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.

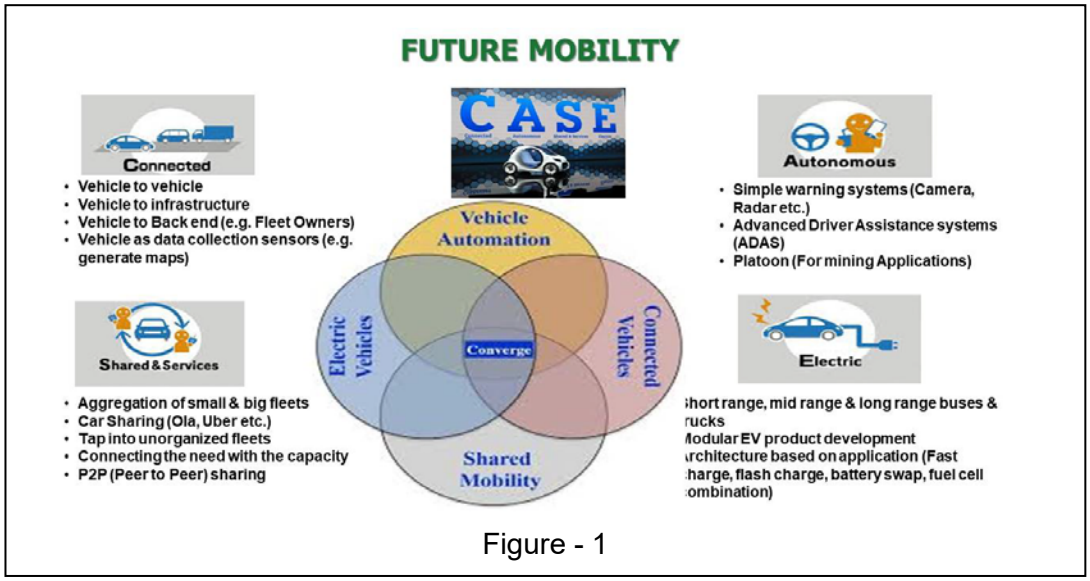

Figure - 1

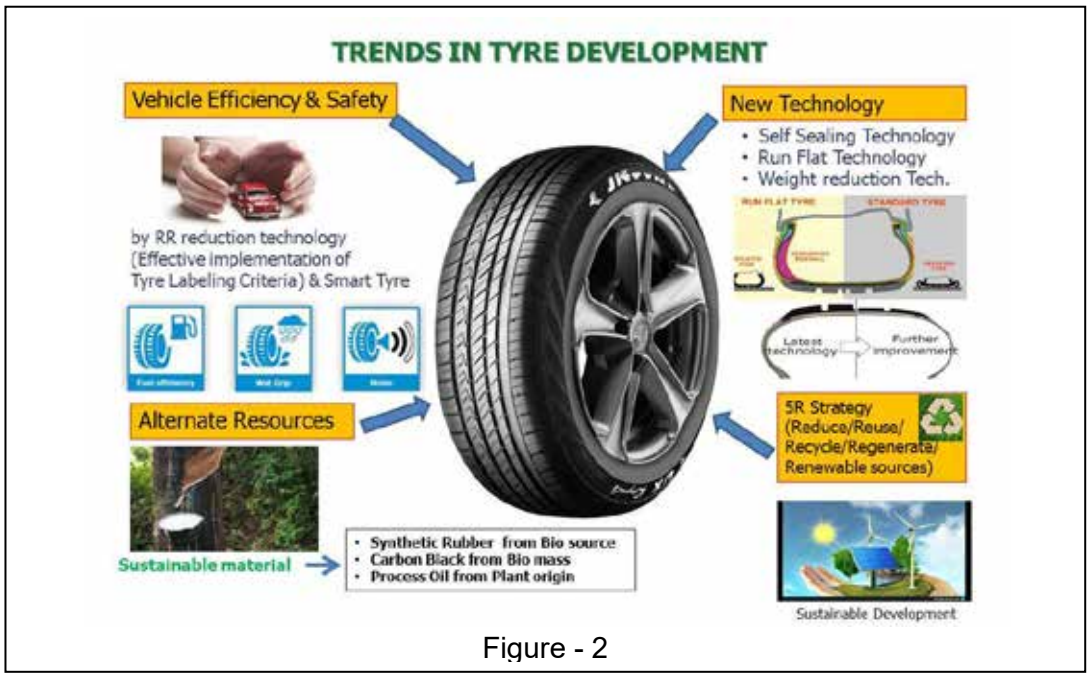

Figure - 2

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.

