-	-	+	-	+	2.70
4	+	+	-	+	-	-	-	2.84
5	-	-	+	+	-	-	+	2.44
6	+	-	+	-	+	-	-	2.10
7	-	+	+	-	-	+	-	2.67
8	+	+	+	+	+	+	+	2.62
Effect	-0.165	0.348	0.152	0.212	-0.034	0.026	-0.065	2.54

Effects are calculated by averaging the values of the response for (+) and deducting the average values of the response for (-). Then the absolute values of the effects are arranged in an ascending order and plot them on an equally spaced cumulative half normal probability chart. If the effects are random then they will fall on a straight line passing through the origin. However, if the effects that are not random will fall outside the line as seen from Figure 2. Each factor or factor combinations that falls outside the line will contribute to the response compared to the others. Therefore to build a mathematical model for this response only these factors are selected. Sometimes depending on the data that is subject to analysis, it will be necessary to use mathematical transformation for better interpretation[2,5,11]. In the present case as mentioned previously a logarithmic transformation is taken.

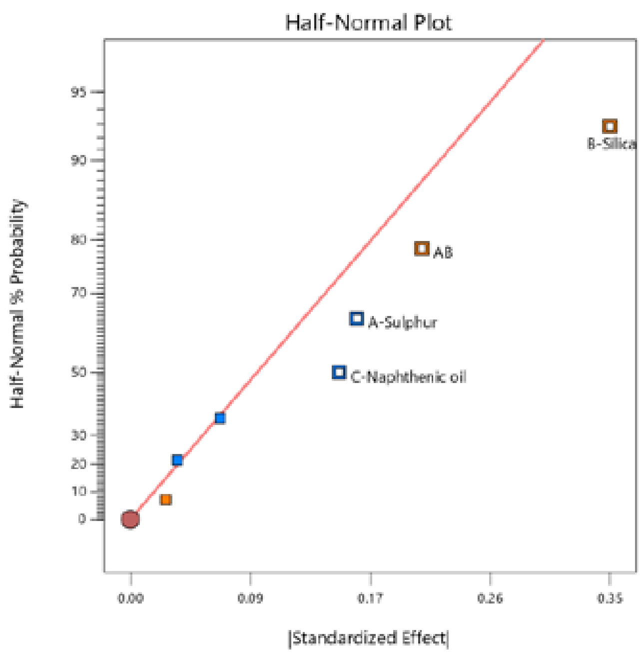

Figure 2. Half normal plot for effects for Tensile Strength

From the half normal plot it can be seen that there are three points that fall on the straight line while A, B, C and AB that fall outside. The effects that fall on the straight line are called trivial effects and they will be used as residual effects in the analysis of variance (ANOVA).

Similarly the same procedure can be done for response 300% modulus. The half normal plot for 300% modulus is shown in Figure 3.

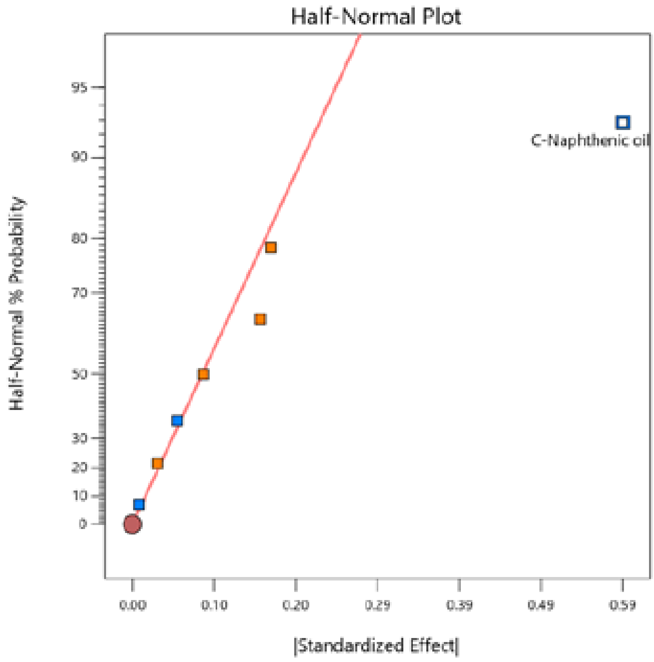

Figure 3. Half normal plot for 300% modulus.

From the plot for 300% modulus only Factor C (naphthenic oil) contributes. It can be seen that from the two analysis each response is sensitive to different factors.

Factor Interaction plot

One of the advantages in factorial design is the factor interaction. It can be seen from Figure 2 the effect AB is significant which indicates an interaction between sulphur (A) and silica (B). Table 4 summarises the data for interaction of sulphur (A) and silica [2](B) when naphthenic oil content at 12 phr.

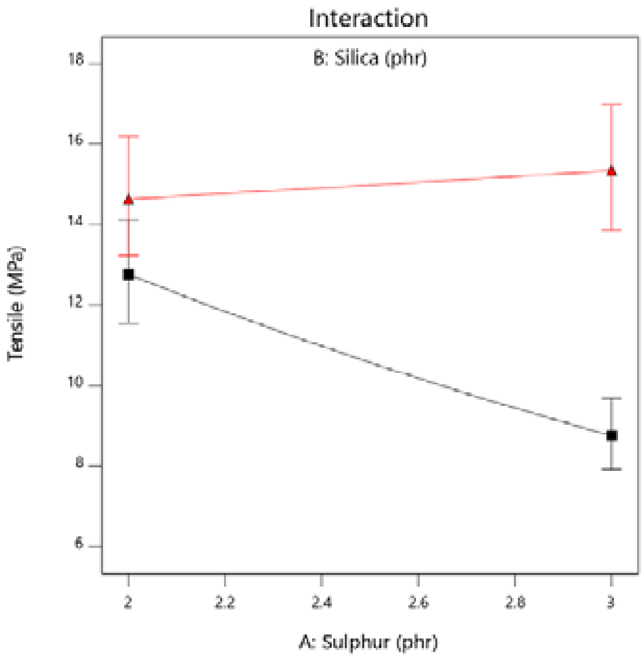

Figure 4. Factor interaction for Tensile Strength

The interaction plot (Figure 4) indicates that with increasing sulphur the tensile strength is reduced at a lower silica loading (black). This can be considered a breakthrough. Similar effects are claimed in literature[12]. This information can be only obtained by considering simultaneous changes to the factors during experimentation. OFAT does not give such information.

Analysis of Variance (ANOVA)

Calculating the analysis of variance (ANOVA) for tensile strenght using two level factorial is shown in Table 5. The sums of squares is calculated[5] as follows:

$SS = N/4 * Effects^2$

Where N is the number of runs, in this experiment it is 8.

$SS_{Model} = SS_A + SS_B + SS_C + SS_{AB}$

$SS_{Residual} = SS_{AC} + SS_{BC} + SS_{ABC}$

Corected Total $= SS_A + SS_B + SS_C + SS_{AB} + SS_{Residual}$ (the total sum of sqares (SS) corrected for the meen)

Table 4. Summary of factor interactions for tensile strength.

Standard	Sulphur(A)	Silica (B)	Tensile Strength MPa (Y,Avg.)
1	-	-	12.77
3	-	+	14.63
5	+	-	8.72
7	+	+	15.34

Table 5. ANOVA for Tensile Strength

Source	Sum of Squares (SS)	Df	Mean Square (MS)	F Value	Prob > F
Model	0.4320	4	0.1080	26.75	0.0111
A-Sulphur	0.0541	1	0.0541	13.41	0.0352
B-Silica	0.2423	1	0.2423	60.02	0.0045
C-Naphthenic oil	0.0459	1	0.0459	11.38	0.0433
AB	0.0896	1	0.0896	22.18	0.0181
Residual	0.0121	3	0.0040	-	-
Corrected Total	0.4441	7	-	-	-

The F-Value is calculated as the mean squares of the factor against the mean squares of the residuals. For the model (MS Model/MS Residual)[5] F-Value is 26.75. Once the F-Values are calculated for appropriate factors it is checked from the F-Value table of 95% confidence. When looking at the values in the table the Df (degrees of freedom) of the numerator (top) is taken as the column and the Df of the denominator (bottom) is taken as the row. If the value in the table is less than the value calculated then the effect for that factor is significant. Using this method it is possible to confirm the selected factors are correct. The procedure is clearly shown in Design Expert software[13]. Once the factors for the model is selected a mathematical relation can be built using regression method for a selected response.

For the tensile strength analysis mathematical relation will be as follows:

Ln (tensile) = 4.5136-1.01101A-0.035501B-0.012639C + 0.021162AB

From this equation predicted values for Tensile Strength response can be calculated. Since a log transformation is used, the tensile is calculated as Ln (Tensile). Table 6 summarised the calculated values. Since we used the log transformation the residuals form the model are calculated by taking the difference between the log values of the actual and predicted values.

Table 6. Prediction Vs actual values for tensile strength

	A	B	C	AB	TS actual MPa	TS predict MPa	Resid Ln(Pred.)-Ln(Act.)
1	-	-	-	+	14.14	13.75	-0.028
2	+	-	-	-	9.41	9.44	0.003
3	-	+	-	-	14.8	15.75	0.062
4	+	+	-	+	17.13	16.52	-0.036
5	-	-	+	+	11.48	11.81	0.028
6	+	-	+	-	8.13	8.11	-0.002
7	-	+	+	-	14.41	13.54	-0.062
8	+	+	+	+	13.68	14.19	0.037

Figure 5 shows the half normal plot for the residual.

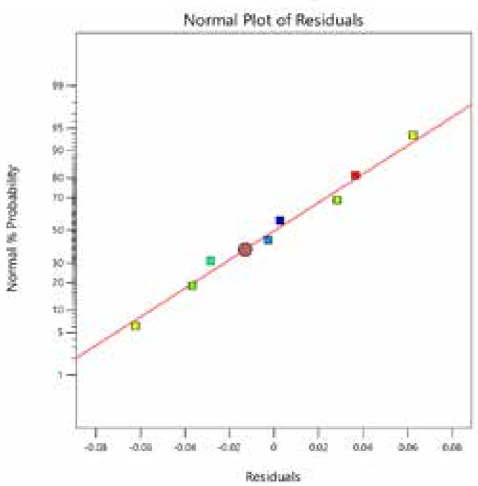

Figure 5. Half normal plot for Tensile strength residuals

From the Figure 5 it can be seen that the residuals fall along a line in a half normal plot which means the residues are normally distributed. This further confirms the analysis is acceptable.

Fractional Factorial

In our previous investigation only three factors were used. However, in most of the investigations it will be necessary to use more than 3 factors. In two level full factorials the number of experiments will be given by the formula 2^k where k is the number of factors that are under investigation. It can be seen that beyond four factors the number of experiments for full factorial run becomes not practical. To overcome this problem statisticians have come out with a method called fractional factorial where fewer number of experiments are conducted for the analysis. Fractional factorial consists of a set of carefully chosen experimental runs from a full factorial. The set of experimental runs are selected so as to exploit the most important factors of the problem under the study with a fraction of an effort of full factorial in terms of experiments and resources. Due to the fewer number of experiments in fractional factorial design it estimates the main effects and the two factor interactions only, but not the three factor or higher order interactions[2]. The following Table 6 shows the number of experiments that are necessary for these runs[5]. Fractional factorial is mainly used in screening of factors when investigating a situation where there are higher number of selected factors. With this method it is possible to select a vital few from trivial many factors.

Table 6. Fractional factorial experiments[5]

Factors	Main effects and Two factor interactions	Full factorial	Fraction for Screening	Savings
4	10	16	12	25%
5	15	32	16	50%
6	21	64	32	50%
7	28	128	32	75%

Since the problem is investigated with a smaller number of experiments, fractional factorial has to be handled carefully. Details of the analysis for fractional factorial can be found in statistical references[1,5].

Response surface methodology

In the previous section two level factorial methods were explained to select factors that will be sensitive to a selected response (property) of a product. Once these factors are selected it will be necessary to find the best combination of the factors to give the optimum response. However, this cannot be done with existing information since the information obtained from two level factorials give mainly linear relationship between factors to a selected response. Therefore it is necessary to use more data points in the design space to find the curvature of the surface. There are many methods[14] to obtain these additional data points. All these methods will lead to map the curvature of the surface to find the optimum value. The flow chart[15] to the procedure is shown in Figure 6. In this additional data points to the two level data are done by using a central composite design space. This includes data point at the centre point plus additional points away from the centre. Central composite design space for a three factorial experiment is shown as in Figure 7.

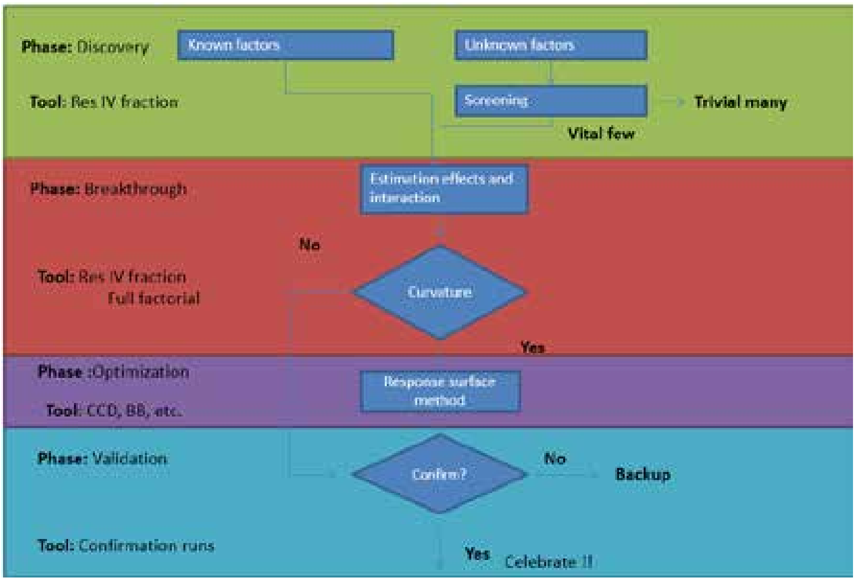

Figure 6. Flow diagram for response surface analysis

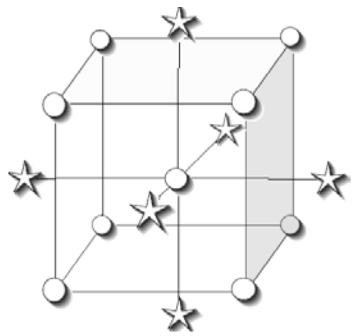

Figure 7. Three factor central composite design.

Using the additional data points experiments are conducted for a selected response. Then sensitive factors and factor combinations for a selected response are determined as before using F-test. Using these factors and factor combinations a mathematical equation is derived to generate the response surface. These equations can be linear, two factor interaction (2FI) or quadratic. Similarly the best relation is found for all other responses. Then optimization can be done for a desirable combination of responses (properties) to find the corresponding all factors (ingredients). Since these operations need many mathematical procedures, computational methods are used.

Response surface for each property is developed using additional data points to what were used in the factorial study. Table 7 shows the design space that was generated with Design Expert software for the set of experiments to determine the response surface. It can be seen in Table 7 that there are experiments that are replicated to determine the pure errors to include in the calculation.

Table 8 shows the set of properties that were obtained for the rubber compounds with different combinations of factor input as in Table7.

Table 7 Design space of the experiments conducted

Experiments	Sulphur phr	Silica phr	Naphane oil phr
1	2	30	18
2	2.5	40	12
3	2	30	6
4	3	50	6
5	3.34	40	12
6	2.5	40	12
7	2.5	40	22.09
8	2.5	40	12
9	3	50	18
10	2.5	40	12
11	2.5	40	1.91
12	2	50	6
13	2.5	56.82	12
14	1.66	40	12
15	2.5	23.18	12
16	2.5	40	12
17	3	30	18
18	3	30	6
19	2.5	40	12
20	2	50	18

Table 8 Data on difference properties for the experiments in Table 7

Experiments	Cure_ Time min.	Mooney Scorch min.	300% Modulus MPa	Tensile MPa	Elongation %	Hardness IRHD	Die_ tear kN/m
1	16.35	32.72	1.23	11.48	740.2	45.97	17.11
2	21.34	33.57	1.65	14.48	721.2	53.57	29.35
3	16.66	31.83	2.84	14.14	624.61	51.03	24.35
4	24.22	37.14	2.70	17.13	753.17	67.23	39.88
5	23.5	40.52	1.66	14.57	830.9	51.19	25.22
6	20.4	34.54	2.00	14.48	728.84	53.02	31.36
7	26.78	32.03	1.26	9.77	811.12	49.63	20.18
8	20.62	33.44	1.70	14.50	739.16	52.72	31.62
9	33.48	35.67	1.73	13.68	847.07	54.15	39.68
10	19.9	34.93	1.73	14.34	723.3	52.93	29.72
11	21.49	36.00	3.55	14.78	610	55.32	28.30
12	23.58	23.70	2.38	14.80	804.1	63.41	39.09
13	25.56	25.90	2.35	15.64	841.61	65.39	47.44
14	20.31	22.52	2.84	14.76	682.57	50.53	33.44
15	14.56	32.89	2.06	7.20	524.39	48.52	12.75
16	19.9	34.93	1.73	14.34	723.3	52.93	29.72
17	19.21	35.01	1.64	8.13	736.909	49.69	15.78

18	17.63	39.17	2.44	9.41	481.96	55.4	21.99
19	21.34	33.57	1.65	14.48	721.21	53.57	29.36
20	24.96	22.23	1.22	14.41	933.86	51.66	28.75

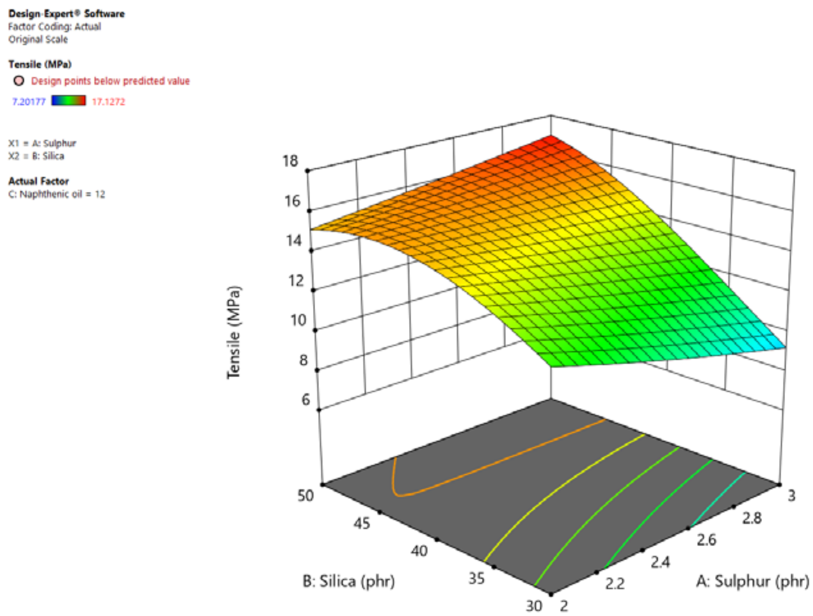

Figure 8. Response surface

Figure 8 shows the response surface for tensile strength with the changes to Silica and Sulphur. This gives a deeper understanding of the recipe.

An optimization for the recipe was done by selecting the properties with desirability i.e. cure_time - minimum, Mooney scorch - maximum, tensile - maximum, elongation - maximum, hardness - optimum, tear -maximum. The Figure 9 shows the amount of sulphur, silica and naphthenic oil for this condition. Figure 10 shows the contour plot of the optimization. Yellow region shows the area where it satisfies the desired properties. Since the study covers a wide design space it will be possible to make changes in a very short time frame to the product's properties, depending on market preference.

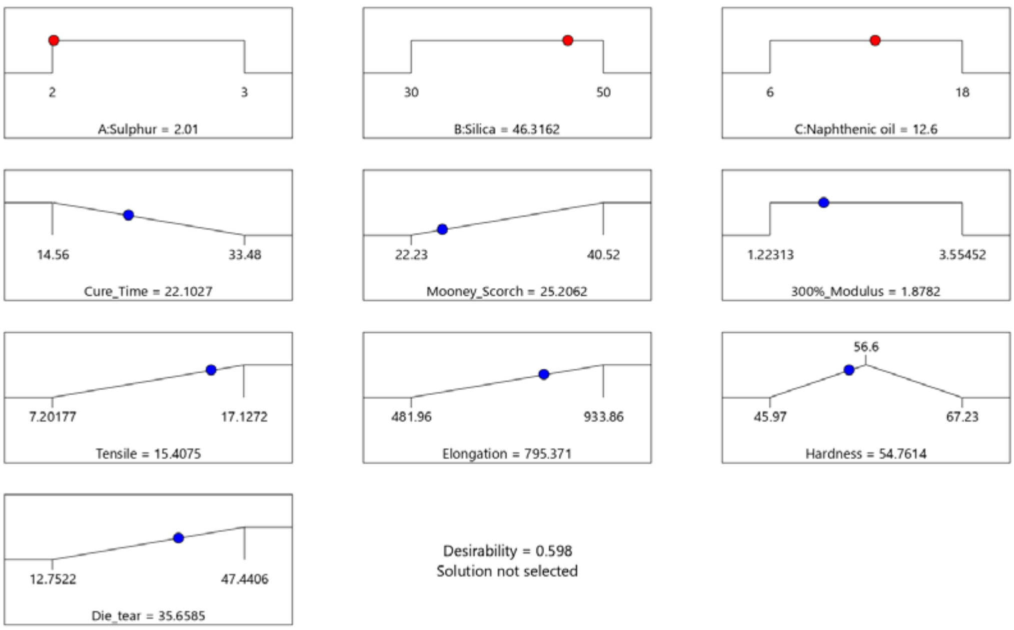

Figure 9 Design Expert optimization output.

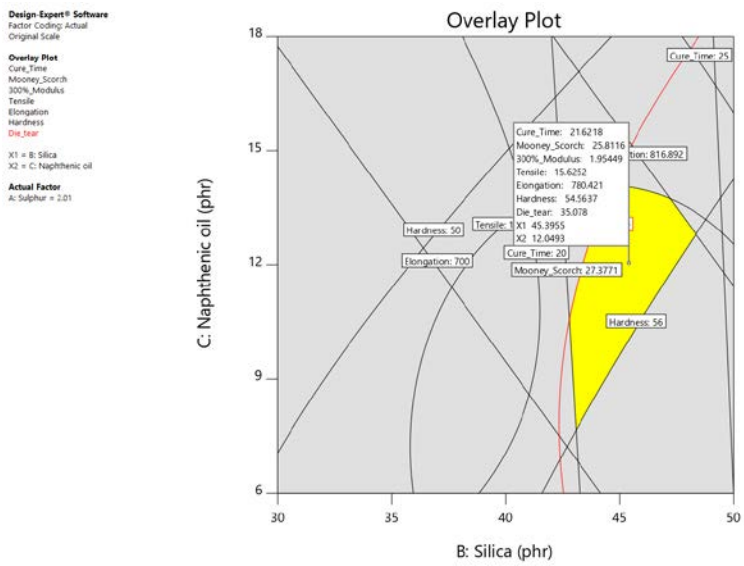

Figure 10 contour plot of the optimization.

In rubber compound recipe, ingredients are used as amounts per hundred parts of rubber. Therefore with such information it will be possible to carry out an analysis as discussed above. Mixture designs[2] are not generally used in this type of experiments because ingredients in a rubber compound recipe are not considered as proportions.

Although the above discussion was on a software based on statistical methods, software based on neural networks[6] and multiple linear iteration methods[7] can be used to predict new formulations. These methods will be an advantage for companies where there are lots of historical data available. These will be discussed in a separate paper.

Conclusion

Design of Experiments is an efficient method to use in development of rubber compounds in product manufacture. Using this method it will be possible to understand how each ingredient in the recipe affects the final properties of the vulcanised product. Using commercial software available today, it has become very effective to optimise a recipe to give the best performance in the final product. This technique will allow a chemist to arrive at a recipe much faster with desired properties. Therefore the time to market a product will be reduced dramatically.

References

(1) Montgomery, D. C. Design and Analysis of Experiments; Wiley, 2012.

(2) Tranter, R. L. Design and Analysis in Chemical Research; Sheffield Academic Press, 2000.

(3) ASTM-E1325−16; ASTM International: West Conshohocken, Pennsylvania 19428-2959, USA, 2016.

(4) Myers, R. H.; Montgomery, D. C.; Anderson-Cook, C. M. Response Surface Methodology: Process and Product Optimization Using Designed Experiments; Wiley, 2009.

(5) Anderson, M. J.; Whitcomb, P. J. DOE Simplified: Practical Tools for Effective Experimentation; Taylor & Francis, 2000.

(6) Roberts, R. J.; Rowe, R. Intelligent Software for Product Formulation; Taylor & Francis, 1998.

(7) Graf, H. J. In Rubber Fibre Plastic Int. ; Dr. Gupta Verlag: Germany, 2013; Vol. 08, p 2

(8) Weissman, S. A.; Anderson, N. G. Organic Process Research and Development 2015, 19, 1605.

(9) Ledolter, J.; Kardon, R. H. Investigative Ophthalmology & Visual Science 2020, 61.

(10) CAD/Chem; www.aiware.com: 1997.

(11) Lee, D. K. Korean J Anesthesiol 2020, 73, 503.

(12) Han, S.; Gu, B.; Kim, S.; Kim, S.; Mun, D.; Morita, K.; Kim, D.; Kim, W. Polymers 2020, 12, 2815.

(13) Design-Expert www.statease.com, 2013.

(14) Myers, R. H.; Montgomery, D. C.; Anderson-Cook, C. M. Response Surface Methodology: Process and Product Optimization Using Designed Experiments; Wiley, 2016.

(15) Anderson, M. J.; Whitcomb, P. J. RSM Simplified: Optimizing Processes Using Response Surface Methods for Design of Experiments; Taylor & Francis, 2005.

Industry 4.0 Adoption Challenges in The Manufacturing Organizations in Developing Nations

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Abstract

Industry 4.0, also refers to fourth Industrial revolution, is currently one of the upcoming trends in manufacturing sector organizations. Rapid technological developments defined previous industrial revolutions. Digitalization, the Internet of Things (IoT), and Cyber Physical Systems (CPS) have gained importance throughout industries as a result of technological advancement. The fourth industrial revolution (Industry 4.0) and its integrated technology dissemination progress, on the other hand, is predicted to evolve rapidly in terms of technical change and socioeconomic implications.

The challenges to implement Industry 4.0 technology in the Manufacturing sector in developing economies are discussed in this paper. Fourteen barriers were identified after a thorough literature review by over thirty-five research articles and the interactions with a panel of industry professionals who are subject matter experts.

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In developing nations, the lack of a digital skills, resource limitations combine to significant Investment requirement and security breach risk appears as the most significant challenge. Value chain integration and technological infrastructure are needed to support the adoption of Industry 4.0 technologies in developing countries, according to the influencing constraints identified.

The purpose of this study is to investigate how Industry 4.0 is being implemented in developing nations. The lack of integrated national policies on Industry 4.0 in emerging nations is causing issues in the diffusion of technological innovation, which may prevent organizations from fully experiencing the Industry 4.0 revolution.

The findings of this study may provide insight to decision-makers and practitioners in overcoming the obstacles and opening the path for a successful implementation of Industry 4.0 in the manufacturing sector Organizations in developing nations.

Keywords: Industry 4.0; Constraints; Barriers, Challenges, Manufacturing Organizations, Developing economy

1. Introduction

Industry 4.0, also refers to fourth Industrial revolution, is currently a blossoming topic in research studies. The preceding industrial revolutions were characterized by rapid technological advancements. However, in terms of technical change and socioeconomic consequence, the fourth industrial revolution (Industry 4.0) and its integrated technology dissemination progress is expected to develop dramatically (Rabeh Morrar, 2017).

The value chains in the manufacturing companies are complex. Digitalization, the Internet of Things (IoT), and Cyber Physical Systems (CPS) have gained importance throughout industries as a result of technological advancement. The Fourth Industrial Revolution (Industry 4.0), also known as a German high-tech plan for future manufacturing industries (Hofmann and Rüsch, 2017), is defined using these terms. The transformation of manufacturing processes in industries by Industry 4.0 has a stunning effect. In other words, with the support of Internet of Things (IoT) and Cyber Physical Systems, Industry 4.0 will play a vital role in transforming traditional firms into Smart Factories (CPS).

In Industry 4.0, a decentralized approach is critical, since it promotes independent management of processes and smart objects throughout the network, allowing real and virtual worlds to interact on activities (Ungurean and Gaitan, 2014). Complexity and agility are boosted by the development of integrated processes and human-machine interaction, as well as data transmission between value chains. Industries will increase operational efficiency in terms of time, cost, and production with the support of Industry 4.0. Building IoT infrastructure allows partners in supply chains to share platforms via cloud systems, allowing business processes to be streamlined (Lu, 2017).

There has been past scientific research on the challenges to Industry 4.0 technology adoption. This scientific discussion is still ongoing, and more research is required before a widespread consensus can be formed. Various research methodologies have been used to study this topic in various nations. As a result, the purpose of this study is to investigate the challenges to implementing Industry 4.0 technology in the manufacturing sector in developing nations.

The barriers studied in this article were identified through a comprehensive literature review and discussion with industry experts in manufacturing sector who have extensive experience in operations management and information technology.

This research article is organized as follows: Section 2 of this research paper discusses Industry 4.0 literature and the challenges to implementing Industry 4.0 technologies. The key findings are discussed in Section 3. A “Technology Acceptance Model (TAM)” in Section 4 and finally, the conclusions and suggestions for future research are outlined in Section 5.

2. Literature Review

This section provides a review of the available recent literature on Industry 4.0, followed by a discussion of the challenges to Industry 4.0 adoption in the manufacturing sector.

2.1. Industry 4.0

In 2011, the phrase "Industry 4.0" was introduced at the Hanover Fair. Following that, the German government designated it as a strategic effort to transform the manufacturing industry in 2013. (Xu et al., 2018). Industry 4.0 has recently gotten a lot of attention because of its multiple advantages for Organizations to be competitive (Dalenogare et al., 2018).

Industry 4.0 includes of several emerging concepts and new technologies, such as artificial intelligence (AI), machine learning (ML), radio-frequency identification (RFID), big data, cloud computing, smart sensors, robotics, additive manufacturing (AM), augmented reality and the Internet of Things (IoT) (Li, 2017; Schwab, 2017).

The concept of Industry 4.0 is defined by nine concepts presented by Boston Consulting Group is presented in figure 1(Rüßmann et al, 2015).

Figure 1: The nine technologies are transforming Industrial Production

Source: BCG

Several researchers (Lu, 2017; Xu et al., 2018; Hofmann and Rüsch 2017) recently conducted literature evaluations to explore potential research options in this field. In their paper, Hofmann and Rüsch (2017) analyze the advantages of Industry 4.0 in terms of logistics. They claim that management is having difficulty implementing Industry 4.0 since organizations may not see any immediate financial benefits.

In a similar manner, Barreto et al. (2017) analyzing the requirements that may help enterprises to be more efficient in implementing Industry 4.0 in the context of logistics. Haddud et al. (2017) and Ben-Daya et al. (2017) take Industry 4.0 beyond logistics and into supply chains. Haddud et al. (2017) focus on the potential benefits and challenges of integrating Industry 4.0 into supply chains, while Ben-Daya et al. (2017) discuss the role of the Internet of Things and its impact on supply chain management.

For Industry 4.0 to be implemented, numerous technologies must be integrated simultaneously across the supply chain. Fettermann et al. (2018) investigate the needs of several technologies, including radio frequency identification, sensors, cloud processing, and cyber-physical systems. Meanwhile, Li et al. (2017) analyze the supply chain's technology drivers of Industry 4.0.

Researchers have attempted to link two different growing concepts linked to operations management, such as lean manufacturing and Industry 4.0, and the circular economy and Industry 4.0, in a number of significant research. Mrugalska and Wyrwicka (2017) investigate how lean manufacturing and Industry 4.0 principles may coexist and complement one another.

Ivanov et al. (2018) investigate the link between big data analytics, additive manufacturing, advanced trace & tracking systems, Industry 4.0, and supply chain disruption threats, as well as how digitalization might help with ripple effect control. These impediments to Industry 4.0 implementation in the manufacturing industry, however, have not yet been examined (Moktadir et al., 2018). These challenges will be discussed in the following section.

2.2 Challenges to the Adoption of Industry 4.0

The majority of scholars agree that the study of challenges to Industry 4.0 adoption is mostly unexplored in the literature and needs further research (de Sousa Jabbour et al., 2018a, b; Kamble et al., 2018; Horváth and Szabó, 2019; Oesterreich and Teuteberg, 2016; Xu et al., 2018).

However, until now, these constraints have only been examined in isolation and from a technology perspective. Industry 4.0 adoption is a complicated process in which multiple elements interact (Horváth and Szabó, 2019); consequently, a thorough examination of all of these factors is required.

According to Machado et al., 2019, the maturity level of a company's digital transformation influences managers' perceptions of barriers to Industry 4.0, and organizational resistance from employees and middle management levels is likely to nullify the adoption of Industry 4.0 technologies in some of developing countries.

Much of the study on challenges to Industry 4.0 adoption has relied on empirical data gathered through survey research (e.g. Turkes et al., 2019; Stentoft et al., 2019) and interview case studies (e.g. Horváth and Szabó, 2019; Machado et al., 2019). These studies point out the roadblocks that prevent organizations in developing nations from being digitally ready.

3. Research methodology

This paper reviews available literature on the basis of the challenges in adopting Industry 4.0 concepts; therefore, several papers are analyzed in accordance with Industry 4.0 and its aspects. A total of over 25 papers were collected by searching for related keywords.

Following the analysis of various research publications, fourteen problems for describing the challenges of Industry 4.0 adoption in the manufacturing sector in emerging economies were identified.

As a result, the challenges of adopting Industry 4.0 are detailed in this article, and how these challenges should be addressed is critical for any manufacturing company that is looking to improve its readiness for a successful implementation of Industry 4.0 concepts.

3.1 Challenges to the Adoption of Industry 4.0

This section provides a discussion of the challenges to Industry 4.0 adoption in the manufacturing sector that identified through literature review and subject matter expert interviews.

3.1.1 Inadequate digital skills

Employees with the requisite knowledge and skills remain critical among the non-technical issues that the IoT (and thus Industry 4.0) faces (Hung, 2016). Many firms admit, according to Breunig et al. (2016), that they lack the essential expertise or abilities to fully fulfill the capabilities of Industry 4.0 applications. Breunig further said that a lack of digital skills and experience paralyzes organizations' capacity to interact with software solution providers because their employees are unable to use what they have purchased. Under-capable individuals are the second key challenge in application Industry 4.0 concepts, as firms become more data-driven and agile, demanding more skilled workforce. (Geissbauer et al., 2014).

3.1.2 Significant Investment Requirement

According to Geissbauer et al. (2014), companies interested in implementing Industry 4.0 projects must commit to increasing their anticipated annual infrastructure investment for the following five years. This not only requires a re-engineering of existing strategies, but it also demands a significant investment to meet Industry 4.0 objectives. Furthermore, Kache and Seuring (2017) reinforce this argument by stating that both at the corporate and supply chain levels, significant investment in people, processes, and technology is required. According to Breunig et al. (2016), most businesses are still hesitant to invest in Industry 4.0-related R&D, which seems to have significant expenditure needs.

3.1.3 Inadequate Infrastructure

In order to accomplish Industry 4.0, a broad internet infrastructure is required. Even in industrialized countries like Germany, a shortage of reliable high-speed broadband for SMEs is a big stumbling block. This kind of technology is now only available to major players with a lot of money (Schröder, 2016). Every channel partner would have to be interconnected as part of Industry 4.0, therefore digital infrastructure is a factor that cannot be overlooked. According to the findings of Penton's poll, 33% of respondents felt that a lack of infrastructure is a barrier to IoT adoption. According to the study, many companies are increasingly collaborating rather than competing to construct the essential infrastructure for Industry 4.0.

3.1.4 Data Quality

According to Chen et al. (2014), consistency, completeness, correctness, and redundancy are four dimensions of data quality. A vast amount of data would be generated in the age of fully realized big data, in which enterprises would have to be networked, and the complex nature of such data, together with its heterogeneity, makes it impossible to measure completeness and data accuracy. As a result, there's a higher chance of making a mistake (Lohr, 2012). Furthermore, data integrity and consistency become a serious difficulty when data changes often and is shared with various contributors (Khan et al., 2014). This will be the case in Industry 4.0, as businesses will be considerably more networked than before.

3.1.5 Inadequate Internal Digital Culture and Training

According to Breunig et al. (2016), in order to realize the benefits of Industry 4.0, the team must have strong internal competencies as well as a culture that encourages innovation and experimentation. Furthermore, it is believed that in such a scenario, employees with these skills would be in considerably higher demand and much lower supply. As a result, businesses would need to be prepared to transfer their operations to where such personnel were available. Such resources would foster an internal digital culture and allow a team of professionals from many fields to work together (Breunig et al., 2016).

3.1.6 Lack of Clarity on the Financial Benefit

Spending on information technology has always been questioned for its productivity improvements and financial advantages (Brynjolfsson, 1993). As a result of the productivity paradox in technology deployment, it is difficult to provide a precise estimation of the economic benefits of technology investment had become a challenge for the implementation of Industry 4.0.

3.1.7 Value-chain Integration Challenges

According to Breunig et al. (2016), difficulty of removing barriers between different organizational units in order to achieve the seamless collaboration that required for a successful Industry 4.0 environment. When numerous firms in the value chain are required to integrate, the problem becomes even more difficult. According to Geissbauer et al. (2014), the importance of horizontal value-chain integration as well as strong collaboration among value-chain partners is a vital factor. Majeed and Rupasinghe (2017) also claim that most businesses fail owing to a lack of IoT integration in an Industry 4.0 context. Dalenogare et al. (2018) highlights value-chain integration challenges as a significant barrier for a successful application of Industry 4.0.

3.1.8 Security Breach Risk

According to Geissbauer et al. (2014), one of the widespread worries about the security risk of sharing data among partner companies is the increased connectivity. It creates complex links between value-chain partners. Breunig et al. (2016) discuss not only enterprises' cyber-security concerns, but also their fear of losing their data to third-party software and service providers as a major concern in application of Industry 4.0. According to Lee and Lee (2015), 'Hackers' could be a severe concern, as consider this issue as one of the potential problems in IoT adoption.

3.1.9 Increasing Inequality

According to Schwab (2017), the labor market will be tense as a result of Industry 4.0. This could have a beneficial or bad impact, but technology will divide the market into low-skill/low-pay and high-skill/high-pay sectors, causing societal conflict. It is also claimed that Industry 4.0 will benefit intellectual capital owners and their shareholders while widening the divide between those who rely on labor and those who rely on capital, hence increasing inequality.

3.1.10 Low Maturity Level of Preferred Technology's

According to Lee and Lee (2015), the possibility for chaos when untested, early-stage technology are deployed that are unreliable. Such technologies may lack consistency in terms of standards, privacy concerns, and data security, and the growing number of untested gadgets might lead to pandemonium. The study goes on to say that while this isn't a big deal in an unconnected world, it might have a big impact on an interconnected system of technologies within Industry 4.0 environment.

3.1.11 Existing Job Disruption

Ryan and Watson (2017), see human displacement as a potential obstacle in a social and organizational setting, although not seeing human resources displacement as a problem. Haddud et al. (2017) emphasizes the issues that Industry 4.0 poses, as well as the issue of job disruption. According to Schwab (2017), advances in Industry 4.0 will enhance inequality and perhaps upset the job market.

3.1.12 Resistance to Change

Employees who are unwilling to modify their work habits are one of the challenges to IoT implementation in firms. These workers are averse to new technologies and the habits that come with them (Haddud et al., 2017). According to Lee and Lee (2015), another aspect of resistance, arguing that various IoT technologies generate massive amounts of personal data, such as home, health-related, and financial behavior-related data, which many organizations might utilize. For fear of information leakage, this discourages businesses and individuals from using IoT.

3.1.13 Inadequate Change Management

According to Anderson and Anderson (2010), Technology has drastically impacted the way change occurs in the recent decade. Change used to be seen as transactional and hence simple to manage; today it is seen as radical, open-ended, ongoing, and difficult. In other words, it has evolved into a transformative process that is extremely difficult to execute well. Increasingly open-ended systems would be more complicated than ever under Industry 4.0, and effective change management would be a major problem for businesses.

3.1.14 Scarcity of resources and a lack of digital strategy

According to Schröder (2016), Industry 4.0 demands the consistent availability and flow of data in and across businesses, both horizontally and vertically. In this setting, SMEs confront significant hurdles because, unlike their larger rivals, they have limited resources. According to Ahlers (2015), the majority of medium-sized businesses reject cloud computing, using the Innovation Readiness Index (IRI).

According to Schröder (2016), this problem stems from top management's apprehension about implementing Industry 4.0 technologies. Furthermore, Ahlers (2015) claims that implementing Industry 4.0 is a strategic decision, and that top management reluctance could make developing a digital strategy to execute Industry 4.0 challenging.

Table 1: Summary of the Industry 4.0 Adopting Challenges

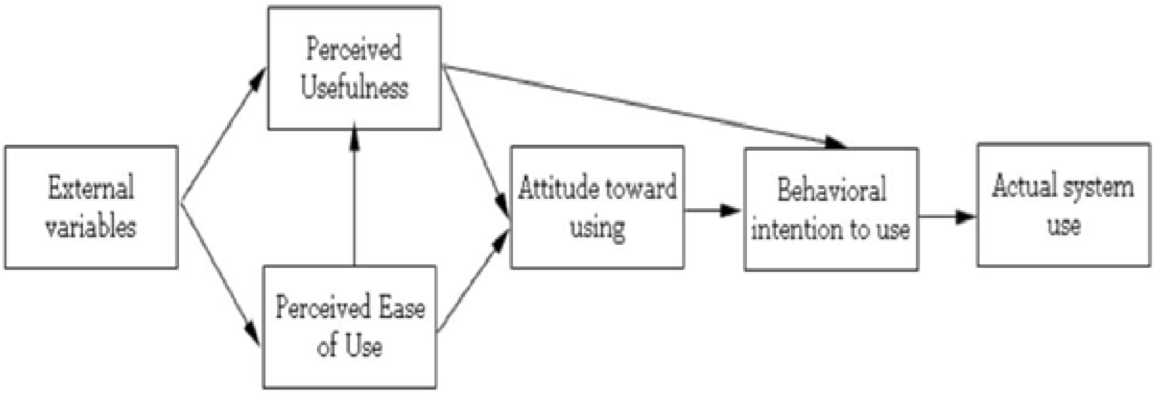
No	Industry 4.0 Adopting Challenge	Reference (Author)
3.1.1	Inadequate digital skills	(Hung, 2016) (Breunig et al., 2016) (Geissbauer et al., 2014)
3.1.2	Significant Investment requirement	(Geissbauer et al., 2014) Kache and Seuring.,2017) (Breunig et al.,2016)
3.1.3	Inadequate Infrastructure	(Schröder, 2016)
3.1.4	Data Quality	(Chen et al.,2014) (Lohr, 2012) (Khan et al., 2014)
3.1.5	Inadequate Internal Digital Culture and Training	(Breunig et al., 2016)
3.1.6	Lack of Clarity on the Financial Benefit	(Brynjolfsson, 1993) (Hofmann and Rüsch, 2017)
3.1.7	Value-chain Integration Challenges	(Breunig et al., 2016) (Geissbauer et al., 2014) (Majeed and Rupasinghe, 2017) (Dalenogare et al.,2018)
3.1.8	Security Breach Risk	(Breunig et al., 2016) (Geissbauer et al., 2014) (Lee and Lee, 2015)
3.1.9	Increasing Inequality	(Schwab, 2017)
3.1.10	Low Maturity Level of Preferred Technology's	(Lee and Lee, 2015)
3.1.11	Existing Job Disruption	(Ryan and Watson, 2017) (Haddud et al.,2017) (Schwab ,2017)
3.1.12	Resistance to change	(Haddud et al., 2017) (Lee and Lee, 2015)
3.1.13	Inadequate Change Management	(Anderson and Anderson, 2010)
3.1.14	Scarcity of resources and lack of digital strategy	(Schröder, 2016) (Ahlers, 2015)

Source: Author's own findings through Literature

4. Technology Acceptance Model (TAM)

The success of new technology implementation, according to the technology acceptance model, is primarily determined by two variables. Perceived utility and perceived simplicity of use are the two criteria. These variables influence how people will use technology and how they will react to change.

Figure 3: Technology acceptance model



(Source: Granić and Marangunić, 2019)

As a result, it is critical to convince people that the technologies are beneficial so that they can readily accept digital technology. Aside from that, it's critical to show people how simple it is to use those tools (Al-Emran et al. 2018). Their acceptance of those technologies will be aided by their ease of use. The organization's ability to successfully deploy Industry 4.0 may improve as a result of this procedure.

5. Conclusion

In the manufacturing industry, the implementation of Industry 4.0 is a top priority for developing economies. Based on a comprehensive literature search and discussions with experts from both established and emerging economies, fourteen challenges to implementation were identified to lessen the probability of failure. The study shows how these constraints have distinct effects in developing economies.

As many authors argued that in developing economies, the lack of a digital skills, resource limitations combine to significant Investment requirement and security breach risk appears as the most significant challenge. "scarcity of resources and a lack of a digital strategy" appeared as the most significant barrier. As a result, it is evident that managers should develop roadmaps and plan strategically in order to direct activities and resource investments in order to make the transition to Industry 4.0 as smooth as possible. Taking on the fundamental causes of the impediments to Industry 4.0 adoption should show to be an efficient strategy to thrive in the digital revolution.

Value chain integration issues and technological infrastructure were identified as the most important influencing elements in developing nations, whereas 'poor maturity level of the required technology' was also identified as a important influencing factor. In this setting, Organizations management, which is reliant on market and regulatory conditions, can address the influencing barrier. As a result, advances in standards and government regulation may make it easier for businesses to embrace Industry 4.0, while infrastructure to support technological systems may encourage the use of Industry 4.0 technology.

Like many other research, this study has gaps. The findings are only based on the Literature reviews and the relationships between the variables has not been tested and understand the significance of the variables.

Future research can investigate other factors that challenge the readiness for Industry 4.0 adoption in manufacturing Industries covering different sectors.

The outcome of the proposed study will help to guide future research on the development of standardized readiness assessment model for Industry 4.0 technology application in manufacturing companies in developing nations.

6. References

Ahlers, T., 2015. Industry 4.0: The Big Unknown? Freudenberg IT. International Journal of Production Economics.

Al-Emran, M., Mezhuyev, V. and Kamaludin, A., 2018. Technology Acceptance Model in M-learning context: A systematic review. Computers & Education, 125, pp.389-412.

Anderson, D., & Anderson, L. A. (2010). Beyond change management: How to achieve breakthrough results through conscious change leadership (Vol. 36). John Wiley & Sons.

Barreto, L., Amaral, A., & Pereira, T. (2017). Industry 4.0

implications in logistics: an overview. Procedia Manufacturing, 13, 1245-1252.

Ben-Daya, M., Hassini, E., & Bahroun, Z. (2017). Internet of things and supply chain management: a literature review. International Journal of Production Research, 1-24.

Breunig, M., Kelly, R., Mathis, R., & Wee, D. (2016). Getting the most out of Industry 4.0. Retrieved Jan 5, 2018, from https://www.mckinsey.com/business. Cross ref

Brynjolfsson, E. (1993). The productivity paradox of information technology. Communications of the ACM, 36(12), 66-77.

Chen, Z. K., Yang, S. Q., Tan, S., Zhao, H., He, L., Zhang, G., & Yang, H. Y. (2014). The Data Allocation Strategy Based on Load in NoSQL Database. In Applied Mechanics and Materials (Vol. 513, pp. 1464-1469). Trans Tech Publications.

Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. International Journal of Production Economics. https://doi.org/10.1016/j.ijpe.2018.08.019

De Sousa Jabbour, A. B. L., Jabbour, C. J. C., Godinho Filho, M., & Roubaud, D. (2018a). Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations. Annals of Operations Research, 1-14.

Fettermann, D. C., Cavalcante, C. G. S., Almeida, T. D. D., & Tortorella, G. L. (2018). How does Industry 4.0 contribute to operations management. Journal of Industrial and Production Engineering, 35(4), 255-268.

Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. International Journal of Production Economics, 210, 15-26.

Friedrich-Ebert-Stiftung, Bonn Stentoft, J., Jensen, K. W., Philipsen, K., & Haug, A. (2019, January). Drivers and Barriers for Industry 4.0 Readiness and Practice: A SME Perspective with Empirical Evidence. In Proceedings of the 52nd Hawaii International Conference on System Sciences.

Geissbauer, R., Schrauf, S. & Koch, V. (2014). Industry 4.0: Opportunities and Challenges of Industrial Internet, Price water house Coopers. Available at: https://www.pwc.nl/en/assets/document

Granić, A. and Marangunić, N., 2019. Technology acceptance model in educational context: A systematic literature review. British Journal of Educational Technology, 50(5), pp.2572-2593.

Haddud, A., DeSouza, A., Khare, A., & Lee, H. (2017). Examining potential benefits and challenges associated with the Internet of Things integration in supply chains. Journal of Manufacturing Technology Management, 28(8), 1055-1085.

Hofmann, E., & Rüsch, M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. Computers in Industry, 89, 23-34.

Horváth, D., & Szabó, R. Z. (2019). Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? Technological Forecasting and Social Change, 146, 119-132.

Hung, M., 2016. IoT Implementation and Management - from the Edge to the Cloud [WWW Document]. Gartner. URL https://www.gartner.com/technology/research/internet-of- things/report/ (accessed 1.23.22).

Ivanov, D., Dolgui, A., & Sokolov, B. (2018). The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics. International Journal of Production Research, 1-18.

Kache, F., & Seuring, S. (2017). Challenges and opportunities of digital information at the intersection of Big Data Analytics and supply chain management. International Journal of Operations & Production Management, 37(1), 10-36.

Kamble, S. S., Gunasekaran, A., & Sharma, R. (2018). Analysis of the driving and dependence power of barriers to adopt industry 4.0 in Indian manufacturing industry. Computers in Industry, 101, 107-119.

Khan, N., Yaqoob, I., Hashem, I. A. T., Inayat, Z., Ali, M., Kamaleldin, W., ... & Gani, A. (2014). Big data: survey, technologies, opportunities, and challenges. The Scientific World Journal, 2014.

Lee, I., & Lee, K. (2015). The Internet of Things (IoT): Applications, investments, and challenges for enterprises. Business Horizons, 58(4), 431-440.

Li, L. (2017). China's manufacturing locus in 2025: With a comparison of "Made-in-China 2025" and "Industry 4.0". Technological Forecasting and Social Change

Lohr, S. (2012). The age of big data. New York Times, 11(2012).

Lu, Y., 2017. Industry 4.0: A Survey on Technologies, Applications and Open Research Issues. Journal of Industrial Information Integration. Available at: http://www.sciencedirect.com/science/article/pii/S2452414X17300043 [Accessed Jan 14, 2022].

Machado, C. G., Winrotha, M., Carlssonb, D., Almströma, P., Centerholtb, V., & Hallin, M. (2019). Industry 4.0 readiness in manufacturing companies: challenges and enablers towards increased digitalization. way, 1(2), 3-4.

Majeed, A. A., & Rupasinghe, T. D. (2017). Internet of Things (IoT) embedded future supply chains for industry 4.0: an assessment from an ERP-based fashion apparel and footwear industry. International Journal of Supply Chain Management, 6(1), 25-40.

Moktadir, M. A., Ali, S. M., Kusi-Sarpong, S., & Shaikh, M. A. A. (2018). Assessing challenges for implementing Industry 4.0: Implications for process safety and environmental protection. Process Safety and Environmental Protection.

Mrugalska, B., & Wyrwicka, M. K. (2017). Towards lean production in industry 4.0. Procedia Engineering, 182, 466-473.

Oesterreich, T. D., & Teuteberg, F. (2016). Understanding the implications of digitization and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. Computers in Industry, 83, 121-139

Rabeh Morrar, H. A. S. M., 2017. The Fourth Industrial Revolution (Industry 4.0): A Social Innovation Perspective. [Online] Available at: https://timreview.ca/article/1117 [Accessed 18 1 2022].

Rüßmann, M., et al., 2015. Industry 4.0: The future of productivity and growth in manufacturing industries. Boston Consulting Group (BCG), pp.1-14.

Ryan, P. J., & Watson, R. B. (2017). Research Challenges for the Internet of Things: What Rol Can OR Play? Systems, 5(1), 24.

Schröder, C. (2016). The challenges of industry 4.0 for small and medium-sized enterprises.

Schwab, K. (2017). The fourth industrial revolution. Crown Business.

Türkeș, M. C., Oncioiu, I., Aslam, H. D., Marin-Pantelescu, A., Topor, D. I., & Căpușneanu, S. (2019). Drivers and Barriers in Using Industry 4.0: A Perspective of SMEs in Romania. Processes, 7(3), 153.

Ungurean, I & Gaitan, V. G., 2014. An Iot architecture for things from industrial environment. In Communications (COMM), IEEE2014 10th International Conference on (pp. 1-4).

Vidanagamachchi et al, 2016. Readiness Assessment for Industry 4.0 in Sri Lankan apperal industry. Proceedings of the International Conference on Industrial Engineering and Operations Management, pp. Dubai, UAE, March 10-12, 2020.