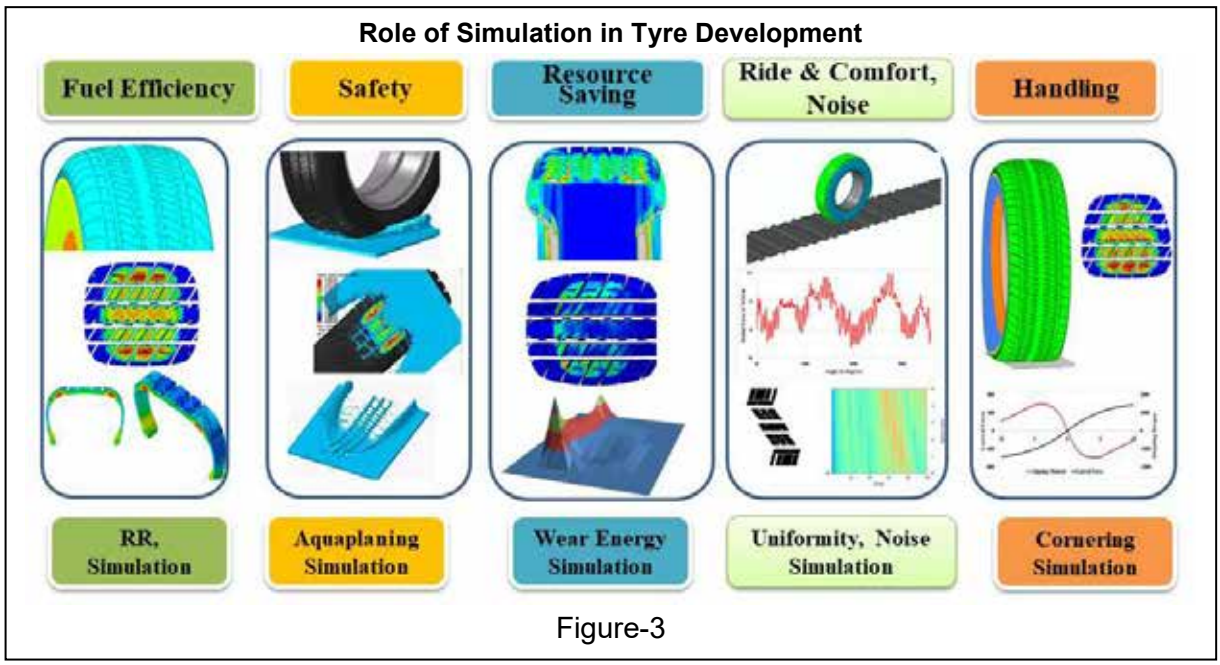

Figure-3

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-

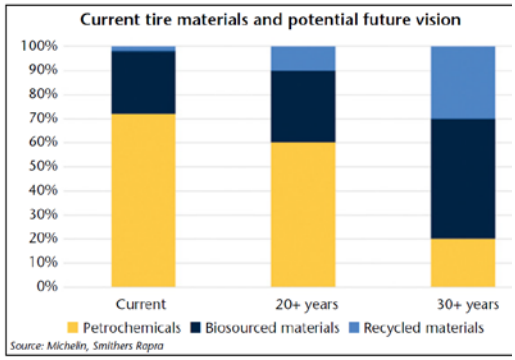

Fig-4

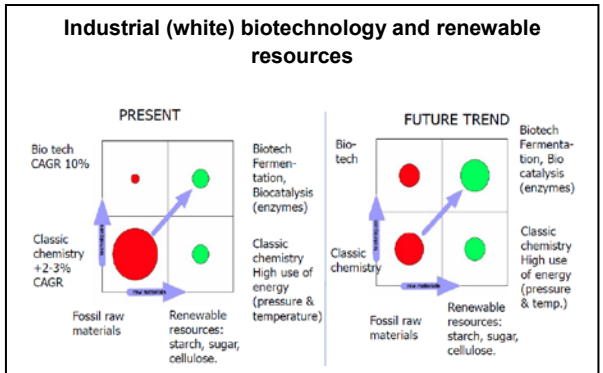

Fig -5