Naturally occurring pigments for intelligent food packaging applications: Recent applications and future perspectives

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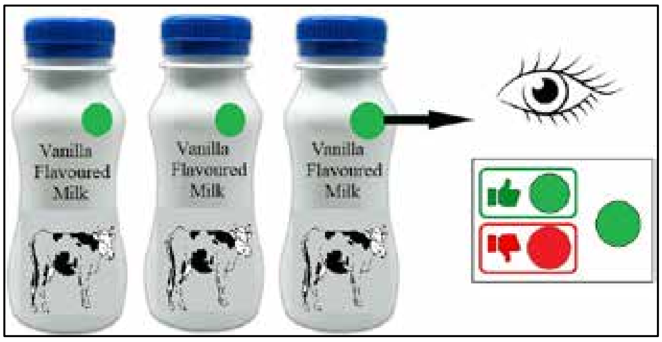
Fresh food products deteriorate rapidly due to physical damage caused by handling, transport, and storage, as well as inherent causes such as chemical reactions, enzyme activity, and microbial deterioration. Packaging is amongst the most important techniques for preserving food quality during transport, storage, and end use. It helps to ensure the food quality and safety for both sellers and buyers, resulting in increased consumer safety and less food wastage. Packaging, on the other hand, may help to keep food fresh by acting as a storefront for information about the food that is inside. This helps to cut down on food waste and deterioration. In this regard, active and intelligent packages are being designed, and they make up a significant contribution to the food packaging sector.

Smart packaging includes active and intelligent packaging solutions that aim to provide consumers with more accurate information on packaged food conditions while also providing a protective function for the food product by incorporating active compounds. The use of compounds that may release directly or indirectly to the food in order to retain quality or prevent deterioration is known as active packaging. Active compounds such as antioxidants, oxygen scavengers, moisture absorbers or antibacterial are added to the polymer matrix used in this method of package.

Intelligent food packaging refers to the techniques that oversee the state of packed food or its surrounding environment by monitoring changes and communicating the conditions which helps to make decision about the packaged food product. In order to achieve this, intelligent packaging contains indicators, data carriers, or sensors. Mainly the indicators are based on time-temperature detection, freshness detection, gas production detection, and convey information through a visual colour variation that the customer may clearly identify. Data carriers are a type of information carrier used in the food supply chain. Barcodes and Radio Frequency Identification chips (RFID) are the most prevalent data carriers. In sensors, physical or chemical



changes in food are detected by a transducer and converted to an electrical signal.

The most common types of indicators used in intelligent food packaging are based on a visual colour change, which is caused due to chemical or microbial alterations in food which interacts with the indicator, indicating alterations in food, which is often caused by pH variation. Indicators function by changing the colour of pigments that have been incorporated to the indicator, which are responsive to pH alterations. Methyl red, bromocresol purple, bromophenol blue, and chlorophenol red are synthetic dyes that have been shown to response the alterations pH effectively. Although they have been proved to be effective, their toxic, carcinogenic, and mutagenic properties make them unsuitable for use in food. Natural pigments, rather than synthetic dyes, are in line with the current consumer trend toward more sustainable and natural healthier alternatives. Natural pigments derived from plant based materials are renewable, nontoxic, and have low impact on the environment.

Many studies on the development, characterization, and use of bio-based indicators in intelligent food packaging have emerged in recent years, and some of them are reviewed and summarized here. Attention has been paid to bio based indicators like anthocyanin, curcumin, and betalains as they have been widely used in recent applications due to their clear and effective colour responses to pH alterations in intelligent food packaging applications.

Anthocyanin as an indicator for intelligent food packaging

Anthocyanins are naturally occurring water-soluble pigments found in a variety of plants and fruits. These are categorized as flavonoids, and research has shown that they have antioxidant, anti-inflammatory, and anticarcinogenic properties. Anthocyanins are accountable for the red, purple, and blue colours seen in a wide range of plants and fruits, and they are very reactive to pH changes (Figure 1) [1].

Because of the nontoxic and biodegradability properties, different types of biopolymers, such as chitosan, cellulose, starch, polylactic acid (PLA) etc., have been widely used in food packaging. The incorporation of bio based indicators for biopolymer food packaging materials provides a sustainable alternative to synthetic dyes and synthetic polymer-based intelligent food packaging materials. For example, Pereira Jr, de Arruda [2] prepared intelligent food packaging film by incorporating anthocyanins extracted from red cabbage into chitosan/PVA films. The film was designed to detect the pH alterations of packed food, when it was exposed to incorrect storage temperatures. When the anthocyanin incorporated chitosan/PVA films were exposed to solutions of varying pH (from pH 1.0 to pH 12.0), a noticeable colour change was observed, varying from bright red to bright green. When milk is heated to a certain temperature, which is higher than the temperature suitable for cooling (7 °C), it starts to breakdown, changing the pH of the milk and decreasing the milk's stability. The films indicated a distinct colour variation after getting in contact with the milk, starting with a dark grey colour at pH 6.7 (fresh milk) and progressively becoming clearer as the pH declined from 6.7 to 5.0. The films showed a dark pink colour at pH 4.6 (due to the spoilage of milk), clearly demonstrating milk deterioration.

Due to its high abundance, film-forming property, and nontoxicity, starch seems to be one of the most appealing biopolymers. Vedove, Maniglia [3] prepared an intelligent food packaging film using cassava starch and anthocyanin to detect changes in pH of meat that was stored at 6 °C. Cassava starch sheets with anthocyanin was prepared using co-rotating twin-screw extruder connected with sheet-forming mold. Results showed that 20 mg anthocyanin/100 g film produced the best pH change indicator performance with most visually

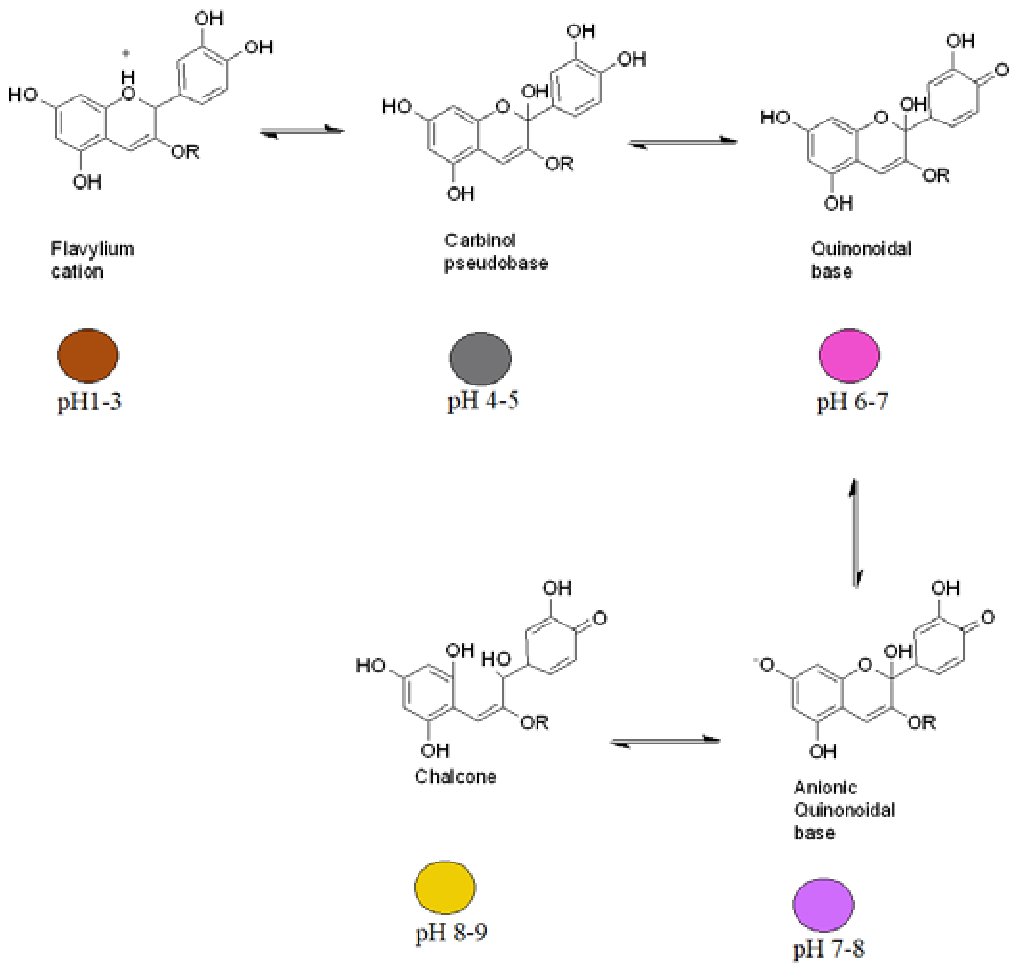


Figure 1. Anthocyanin structural changes and colour variations at various pH levels.

notable colour change. The high meat pH is caused due to evolving volatile nitrogenous compounds such as ammonia as a result of the act of microorganisms on meat proteins. When exposed to the sheet, this gas diffuses into it and subsequently hydrolyses the indicator anthocyanin. The change in anthocyanin colour with the increase of pH from 5 to 9 is due to the anthocyanin structure changing from a flavylium cationic form to a pseudo-base carbinol form and finally to its anionic form, which reduces the contribution to red colour.

Though previous studies were focused on pH-induced anthocyanin composite film colour changes, Zhang, Zou [4] highlighted that the colour is directly affected by the stability of the composite film, thus it is important to analyze the film's stability before using it in intelligent food packaging applications. Their results depicted that these indicator films stored at high temperature (25 °C) showed a higher colour change compared to the films stored at lower temperatures (4° C). This was due to the pyrylium ring opening of anthocyanins at high temperatures, producing a chalcone structure and yellow coloration. Among the films prepared, the starch/PVA hydrogel films showed highest colour stability compared to the starch/chitosan hydrogel and PVA/chitosan hydrogel films. The starch/PVA/anthocyanin (extracted from roselle calyx) hydrogel film was used to monitor the pork freshness and it showed a purple colour at first and brown colour after 48 hours and lastly a yellow colour at 72 hours. Meat proteins are particularly susceptible to bacterial and mildew growth. During spoiling, many volatile nitrogenous chemicals, such as ammonia and amines, are formed. The mechanism is that ammonia is diffused into the film, then hydrolysed to release hydroxyl ions, resulting in increased pH levels of the film. This leads to a change in the anthocyanin structure to chalcone, causing the colour of the composite hydrogel films to change.

Curcumin as an indicator for intelligent food packaging

Curcumin is a hydrophobic polyphenol derived from turmeric that has antioxidant, antibacterial, and anti-inflammatory properties and a bright yellow colour. Curcumin has a yellow colour between pH 1 and 7, and a red–orange colour at pH 8 [1].

Besides anthocyanin, curcumin has also been employed as a bio-based indicator in intelligent packaging applications. Curcumin's colour changes are less diverse than anthocyanin's, but its sensitivity to alkalinity is highly noticeable. Musso, Salgado [5] prepared smart edible films using gelatine and curcumin. A casting method was used to prepare the film with water and an ethanol-water mixture (1:1 v/v) as solvents. Their findings revealed that films at pH of 6 become orange-red when exposed to basic gases, fluids, and semi-solids, and films at pH 11 become yellow when exposed to acidic medium. Further, they mentioned that the film reactions were rapid and distinct with liquids and gases than those with semisolid substrates, particularly for films formed from aqueous dispersions. The decreased diffusive processes are most likely the reasons for slower turning kinetics in semisolid media.

According to some studies, the relative humidity of the environment influences the colour variation of curcumin-incorporated food packaging films. However, this effect also varies with the type of the film, whether it is hydrophobic or hydrophilic. For example, Zhai, Wang [6] used a melting extrusion process to prepare a hydrophobic film from low density polyethylene (LDPE) and curcumin. With exposure to NH_3 at various relative humidity (RH) levels, the film's colour changed from light yellow to brown. According to the results, the film's colour change was more intense at low RH values compared to high relative humidity values. At higher RH, more NH_3 dissolved in water and form $NH_3{\cdot}H_2O$, and then ionize into ammonium and hydroxyl ions. The hydrophobic feature of the film prevented hydroxyl ions in water drops from diffusing into the film and causing curcumin colour change. The impact of RH on the curcumin colour change for hydrophobic LDPE films was quite different compared to the curcumin incorporated hydrophilic films reported in previous studies. Films changed from light yellow-to-light brown with the storage of beef and silver carp at 4 °C due

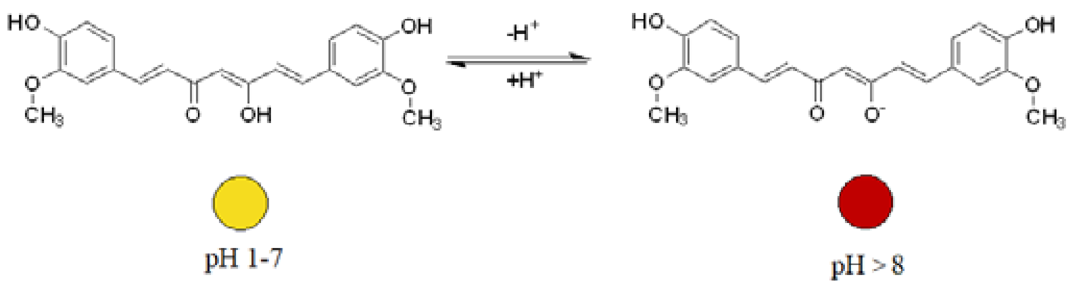


Figure 2. Curcumin structural changes and colour variations at various pH levels.

to the increased levels of total volatile basic nitrogen compounds.

Curcumin has been shown to lose its functionalities as a consequence of exposure to high temperatures, light, and oxidation during the production and storage processes. Because curcumin is highly unstable, it is possible that intelligent packaging won't accurately reflect the quality of the food it contains. Liu, Dang [7] incorporated pickering emulsion for curcumin-loaded corn starch/PVA films for use in intelligent packaging to increase the stability of curcumin. The films' antioxidant activity was determined, indicating that pickering emulsion could minimize curcumin degradation throughout the production and storage phase. During the monitoring of the fish freshness, the colour of the film changed (bright yellow to reddish-brown) considerably when the fish was close to deteriorating after 48 hours. In contrast, the curcumin and pickering emulsion incorporated films showed a more noticeable colour change compared to the films loaded with curcumin only, and the colour change became more intense as the quantity of curcumin increased.

Betalains as an indicator for intelligent food packaging

Betalains are naturally occurring nitrogen-containing pigments present in the vacuoles of certain plant tissue. They have antioxidant properties and serve as radical scavengers, inhibiting lipid peroxidation and heme breakdown at low concentrations. Betalamic acid is a common biosynthetic precursor, and it seems to be stable at pH ranges between 3 and 8 [1].

Betalains can be extracted from plant species belonging to the families of Caryophyllales. Yao, Hu [8] extracted betalains from cactus pears (order- Caryophyllales) to develop quaternary ammonium chitosan (QAC), polyvinyl alcohol (PVA) and betalains film to use as freshness indicators of shrimp. Cactus pears extract (CPE) is rich in betalains, which have antioxidant and antibacterial properties. QAC and PVA were dissolved in distilled water with various concentrations of CPE and 10% glycerol to form the films. At pH 3–8, CPE solution had a purple/red colour and a noticeable absorption band at 535 nm. Exposure to ammonia with varying exposure times was used to assess the pH sensitivity of films containing different contents of CPE. The film containing 3 wt% CPE exhibited notable colour variations from purple to yellow as the exposure duration was increased. This was confirmed by placing the films in the headspace of a container containing fresh shrimp and monitoring their colour change with the deterioration of fresh shrimp. The colour of the film added with 5 wt% and 3 wt% CPE changed from purple (0–12 h) to orange (24 h) and yellow (36 h), showing that these two films could be used to detect shrimp freshness.

Hu, Yao [9] extracted betalains from vegetable amaranth (order-Caryophyllales) to prepare quaternary ammonium chitosan/fish gelatin and betalains film for multifunctional food packaging applications. pH sensitivity studies showed that the amaranth extract changed its colour from purplish red to yellow with the increase of pH from 8 to 12. This was due to the structural conversion of betalains to betaxanthins in alkali environment. Because volatile ammonia may penetrate into the film and produce $NH_3.H_2O$, which subsequently converts to NH_4^+/OH^- and creates an alkaline pH, films changed colour from pink to yellow when exposed to ammonia. Furthermore, during the monitoring of the freshness of shrimp, films changed their colour to yellow at 24 h, proving the film's suitability to monitor shrimp freshness.

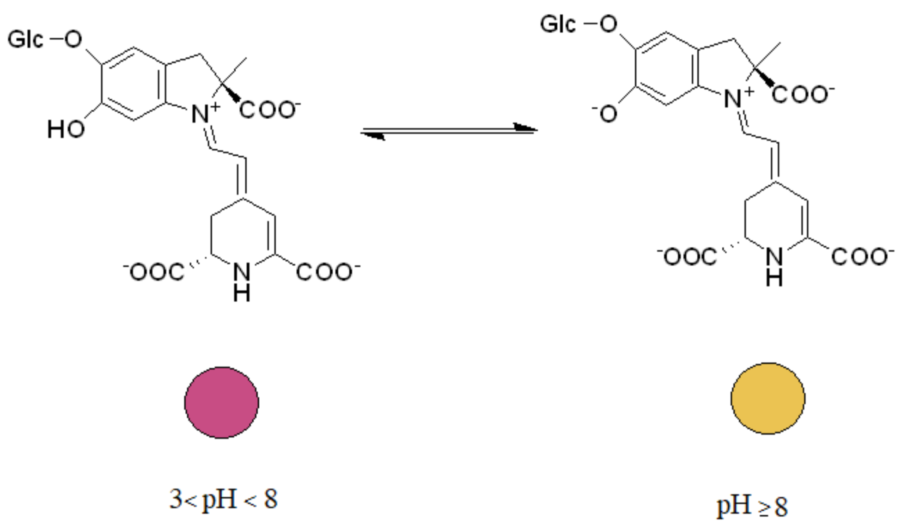


Figure 3. Betalains structural changes and colour variations at various pH levels.

In another study, Qin, Liu [10] extracted betalains from red pitaya (order-Caryophyllales) peel to incorporate into starch/PVA film in intelligent food packaging applications. At pH 3–7, red pitaya peel extract appeared in red colour, indicating that betalains remained stable at this pH. At high pH values, red pitaya peel extract solution appeared in orange colour (at pH 8–9) or yellow colour (at pH 10–12). During the ammonia test, the pink colour of the films faded after 10 min exposure to ammonia. After 20 minutes of exposure to ammonia, the films became yellow and the yellowness level steadily increased. The pink colour of the films remained after 12 hours of monitoring the freshness of shrimp. The film changed to pale yellow at 24 h and completely changed to yellow at 48 h, showing that proteins in shrimp had degraded into organic amines.

The different types of naturally occurring pigments used in intelligent packaging applications are summarized in Table 1.

Table 1. Summary of the different types of naturally occurring pigments used in intelligent packaging applications.

Matrix	Indicator(pigment)/source	Colour change	Food type	
Chitosan/PVA	Anthocyanin/Red cabbage	Dark grey colour at pH 6.7 (fresh milk). Dark pink colour at pH 4.6 (due to the spoilage of milk).	Milk	[2]
Cassava starch	Anthocyanin/Purchased	Decreased the reddish contribution with increase of the pH from 5 to 9	Fish Meat	[3]
Starch/PVA	Anthocyanin/Roselle calyx	Varied the colour during the storage of pork (purple colour at first, brown colour after 48 hours and yellow colour at 72 hours)	Pork	[4]
Gelatine	Curcumin/Purchased	At pH 6 become orange-red, At pH 11 become yellow	Food head space, Semisolid food, Solid food	[5]
LDPE	Curcumin/Purchased	Colour changed from light yellow-to-light brown due to the increased levels of total volatile basic nitrogen compounds	Beef and silver carp	[6]
Corn starch/ PVA	Curcumin/Purchased	Varied the colour during the storage of fish. Bright yellow changed to reddish-brown after 48 hours	Fish	[7]
QAC/PVA	Betalains/Cactus pears	Varied the colour during the storage of shrimp. Purple (0–12 h) to orange (24 h) and yellow (36 h)	Shrimp	[8]
Chitosan/fish gelatin	Betalains/Vegetable amaranth	Varied the colour during the storage of shrimp. From pink to yellow at 24 h	Shrimp	[9]
Starch/PVA	Betalains/Red pitaya peel	Varied the colour during the storage of shrimp. The pink colour remained after 12 h, changed to pale yellow at 24 h and completely changed to yellow at 48 h	Shripm	[10]

Concluding remarks and future perspectives

Intelligent food packaging offers a novel approach to communicate the quality of food which it is being packed and identify the spoiled food not just for suppliers, but most specially for customers. Furthermore, it can be used to develop biobased food packaging solutions to address environmental problems created with petroleum-based materials.

Anthocyanins, curcumin, and betalains are pigments that are extracted from different parts of plants and that have been the most commonly investigated options for developing bio-based sensors. The above pigments are both antibacterials and antioxidants, and when integrated with packaging, they may offer functionality to the polymer matrix, increasing the shelf life of the foods being packaged. As a result, these naturally extracted indicators have the possibility of being used in smart packaging solutions in the food industry.

In addition to their potential for use as pH indicators, there are some issues related to their stability when exposed to certain temperatures, O_2, and light. Therefore, investigations are required to increase the indicators' effectiveness and stability in the polymer matrix. Incorporation of the pigments within solid particles or liquid vesicles and the use of UV-light blocking agents such as ZnO nanoparticles have shown encouraging results in terms of pigment stabilizers. In addition, a combination of pigments can be used to improve the stability and effectiveness of indicators. For example, the mixing of water-soluble and alcohol-soluble pigments allows one to detect the condition of water-soluble and oil-soluble foods. Moreover, these pigments have certain limitations such as less contact with solid or semi solid food stuff and some diffusivity problems with food packaging materials. As a consequence, further research is required to fully comprehend how these natural pigments interact with food.

Additionally, if intelligent packaging systems could monitor leakages in packing or respond to pathogens, toxins, allergens, or how long a temperature breach has persisted throughout cold storage food supply chains, the food supply sector would be delighted. This would contribute to minimizing food wastage and improving the sustainability of the food supply chain.

References

1. Rodrigues, C., et al., *Bio-based sensors for smart food packaging—Current applications and future trends.* Sensors, 2021. **21**(6): p. 2148.
2. Pereira Jr, V.A., I.N.Q. de Arruda, and R. Stefani, *Active chitosan/PVA films with anthocyanins from Brassica oleraceae (Red Cabbage) as Time–Temperature Indicators for application in intelligent food packaging.* Food Hydrocolloids, 2015. **43**: p. 180-188.
3. Vedove, T.M., B.C. Maniglia, and C.C. Tadini, *Production of sustainable smart packaging based on cassava starch and anthocyanin by an extrusion process.* Journal of food engineering, 2021. **289**: p. 110274.
4. Zhang, J., et al., *Preparation of an intelligent pH film based on biodegradable polymers and roselle anthocyanins for monitoring pork freshness.* Food Chemistry, 2019. **272**: p. 306-312.
5. Musso, Y.S., P.R. Salgado, and A.N. Mauri, *Smart edible films based on gelatin and curcumin.* Food hydrocolloids, 2017. **66**: p. 8-15.
6. Zhai, X., et al., *Extruded low density polyethylene-curcumin film: A hydrophobic ammonia sensor for intelligent food packaging.* Food Packaging and Shelf Life, 2020. **26**: p. 100595.
7. Liu, D., et al., *Corn starch/polyvinyl alcohol based films incorporated with curcumin-loaded Pickering emulsion for application in intelligent packaging.* International Journal of Biological Macromolecules, 2021. **188**: p. 974-982.
8. Yao, X., et al., *Development of antioxidant, antimicrobial and ammonia-sensitive films based on quaternary ammonium chitosan, polyvinyl alcohol and betalains-rich cactus pears (Opuntia ficus-indica) extract.* Food Hydrocolloids, 2020. **106**: p. 105896.
9. Hu, H., et al., *Development of multifunctional food packaging by incorporating betalains from vegetable amaranth (Amaranthus tricolor L.) into quaternary ammonium chitosan/fish gelatin blend films.* International Journal of Biological Macromolecules, 2020. **159**: p. 675-684.
10. Qin, Y., et al., *Development of active and intelligent packaging by incorporating betalains from red pitaya (Hylocereus polyrhizus) peel into starch/polyvinyl alcohol films.* Food Hydrocolloids, 2020. **100**: p. 105410.

Obtaining a minimum electrochemical surface area (ECSA) reduction by using polybenzimidazole (PBI) wrapped carbon nanotubes as catalyst supports for polymer electrolyte membrane fuel cells (PEMFCs).

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What is a fuel cell?

A fuel cell is a device that supply energy in the form of electrochemical energy. Most common device in today's world that we use to generate electrochemical energy is a battery. There are many types of fuel cells. Table 1 lists most common types of fuel cells (FCs), such as, Molten carbonate fuel cells, Solid oxide fuel cells, Alkaline FCs, Phosphoric acid FCs, Polymer Electrolyte Membrane Fuel Cells or PEMFCs, Microbial FCs and Direct methanol FCs. As a fuel all of them uses O_2 gas plus various constituents as fuel like CO_2 natural gas, H_2 gas, organic matter or methanol. Depending on the type of FC, their operating temperature vary largely from room temperature to about 1,000 ^{0}C. First fuel cell was realized as a unit in 1958, however the concept of fuel cells was discovered way back in 1838. from all these types of fuel cells PEMFCs are special due to its attractive advantages.

Table 1 – Types of fuel cells and their details

Name	Fuel (+ O_2)	Operating Temperature (RT-Room temperature)	Invented year
Molten carbonate FCs	CO_2	620°C – 660°C	1958
Solid oxide FCs	Natural gas	800°C – 1000°C	1959
Alkaline FCs	H_2 gas	RT - 90°C	1960
Phosphoric acid FCs	H_2 gas	150°C – 200°C	1961
PEMFCs	H_2 gas	RT - 80°C	1965
Microbial FCs	Organic matter	RT	1976
Direct methanol FCs	Methanol	130°C	1990

PEMFCs are energy devices which comprises with a polymer electrolyte membrane or PEM in the middle shown in light blue color sandwiched between two electrodes on Figure 1 which will act as either anode or cathode. Anode, cathode and PEM altogether is known as the membrane electrode assembly or MEA. PEMFCs have various advantages like, High efficiency, high energy density, low environmental impact and low operating temperatures. PEMFCs have commercial applications in automobile devises and currently fuel

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cell vehicles with PEMFCs are being manufactured by Toyota and Honda in Japan. Also, residential power devices are manufactured in the brand name of Ene-farm.

PEMFCs use hydrogen as a fuel. This hydrogen when inserted is oxidized at the anode converting to H+, then this H+ will travel through this gas impermeable PEM towards the cathode. The generated electrons travel through the external circuit to produce power. If we look inside the electrode (Figure 1, inset), reaction catalyst Pt shown as small purple spheres, can be found deposited as nano particles on a catalyst support, commonly on CB shown as large gray particles. These are Covered with an electrolyte solution called an ionomer shown in light blue. This total section is called the catalyst layer. At the cathode catalyst layer, the H+ coming from the PEM swims through the ionomer and electrons travel through CB and meets on the surface of Pt to combine with adsorbed oxygen obtained from air to produce water. And this produced water will be ejected from the cathode as the only by-product. PEMFCs are gaining attention as it has the potential of becoming an energy platform for future applications rather than a single energy device.

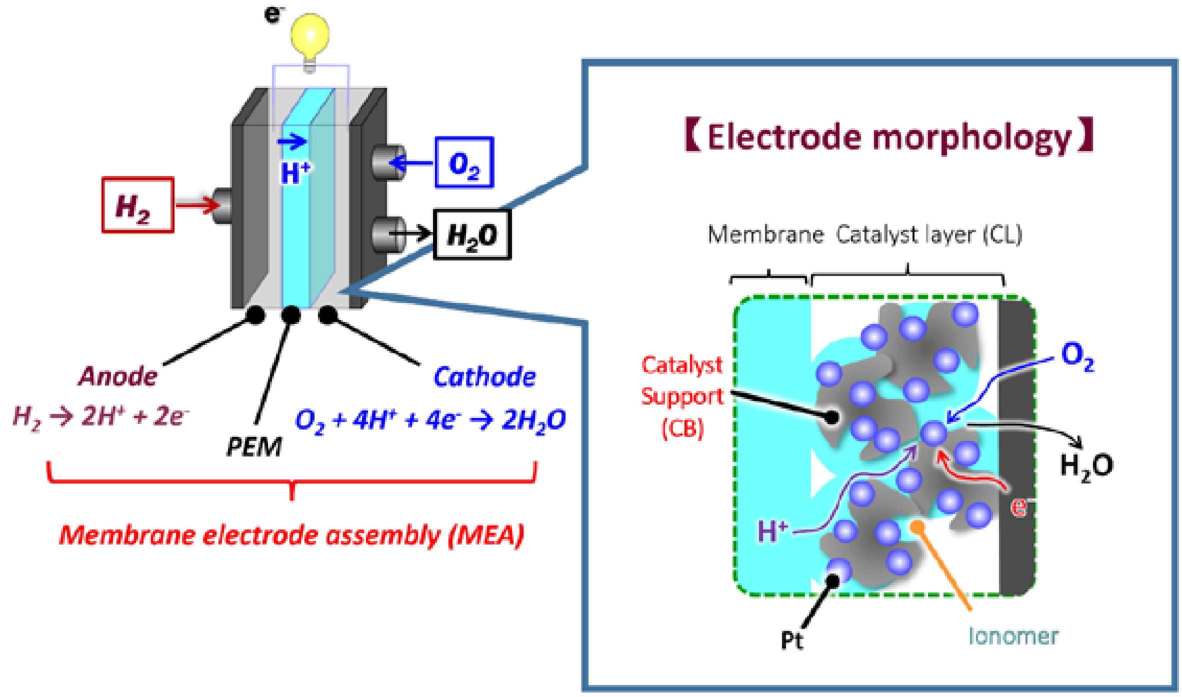

Figure 1 – Section of a PEMFC and the electrode morphology

Advantages and Disadvantages of fuel cells

However, despite the advantages discussed above, there are few problems regarding PEMFCs like High cost and Low durability. High cost arises mostly due to the usage of expensive Pt, whereas low durability arises due to corrosion of the carbon support, loss of the active chemical surface area of Pt, loss of gas permeation and many more [1-4]. For example, corrosion of the carbon support occurs due to the high acidic and high potential environment inside PEMFCs, that chemically corrodes C to CO_2. as a reason of this carbon corrosion, Pt nanoparticles that was attached on to the carbon will be lost. Also, Pt particle agglomeration will happen, these all together Reduce the precious Pt[5,6] (Figure 2). Therefore, reduction of the carbon support corrosion of PEMFC is very important[7]. One alternative we can do to minimize this carbon corrosion is avoid the use of unstable CB and replace it with more electrochemically stable material like CNTs [8-15].

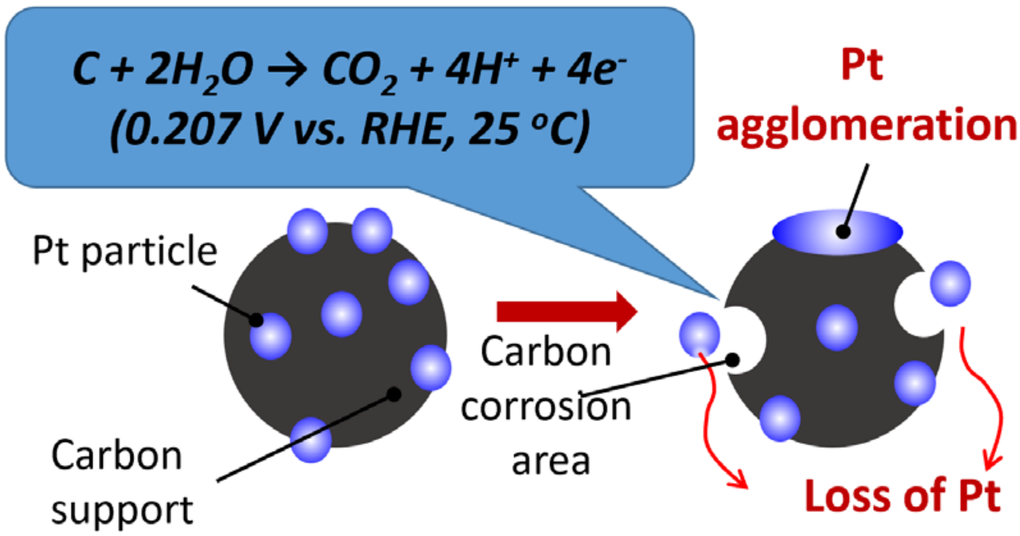

Figure 2 – Carbon corrosion and its effects

How effective is PBI wrapping?

To be used as catalyst supports, first CNTs should be oxidized to create damages on the surface with COOH groups (Figure 3 a), this is because un-damaged CNTs have no anchorage sites for Pt. After generating the COOH groups, loading of Pt nano particles can be done. However, this oxidative damaging of the CNTs reduce the sp^2 amount thus reducing CNTs inherent high electrochemical stability[16]. As a solution for this, My PhD study group has developed a new method of Pt loading which does not require oxidation. We call it polybenzimidazole or PBI method. PBI is a polymer which has a benzene ring backbone and N atoms. First the CNTs are wrapped by the PBI and then the loading of the Pt nano particles was done by reducing a Pt salt (Figure 3 b). PBIs benzene rich backbone structure binds well with the walls of CNTs using pi-pi interactions and the N- atoms of PBI act as anchorage sites for Pt nano particles[17-20] (Figure 3 b). Therefore, oxidation of the CNTs to create COOH bonds are no longer needed. Therefore, through our PBI method sp^2 content of CNTs can be preserved.

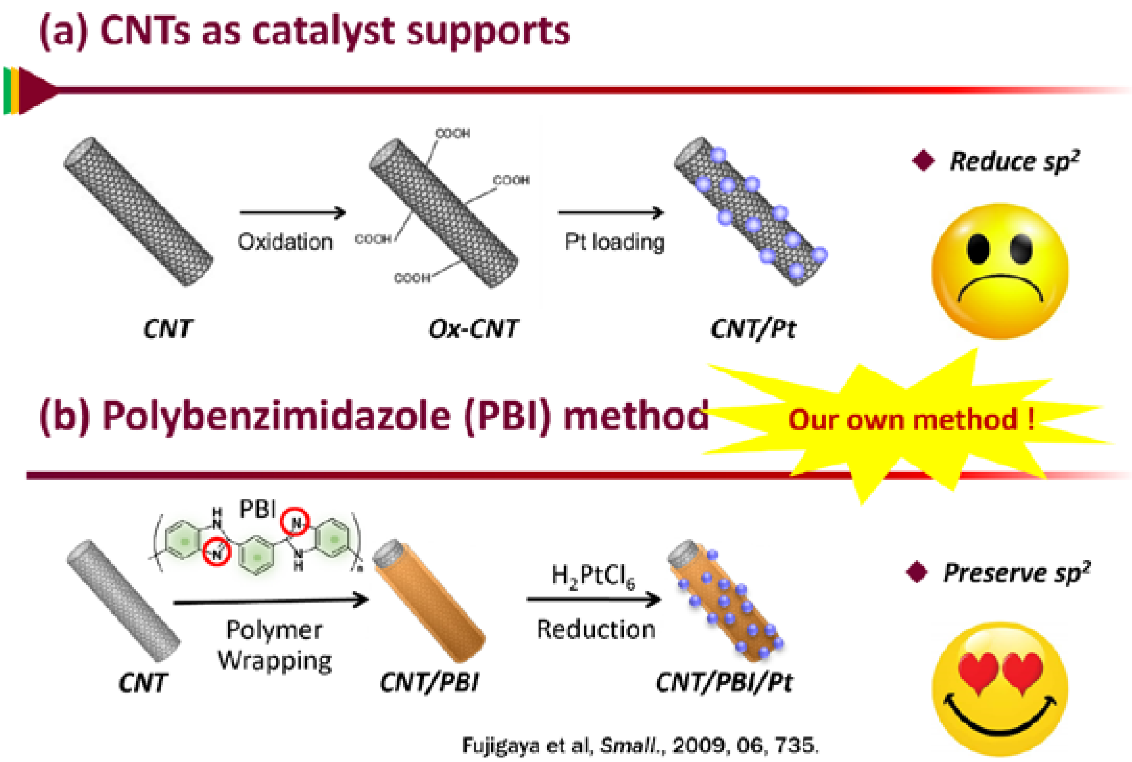

Figure 3 – (a) General procedure of oxidation for using CNT as catalyst support and (b) Method of PBI wrapping that preserves sp^2 content.

Figure 4 (a) shows a Transmission electron micrograph or TEM image of commercial CB/Pt composite, with Pt particles seen as tiny black dots resting on large gray colored spherical CB particles. Figure 4 (b) shows a TEM image of Pt particles loaded on to an undamaged CNT. The Pt particles are highly agglomerated due to lack of anchorage sites. Figure 4 (c) shows a Pt composite on oxidized CNT. Figure 4 (d) shows an image of Pt composite prepared by PBI method. There the Pt nano particles are homogeneously distributed. Graph on Figure 4 (e) shows the loss of Pt, as loss of electrochemical surface area or ECSA with number of potential cycles, conducted in a half-cell environment. There, the relative loss of Pt or the loss of ECSA is highest in CB/Pt composites as described earlier as a major problem of PEMFCs. By replacing CB with Ox-CNTs the ECSA reduction was mitigated largely. Moreover, by using our PBI method ECSA reduction was observed at minimum, giving an ultimate chemical stability to PEMFC Pt composites, showcasing the inherited chemical stability of CNTs[21-23].

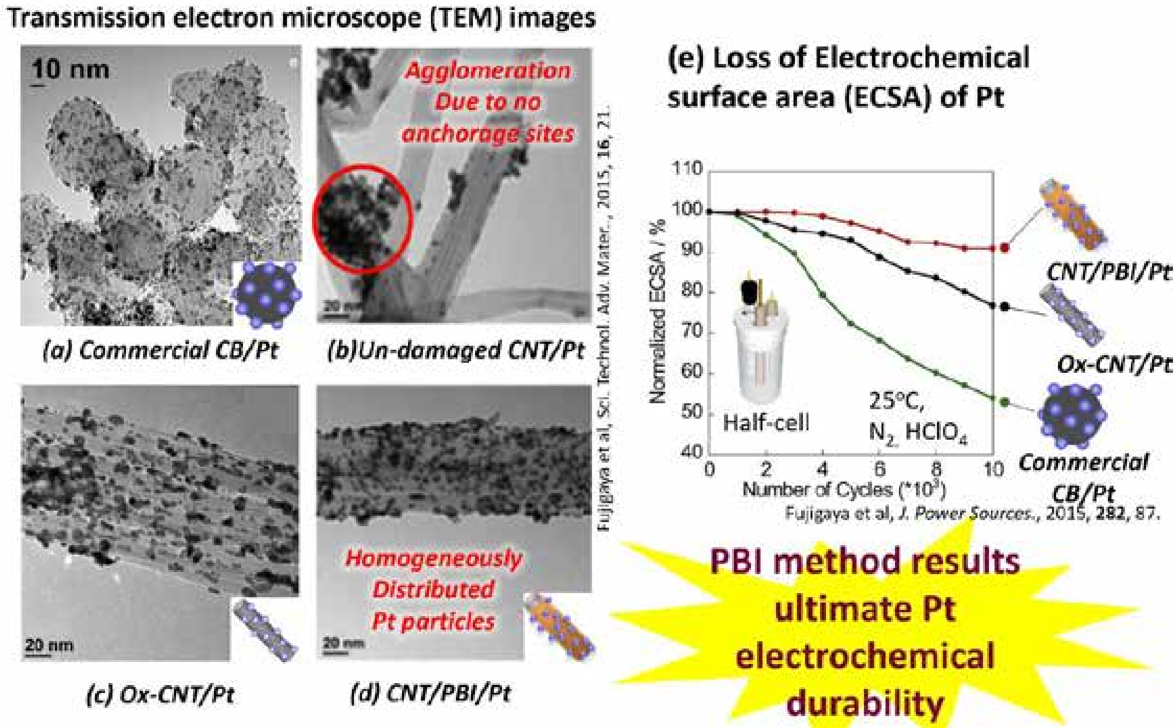

Figure 4 – TEM images of Pt particles deposited on (a) commercial CB, (b) an un-damaged CNT, (c) oxidized CNT, (d) PBI wrapped CNT and (d) a graph showing loss of electrochemical surface area with number of potential cycles.

References

1. Kim, J.H., et al., *Effects of Cathode Inlet Relative Humidity on PEMFC Durability during Startup–Shutdown Cycling: II. Diagnostic Study.* Journal of The Electrochemical Society, 2010. **157**(5): p. B633-B642.
2. Kim, J.H., et al., *Development of a Durable PEMFC Startup Process by Applying a Dummy Load: I. Electrochemical Study.* Journal of The Electrochemical Society, 2009. **156**(8): p. B955-B961.
3. Cai, M., et al., *Investigation of thermal and electrochemical degradation of fuel cell catalysts.* Journal of Power Sources, 2006. **160**(2): p. 977-986.
4. Virkar, A.V. and Y. Zhou, *Mechanism of Catalyst Degradation in Proton Exchange Membrane Fuel Cells.* Journal of The Electrochemical Society, 2007. **154**(6): p. B540-B547.
5. Young, A.P., J. Stumper, and E. Gyenge, *Characterizing the Structural Degradation in a PEMFC Cathode Catalyst Layer: Carbon Corrosion.* Journal of The Electrochemical Society, 2009. **156**(8): p. B913-B922.
6. Yu, X. and S. Ye, *Recent advances in activity and durability enhancement of Pt/C catalytic cathode in PEMFC. Part II: Degradation mechanism and durability enhancement of carbon supported platinum catalyst.* Journal of Power Sources, 2007. **172**(1): p. 145.
7. Ye, S., M. Hall, and P. He, *PEM Fuel Cell Catalysts: The Importance of Catalyst Support.* ECS Transactions, 2008. **16**(2): p. 2101-2113.
8. Shao, Y., et al., *Durability Study of Pt/C and Pt/CNTs Catalysts under Simulated PEM Fuel Cell Conditions.* Journal of The Electrochemical Society, 2006. **153**(6): p. A1093-A1097.
9. Wang, X., et al., *Durability investigation of carbon nanotube as catalyst support for proton exchange membrane fuel cell.* Journal of Power Sources, 2006. **158**(1): p. 154-159.
10. Yang, W., et al., *Bamboo-like Carbon Nanotube/Fe3C Nanoparticle Hybrids and Their Highly Efficient Catalysis for Oxygen Reduction.* Journal of the American Chemical Society, 2015. **137**(4): p. 1436-1439.
11. Shao, Y., et al., *The corrosion of PEM fuel cell catalyst supports and its implications for developing durable catalysts.* Electrochimica Acta, 2009. **54**(11): p. 3109-3114.
12. Li, W., et al., *Preparation and Characterization of Multiwalled*

Carbon Nanotube-Supported Platinum for Cathode Catalysts of Direct Methanol Fuel Cells. The Journal of Physical Chemistry B, 2003. **107**(26): p. 6292-6299.

13. Huang, X.X., et al., *Porous-structured platinum nanocrystals supported on a carbon nanotube film with super catalytic activity and durability.* Journal of Materials Chemistry A, 2015. **3**(15): p. 7862-7869.
14. Schonvogel, D., et al., *Stability of Pt Nanoparticles on Alternative Carbon Supports for Oxygen Reduction Reaction.* Journal of The Electrochemical Society, 2017. **164**(9): p. F995-F1004.
15. Sheng, W., et al., *Synthesis, Activity and Durability of Pt Nanoparticles Supported on Multi-walled Carbon Nanotubes for Oxygen Reduction.* Journal of The Electrochemical Society, 2011. **158**(11): p. B1398-B1404.
16. Yang, Z., T. Fujigaya, and N. Nakashima, *Homogeneous coating of ionomer on electrocatalyst assisted by polybenzimidazole as an adhesive layer and its effect on fuel cell performance.* Journal of Power Sources, 2015. **300**: p. 175-181.
17. Fujigaya, T., M. Okamoto, and N. Nakashima, *Design of an assembly of pyridine-containing polybenzimidazole, carbon nanotubes and Pt nanoparticles for a fuel cell electrocatalyst with a high electrochemically active surface area.* Carbon, 2009. **47**(14): p. 3227-3232.
18. Matsumoto, K., et al., *Bottom-up design of carbon nanotube-based electrocatalysts and their application in high temperature operating polymer electrolyte fuel cells.* Journal of Materials Chemistry, 2011. **21**(4): p. 1187-1190.
19. Fujigaya, T. and N. Nakashima, *Fuel Cell Electrocatalyst Using Polybenzimidazole-Modified Carbon Nanotubes As Support Materials.* Advanced Materials, 2013. **25**(12): p. 1666-1681.
20. Okamoto, M., T. Fujigaya, and N. Nakashima, *Design of an Assembly of Poly(benzimidazole), Carbon Nanotubes, and Pt Nanoparticles for a Fuel-Cell Electrocatalyst with an Ideal Interfacial Nanostructure.* Small, 2009. **5**(6): p. 735-740.
21. Berber, M.R., et al., *Durability analysis of polymer-coated pristine carbon nanotube-based fuel cell electrocatalysts under non-humidified conditions.* Journal of Materials Chemistry A, 2014. **2**(44): p. 19053-19059.
22. Berber, M.R., et al., *Remarkably Durable High Temperature Polymer Electrolyte Fuel Cell Based on Poly(vinylphosphonic acid)-doped Polybenzimidazole.* Sci. Rep., 2013. **3**: p. 1764.
23. Yang, Z., M.R. Berber, and N. Nakashima, *Design of Polymer-Coated Multi-Walled Carbon Nanotube/Carbon Black-based Fuel Cell Catalysts with High Durability and Performance Under Non-humidified Condition.* Electrochimica Acta, 2015. **170**: p. 1-8.

Evaluation of the cure characteristics and physico-mechanical properties of treated Oil Palm Fiber based Natural Rubber Composites

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Abstract

The global production of palm oil has grown with the emerging demand for vegetable oils in the past decades which produced 71 million tonnes of oil as at 2018 (Ritchie and Roser, 2021). This industry produces different types of waste materials such as empty fruit bunch, palm kernel shells, etc. during the process. This research was carried out to identify the application of the waste, mesocrap fiber part of the oil palm fruit (OPF) as a potential filler material in natural rubber composites by studying the cure characteristics and physico-mechanical properties. The fiber size of the OPF was reduced to micro size with a mechanical treatment followed by a chemical treatment and composites were prepared with different fiber sizes. The results revealed that the application of 2 phr loading of treated OPF enhances certain physico-mechanical properties and cure characteristics compared to a carbon black filled control compound.

Introduction

Natural fiber has attracted great interest in the rubber processing industry due to the growing concerns in developing green materials. Numerous types of natural fibers are being studied which are generated from animals, plants and other natural materials. The properties of the fibers again differ with the source of fiber generating area such as leaf, bast, seed, fruit, root etc. The chemical composition and structural variations within the fibers enable to generate different physico-mechanical properties in various applications. Plant fibers such as cotton, jute, hemp, coir has been widely used for different studies (Lila, *et al*., 2016) for full or partial replacement for hazardous filler materials such as Carbon black or Silica.

The adhesion of the interface between the rubber polymer and the fiber matrix acts as a crucial point when determining the physical properties (Zafeiropoulos, 2008). The common disadvantages existing in natural fiber materials are the heterogenic, hydrophilic nature and polarity. As a result, the incorporation of fiber to the rubber matrix requires a modification of the fiber or a modification in the rubber matrix to enhance the resultant properties.

The modification of the fiber material before incorporating to the rubber phase can be conducted by chemical treatment, physical treatment or both. Silylation, mercerization and other related modifications (Lila, *et al*., 2016) (Faruk *et al.*, 2012) can be considered for chemical modifications whereas the use of shearing based mechanical actions are widely used for particle size variation.

Several studies have been conducted by incorporating short fibers in rubber compounds*(Jacob et al.*, 2004). The main idea is to increase the interfacial adhesion by introducing a higher surface area with a low amount of

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loading. Additionally the ease of process, reduction of cost and at the same time improvement in the physical, chemical properties were expected with the substitution of natural fibers (Joseph *et al.,* 2006). In this study variation of fiber size was generated from the mesocrap part of the Oil Palm Fiber (OPF). The OPF used was generated as a waste material in the palm oil processing. When considering the palm oil process only 30% of the total weight of the plam oil tree's fresh fruit bunch is utilized for the oil production and the rest 70% is generated as a waste (Nugroho and Susanto, 2021)PKS (Palm Kernel Shell. Several studies have been carried out by incorporating empty fruit bunch fiber for plastic, PP, epoxy and polyester resin composites to investigate the reinforcement level, dynamic electrical properties and mechanical properties (Faruk *et al.*, 2012). OPF is a lignocellulosic fiber obtained from the oil palm tree (*Elaeis guineensis*) which is a hard, tough material which can be used with natural rubber as a potential reinforcing agent. Application of micro sized cellulose fibers can broaden its applications from next generation smart sensors, miniature computer components which requires high thermal stability, strechability to automotive components such as bumpers, which requires high level of shock absorbance (Kato *et al.*, 2015).

The main objective of this study is to compare and contrast the effect of OPF micro sized particles on cure characteristics and physico-mechanical properties at a low loading level.

Materials

Natural rubber (RSS 2) was supplied from the Dartonfield Estate, Agalawatta, Sri Lanka. Rubber compounding ingredients such as zinc oxide (ZnO), stearic acid, TMQ (2,2,4 trimethyl 1,2-dihydroquinoline), CBS (N-cyclohexyl-2-benzothiazole sulfenamide), sulphur were purchased from Glorchem Enterprise, Colombo, Sri Lanka. Chemicals for synthesizing micro size OPF namely sodium hydroxide, sodium chlorite and oxalic acid were purchased from Organic Trading (Pvt.) Ltd., Sri Lanka.

OPF waste of the oil palm fruit was sourced from Nakiyadeniya Oil Palm Mill.

Experimental Procedure

Synthesis of chemically treated micro sized OPF

The waste OPF was initially washed with clean water to remove the impurities and oven dried at 100°C for 48 hours. The samples were then cut into pieces and ground using a mechanical grinder.

Chemical treatment

Oil palm fibers were soaked in 2 % sodium hydroxide and placed for six hours at room temperature. Alkali treated fibers were then subjected to the steam explosion and a laboratory autoclave, which work with 0.1 MPa pressure was used for steam treatment. Steam explosion technique was applied on the alkali treated fiber for half an hour. Steam pre-treatment was performed by loading the lignocellulosic material directly into the steam gun and treating it with high pressure steam at a temperature of 120 °C.

The steam exploded fiber was then subjected to bleach. A sodium chlorite ($NaClO_2$) solution (pH 2.3) was used for this for 1 hour at 50 °C. This was performed to remove the remaining lignin.

The bleached sample was then subjected to mild acid treatment. 5 % oxalic acid was used for the acid hydrolysis followed by second step of steam explosion for half an hour. A pressure of 0.1 MPa was used and the fibres were then sonicated for half an hour to reduce the size further (Abraham *et al.,* 2013). The sonicated fiber sample was then centrifuged for half an hour in a centrifuge machine with a rotor speed of 9000 rpm. The fiber portion of the centrifuged sample was then separated and washed thoroughly using distilled water to remove the excess chemicals. Washed sample was then oven dried at 70 °C. The dried sample was sieved using meshes in the range of 25 μm to 350 μm.

Preparation of dry rubber composites

Six different types of dry rubber composites were prepared using the formulation described in Table 1. The sample with carbon black (2phr) was considered as the control sample C0 and the rest of the samples were classified as below according to the variation of fiber size.

C0 - Control sample with carbon black added as filler

C1 - (250 μm -350 μm) size fiber particles

C2 - (125 μm -175 μm) size fiber particles

C3 - (75 μm -125 μm) size fiber particles

C4 - (25 μm -75 μm) size fiber particles

C5 – (below 50 μm) size fiber particles

The compounds were then prepared using a two roll mill. The total mixing time was kept as a constant for 8 minutes as described in Table 2.

Table1: Formulation of NR/OPF fiber compounds

Ingredient	Phr (Parts per hundred parts of rubber)	
	C0 (Control)	C1-C5
RSS 2	100	100
ZnO	5	5
Stearic acid	2	2
TMQ	1	1
CBS	1	1
Sulphur	2	2
Carbon black	2	-
OPF	-	2

The mixing cycle used is stated in Table 2. Samples were then molded using a laboratory scale hydraulic hot press machine.

Table 2: Mixing cycle used in the preparation of NR/OPF compounds

Chemical added	Time (min)
NR	0
ZnO + Stearic acid + TMQ	2
Filler	3
CBS	5
Sulphur	6
Dump	8

Determination of the cure characteristics of the composites

Rheological properties of compounded samples were analyzed using D-RPA 3000 Dynamic Rubber Process Analyzer (MonTech) at the temperature of 150 °C.

Measurement of physico-mechanical properties of the composites

The tensile properties were measured using Instron tensile testing machine. The properties tensile strength of the vulcanisates were measured in accordance with ISO 37: 2017 at room temperature (27 ± 2°C) at a grip separation rate of 500 mm / min. Tear strength of the vulcanisates was measured using angle (Die B) test pieces with the aid of the same machine as per ISO 34-1:2010. The hardness (Shore-A) of the rubber compounds were determined according to the ASTM D2240 test method.

The water absorption percentage of the vulcanizates was measured by immersing vulcanized pieces of the composites for three days and calculating the results according to the following formula.

$$\text{Water absorption (\%)} = \frac{(m_2 - m_1)}{m_1} \times 100$$

Where,

m_1= Initial mass of the test piece (g)

m_2= Final mass of the test piece (g)

Morphology

Surface morphology of the treated fibers on the size range of less than 50 µm was examined by Scanning Electron microscopy (SEM) using a ZEISS EVO LS 15 Microscope (Figure 1). The specimen was sputter coated with a thin layer of gold to avoid electrostatic charging during examination.