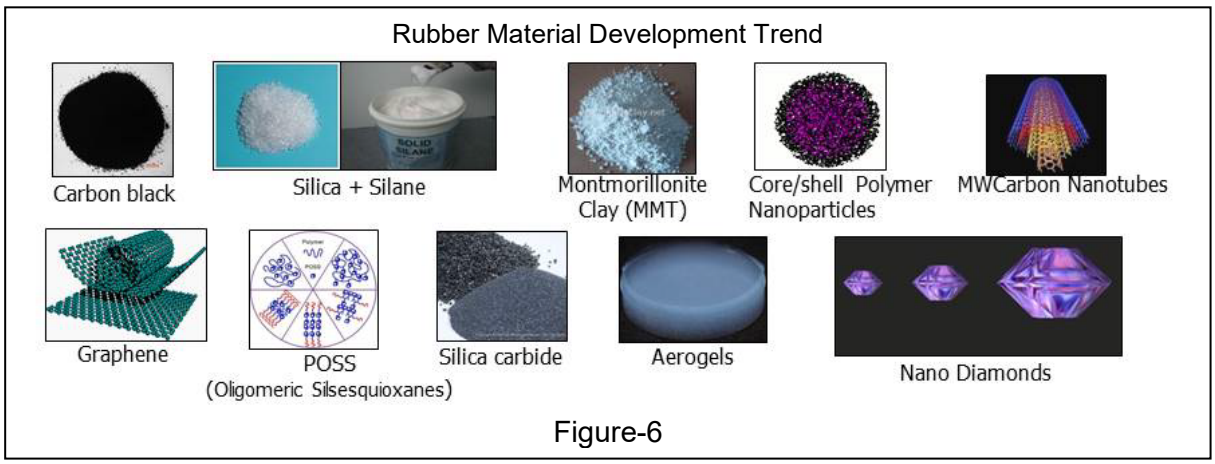

Figure-6

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

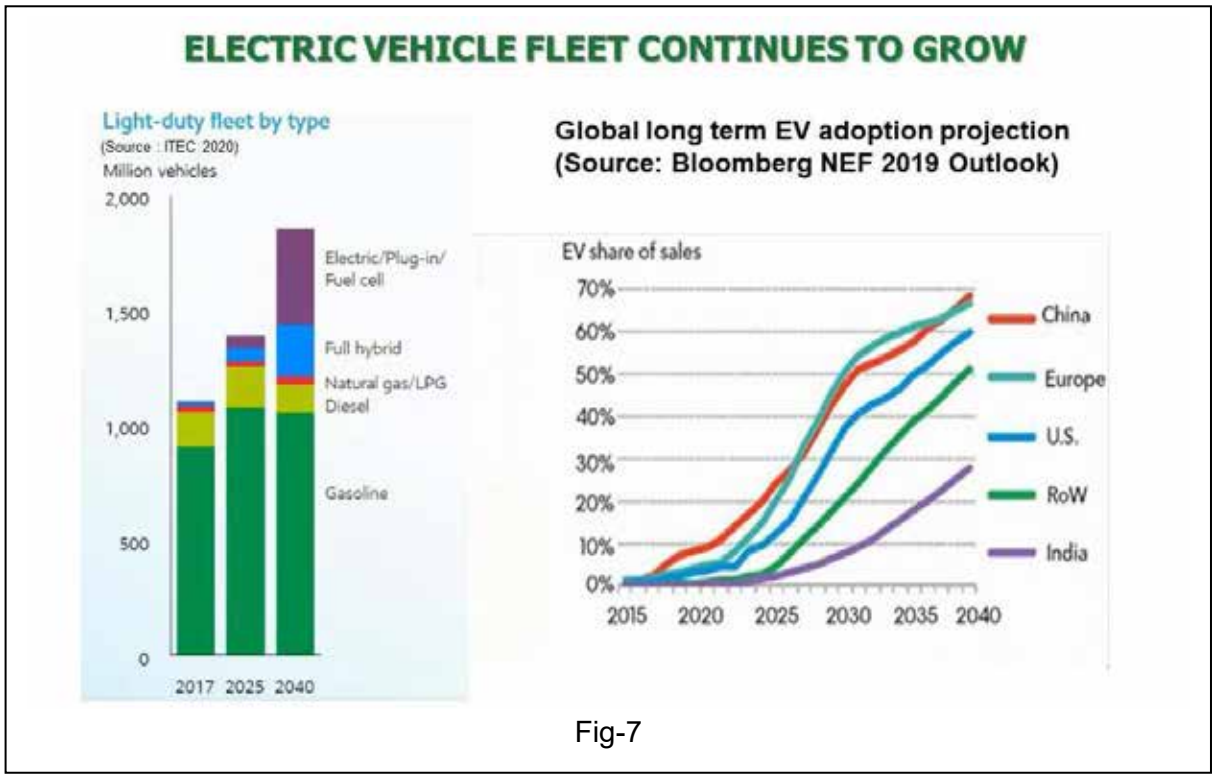

Fig-7

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.