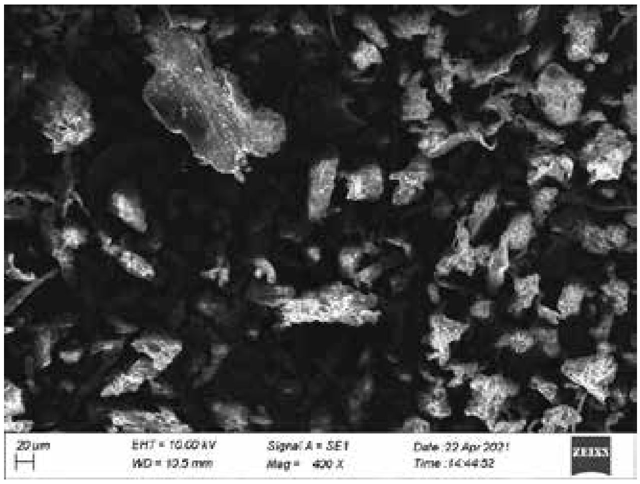

Figure 1. Morphology of treated OPF in the size range of less than 50µm

Results and Discussion

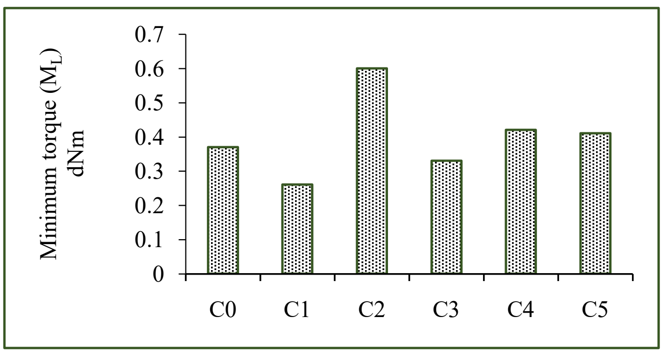

Figure 2. Minimum torque of NR/OPF composites

The minimum torque (M_L) of a compound relates to processability and stock viscosity of unvulcanized rubber (Edirisinghe *et al.*, 2015). According to the results obtained (Figure 2), it was perceived that the composite C2 (with 125 µm -175 µm size OPF) indicated a comparatively high value compared to the control composite and other composites. This indicates a poor dispersion of the OPF within the matrix with the size range of 125 µm -175 µm, which can lead to reduce processability. Additionally, the rest of the composites have indicated almost similar values to that of the control composite with satisfactory level of processability.

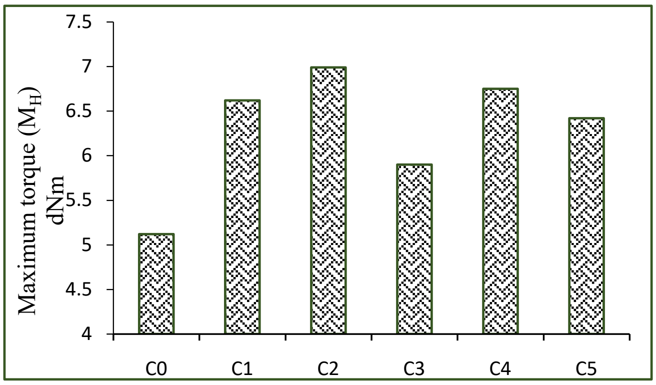

Figure 3. Maximum torque of NR/OPF composites

The stiffness of the fully vulcanized compound is represented by the maximum torque (M_H) value. With the initiation of the curing process the torque value tends to increase with the generation of crosslinks. According to the Figure 3, all the samples have torque values greater than the control composite. However, a systematic trend of the M_H values cannot be observed in the samples C1-C5. The reason for this can be the different levels of fiber entanglements occurring within the matrix. The highest stiffness can be expected with the composite C2, which has the highest torque value. This result is further evident from the hardness values obtained in Figure 10.

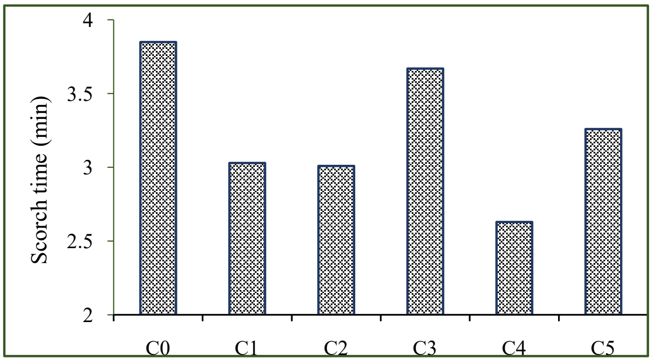

Figure 4. Scorch time of NR/OPF composites

The scorch time represents the processing safety feature of the sample (Formela *et al.*, 2015)static mechanical properties (tensile strength, elongation-at-break, hardness and resilience and according to the results (Figure 4) an increased processing safety can be seen with the C3 composite which has a close value to the C0 composite.

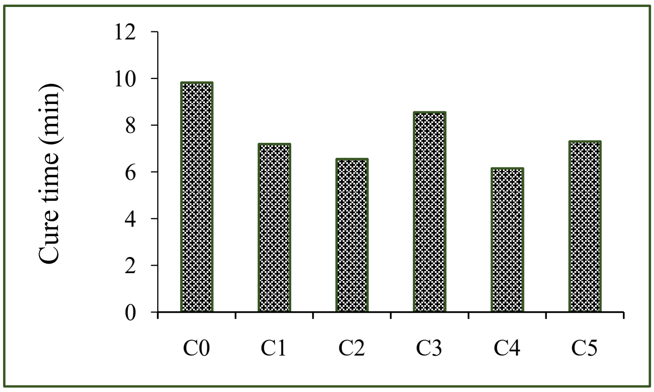

Figure 5. Cure time of NR/OPF composites

The variation of 90% cure time of the composites is represented in Figure 5 and according to the results the highest cure time has been obtained by the control composite. The values vary in the range of 6-10 minutes and the results reveal that the OPF fiber size range has no effect on the cure time since a significant trend is not available even though lower time has been consumed to cure the rubber article compared to the composite C0.

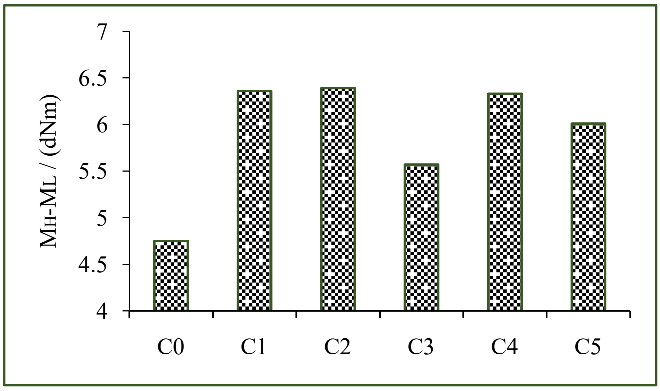

Figure 6. Delta cure of NR/OPF composites

The difference between maximum torque and minimum torque indicates the level of crosslink density of a composite. The variation of delta cure values of the composites is illustrated in Figure 6. The delta cure results of composites C1-C5 have generated high values compared to that of the control composite, which indicates greater rubber-filler interaction than filler-filler interaction existing in the OPF filled composites. This indicates that the addition of OPF to the matrix has uplifted the crosslink generation process.

Physico-mechanical properties

The variation of tensile strength of NR/OPF based composites is illustrated in Figure 7. The results indicate favorable values when compared to the control composite prepared with the filler carbon black. The composites C1-C5 have generated 17-33% increment in tensile strength compared to the control composite with a tensile strength of 16.2MPa. This indicates that incorporation of treated OPF has generated better NR-filler adhesion than the carbon black filled composite. The highest value of 24.4MPa has been generated by the composite C2. However, the reduction in fiber size has not presented a significant property enhancement for the same level of fiber loading. A study carried out by Joseph *et al*. (2006) revealed that the physical properties of a composite can vary not only with the aspect ratio of the fibers, but also with different other factors such as fiber orientation, fiber dispersion and fiber-matrix adhesion. These can be possible reasons for the fluctuated values of tensile strength of the composites C1-C5.

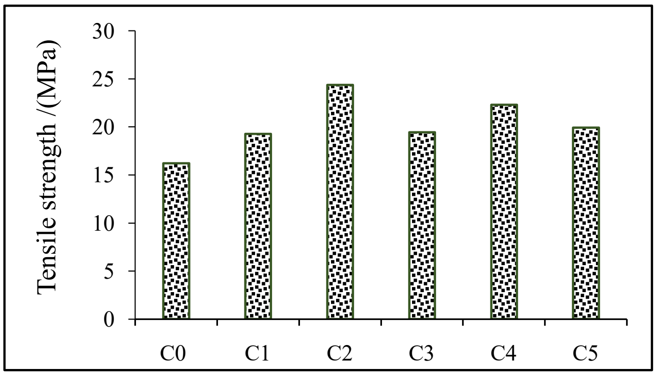

Figure 7. Tensile strength of NR/OPF composites

The elongation at break values has not shown a significant variation within the composites C1-C5 (Figure 8). However, when compared to the C0 composite, elongation at break values are lower. These values can be related to the trend in hardness observed in Figure 10, where the control composite has generated the lowest hardness of 28 Shore A and the NR/OPF composites have generated higher hardness values.

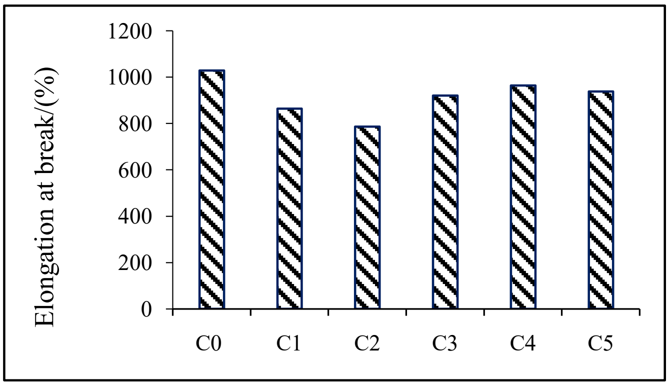

Figure 8. Elongation at break of NR/OPF composites

The tear strength of the composites C1-C5 has varied in the range of 27.44 N/mm to 175.1N/mm (Figure 9). A significant increase in tear strength in the latter composites can be observed with the decrease in fiber size. The control composite has generated a value of 131.9N/mm. This represents the variation of the dispersion of the larger fiber sizes compared to the smaller fiber sizes. The crack propagation has been a stress-free task for the composites C1, C2. One possible reason is the poor dispersion of the filler material in the NR matrix. This can be due to the reduced effective surface area of the larger size fibers and possible agglomerations. However with the higher effective surface area of the filler with lower fiber size, rubber-filler interactions have been improved, resulting in increased tear strength for the C3-C5 composites, which is greater than that of the control composite.

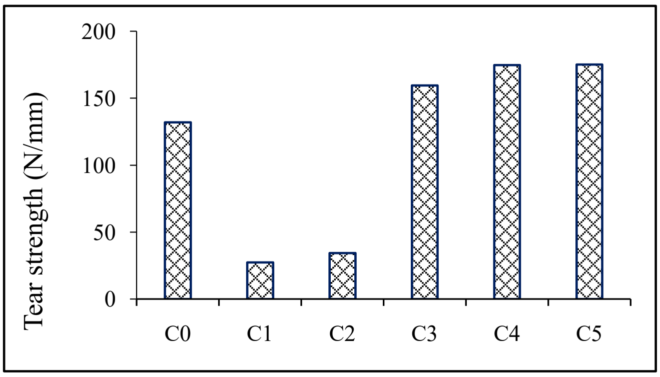

Figure 9. Tear strength of NR/OPF composites

The hardness values (Figure 10) are in agreement with the MH trend of cure characteristics (Figure 3) and the elongation at break results (Figure 8). All the composites with OPF has generated high hardness values when compared to the control composite (28 Shore A), which indicates enhanced compound stiffness generated by treated OPF. This can be attributed to increased compatibility between the treated OPF fiber and NR compared to that of carbon black filler. As the size of the OPF decreases, hardness has represented decreased values from C3-C5. This indicates that the larger fiber size has enhanced the hardness property than the smaller fiber sizes.

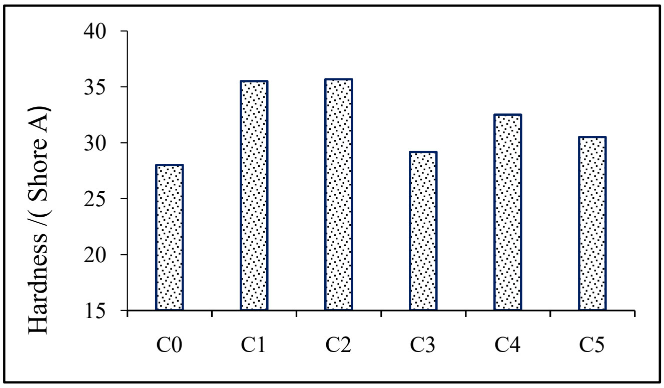

Figure 10 Variation of Hardness

The water absorption level of the fiber composites has generated higher values compared to that of the control composite (Figure 11). The main reason can be the affinity of cellulose rich natural fibers towards the water molecules and the porosity existing with the OPF, which then results in providing a cooling effect to the matrix. A study carried out by Bopada *et al.* (2021) revealed that the mesocrap part of the OPF has increased the level of water absorption regardless of the duration of immersion in water of OPF based fiber cement mortar composite. The uptake of the water molecules has increased with the decreasing fiber size and a sudden drop can be seen in the final composite C5. This may be due to possible agglomerates generated within the composite leading to lower the effective surface area.

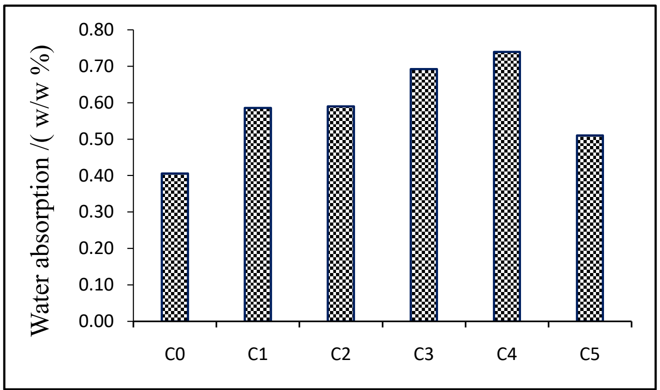

Figure 11. Water absorption of NR/OPF composites

Conclusions

The incorporation of chemically treated OPF into NR compounds has generated enhanced tensile strength and hardness for the composites compared to the control composite filled with carbon black. The analysis of cure characteristics indicated enhanced crosslink density and favorable cure time for the NR composites prepared with treated OPF, whereas the scorch time was reduced for the same. However, the reduction in particle size did not demonstrate a significant trend in regard to the cure characteristics. One possible reason is the amount of OPF loading (2phr) used to evaluate the effect of compatibility of micro size OPF with NR. Nevertheless, even with such a low loading level the enhancement of the mechanical properties provides an idea about the novel economical and eco-friendly approach to use treated OPF as a substitute to synthetic filler materials for highly flexible, low hardness property related applications.

References

1. Hannah Ritchie and Max Roser (2021) - "Forests and Deforestation". *Published online at OurWorldInData.org.* Retrieved from: 'https://ourworldindata.org/forests-and-deforestation' [accessed on 28/12/2021]

2. N.E. Zafeiropoulos , Chapter 3 - Engineering the fibre – matrix interface in natural-fibre composites, Editor(s): Kim L. Pickering, In Woodhead Publishing Series in Composites Science and Engineering, Properties and Performance of Natural-Fibre Composites, Woodhead Publishing, 2008, Pages 127-162

3. Abraham E.B., Deepa, (2013), Environment friendly method for the extraction of coir fiber and isolation of nanofibers, Carbohydrate polymers,92(2),1447-1483

4. Formela, K., Wąsowicz, D., Formela, M. *et al.* Curing characteristics, mechanical and thermal properties of reclaimed ground tire rubber cured with various vulcanizing systems. *Iran Polym J* **24,** 289–297 (2015). https://doi.org/10.1007/s13726-015-0320-9

5. Edirisinghe, D. G., Sampath, W. D. M. and Wettasinghe, P. C. (2015) 'Effect of latex coated coconut fibre on cure characteristics and physico mechanical properties of natural rubber-coir composites', *Journal of the Rubber Research Institute of Sri Lanka*, 95(0), p. 1. doi: 10.4038/jrrisl.v95i0.1832.

6. Faruk, O., Bledzki, A.K., Fink, H.P. and Sain, M. (2012) Biocomposites Reinforced with Natural Fibers: 2000-2010. Progress in Polymer Science, 37, 1552-1596. http://dx.doi.org/10.1016/j.progpolymsci.2012.04.003

7. Formela, K., Wąsowicz, D., Formela, M.. Curing characteristics, mechanical and thermal properties of reclaimed ground tire rubber cured with various vulcanizing systems. *Iran Polym J* **24,** 289–297 (2015). https://doi.org/10.1007/s13726-015-0320-9

8. Jacob, M., Thomas, S. and Varughese, K. T. (2004) 'Natural rubber composites reinforced with sisal/oil palm hybrid fibers: Tensile and cure characteristics', *Journal of Applied Polymer Science*, 93(5), pp. 2305–2312. doi: 10.1002/app.20696.

9. Joseph, S., Joseph, K. and Thomas, S. (2006) 'Green composites from natural rubber and oil palm fiber: Physical and mechanical properties', *International Journal of Polymeric Materials and Polymeric Biomaterials*, 55(11), pp. 925–945. doi: 10.1080/00914030600550505.

10. Kato, H., Nakatsubo, F., Abe, K., Yano, H. (2015) 'Crosslinking via sulfur vulcanization of natural rubber and cellulose nanofibers incorporating unsaturated fatty acids', *RSC Advances*, 5(38), pp. 29814–29819. doi: 10.1039/c4ra14867c.

11. Lila, M. K., Komal, U. K. and Singh, I. (2016) 'Cellulose based Nano-composites: Synthesis and Application', *International Conference on Nanotechnology for Better Living - ICNBL-2016*, (June), pp. 1–2.

12. Nugroho, N. and Susanto, D. (2021) 'Natural Fiber Waste from Palm Oil Tree: An Overview of Potential Usage for Indonesia's Affordable House Building Materials', *Journal of Architectural Research and Design Studies*, 5(1). doi: 10.20885/jars.vol5.iss1.art3.

The Effect of the Working Environment on the Productivity of the Employees

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Abstract

It is crystal clear that the condition of the work environment affecting the productivity of the workers.This also inspires the workers to reduce the absenteeism, attendance to work, accidents and other negative attitudes. Therefore, this article confirms the importance of improving the work environment and its impact on the productivity of the workers.

Introduction

It is a fact that human workforce is needed in some way to drive any organization. Thus, every activity that they do, follows the targets of the organization. Hence, the work environment in which they perform helps to enhance the productivity. Therefore, the condition of the work environment has a direct contribution to achieve the set targets of the organization.

The working environment includes the infrastructure, noise levels, dust, temperature, and ventilation, so on. Even though, some of the organizations are reluctant to invest on improving the working environment thinking that they will not gain any profit, it is the prime responsibility of the employer to improve the working environment to facilitate the employees as it directly affecting to achieve the given targets. It is same as the two sides of a coin. Moreover, the employer is legally bound to provide safe and sound work environment to the workers.

Furthermore, the experiences are shown the workers perform more efficiently in sound working environments, whereas low productively observed, in poor working environments.

Types of work Environments

There are two categories of work environments. Such as;

- Internal
- External

➢ **The Internal work environment**

Internal work environment is seen as the surroundings such as; things concerned with the operation. Molokwu (1993) viewed internal work environment as buildings, furniture, layout, as well as the physical conditions under which employees operate.

➢ **The External work environment**

Molokwu (1993) sees external work environment as a result of factors such as customs and laws of the community within which the business operates, weather conditions, policies, etc. outside the work environment.

Kochan (1980) was of the opinion that external work environment exhaustively discussed as under the contexts such as economic context, public, policy context, etc.

Factors in the work environment that influence the productivity of the employees

➢ **Safety measures**

It is obvious that the safety measures are one of the key elements of an organization. In addition, this is considered as a legal requirement as per the Factories Ordinance No. 45 of 1942. Hence the employer is responsible for assuring the health and safety of the workers by complying with the relevant guidelines related to work environment and providing awareness with necessary PPEs. That definitely improve the moral of the employees. As result, the employees will immensely contribute towards the success of the organization.

➢ **Preventing the Overcrowding**

Molokwu (1993) emphasizes that there should be an enough space for movements of both workers and materials also, to enhance the effective operational process. As per the Factories ordinance No. 45 of 1942 PART II Section 07 speaks about the Overcrowding. As per the regulation there should be 400 cubic meters per person. Hence it is understood that the workers should be provided enough space in the working environment to relieve their working stress and to perform their operation in more safe and productive manner.

- **Ventilation**

Grott (1964) Stated that stuffy atmosphere reduces capacity to think and act, this reduces the output of workers. He went on stating that, proper ventilation, makes for a healthy working environment, avoid fatigue, laziness, etc. and consequently promotes worker efficiency.

As per the Factories Ordinance PART II Section 12 there should be an effective and suitable provision made for securing and maintaining by the circulation of fresh air in each workroom, the adequate ventilation of the room and for rendering harmless, so far as practicable all fumes, dust and other impurities injurious to health that may be generated in the course of any process or work carried-on in the factory.

- **Adequate light Levels**

Infact there should be a suitable light level in the working environment in order to perform any operation. Also the required light level defers from activity to activity considering sensitivity. Onibon (1974) pointed out that inadequate lighting affects workers' interest and attitude towards their work and make them suffer from degree of age strains and fatigue.

As per the Factories Ordinance Part II Section 13, effective provision shall be made for securing and maintaining sufficient and suitable lighting, whether natural or artificial in every part of a factory in which persons are working or passing. As per the Sri Lankan Gazette No. 2142/90 published in September 27, 2019, tasks wise light levels are defined.

SCHEDULE		
	Area of workplace	**Level of Illuminance**
a	Stores	100 to 150 lux
b	Rough work or heavy work (tasks with limited visual requirements)	150 to 300 lux
c	Factory including cubicles/ rooms of office and Cashiers, kitchens, class rooms, dining rooms, computer rooms	300 to 500 lux
d	Factory assembly lines, grinding, sewing, drilling enameling, machine work (tasks with normal visual requirements)	500 to 750 lux
e	Instrument assembly lines, fine work	750 to 1000 lux
f	Very fine work, Color matching, fabric inspection Jewelry assembling and repairing (task with special visual requirements)	1000 to 2000 lux
g	Micro - electronics, watch making etc. (Prolong tasks that require precision)	2000 to 3000 lux

- **Noise Level**

Noise also plays a vital role in relation to job performance of the employees, as high noise can generate additional pressure towards the job performance of the employees. And that can slow down the productivity.

According to Betts (1995) noise has been criticized as having detrimental effect on mental and physical health mechanism of employees. And overall productivity. For him, the effect of noise on productivity include, irritation, different in concentration, fatigue and low moral on employees.

As per the Sri Lankan Gazette No. 2142/90 published in September 27, 2019 permissible noise level for 8 hours is 85dB. If the employees exposing more than 85dB in their work places, relevant engineering controls, administrative controls and PPEs are to be implemented by the employer as the high noise can slow down the productivity and increases the risk level for health and safety of the employees. Therefore, sound pressure level wise exposing time is defined.

Schedule	
Maximum Permissible Sound Pressure Levels	
Duration per day (in hours)	**Equivalent Sound pressure level dB (A) slow/TWA**
8	85
4	88
2	91
1	94
½	97
¼	100

- **Back ground Coloration**

Coloration in the working area also has an impact on the performance of the workers. As Molokwu (1993) states that bright and cheerful color base have great effect on employees' efficiency. Even these types of factors also having concern towards job performance.

- **House keeping**

As per the Factories Ordinance No.45 1942 this is a legal requirement. Apart from that cleanliness of the work environment has a significant impact for the job performance of the employees too. If the working environment is full of dust and dirt the job performance of the employees will be reduced as they find uneasy to work. Also their focus for the job is gone.

As per Molokwu (1993) unclean environment affects employees' life and health condition. Poor sanitary facilities will reduce the employees' productivity.

Developing a positive work environment

It is the responsibility of the management to create a positive work environment for the workers. In other words,it is setting the right tone at the work place. The best motivation and platform that the management can provide to the workers is to providing a well maintained and well-conditioned working environment in order achieve their set goals.

They say even for the cricketers to play the match the pitch has to be in standard condition.

Hence, it is understood, that the working environment has a direct influence on the job performance of the employees. A positive work environment helps to yield better performance and results for both employees and employer.

Characteristics of Positive work environment as follows;

- **Clear communication**

The effective communication from top to bottom and bottom to top is an essential phenomenon for developing a Positive environment. Employees need to identify the expectation of the employer and vice versa. That drives the way to achieve the planned goals of the Organization.

- **Rewarding**

In an Organization it is a need to have a system to evaluate the job performance of the employees through which we can appreciate and reward the workers for their dedicated work. Definitely that will motivate the employees to go extra mile with the organization and to keep up their dedicated work.

- **Engagement**

They say that the happier worker perform well. Therefore it is a need of an organization to develop an engaged work force. For that the management has to plan different activities other than the routine job. Specially by implementing the tools of team games, 5S, Cell systems, Quality circles etc, the management can build an engaged work force and that will do wonders within the organization. In addition, their creative ideas will strengthen the organization.

It has been revealed that the depressing and defected work environment reduces employee's moral and promote absenteeism, lateness, low labor turn over, waste of resources and other negative attitudes among employees. Whereas the provision of good working environment increases the moral, interests and job performance of the employees. Furthermore each of the various factors related to the work environment has significant impact in enhancing the employee's "morale". By improving the work environment, the capacity of the group of workers who are persistently moving ahead to achieve the given targets can be further enhanced. Thereby the employer is able to create the work place as an ideal home to enhance the job satisfaction and motivation for the workers.

Conclusion

From the perspective of workers, the working environment is of utmost important as that can impact their health and safety aspects. It's a challenge for most of the organizations to spend money on developing the factory work environments due to the present financial crisis. But still, it is required by the law itself.

On the other hand for achieving the organizational goals and targets work, environment plays a vital role. If the workers are provided with good environment that will carry a long way to enhance their moral and performance. If the work environment is neat and tidy, properly arranged, well illuminated and ventilated, the employees will feel a sense of belonging and this will make them to work efficiently and effectively towards the betterment of the organization. Hence,amidst of all the financial challenges, the investments for improving the work environment of the employees will yield priceless abundant fruits of success for the Organization.

References

1. Kochan, T. A. (1980). *Collective Bargaining and industrial relation. Richard D. Irwin USA.*
2. Grott, A. (1964). *Management in Organization New Alexander Hamilton Institution.*
3. Factories Ordinance No.45 (1942)

Evaluation of suitability of urea as a preservative in low ammonia centrifuged natural rubber latex

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Abstract

Low ammonia centrifuged natural rubber latex is generally preserved with the secondary preservative system, tetramethyl thiuram disulphide (TMTD) and zinc oxide (ZnO). This system is known to be carcinogenic due to the generation of nitrosamines. Hence the aim of this study was to evaluate the suitability of urea as an alternative for the TMTD/ZnO preservative system. Field latex was treated with the TMTD/ZnO system (Control) and varying quantities of urea to produce centrifuged latex. Latex was stored for 0, 15, 45 and 60 days and characterized. Physico-mechanical properties and resistance to thermal degradation were evaluated using cast latex films. The standard test for total extractable proteins, GC/MS analysis for nitrosamines and the standard microbiological examination were conducted. For urea treated latex, most of the characteristics were in accordance with the ISO specifications. Physical properties of the cast films produced with this latex were in accordance with the requirement for cast films. Aging studies of these films indicated higher resistance to thermal degradation than the Control. Also, a marked reduction in the total extractable protein content was observed in comparison to the Control. Microbiological examination further implies the suitability of urea as a preservative agent. In the GC/MS analysis, peaks accountable for N-Nitrosodibutylamine were identified only in the spectrum of the film produced with TMTD/ZnO system, but not in those produced with urea. Results in overall showed that urea, which does not indicate generation of nitrosamines could be an alternative for the TMTD/ZnO preservative system. The 0.021% urea treated latex sample and its cast film showed the best properties.

Introduction

Trees of the species *Hevea brasiliensis* produce the natural latex that consists of cis-1,4 polyisoprene, which is ultimately used in the production of a wide range of rubber articles.[1] Within few hours of collection, fresh natural rubber (NR) latex tends to coagulate spontaneously as a result of destabilization by microbial infection.[1] Hence NR latex should be preserved with long term or short term preservatives depending on the situation. Short term preservatives, also known as anticoagulants, such as ammonia and sodium sulphite are used to prevent coagulation until it reaches the factory.[2] Ammonia itself improves preservation.[3] Ammonia is a bactericide[3,4] and it enhances the colloidal stability of latex by generating the anionic form of the acidic groups at the surface of the rubber particles ensuring repulsion between the colloidal rubber particles.[4] Further, ammonia neutralizes some trace metal ions such as calcium and magnesium, preventing calcium and magnesium salt formation.[4]

High concentration of ammonia can cause irritating vapors, health hazards and also some damages to plant and equipment by means of corrosion.[5,4] Therefore, a reduced amount of ammonia in combination with a bactericide where the concentration of ammonia is reduced to about 0.2% (w/w) on total latex and the amount of bactericide ranging from 0.005 - 0.1% (w/w) on total latex[4] is known as the low ammonia (LA) preservation system. Formaldehyde, alkyl dithiocarbamates, zinc oxide, tetra-alkyl thiuram sulphides are some of the typical bactericides.[4]

Tetramethylthiuram disulphide (TMTD) with zinc oxide (ZnO) in 0.025% on latex[2] is the most common secondary preservative system for NR latex. TMTD, during vulcanization process can produce reactive intermediate structures that contain secondary amines.[6] When the intermediates react with nitrosating agents, nitrosamines are formed.[6] Nitrosamines are identified as potential carcinogens for animals including humans.[7,8] These substances have been demonstrated as carcinogenic for several species of animals and therefore identified as related to human cancers.[8] More than 90% of the identified 300 nitrosamines are classified as carcinogens or mutagens, and the target organs of nitrosamine attack are liver and lungs.[9] Moreover, most nitrosamines are volatile at low temperatures and the leaching of nitrosamines in production areas and warehouses can affect the planet's air quality.[9] Therefore, the world today is more and more concerned about nitrosamines and ASTM standard F 1313-90 limits the inclusion of N-nitrosamines to 10 μg/kg or less per chemical compound.[8] Considering the rapidly developing standards for rubber products all over the world, the purpose of this study was to evaluate the suitability of urea as a replacement for TMTD which would eliminate the generation of nitrosamines.

Urea has bacteriostatic properties.[10,11] The two scientists Symmers and Kirk have recommended urea as an antiseptic in 1915[10], and it is widely used as a disinfectant. Specially, urea is known for its ability for the deproteinization of natural rubber latex.[12] Urea can chemically denature proteins by changing the conformation of proteins through interactions.[13,14] The first step in unfolding proteins is the expansion of the hydrophobic core and then the core is solvated by water and later by urea.[13] Urea has the ability to interact directly with polar residues and the peptide backbone, and thereby stabilizes non-native conformations, thus urea can denature proteins by both direct and indirect mechanisms.[13,14] Exposure to proteins derived from NR latex can cause allergies.[15] Hence, the use of urea as a preservative is expected to be beneficial in eliminating nitrosamine generation as well as in deproteinization of NR latex. In aqueous solution, urea gradually degrades into ammonia and carbon dioxide in one of the three possible non-enzymatic hydrolysis pathways, acid catalyzed, base catalyzed or neutral.[16] Thus urea can improve preservation. Moreover, urea is known to be a cheap, readily available and non-toxic chemical and essentially no danger to the environment, animals, plant life and human beings.[17] Urea dissolves in water completely making it easier to incorporate with NR latex.

Materials and methodology

Field latex was obtained from the Dartonfield Estate of Rubber Research Institute of Sri Lanka, Agalawatta from selected healthy rubber trees of the same clone. All the other chemicals and compounding ingredients were purchased from a local supplier. A 15% solution of diammonium hydrogen phosphate (DAHP) was added to field latex and kept overnight for magnesium sedimentation in order to reduce the magnesium content to 80-100 ppm level[2]. A quantity of three litres of field latex was used for each system where TMTD/ZnO was added as the Control and varying quantities of urea from 0.016% w/w to 0.036% w/w of latex were added for the samples 1 to 5. The preservative systems used are given in Table 1. The samples were centrifuged at a speed of 8000 rpm using a centrifuge. Characteristics of the six centrifuged latex samples were evaluated as per the relevant ISO/EU standards. Thus, pH was determined according to ISO 976:2013 (E)[18]. Total solids content (TSC), dry rubber content (DRC), volatile fatty acid (VFA) number and mechanical stability time (MST) were determined according to ISO 124:2014 (E)[19], ISO 126: 2005[20], ISO 506:1992(E)[21] and ISO 35:2004 (E)[22], respectively. Characterization was repeated at 15, 30, 45- and 60-days intervals.

Table 1: Chemical components of preservative systems

System	Sample	TMTD (%)	Urea (%)	ZnO (%)	NH_3(%)	Amm-onium laurate (%)
LA-TMTD/ZnO	Control	0.013	-	0.013	0.3	0.05
Urea	1	-	0.016	-	0.3	0.05
Urea	2	-	0.021	-	0.3	0.05
Urea	3	-	0.026	-	0.3	0.05
Urea	4	-	0.031	-	0.3	0.05
Urea	5	-	0.036	-	0.3	0.05

Latex compounding was carried out for each system to produce cast films. Compounding was followed by stirring the latex samples at 300 rpm for 30 minutes using a mechanical stirrer. The formulation used in compounding is given in Table 2. Compounded latex was poured into glass moulds with 3 mm depth and kept undisturbed for 3 days to form dried films, before vulcanizing in the oven at 100 °C for 30 minutes.

Table 2: Formulation used in the preparation of cast latex films

Ingredient	Wet weight (pbw)[(a)]
60% NR latex	167
20% Solution of KOH (stabilizer)	2
50% Dispersion of sulphur	4
50% Dispersion of ZDC (accelerator)	2
50% Dispersion of ZnO	3
50% Dispersion of WSP (phenolic antioxidant)	2
50% Dispersion of whiting	40

pbw[(a)] = parts by weight

Tensile properties namely, tensile strength, elongation at break and modulus at 100% and 300% elongations were measured according to the standard ASTM D 412[23] and tear strength was measured according to ASTM D 624[24].Hardness of the specimens was measured by a type A durometer as per the standard ASTM D 2240[25]. The dumbbell shaped specimens for determination of tensile properties and angle shaped specimens for determination of tear properties were cut using metal dies. The thickness of the specimens was measured by a Wallace thickness gauge before subjecting to testing using an Instron 5943 standard universal testing machine at a grip separation rate of 500 mm / minute.

Also, the vulcanized latex films were aged for 72 hours at 70°C in an aging oven as per ASTM 3578-91[26]and tensile properties of the aged films were evaluated.

The EU directive standard EN 12868[27], a method for the isolation, identification and determination of N-nitrosamines was carried out for the cast films after aging. The nitrosamines, if present, were extracted to a nitrite containing artificial saliva salt solution and the solution was examined by gas chromatography (GC). The artificial saliva was prepared as described by the EN 12868 method, by dissolving 4.2g sodium hydrogen carbonate, 0.5g of sodium chloride, 0.2g of potassium carbonate and 30mg of sodium nitrite in water and by diluting to 900 ml with distilled water. Thereafter, the pH was adjusted to 9 with 0.1 M NaOH and diluted with distilled water to obtain a total volume of 1000 ml. Latex film samples of 10g were dipped into artificial saliva solution and the nitrosamines were extracted according to the conventional liquid-liquid extraction technique with dichloromethane as described in EN12868. The samples (1.0 µl aliquot) were analyzed by Agilent Technologies 7890A GC system coupled with an Agilent 5975C mass selective detector (Shimadzu GCMS-QP2010). A HP-5MS capillary column of 30 m x 0.25 mm internal diameter x 0.25µm film thickness was used. The flow rate of helium was 1.0 mL/min. The injector port was in split mode with split ratio of 1:1. The injector port temperature was 120 °C and the column temperature was programmed in two steps from 50 °C (held for 2 min.) to 160 °C at a rate of 10 °C/min and to 250 °C at a rate of 10 °C/min. The mass spectra were obtained by electronic impact at 70 eV and detection of compounds was carried out in selective ion monitoring (SIM) mode.

The standard test for proteins ASTM-D 5712-15[28] was carried out to determine the amount of total extractable proteins associated with NR latex films. Cut pieces of each test film was extracted in 0.01M phosphate buffer (pH 7.4) at 25 °C for 2 hours. The extracts were centrifuged at 500 rpm for 25 minutes to sediment particles. Protein precipitation was carried out using trichloroacetic acid (TCA) and phosphotungstic acid (PTA) solution followed by sodium deoxycholate (DOC) solution. The solution was centrifuged at 6000 rpm for 15 minutes and the resulting pellet was re-dissolved in 0.2 M sodium hydroxide, and the concentration of proteins was determined by Lowry micro-assay. Absorbance recorded at 750 nm were calibrated against standard Ovalbumin solution (1mg/ml) and the results were expressed as µg/g of latex film.

The standard test ISO-9252 was carried out for the examination of the rubber latices for presence and approximate concentration of viable aerobic and facultative anaerobic organisms. The test was done in the 60th day of latex storage. Identification of micro-organisms was outside the scope of this study. A nutrient medium was selected on the basis of the pH of the latex. Since pH of latex was above 7, beef extract agar was used. The composition of beef extract agar was 300g of beef extract, 5g of peptone, 5g of NaCl, and 10g of agar in 1 liter of water. Quarter strength (one part of the solution diluted with 3 parts of water) Ringer's solution containing 9 g of NaCl, 0.42g of anhydrous $CaCl_2$ and 0.20g of $NaHCO_3$ was used as the dilution fluid. A test portion of latex was serially diluted, and aliquots of each dilution were spread over the surface of the nutrient medium in a petri dish, followed by incubation at 30 °C for 3 days. The number of colonies of micro-organisms that developed were counted, multiplied by the dilution factor and recorded as colony-forming units per cm^3 of the original sample.

Results and Discussion

1. Characterization of Latex

pH

The graph of pH versus storage period was constructed using the average pH of 3 trials. The pH of the 0.016% urea solution is 7 and overall pH increases upon the concentration of urea samples. With the increase of storage period, there is a decrease in pH in all the samples including the Control. With the release of NH_3 to the outer environment, the basicity of the latex decreases. Possible release of amino acids by hydrolysis of the proteins and hydrolysis of lipids in basic medium to higher fatty acids, the total acid content could go up during storage.[2] Thus, the pH value of latex decreases. Bacterial action on non-rubbers such as proteins and carbohydrates present in latex can result in the formation of volatile fatty acids, which can also lower the pH of the latex.[2,4] All the five samples, which were treated with urea using different concentrations, show a higher pH than the Control (Figure 1). This could be because urea can be enzymatically hydrolyzed to ammonia and carbon dioxide by urease[29], which might be present in latex in minor quantities, in turn may contribute to the increase of pH.

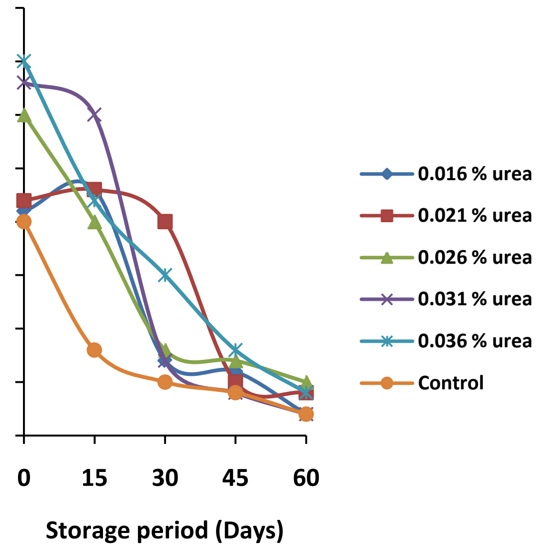

Figure 1. Variation of pH with storage period

Volatile Fatty Acid (VFA) Number

NR latex contains about 4-5% non–rubber constituents consisting mainly of carbohydrates, proteins and lipids.[30] VFA number of NR latex is an indication of bacterial action on carbohydrates.[31] Most predominantly a sugary substance present in latex namely, quebrachitol is consumed by bacteria in the presence of oxygen to form volatile fatty acids such as acetic and formic acids,[2] which increase the VFA number resulting in coagulation. Even though addition of DAHP can remove Mg^{2+} ions as magnesium ammonium phosphate $[Mg(NH_4)PO_4]$, there can be residual ions, which could enhance bacterial growth.

Variation of VFA number with storage period is shown in Figure 2. VFA number does not exceed the ISO 2004:2010(E)[32] specified value of 0.06 for concentrated latex.

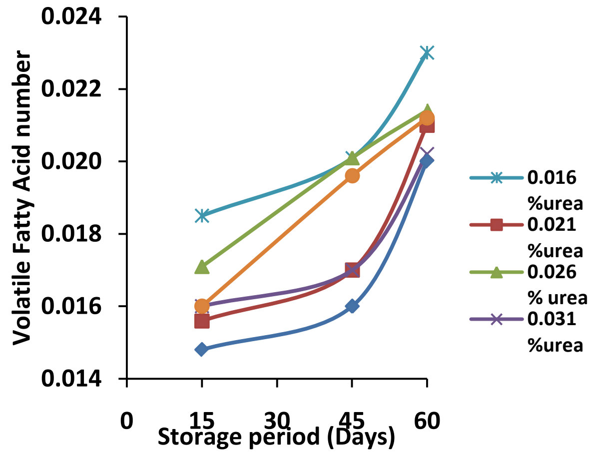

Figure 2. Variation of VFA number with storage period

The 0.016% urea preserved latex shows the highest VFA number (0.0185) at 15 days. This can be because of the comparatively low concentration of the secondary preservative urea, causing a lower bactericidal effect. Also, there is a remarkable decrease of VFA number in the sample prepared with 0.036% urea at all three storage periods and this indicates a better preservation. In the sample which 0.026% urea was added, a VFA number similar to that of the Control can be observed.

Mechanical Stability Time (MST)

The MST values determined were in between 800 to 1150 seconds and were found to be higher than the specified value of 650 seconds. Figure 3 below represents the variation of MST with storage period.

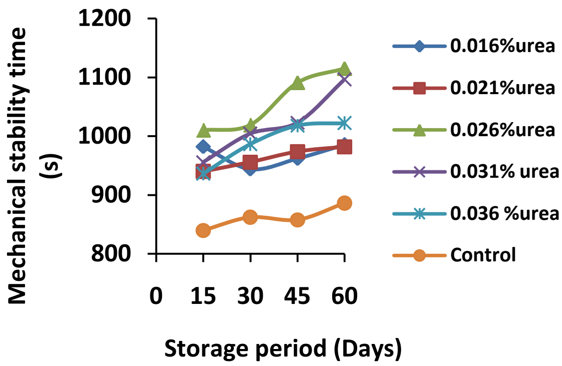

Figure 3. Variation of MST with storage period

An MST value higher than the expected is probably an outcome of higher pH. Samples containing 0.016% and 0.021% of urea, are the samples with low MST. More the anionic charges around the rubber particles, more the stability of latex towards mechanical agitation. Anions around the rubber particles keep them apart because of repulsive forces between each other. This leads to higher stability towards mechanical agitation. During the storage of latex, naturally occurring lipids present in NR latex undergo hydrolysis in a basic medium to form long chain fatty acids, which in turn enhance the negative charge density around the rubber particles increasing the stability of latex with time.[2]

Total Solids Content (TSC)

The total solids content of all six samples do not vary considerably (Table 3) and this suggests that TSC and in turn viscosity of latex is not affected by urea. Average viscosity of urea preserved samples is 79 cP, while that of the Control is 80 cP. This would then suggest that urea as the secondary preservative does not affect the total solids content or other parameters such as particle size distribution that could affect viscosity.

Table 3. Variation of TSC with storage period

Concent-ration of urea (%)	Total solids content (%)				
	0 days	15 days	30 days	45 days	60 days
0.016	63.30	63.48	63.45	63.38	63.46
0.021	63.40	63.45	63.34	63.41	63.40
0.026	63.40	63.32	63.36	63.42	63.38
0.031	63.40	63.41	63.21	63.30	63.38
0.036	63.42	63.54	63.32	63.48	63.42
Control	63.46	63.37	63.43	63.52	63.50

Dry Rubber Content (DRC)

Dry rubber content, which is the amount of rubber present in latex, gives a lower amount than TSC as expected. Moreover, the DRC of all samples do not show a significant alteration with storage period (Table 4).

Table 4. Variation of DRC with storage period

Concentration of urea (%)	Dry Rubber Content (%)				
	0 days	15 days	30 days	45 days	60 days
0.016	62.32	62.06	62.21	62.34	62.28
0.021	62.22	62.12	62.41	62.28	62.32
0.026	62.20	62.21	62.40	62.34	62.32
0.031	62.45	62.36	62.40	62.44	62.42
0.036	62.33	62.30	62.25	62.41	62.21
Control	62.12	62.20	62.34	62.26	62.16

2. Vulcanizate Properties of Latex Films

Tensile strength

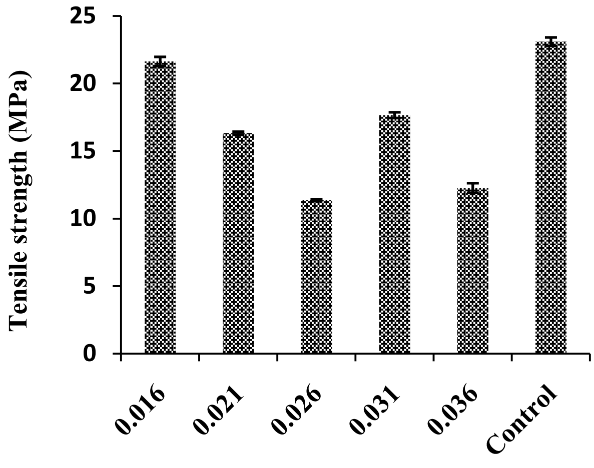

Figure 4. Variation of tensile strength with amount of urea

Ultimate tensile strength is known to be as the maximum stress the test pieces can withstand while being stretched, without fracturing**.** The Control shows a tensile strength of 23.08 MPa, which is higher than that of the urea treated samples (Figure 4). Control containing TMTD and ZnO can react together to form the active sulfurating agent facilitating vulcanization.[33] Thus, there will be more sulphur crosslinks forming in the Control. Failure properties like tensile strength increases upto a maximum value as crosslink density increases and then decreases.[33,34]the fraction p of cross-linked units in the products ranging from 0.10x 10?2 to 8.0 x 10?2. In spite of the small dimensions of the test specimen (cross section 0.10 in. by about 0.005 in. Crosslink density might be affected by addition of urea.

Modulus at 100% elongation

Variation of modulus at 100% elongation with the percentage of urea is presented in Figure 5.

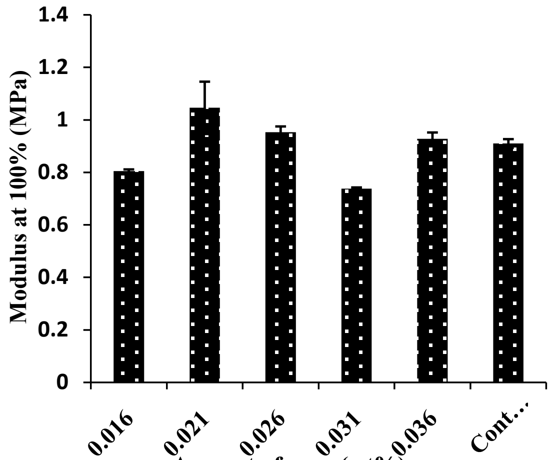

Figure 5. Variation of modulus at 100% elongation with amount of urea

Generally, modulus at 100% elongation is directly proportional to the stiffness or hardness. Higher the hardness, higher the amount of force required to elongate the film. The highest hardness is recorded for the 0.021% urea treated film, which also records the highest modulus at 100% elongation. The average of three experiments has been used in developing the graphs. As expected, modulus at 100% elongation shows a direct correlation with hardness.

Table 5. Hardness of cast latex films

Sample	Modulus at 100% elongation (MPa)	Hardness (Shore A)
0.016% urea	0.81	34
0.021% urea	1.05	47
0.026% urea	0.95	30
0.031% urea	0.74	34
0.036% urea	0.93	41
Control	0.91	43

Elongation at break

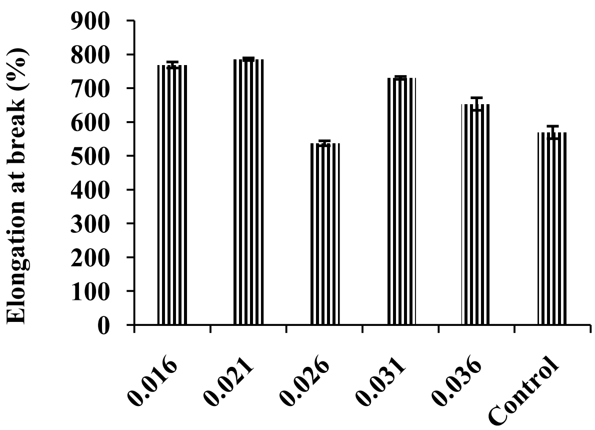

Figure 6. Variation of elongation at break with amount of urea

Urea treated cast latex films except that treated with 0.026% urea, show a higher elongation at break in comparison to the film prepared with TMTD/ZnO preserved latex (Control). As stated earlier, in the Control there could be more crosslinks formed due to the presence of TMTD and ZnO and this in turn would reduce elongation at break.

Tear strength

It is known that hardness increases with increase in crosslink density[33]. Hence out of the urea treated samples, the maximum crosslink density is expected in 0.021% urea treated sample. Figure 7 shows the expected variation in tear strength with the amount of urea. The highest tear strength shown by the Control could be attributed to thiuram accelerated vulcanisation operative in the presence of TMTD/ZnO[33], which enhances crosslink formation.

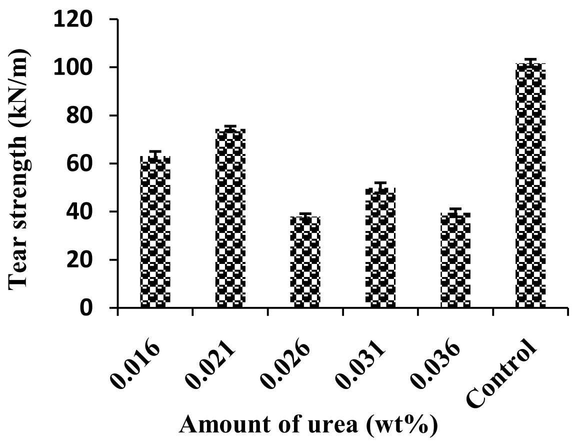

Figure 7. Variation of tear strength with Amount of urea

Tensile properties of cast films after ageing

Percentage retention of modulus, tensile strength and elongation at break after ageing at 70°C for 72 hours are tabulated in Table 6. Figure 7 shows the variation in tear strength of each sample.

Table 6. Percentage retention of tensile properties after aging

Concentration of urea (%)	0.016	0.021	0.026	0.031	0.036	Control
% retention of tensile strength	94	91	113	58	125	53
% retention of modulus at 100% elongation	101	70	123	96	88	137
% retention of modulus at 300% elongation	96	77	109	76	59	157
% retention of elongation at break	99	116	97	104	100	87

Urea treated NR vulcanizates show a higher percentage retention of tensile strength and elongation at break compared to the Control. However, the Control sample shows a much higher retention of moduli compared to urea treated samples, probably due to more crosslink formation during ageing due to thiuram acceleration.

3. Total Extractable Protein Content

Natural rubber products contain two kinds of proteins; proteins that are adsorbed to the rubber particles and serum derived soluble proteins, which contain most of the extractable proteins.[35]"container-title":"Journal of Bioscience and Bioengineering","page":"628-634","volume":"111","issue":"6","abstract":"ABSTRACT\nNon-rubber components present in natural rubber (NR The Lowry method involves an extraction and precipitation procedure followed by an assay of protein content, where a reduction of peptide bonds is identified.[36] The extractable protein content vary from 30 to 700 μg/g in latex based products.[36] Water extractable proteins are responsible for most allergic problems and urea brings an added advantage when extractable proteins are removed.

Figure 8 shows the protein concentration of each film. Urea treated samples show a lower amount of extractable proteins than the Control and can be attributed to protein denaturing ability of urea.

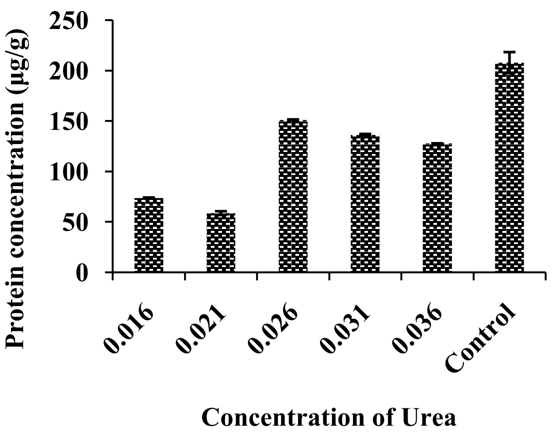

Figure 8. Total extractable protein content of cast films

4. Anti-microbial Activity of Urea

As per the Tables 7 and 8, urea treated latex samples do not show a significant contamination of bacteria.