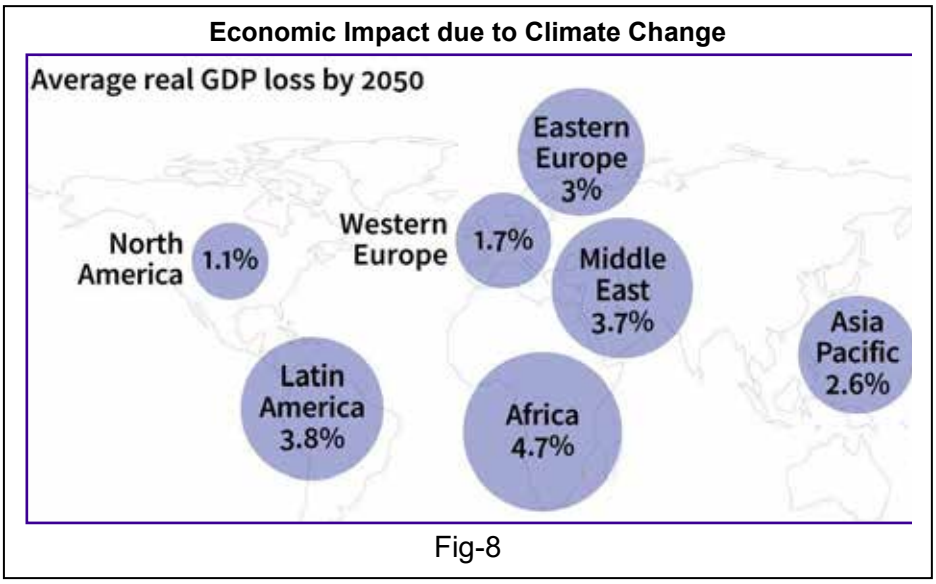

Fig-8

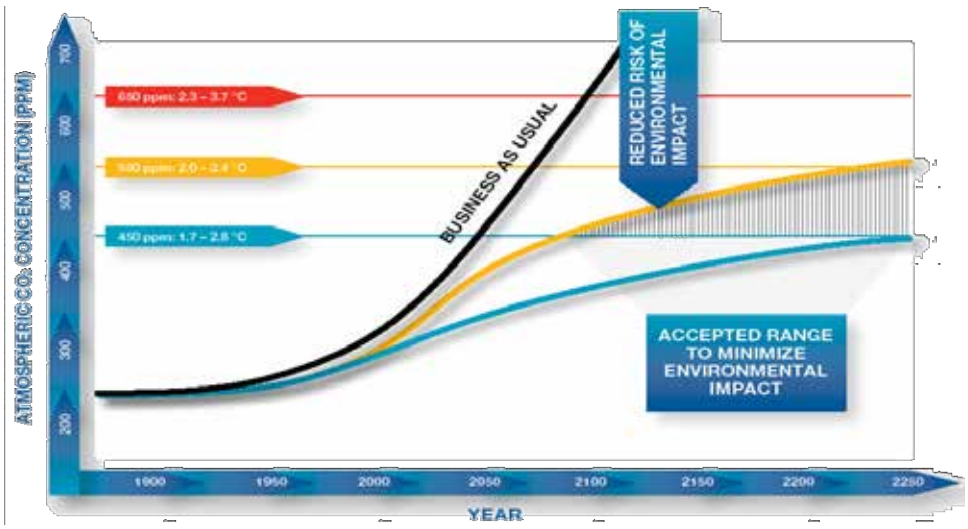

Fig-9

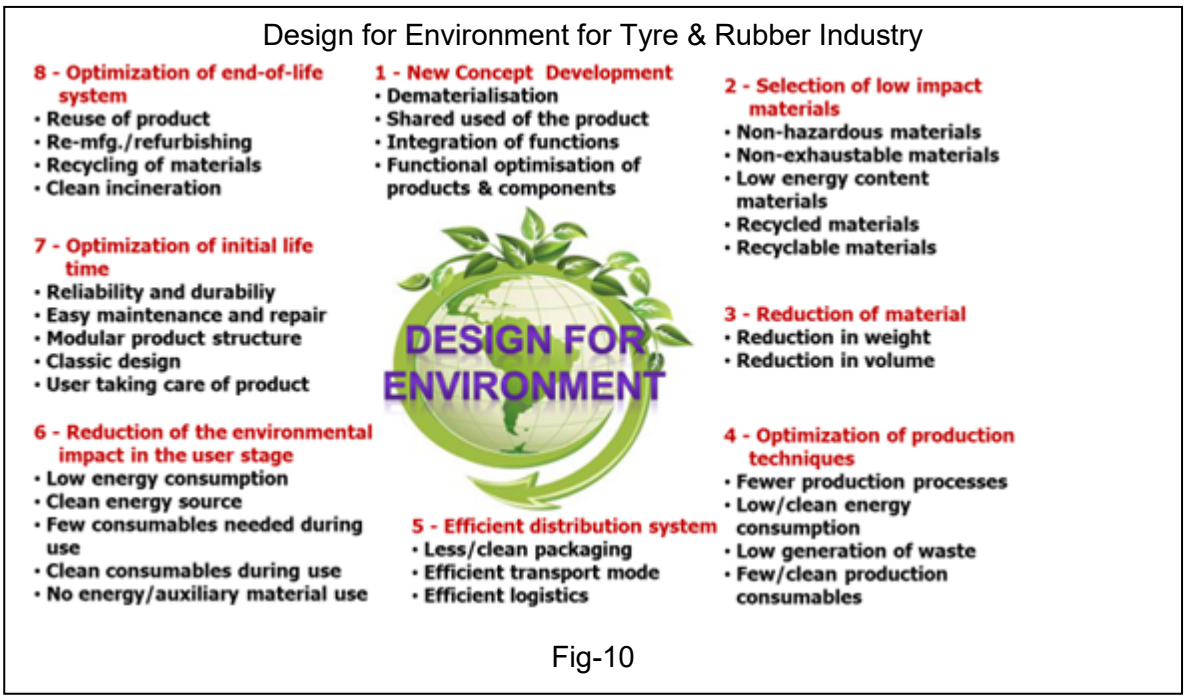

Fig-10

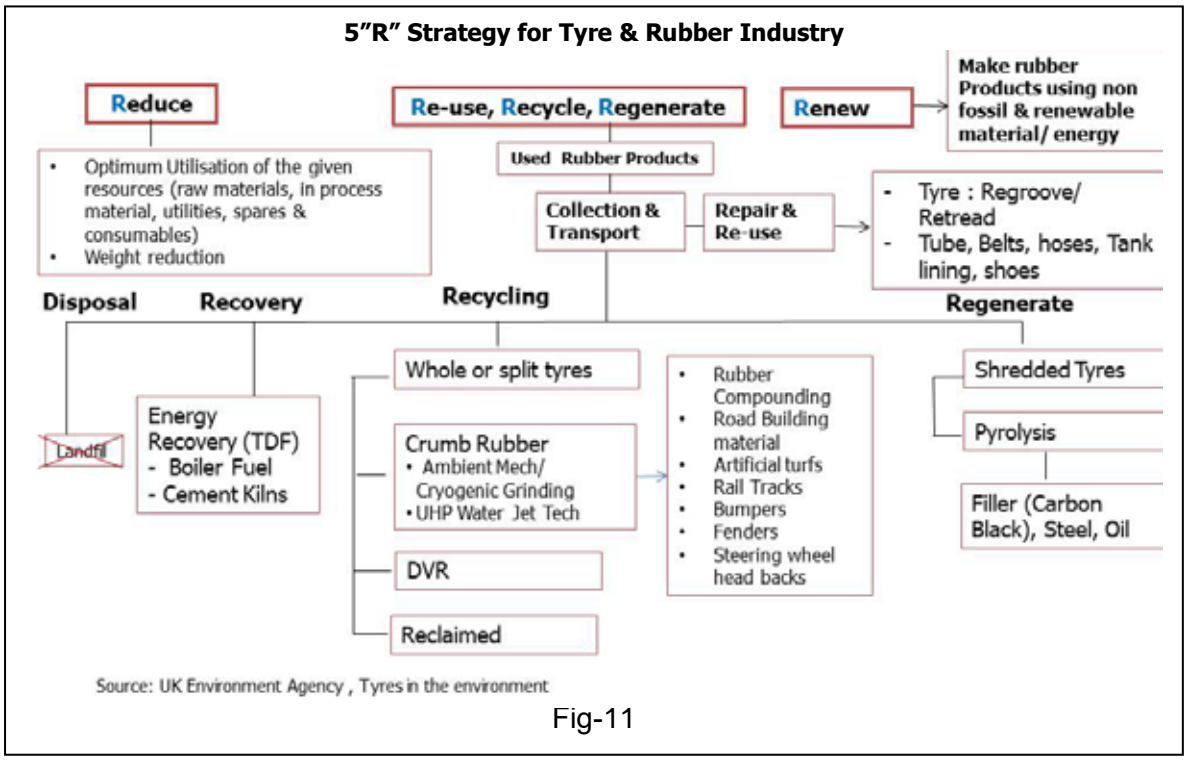

Fig-11

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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2nd	JSR HP755, JSR HP776	High-strength grade suitable for high-performance tires
3rd	JSR HPR350, JSR HPR355 JSR HPR355H, JSR HPR355A	Basic grade for CB/Silica compounds. Chain end modifier enables excellent Silica dispersion
4th	JSR HPR850, JSR HPR840 & JSR HPR830E	Grade for High Silica loading compound with low energy loss and processability