Table 7. Microbial count

Urea concentr-ation	Dilution	Rough count (visual)	Dilution factor	Count x dilution factor
0.016%	10^{-1}	1	X10	10
0.021%	10^{-1}	1	X10	10
0.026%	10^{-1}	1	X10	10
0.031%	10^{-1}	1	X10	10
0.036%	10^{-1}	0	X10	0
Control	10^{-1}	3	X10	30
Blank	10^{-1}	0	X10	0

Table 8. Interpretation of microbial count

Count	Interpretation
Below 30	No significant contamination
= 10^3	Slight contamination
Above 10^4	Contamination
Above 10^5	Heavy contamination

The antimicrobial effect of urea could be because of its protein denaturing ability, where the portentous membranes of bacteria can be destroyed by urea.

5. GC/MS Analysis for Nitrosamines

As per the standard EN 12868, 11 kinds of N-Nitrosamines that can be identified from the analysis were targeted (Table 9).

Table 9. Nitrosamines targeted from the analysis [27]

N-Nitrosamines	
NDMA	N- Nitrosodimethylamine
NDEA	N-Nitrosodiethylamine
NDiPA	N-Nitrosodiisopropylamine
NDPA	N-Nitrosodipropylamine
NDBA	N-Nitrosodibutylamine
NPIP	N-Nitrosopiperidine
NPYR	N-Nitrosopyrrolidine
NMOR	N-Nirosomorpholine
NEPhA	N-Nitroso N-ethyl N-phenylamine
NMPhA	N-Nitroso N-methyl N-phenylamine
NDBzA	N-Nitrosodibenzylamine
NDiNA	N-Nitrosodiisononylamine

Based on the SIM (Selective Ion monitoring) chromatogram of the standard solution and the test solutions, NDMA (N- Nitrosodimethylamine) was detected only in the Control. The following m/z values[37] were selected for each compound, in which the base peak is in bold. NDMA (42,43,**74**), NDEA (42,44,**102**), NPYR (41,42,**100**), NMOR (56,86,**116**), NPIP (42,55,**114**) and NDiPA (43,70,**130**). No any nitrosamines were found in urea-based films.

Conclusion

Results in overall indicate that urea could be an alternative to the conventional secondary preservative system TMTD/ZnO used in the production of low ammonia centrifuged latex. The 0.021% urea treated latex sample and its cast film showed the best properties.

Acknowledgement

The authors thank the Rubber Research Institute of Sri Lanka and University of Sri Jayewardenepura for providing laboratory facilities and chemical analyses.

References

(1) BLACKLEY, D. C. *Polymer Lattices Science and Technology Types of Lattices*, 2nd ed.; London: Chapman & Hall, 1997; Vol. 2.

(2) Tillekeratne, L. M. .; Nugawela, A.; Seneviratne, W. M. . *Handbook of Rubber, Processing Technology*; Rubber Research Institute of Sri Lanka, 2003; Vol. 2.

(3) Santipanusopon, S.; Riyajan, S.-A. Effect of Field Natural Rubber Latex with Different Ammonia Contents and Storage Period on Physical Properties of Latex Concentrate, Stability of Skim Latex and Dipped Film. *Phys. Procedia* **2009**, *2* (1), 127–134. https://doi.org/10.1016/j.phpro.2009.06.020.

(4) Booten, K.; Yatim, A. H. B.; Singh, M. Natural Rubber Latex Preservation, August 2011.

(5) Loykulnant, S.; Kongkaew, C.; Chaikumpollert, O.; Sanguanthammarong, P.; Na Ubol, P.; Suchiva, K. Study of Chitosan and Its Derivatives as Preservatives for Field Natural Rubber Latex. *J. Appl. Polym. Sci.* **2012**, *123* (2), 913–921. https://doi.org/10.1002/app.34533.

(6) Desai, P. S. P. R. N. Replacing TMTD with Nitrosamine Free TBzTD-Accelerator in Curing of Rubber.

(7) Yu, W.; Gui, H.; Wang, T.; Wang, J.; Zeng, R.; Huang, M. Effects of Ammonia/HTT Compound Preservative on the Preservation and Properties of Concentrated Natural Rubber Latex. **2015**.

(8) Mutsuga, M.; Yamaguchi, M.; Kawamura, Y. Analysis of <i>N</I>-Nitrosamine Migration from Rubber Teats and Soothers. *Am. J. Anal. Chem.* **2013**, *4* (6), 277–285. https://doi.org/10.4236/ajac.2013.46035.

(9) Desai, P. S. P. R. Nitrosamine Generating Accelerators in Curing of Rubber.

(10) Schlegel, J. U.; Cuellar, J.; O'Dell, R. M. Bactericidal Effect of Urea. *J. Urol.* **1961**, *86* (6), 819–822. https://doi.org/10.1016/S0022-5347(17)65264-9.

(11) Foulger, J. H.; Foshay, L. The Antiseptic and Bactericidal Action of Urea. *J. Lab. Clin. Med.* **1935**, *20* (11), 1113–1117. https://doi.org/10.5555/uri:pii:S0022214335902414.

(12) Kawahara, S.; Klinklai, W.; Kuroda, H.; Isono, Y. Removal of Proteins from Natural Rubber with Urea. *Polym. Adv. Technol.* **2004**, *15* (4), 181–184. https://doi.org/10.1002/pat.465.

(13) Bennion, B. J.; Daggett, V. The Molecular Basis for the Chemical Denaturation of Proteins by Urea. *Proc. Natl. Acad. Sci.* **2003**, *100* (9), 5142. https://doi.org/10.1073/pnas.0930122100.

(14) Rossky, P. J. Protein Denaturation by Urea: Slash and Bond. *Proc. Natl. Acad. Sci. U. S. A.* **2008**, *105* (44), 16825–16826. https://doi.org/10.1073/pnas.0809224105.

(15) Sussman, G. L.; Beezhold, D. H.; Kurup, V. P. Allergens and Natural Rubber Proteins. *J. Allergy Clin. Immunol.* **2002**, *110* (2, Supplement), S33–S39. https://doi.org/10.1067/mai.2002.124969.

(16) Yao, M.; Tu, W.; Chen, X.; Zhan, C.-G. Reaction Pathways and Free Energy Profiles for Spontaneous Hydrolysis of Urea and Tetramethylurea: Unexpected Substituent Effects. *Org. Biomol. Chem.* **2013**, *11* (43), 7595–7605. https://doi.org/10.1039/C3OB41055B.

(17) Sahu, J. N.; Gangadharan, P.; Patwardhan, A. V.; Meikap, B. C. Catalytic Hydrolysis of Urea with Fly Ash for Generation of Ammonia in a Batch Reactor for Flue Gas Conditioning and NOx Reduction. *Ind. Eng. Chem. Res.* **2009**, *48* (2), 727–734. https://doi.org/10.1021/ie801491j.

(18) The International Organization for Standardization, ISO 976: 2013 (E) Rubber and Plastics-Polymer Dispersions and Rubber Latices - Determination of pH 4th Edition, ISO Copyright Office, Switzerland (2013).

(19) The International Organization for Standardization, ISO 124:2014(E), Determination of Total Solids content,7 Th Edition, ISO Copyright Office, Switzerland (2014).

(20) The International Organization for Standardization, ISO 126:2005(en), Natural Rubber Latex Concentrate -Determination of Dry Rubber content,5 Th Edition, ISO Copyright Office, Switzerland (2005).

(21) The International Organization for standardization,ISO 506:1992(E), Rubber Latex, Natural, Concen- Trate-Determination of Volatile Fatty Acid Number, 3rd Edition, ISO Copyright Office, Switzerland (1992).

(22) The International Organization for Standardization, ISO 35:2004, Natural Rubber Latex Concentrate -- Determination of Mechanical Stability, 5 Th Edition, ISO Copyright Office, Switzerland (2004).

(23) American Society for Testing and Materials ASTM D412-16, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension, ASTM International, West Conshohocken, PA, 2016, Www.astm.org.

(24) American Society for Testing and Materials ASTM D624-00(2012), Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers , ASTM International, West Conshohocken, PA, 2012, Www.astm.org.

(25) American Society for Testing and Materials, ASTM D2240-15e1, Standard Test Method for Rubber Property—Durometer Hardness, ASTM International, West Conshohocken, PA, 2015, Www.astm.org.

(26) American Society for Testing and Materials ASTM D3578-01, Standard Specification for Rubber Examination Gloves, ASTM International, West Conshohocken, PA, 2001, Www.astm.org.

(27) Child Use and Care Articles. Methods for Determining the Release of N-Nitrosamines and N-Nitrosatable Substances from Elastomer or Rubber Teats and Soothers. EN 12868. European Committee for Standardization. 1999.

(28) American Society for Testing and Materials ASTM D5712-15 Standard Test Method for Analysis of Aqueous Extractable Protein in Latex, Natural Rubber, and Elastomeric Products Using the Modified Lowry Method , ASTM International, West Conshohocken, PA, 2015, Www.astm.org.

(29) Tabatabai, M. A.; Bremner, J. M. Assay of Urease Activity in Soils. *Soil Biol. Biochem.* **1972**, *4* (4), 479–487. https://doi.org/10.1016/0038-0717(72)90064-8.

(30) Subramaniam, A. *The Chemistry of Natural Rubber Latex*; 1995; Vol. 15.

(31) Narongwongwattana, S.; Rittiron, R.; Lim, C. *The Rapid Determination of Volatile Fatty Acid Number in Para Rubber Latex Using Fourier Transform - Near Infrared Spectroscopy Based on Quantification and Discrimination Model*; 2015; Vol. 8. https://doi.org/10.1142/S179354581550042X.

(32) The International Organization for Standardization, ISO 2004:2010(E), Natural Rubber Latex Concen- Trate- Centrifuged or Creamed, Ammonia Preserved Type-Specifications,5th Edition, ISO Copyright Office, Switzerland (2010).

(33) Mark, J. E.; Erman, B.; Eirich, F. *The Science and Technology of Rubber*, 3 rd.; Elsevier Academic press, 2005.

(34) Flory, P. J.; Rabjohn, N.; Shaffer, M. C. Dependence of Tensile Strength of Vulcanized Rubber on Degree of Cross-Linking. *J. Polym. Sci.* **1949**, *4* (4), 435–455. https://doi.org/10.1002/pol.1949.120040402.

(35) Sansatsadeekul, J.; Sakdapipanich, J.; Rojruthai, P. Characterization of Associated Proteins and Phospholipids in Natural Rubber Latex. *J. Biosci. Bioeng.* **2011**, *111* (6), 628–634. https://doi.org/10.1016/j.jbiosc.2011.01.013.

(36) De Silva, K. G. Analysis of Extractable Proteins in Rubber Products. *Bulletin of Rubber Research institute of Sri Lanka*. 2003.

(37) Feng, D.; Liu, L.; Zhao, L.; Zhou, Q.; Tan, T. Evaluation of Simulant Migration of Volatile Nitrosamines from Latex Gloves and Balloons by HS-SPME-GC-MS. *J. Chromatogr. Sci.* **2012**, *50* (8), 733–738. https://doi.org/10.1093/chromsci/bms057.


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Physical Testing of Rubber

Samar Bandyopadhyay and R. Mukhopadhyay

Indian Rubber Institute (IRI)

Introduction :

- Rubber has unique and wide range of properties, understanding of which is required to incorporate them in a variety of products and applications, like tires, hose, conveyor belt, bridge bearings, shoe sole, cable, mounts, gaskets, seals, rocket insulation etc. etc.
- Rubber differs considerably from other engineering materials for example, it is the most highly deformable material, exhibiting virtually complete recovery, and it is virtually incompressible with a bulk modulus some thousand times greater than its shear modulus.

REASONS FOR PHYSICAL TESTING :

- Quality control of incoming material
- Quality control of in-process material
- Quality control of finished goods
- Factory Technical Service
- Customer Technical Service
- Preparation of Samples for Sales department
- Development compounding
- Research
- Advertising assistance
- Product performance Testing

CLASSIFICATION OF TESTINGS :

- Testing of new materials
- Evaluation of processing behaviour of rubber compounds
- Testing of vulcanizates
- Testing of finished products

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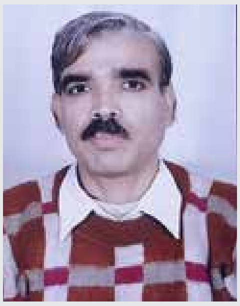


Brief Personal Biography:

- Completed M. Tech Degree in Plastics and Rubber Technology in 1992 from Department of Polymer Science and Technology, University of Calcutta, India
- Received Ph.D degree in Rubber Recycling during December 2007 from Mohan Lal Sukhadia University Udaipur, Rajasthan, India.
- Joined HASETRI in 1992 and worked for more than 23 years.
- Worked as Head (R&D) of Pidilite Industries Ltd. at Dahej, Gujarat for one and half years.
- Currently working as Business Head in Pukhraj Additives LLP for more than 5 years.
- Acting as a faculty member of IRI in PGDIRI – DIRI National Level Crash Course.
- Lead Assessor of National Accreditation Board of Testing and Calibration Laboratories (NABL) in the field of Testing and Proficiency Test Program.
- Fellow Member of Indian Rubber Institute (FIRI) and Institute of Engineers (India) Ltd (FIE).
- 60 numbers of Technical papers and 3 book chapters.

TESTING OF ELASTOMERS:

Viscous properties	Elastic properties
• PRI, Mooney , Rheo, Processing • Rebound Resilience • Deformation set • Relaxation and Creep test • Mechanical loss factor • Temperature increase (Flexometer test)	• Stress at 300% strain • Compression modulus • Shear modulus • Hardness • Dynamic modulus

PROCESSABILITY TESTS

- **PLASTICITY AND RECOVERY TEST**

International Standards :

ASTM D 926 - 93

Significance of testing :

It is a very rapid test and needs very small test piece. In this test the test piece is compressed between two parallel plates under a constant force and the compressed thickness is measured. The extent of compression gives a measure of plasticity of the rubber. This test has been found very useful for routine testing, particularly of raw rubber like Natural Rubber.

Procedure :

ASTM D 926 describes the above test based on William's Plastimeter with plates 4 cm in diameter. The test piece is 2.00 ± 0.02 cm^3 in volume and can conveniently be a cylinder of 16 mm diameter and 10 mm thick. The test piece is preheated for 15 min at a temperature of 100^{o}C and compressed under a force of 5 kgf for around 3 - 10 mins.

Measurement and Calculation :

The thickness of the compressed test piece is measured in mm and this value is multiplied by 100 is quoted as the plasticity number.

After this the test piece is allowed to cool for 1 min and its height is measured. The 'recovery value' is reported as the difference between plasticity number and recovered height, it is intended to be a measure of the elastic component.

The plasticity measurements are made before and after ageing for the determination of Plasticity Retention Index (PRI). Test pieces are aged at 140 ± 0.2^{o}C for 30 ± 0.25 min and cooled to room temperature before making the plasticity measurements. PRI is calculated as follows :

$$PRI = \frac{\text{aged rapid plasticity number}}{\text{unaged rapid plasticity number}} \times 100$$

Limitations :

Shear rate encountered in rubber processing operation is very high, ~ 10^4 sec^{-1}. But Plasticity tests operate at much lower rate, ~ 0.0025 to 1 sec^{-1}, thus having no correlation with injection moulding.

- **MOONEY VISCOSITY, STRESS RELAXATION, MOONEY SCORCH AND DELTA MOONEY TEST**

International Standards :

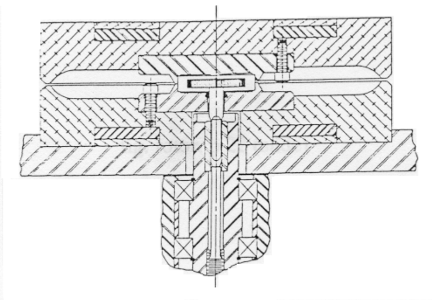
ASTM D 1646-96, SS-ISO 289, ASTM 3346-90

Significance of testing :

These tests are for predicting processing characteristics where correlation between viscosity values and molecular mass is present. Viscoelastic characteristics can be correlated with stress relaxation. It can also predict the rate of cure and incipient cure time during very early stages of vulcanization.

Procedure :

A Mooney viscometer is the most common equipment for these tests. The instrument consists of a motor driven disk within a die cavity formed by two dies maintained at specified conditions of temperature and die closure force. Two rotors are used, larger one with 1.5 inch dia and smaller one is of 1.2 inch dia. The test consists of determining the torque necessary to rotate the disk in the chamber filled with rubber. A number proportional to this torque is taken as an index of the viscosity of the rubber where 8.3 ± 0.02 Nm equals 100 Mooney Units (MU). The rotor is driven at 2 rpm. Generally Mooney Viscosity, Stress Relaxation and Delta Mooney tests are carried out at 100^{o}C and Mooney Scorch at 135^{o}C. For stress relaxation test after completion of the test time (usually 4 min) the test is run for another 2 min while the motor is in rest.



Measuren

Mooney viscosity is usually expressed as, 50 ML_{1+4} @ 100°C,

where 50 is the viscosity in MU, L indicates the Large (standard) rotor, 1 is the pre-heating time and 4 is the test time and 100°C is the test temperature. Other parameters which can be calculated by a Mooney viscometer are Scorch time, Cure index, Optimum cure time, Delta Mooney etc. Typical Stress Relaxation and Mooney cure curves are shown below.

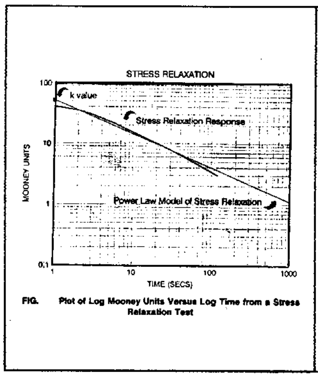


FIG. Plot of Log Mooney Units Versus Log Time from a Stress Relaxation Test

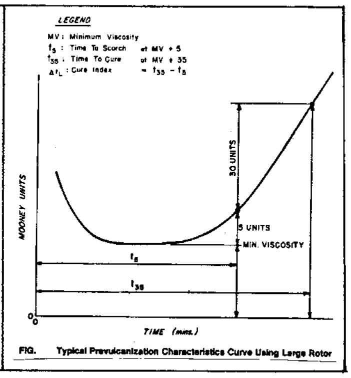


FIG. Typical Prevulcanization Characteristics Curve Using Large Rotor

Limitations :

The shear rates produced are not uniform but range from zero at the center to maximum at the periphery and the average shear rate of this m/c is ~ 2 sec^{-1} which is substantially below than encountered in extrusion and injection moulding.

This test method cannot be used to study complete vulcanization because the continuous rotation of the disk will result in slippage when the specimen reaches a stiff consistency.

- **EXTRUDABILITY**

International Standards :

ASTM D 2230 - 96

Significance of testing :

One objective in the extrusion of rubber compounds is to obtain a smooth extrusion that closely reproduces the contours of the extrusion die. This test method provides for a subjective determination of this under controlled conditions and it simulates to some extent the processing operations of extrusion and injection moulding. Apart from this it has the important advantages that much higher shear rates are possible than normally used other instruments and it is comparable with those encountered in actual processing at shop floor.

Procedure :

In this test rubber is forced through a small cylindrical die under a known pressure and the volume extruded in a given time is measured. Apart from the rate of extrusion it is also possible to visually estimate the quality of the extrusion, for which the cylindrical die could be replaced with one having more complicated cross section (Garvey die) which was designed to show up typical faults that can occur in a mix with poor extrusion characteristics.

Measurement and Calculation :

The Garvey die has an acute angled wedge portion (X). Mixes are rated by assigning a numerical value or score to each of the characteristics like; (a) surface, (b) sharpness of the 'edge' X, (c) the two 'corners' Y and Z, and (d) cross sectional dimensions, i.e., die swell. Rating figures can be seen from the above mentioned ASTM standard.

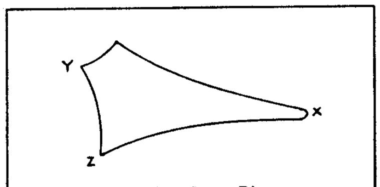


Fig : Cross section of the Garvey Die

Limitations :

As the rating is subjective, it does not lend itself readily to incorporation as a specification requirement. It does not measure other aspects of extrudability such as rate of extrusion or die swell in a quantitative manner. The short period of shearing is insufficient to break down thixotropic structures completely.

- **VULCANIZING CHARACTERISTICS**

International Standards :

ASTM D 2084-95, ASTM D 5289-95, SS-ISO 3417-91, SS-ISO 6502-91

Significance of testing :

This test is used to determine the vulcanization characteristics of vulcanizable rubber compounds and mainly used in quality control process, R&D activity.

The effect of compound changes on the viscosity and scorch characteristics can be determined from the initial portion of the curve while the effect on the rate of the cure and the modulus of the cured compound can be detected in the latter portion of the curve. This is a very rapid test and hence evaluation of the stock prior to final fabrication is easy. A good agreement between cure meter results and tensile modulus measurements make the cure meter an alternative method for controlling the production step and for testing of raw materials like polymers and fillers. Even the batch consistency can be checked easily with this equipment.

Procedure :

In the oscillating disk type rheometer (like, Monsanto R100) a bi-conical disk is embedded in the rubber in a closed cavity and the disk is oscillated through constant angular displacement (1,3,5^o). In case of rotorless rheometer (like, Monsanto Moving Die Rheometer, MDR 2000) the sample is sealed within a cavity formed by the upper and the lower dies, which oscillates through and arc of ± 0.5, 1, 3^o. In both the cases torque is monitored and if needed can be plot against time scale.

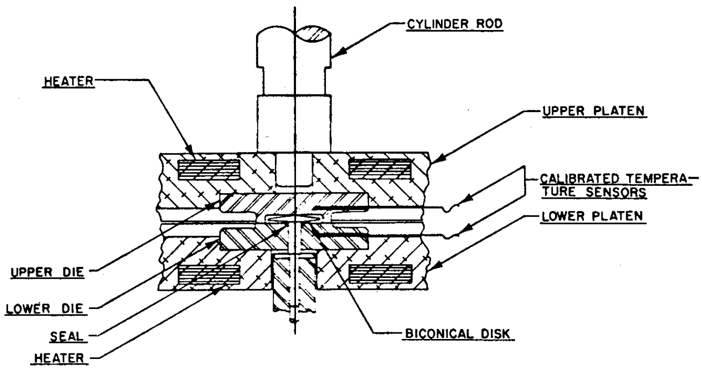


FIG. Cure Meter Assembly

Measurement and Calculation :

Typical curves obtained from an oscillating disk rheometer are shown below.

The information that can be deduced from a typical rheo curve are :

Minimum (M_L) and Maximum torque (M_H); Scorch time (t_s2) - time for two units rise in torque value from the minimum torque; Optimum cure time (T_c90) - time corresponding to the optimum torque value which determines the time of moulding (minutes to ML + 90(MH - ML)/100 torque).

Limitations of ODR over MDR :

The major advantages of MDR over ODR are: high precision m/c, unique die design, less amount of sample requirement, rapid thermal recovery, digital temperature control, integral data system etc.

- **TACK**

International Standards :

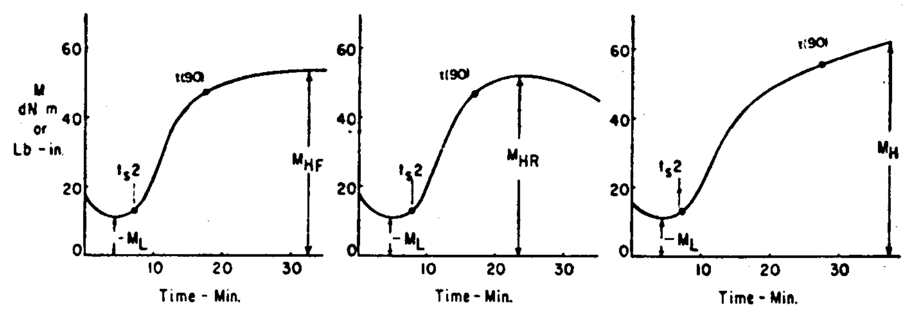
Not Available, generally measured as per instrument manufacturer's instruction manual

Significance of testing :

Tackiness is the property of two pieces of rubber to stick when pressed together and is also known as auto-adhesion. This is an important property as far as the built-up products such as tyres, foot wears, belts are concerned. Solvent based glues generally leave residues which may cause blow holes after moulding, it is therefore desirable to have a better self adhesion in the compound itself, that's why it is an important properties that decides the consolidation of components of a product.

Procedure :

In Monsanto Tel-tack meter two strip test pieces (10 mm) are placed together at right angles to give a known contact area (100 mm^2). After a set contact time (usually 30 sec) under known load (8 ozs), the two test pieces are separated in direct tension at fixed rate of grip travel.



Measurement and Calculation :

Maximum separation force (ozs) and separation time (sec) needed to separate the two specimens is noted from the dial gauge and stop watch respectively. Then 'tack index' is calculated by using the formula below.

$$\text{Tack Index} = \frac{\text{Separation force X (Separation time)}^{1/3}}{\text{Contact force X (Contact time)}^{1/3}}$$

Limitations :

Tack is basically a qualitative test and much depends upon the operator. It is very much sensitive to variations in temperature, pressure, rate of application and removal of pressure and time of contact and surface area of the specimens. So during testing of tack special care is to be taken.

- **SWELLING INDEX**

International Standards :

ASTM D 3616-95

Significance of testing :

Swelling index is a measure of the type of gel. Gel with a low swelling index is referred to as 'hard gel' and usually indicates the presence of material that does not break down readily. A high swelling index normally indicates the presence of a 'loose gel' that may be broken down easily.

Procedure :

A weighed sample is allowed to stand in a suitable solvent till equilibrium swelling (~ 48 hours). The sol or soluble portion is removed from the sample. Sample is taken out from the solvent and the swollen weight is taken. Swelling index is measured by dividing swollen weight with the original weight.

Measurement and Calculation :

Swelling index = Swollen weight / Original weight

Limitations :

Equilibrium swelling is necessary to get informative results. Swelling index can not gives accurate state of cure, it provides only the apparent values.

VULCANIZATE TESTING

INTRODUCTION :

Tests on rubber products can be generally classified into two categories - compound tests and tests on actual products. The former is mainly intended for compound evaluation which is useful in quality control and developmental studies. Tests on actual finished products are designed to give performance characteristics of the product.

Rubber must be tested under carefully prescribed conditions. When products are made to a customer's satisfaction, it is essential that when the customer tests the product he is able to obtain the same results, within narrow limits, as the manufacturer obtained when the goods were produced. Similarly raw materials are tested in the producer's laboratory and subsequently in the customer's laboratory, the results must agree closely.

The international organisation which serves to standardise the test methods for rubber in the American Society for Testing and Materials (ASTM) which is supported by committees made up of industry representatives. In India the standardisation work is carried out by the Bureau of Indian Standards (BIS) formerly known as ISI.

Preparation and Conditioning of the Test Pieces :

Except in case of complete products, a test piece must be formed and properly conditioned before the test can be carried out. The specimens are generally directly moulded or cut and/or buffed or sliced to some particular geometric shape. The specimen preparation and conditioning is done under standard specification to yield a more meaningful and repeatable test data. ASTM D 3182 covers the same.

The properties of rubber depend on its history before test and the atmospheric conditions under which the test was carried out. That is results are affected by the age of the rubber, the conditions such as temperature and humidity under which it was stored, any mechanical deformation before test and humidity at the time of the test. Hence, to produce consistent results it is essential that these factors are controlled within suitable limits. Virtually all test methods specify a conditioning period prior to test, in a standard atmosphere. The standard conditions are $23 \pm 2^{o}C$ and 50 ± 5 % RH.

When both temperature and humidity are controlled, the standard conditioning time is a minimum of 16 hours and where temperature only is controlled, conditioning requires minimum of 3 hours.

- **HARDNESS**

International Standards :

ASTM D 2240-95, ASTM D 1415-88, SS-ISO 7619, SS-ISO 48

Significance of testing :

A hardness measurement is a simple way of obtaining the mechanical properties. The real purpose of running hardness test is to determine the elastic modulus of a rubber under conditions of small strain by determining its resistance to rigid indentor to which a force is applied. The hardness test can also predict the degree of cure. IRHD hardness bears a known relation to Young's modulus also.

Procedure :

In determining the hardness of a piece of rubber, the indentor is pressed down firmly under an applied force. The surface of the specimen must be flat enough for applying uniform load. The sample must be ~ 8 - 10 mm in thickness and have sufficient surface area for the base of the indentor, otherwise wrong value may be obtained.

Measurement and Calculation :

In case of Shore-A durometer the pointer reads at its maximum in a scale of 0 to 100. The internationally accepted standard dead load hardness (IRHD) method covers rubbers in the range of 30 to 85 IRHD. For the normal test a ball indentor of either 2.38 mm or 2.5 mm diameter is used, acting under a total force of 5.53 or 5.7 N respectively. The indentation of the ball is made relative to the surface of the test piece after a fixed time of 30 secs after applying the force.

Limitations :

Hardness is criticized on two counts. (1) the measured values are unreliable because of mechanical considerations and the failure of operators to follow the standard technique of operation; and (2) the characteristic that is measure, surface indentation, rarely bears any relation to the ability of a rubber product to function properly.

- **TENSILE STRESS AND STRAIN INCLUDING TEAR**

International Standards :

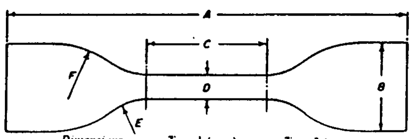
ASTM D 412-92, ASTM D 624-91, SS-ISO 1798, SS-ISO 37, SS-ISO 34-1

Significance of testing :

To the experienced rubber technologist, these tests are useful in many ways - for compound development, for manufacturing control and for determining a compound's susceptibility to deterioration by oil, heat, weathering etc. These tests are almost universally used as a means of determining the effect of various compounding ingredients and are particularly useful when such ingredients affect the rate and state of vulcanization of the composition. The 'retention' properties are much more significant than the absolute values before and after exposure to deteriorating influences. Tear test can predict qualitatively the service performance of the product against any cut.

Procedure :

The determination of tensile properties starts with a piece taken from the sample and includes the preparation of the specimen and testing of the specimen. Specimens may be in the shape of dumbbell, ring or straight piece of uniform cross section. Test pieces are strained at a



Dimensions	Type 1 (mm)	Type 2 (mm)
A	115 minimum	75 minimum
B	25 ± 1	12·5 ± 1
C	33 ± 2	25 ± 1
D	$6{\cdot}0\,^{+0{\cdot}4}_{-0{\cdot}0}$	4 ± 0·1
E	14 ± 1	8 ± 0·5
F	25 ± 2	12·5 ± 1·0

Fig. : Dumb-bell specimen for tensile test

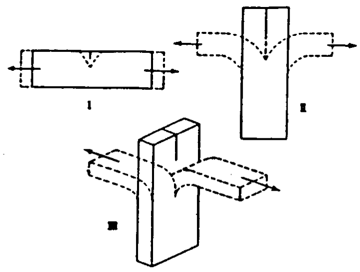


Fig. : Types of tear test pieces
original shape ------- shape after tearing

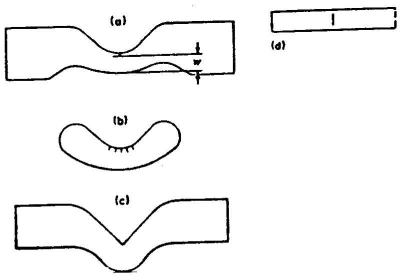


Fig. : Forms of tear test piece
(a) crescent with enlarged ends for gripping w = initial untorn width (b) simple crescent (c) angle (d) Delft

constant rate of traverse and force vs. extension is recorded. Different types of dumbbell and tear test specimens are used for this testing as follows.

Measurement and Calculation :

Tension tests shall be made on power driven machine equipped to produce a uniform rate of grip separation of 500 ± 50 mm/min. The force readings are expressed as stresses by reference to the original cross-sectional area of the test piece. The exact elongation is recorded by the extensometer and the load is monitored by the load cell attached with the Universal Testing Machine (UTM). After completion of the test modulus values at different elongation, tensile strength, elongation at break can be determined or can obtained directly from the computer, if the instrument is equipped with a computer and proper software. Similarly tear results can also be obtained after completion of the test.

Limitations :

Tensile and tear tests have limited significance to the design or application engineer who is interested in determining the suitability of a composition for use in a specific product. They can not be used in design calculations and they bear little relation to a rubber part's ability to perform its function because the rubber products are seldom approach to their ultimate strength or elongation and find no similarity in service life.

- **ABRASION RESISTANCE**

International Standards :

DIN 53516, ASTM D 5963-96, ASTM D 1630-94, ASTM D 2228-88, SS-ISO 4649

Significance of testing :

Abrasion resistance is a performance factor of paramount importance for many rubber products such as tyres, conveyor belts, poser transmission belts, hoses, footwear and floor covering. These tests may be used to estimate the relative abrasion resistance of different vulcanized rubber compounds and are suitable for comparative testing, quality control and R&D work.

Procedure :

There are various type of abraders are available where either loose or solid abradant is used. A loose abrasive powder can be used either in the manner of a shot blasting machine or between two sliding surfaces. Solid abradant consists of abrasive wheels, abrasive papers or cloth and metal knives. Some of the configurations of test piece and the abradant are shown below. The most common used instrument is the Din Abrader which uses a disc test piece of diameter 16 mm and height 6-10 mm in a suitable holder under a load of 10 N which is traversed across a rotating drum of 150 mm diameter with a rotating speed of 40 rpm covered with a sheet of emery paper and provides a abrasion path of 40 m. Running of a standard rubber sample is required to know the abrasiveness of the emery paper.

Measurement and Calculation:

The weight loss is measured after running the experimental sample in the Din abrader. Knowing the specific gravity of the sample and the standard abrasiveness of the emery paper it is possible to calculate the volume loss of the experimental sample using the formula below.

$$\text{Abrasion loss (mm3)} = \frac{\text{Mass loss} \times 200}{\text{Sp. gr.} \times \text{Abrasiveness degree}}$$

Limitations :

Since conditions of abrasive wear in service are complex and vary widely, no direct correlation between these tests and actual performance can be assumed. The common mistake is to think of abrasion resistance as a single entity, like modulus of elasticity. That is not the case. Modulus is a constant and remains the same, no matter what product the compound is used for. Abrasion resistance, on the other hand, is a complex of properties - resilience, stiffness, thermal stability, resistance to cutting and tearing - and different applications require these component properties in widely differing proportions. There are also some purely mechanical testing difficulties which may produce misleading results. For example, an undercured composition (soft and gummy) or one with a wax or oil 'bloom' will appear to have excellent abrasion resistance merely because the abrasive has been clogged or lubricated by material removed from the surface of the specimen.

- **RESILIENCE**

International Standards:

ASTM D 2632-92, ASTM D 1054-91, SS-ISO 466

Significance of testing:

This is a very basic form of dynamic test and is a function of both dynamic modulus and internal friction of a rubber. Some knowledge of these dynamic properties are essential in understanding the performance of those products which in service are subjected to deformations of varying frequency and amplitude. These properties are important in engineering applications of rubbers including spring and dampers.

Procedure :

Rebound resilience can be measured by different type of equipment; one of them is Dunlop Tripsometer. It consists of 42 cm dia and 1.4 cm thick steel disc mounted on bearings and with an out of mass balance in the form a bracket carrying the 4 mm dia indentor attached to its periphery. The scale graduated in degrees to measure the angular displacement of the disc which can be held in any desired position. The test piece shall be a cylindrical block of 8 mm^2 and 4 mm thick. The test specimen shall be conditioned well before the test, specially if the testing is carried out at elevated temperature. After loading the specimen the disc is allowed to strike the specimen from an angle of 45^o and the angular displacement of the rebound is noted.

Measurement and Calculation :

Resilience is approximately related to the loss tangent by,

$R = E_R / E_T = \exp(-\Pi \tan\delta)$; or $E_A / E_R = \Pi \tan\delta$,

where E_R is reflected, E_T is the incident and E_A is the absorbed energy.

In case of Dunlop Tripsometer, the calculation of rebound resilience is as follows.

Rebound Resilience (%) = $(1 - \cos\alpha) / (1 - \cos 45^o)$,

where, α is the rebound angle and 45^o is the initial angle.

Limitations :

The magnitude of the resilience measurement depends upon the size and shape of the pendulum hammer, the size, shape and the stiffness of the rubber specimen and upon the effective height of fall of the pendulum. Besides, the frequency is not of the same order of magnitude as that of many applications involving vibration.

- **HEAT BUILD UP**

International Standards :

ASTM D 623-93, SS-ISO 4666

Significance of testing :

This test describes about the heat rise in a vulcanized rubber cylinder after repeated compressive flexing and allow a fairly accurate prediction of the equilibrium operating temperature of a rubber product like tyre, V belt, in service and operating temperature will have an important effect on its physical properties. The data obtained by this test can be used to estimate relative service quality of different compounds, and are often applicable to R&D studies.

Procedure :

In case of Goodrich Flexometer a definite compressive load (143 psi) is applied to a cylindrical test specimen (having a dia 17.8 ± 0.1 mm and a height of 25 ± 0.15 mm) through a lever system having high inertia, while imposing on the specimen an additional high-frequency (1800 ± 10 rpm) cyclic compression of definite amplitude (generally 4.45 mm). The performance of the machine is checked by studying a control compound.

Measurement and Calculation :

The increase in temperature at the base of the test specimen is measured after an interval (25 min) with a thermocouple to provide a relative indication of the heat generated in flexing the specimen. By comparing the change in height, the ‘permanent set’ can be calculated which indicates the degree of stiffening or softening of the test specimen. After completion of the test ΔT is calculated, which is commonly known as the ‘heat build up’.

Limitations :

Because of wide variation in service conditions, no correlation between this accelerated test and service performance is given or implied. The results of flexometer tests are not suitable for control or classification purposes, nor are they applicable for use in purchase specifications.

- **FATIGUE TEST**

International Standards :

ASTM D 4482-85, ASTM D 813-95, SS-ISO 132

Significance of testing :

These tests are used to determine fatigue life at various extension, compression and repeated distortion by bending. These tests give an idea about the crack initiation behaviour of a rubber vulcanizate and only a very approximate measure of the crack propagation rate. It is possible to have an estimate of the ability of a rubber vulcanizate to resist crack growth of a pierced specimen when subjected to flexing. The information obtained may be useful in predicting the flex-life performance of a compound in active service, such as tyre side wall compounds. These tests are useful in R&D work, especially when an unknown compound or construction is compared in simultaneous test with a construction whose performance has been established in service.

Procedure :

Different types of fatigue test are carried out, like, Fatigue to Failure Test, De Mattia Fatigue test, Ross Fatigue etc. In each case the test specimens are cyclically strained at a fixed frequency and this cyclical straining action is called flexing. As a result of the flexing, cracks usually initiated by naturally occurring flaw, grow and ultimately cause failure which is defined as complete rupture of the test specimen. The number of cycles to failure, i.e., fatigue life, is recorded. Sometime a intentional cut is given on the specimen and cut growth rate is measured after certain interval. The test specimen for De Mattia tester is usually a 6” X 1” moulded strip of thickness 6.4 ± 0.1 mm with a circular groove at the center. For FTFT, the specimen is a dumbbell with two beads at each of the end.

Measurement and Calculation:

In case of FTFT, generally 6 specimens are tested and the 4 closest values are used for calculating the average fatigue life as follows.

JIS average = 0.5A + 0.3B + 0.1 (C + D),
Where, $A > B > C > D$

In case of De Mattia test generally three test specimens are tested; the data may be reported as the number of cycles required to reach a specified crack length, or as the average rate of crack growth over the entire test period or as the rate of cracking in millimeters (or inches) per kilocycle during a portion of the test.

Limitations :

No exact correlation between these test results and service is implied due to the varied nature of service conditions and are not suited for use in purchase specification requirements because the results from duplicate specimens do not check with sufficient precision.

- **DYNAMIC PROPERTY (FORCED VIBRATION)**

International Standards :

ASTM D 2231-94, SS-ISO 4664

Significance of testing :

Increased usage of rubber in vibrational and damping applications has resulted in a corresponding increased interest in the characterization of rubbers through dynamic mechanical testing. By this test one can measure Storage Modulus, Loss Modulus, Complex Modulus and which has a relation with tyre rolling resistance and in turn fuel economy of the vehicle. Heat Build Up results can also be correlated with the tanδ values. Characterisation of rubber by knowing its glass transition temperature (T_g) is also possible.

Procedure :

Rheovibron Dynamic Viscoelastometer is one of the equipment by which the above test can be carried out. The test can be carried out from sub-ambient temperature to high temperature. A strip of rubber sample (3 X 0.6 X 0.2 cc) is placed in between the chuck and by a servo hydraulic valve it is oscillated at four different frequencies, viz. 3.5, 11, 35 and 110 Hz. If the instrument is attached with a computer with proper software, continuous scanning of the data is possible with respect of temperature; otherwise calculate the dynamic parameters as follows (tanδ comes from direct reading of the scale)

Absolute Modulus, $|E^*|\ (\text{dyne/cm}^2) = \dfrac{L \times 10^{12}}{8ADS}$

Storage Modulus, $E'\ (\text{dyne/cm}^2) = |E^*| \cos\delta$

Loss Modulus, $E''\ (\text{dyne/cm}^2) = |E^*| \sin\delta$

where, L is the length of the sample (cm); S is the Sectional area (cm2); A is the amplitude factor and D is the dynamic force.

Limitations :

No exact correlation can be made between these test results and the service life due to the varied nature of service conditions.

AIR AGEING IN TEST TUBE ENCLOSURE

International Standards :

ASTM D 865-88, SS-ISO 188

Significance of testing :

Rubber and rubber products must resist the deterioration of physical properties with time caused by oxidative and thermal ageing. Accelerated ageing study can help the compound developers to predict the right composition which can withstand the actual service conditions. The isolation of specimens by the use of individual circulating air test tube enclosures prevents any cross contamination from volatile products and permits a more representative assessment of ageing performance. In these tests, the tensile properties and hardness of specimens are determined before and after exposure in order to establish the extent and rate of deterioration.

Procedure :

The tensile specimens are die out from the slabs and kept a large test tube which will accommodate only limited no. of specimens. Air circulation is properly maintained through out the ageing period. Different temperatures and period can be possible depending upon the application; but generally 70°C is used for natural rubber based compounds and 105°C is used for synthetic rubber based compounds. After the completion of the exposure period, the specimens are taking out and conditioned at room temperature for at least 8 hours before go for hardness and tensile testings.

Measurement and Calculation :

After proper conditioning of the aged specimens, normal hardness and tensile testing are carried out as done for original testing from the same lot of specimens. Results may be reported as either percent loss or percent retained of the physicals. Often a percent is not used, both the original and aged properties are being reported.

$$\text{Retention (\%)} = \frac{\text{Aged values X 100}}{\text{Original values}}$$

Limitations :

Although the different ageing studies help a lot to simulate the service life, but no direct correlation between this accelerated ageing test and natural life of rubber is implied. Since the rate at which deterioration proceeds during the normal life of rubber varies widely, depending on conditions of exposure to heat, light, air, local climate and on the composition and state of cure of the rubber, this accelerated test is comparative only and must be evaluated against the performance of the rubber compounds of which both the natural and accelerated ageing characteristics are known.

- **OZONE RESISTANCE**

International Standards :

ASTM D 1149-91, ASTM D 3395-86, SS-ISO 1431-1,2

Significance of testing :

Ozone is a form of oxygen which occurs naturally in concentrations generally from 2 to 20 parts per 100 million (pphm). Ozone attacks unsaturated rubber, like NR, SBR, NBR very rapidly particularly when they are in stressed condition. To sort out this problem accelerated ozone ageing test is carried out at laboratory. This test is mainly used to differentiate, in a comparative sense, between different degrees of ozone resistance under the limited and specified conditions. These tests basically indicates the protective power of the waxes and other anti-ozonents used in rubber vulcanizates.

Procedure :

Different type of test specimens are used for different mode of test. For static test, 6" X 1" rubber strips are given 20% stretch; for dynamic test 4" X 0.5" rubber strips are given 25% stretch; for bend loop test 3.75" X 1" rubber strips form a loop of varying stretch form 0 - 25%. All of them are pre-conditioned at stretched for 24 hours in stretched condition so that waxes and other anti-ozonants may come out to the surface of the specimens. After the pre-condition time the specimens are exposed to an ozone atmosphere of 50 pphm at a temperature of 40°C for a definite period (~ 120 hr).

Measurement and Calculation :

After a certain interval the samples are checked by magnifying glass and the first appearance of crack is noted. Sometimes a gradation is also given to identify the nature of the crack, as 0 means no crack to 4 means extensive cracks. It is always better to use a reference compound alongwith the experimental one whose values are known.

Limitations :

Although these tests are helpful for comparative purpose, but may not give correlation exactly with the outdoor performance because service performance also depends on other conditions such as rainfall, ambient temperature, etc. A factor which complicates the ozone cracking problem is the effect produced by exposure to sunlight, known is 'crazing' which is different from ozone cracks. Crazing occurs whether or not the specimen is elongated and they are not in uniform direction but extend in all directions. This effect has been shown to be due to oxidation catalyzed by sunlight and rain water soluble products. These can not be judged by the indoor ozone testing.

- **EFFECT OF LIQUIDS**

International Standards :

ASTM D 471-95

Significance of testing :

Certain rubber articles, like, seals, gaskets, hoses, diaphragms may be exposed to oils, greases, fuels during service. Properties of these rubber articles deteriorate during exposure to these liquids, affecting the performance of the rubber part, which can result in partial failure. This test is suitable for specification compliance testing, quality control and R&D work.

Procedure :

This test method provides procedures for exposing test specimens to the influence of liquids under definite conditions of temperature and time. The resulting deterioration is determined by measuring the changes in physical properties, such as stress-strain properties, Hardness and changes in mass, volume and dimension, before and after immersion in test liquids, such as ASTM Oil No. 1 & 5, IRM 902 & 903; ASTM Reference Fuel A to I & K; ASTM Series liquids 101 to 104.

Measurement and Calculation :

$$\Delta Z, \% = \frac{(Z_2 - Z_1) \times 100}{Z_1}$$

where,

ΔZ = is the change in property, like Tensile Strength, Mass, Volume etc.,

Z_2 = Change in property of the specimen after immersion in test fluids

Z_1 = Original property of the specimen

Limitations :

This test method attends to simulate the service condition through controlled accelerated testing, but may not give any direct correlation with actual part performance, since service condition vary too widely. It yields comparative data on which to base judgement as to expected service quality.

PERMANENT SET

International Standards :

ASTM D 395-89

Significance of testing :

Permanent set tests are intended to measure the ability of rubber compounds to retain elastic properties after prolonged action of compressive and tensile stresses. These tests judge the ability to sustain stress or strain under specified conditions, like gaskets, O-rings, oil seals, tubes, bladders etc.

Procedure:

The test specimen is compressed or elongated to either a deflection (constant strain) or by a specified force (constant stress) and maintain under these condition for a specified time (generally 22 hours) and at a specified temperature (70^{o}C). For constrain strain test, usually 25% strain and for constant stress test, usually 1.8 kN (400 lbf) force is applied. In both the cases the thickness of the specimen (of proper dimension) is measured before and after testing.

To measure the tube / bladder growth, some users' developed test methods are also available, like Exxon's test method, where dumbbell specimens are elongated to 50% with respect to an one inch bench mark in a tensile set apparatus. The stretched specimens are kept in an air ventilated oven at 105^{o}C for 5 hours. After the completion of the ageing, the specimens are conditioned at room temperature at stretched condition for another 2 hours after which the stress is released. Final length is measured after 16 hours.

Measurement and Calculation :

The set at constant stress is calculated as a percentage of the original thickness.

$$C, \% = \frac{(C_1 - C_2) \times 100}{C_1}$$

where,

C = is the permanent set at constant stress

C_1 = original thickness

C_2 = final thickness

The set as per Exxon method is calculated as follows.

$$S, \% = \frac{(S_3 - S_1) \times 100}{S_2 - S_1}$$

where,

S = is the permanent set as per Exxon method; S_1 = original length (1 inch);

S_2 = elongated length (1.5 inch); S_3 = recovered length (in inch)

Limitations:

The actual stressing service may involve the maintenance of a definite deflection, the constant application of a known force, or the rapidly repeated deformation and recovery resulting from intermittent compressive forces, its effects as a whole can not be simulated by the above tests.

- **ADHESION**

International Standards :

ASTM D 413 - 82

Significance of testing :

These test methods cover the determination of the adhesion strength between plies of fabric bonded with rubber or the adhesion of the rubber layer in articles made from rubber attached to other material. These are applicable only when the adhered surfaces are approximately plane or uniformly circular as in belting hose, tyre carcasses etc.

These test methods are used to ensure the quality of a product by determining the force per unit width required to separate a rubber layer from a flexible substrate such as fabric, fiber or wire.

Procedure:

Strip Specimen : Type A, 180^{o} Peel - Measure the width of the strip cut to the nearest 0.22 mm (0.01 in.) and record. Separate the parts to be tested by hand at one end of the strip specimen and at a sufficient distance to permit the jaws of the testing clamp to be attached. Apply a specified or known mass by means of a clamp and mass carrier to the layer of which the adhesion is being determined.

Measurement and Calculation :

Report the adhesion value as separation force per unit width.

Limitations:

When the adhered surfaces contain sharp bends, angles, or other gross irregularities that cannot be avoided in preparing test specimens, then special test methods must be employed for evaluating adhesion.

The acceptable value of adhesion measured will, of course, vary from product to product due to different rubber formulations, flexible substrate and types of products.

References

1) Physical Testing of Rubber, R. P. Brown, Third Edition, 1996

2) Rubber Science and Technology, Edited by R. Mukhopadhyay, 2002

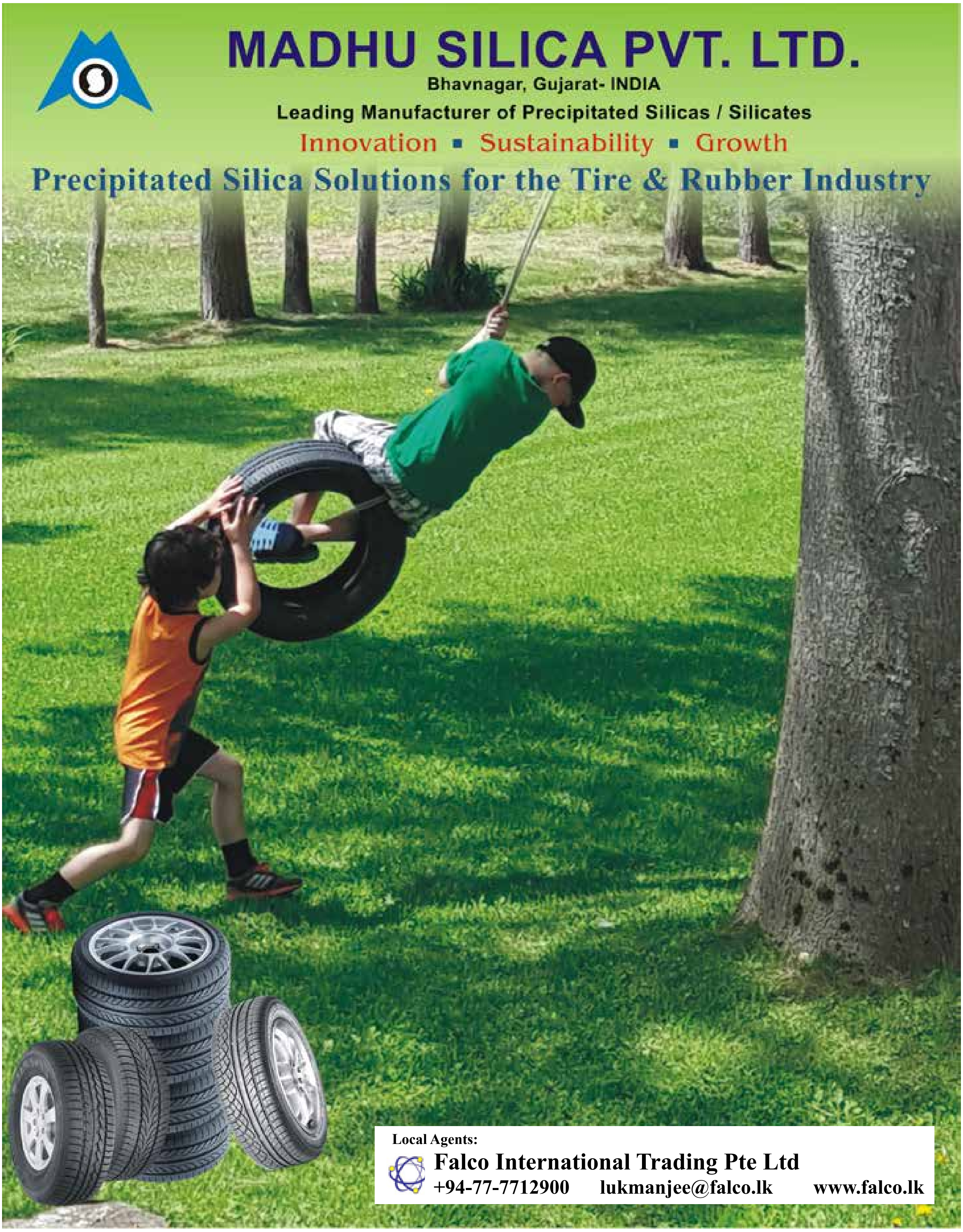
3) Rubber Technology: Compounding and Testing for Performance Edited by John S Dick, 2001

4) Rubber Technology, Edited by Morris Morton,1987

5) Rubber Technology and Manufacture, Edited by C. M. Blow and C Hepburn, 1982

6) Rubber Products Manufacturing Technology, Edited by Anil Bhowmick, 1994

7) Basic Rubber Testing: Selecting Methods for your Rubber Test Program, Edited by John S Dick, 2003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