5th	JSR HPR950	Silica compound with improved low energy loss. Most advanced grade in our line up

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E-SBR Grade	Mooney Viscosity ML_{1+4}(100°C)	SP Gravity (g/cm³)	Product Stain	Coagulant	Bound Styrene (%)	Application
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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JSR CHLOROBUTYL 1066	NS	Cl 1.2	38	0.92	Inner tube, inner liner, Automotive Parts, Electric wire & Industrial goods
JSR BROMOBUTYL 2222	NS	Br 2	32	0.93	Inner Line, Bladders, Shoesole, Sports Ball

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1	**Better processing :** Lower compound viscosity and Improved Mold Flow & Anti-Sticking
2	**Barrier effect :** Lower Gas and Liquid Permeability
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 m^2/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 :

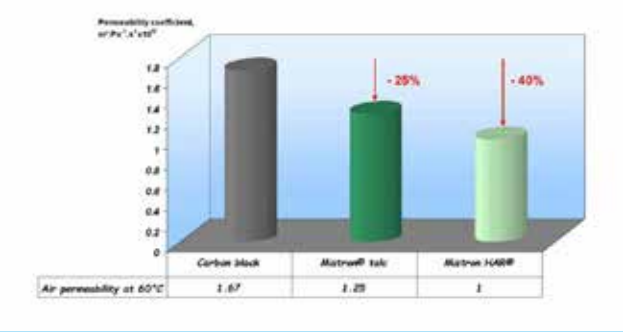
1. Retention of properties after Air Ageing also maintained
2. Further Permeability reduction possible without Carbon Black

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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