Nanotechnology in Automobiles - A OEMS Viewpoint

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Abstract. For the development of the societies into modern world, people have a very basic need that is mobility. And in this context automobiles do have a very vital role to play. By 2030, vehicle tally must reach upto “1.5 Billion” approx. utility and passenger vehicle, when estimated worldwide. As the number of vehicles would increase so as the energy demand worldwide also as resultant would be increasing. Related to this many more challenges arose regarding cumber in safety of passengers, curtailment of pollutants, traffic guidance system, efficacious recycling of life of the vehicle so that the scant resources can be saved significantly. Considering this, for automobile manufacturers a large number of opportunities are getting generated. For future needs sustainable advantages of mobility can be achieved because of which OEMs are aiming their efforts by acclimatizing the comfort ability, safety and environment friendliness.
Nanotechnology can assume a huge job by adding to the fundamental developments and production of creative materials and processes in the automotive field. Auto OEMs look to the domestic industry to use the unique innovation potentials of nanostructured materials, thereby protecting and expanding their own position. It appears that the opportunities offered by nanotechnology has not been tapped sufficiently yet. There is a need for the domestic enterprises, the auto industry & research institutions to work together to identify and initiate necessary innovation processes through nanotechnology. The paper is an endeavor to distinguish the assortment of applications for nanotechnologies in the automotive space from an auto OEM point of view and investigate the financial and technical potential to additionally develop them.

Keywords: Nanotechnology, nanomaterial, nanoparticle, nanostructure, nanotube, nanometer, functionalities

1. Introduction
Nanotechnology may be defined as a deliberate process to engineer matter on a scale between 1 and 100 nm to achieve modified or new properties Nanotechnology is becoming increasingly economically significant worldwide. It seems to affect all everyday issues, along these lines on the economy. Nanotechnology can be applied in practically all ventures and advancements due to its effects and functionalities. Given their cross-sectional limit, nanotechnology is even more critical in automotive engineering. [1]
Many authors sought to research the effect of GO and TiO2 nanoparticles on efficiency, of the construction of automobile parts.[2]
For the upgradation of vehicle performance so as to meet the legislation with respect to emission and safety, the automotive industries are so quick to use advancements that propose economically cheaper upgrades.

In the automotive industry, upgradation in numerous products and procedures done by nano materials has a large impact. For fuel system components, consisting CNT coatings for EMI and ESD, structural support and safety have been incorporated by nano composites, for (“lubrication, easy clean, self cleaning, anti-fogging, anti-abrasion, anti-corrosion and self-repairing coatings”) nano-additives. Organizations like “Toyota, General Motors, Ford & Rolls Royce” empowered in-house R&D with joint efforts of innovative developers of applications of nanomaterials in both research and business network, which makes them the leader in creating advancements[3]. A specially built sample package, comprising a glass microfiber filter paper supported on a mild steel wire frame, was obtained from the samples or parts of automobiles.[4] With applications in the automotive sector, these products fall in the upgraded products of “first generation”. Whereas products of “Second-generation” will include “fuel cells; smart tyres shape memory materials, multifunctional high-strength and lightweight structure materials, sensors”. This research focuses on the current market scenario of “first-generation” and the economical aspects of the “second-generation” products that are about to come in the next future say 5-7 years.

Materials that were characterized for nanostructure and morphology of the nanocomposites GO, TiO2, GO2-TiO2 to demonstrate the shape of the nanoparticles for the body of different automobiles.[5]

2. Nanotechnology Goals in Auto Sector

Goals for the application of nanotechnology in automobiles are:

2.1. Environment
- Resource efficiency
- Catalysts
- Fuel cells

2.2. Comfort
- Product quality
- Ease of operation
- Passenger convenience

2.3. Safety
- Active safety
- Passive safety
- Easy maintenance

3. Potential Functionalities in Automobiles

Functionalities pertaining to the auto arena are as given below:

3.1. Mechanical

At low temperature, a much better “hardness, breaking strength and fracture toughness” are the key properties which are enhanced to make nanostructured solids as a result of which grain size were reduced to eliminate deformation mechanisms in the grains, which leads to a longer durability of tools used in production, efficacious lubrication and enhanced light-weighting materials. Under this category, some conditions do also falls-in i.e. “hardness, friction, tribological properties and breaking resistance”.

3.2. Geometric effects
Reactions between solid matter in the nanometer range and fluidic substances happen on contact surfaces. Surface to volume ratio becomes prominent due to small size of nanostructures. Chemical reactivity is influenced by nanostructured materials having explicit surface and its properties. One such model-nanofilters had a normal impact because of its nanometered pores in the material. Normal Resistance is resulted against “oxidation, corrosion, mechanical abrasion, and high temperature properties”. Enormous “surface to volume ratio and pore size” results in geometric impact.

3.3. Electronic / magnetic functionalities
Significant impacts are seen in the nanometer range that may not be seen in bigger objects. The versatility of charge carriers is firmly affected by nano-objects by virtue of their restricted measurements. An expansion can be seen in electrical resistance and temperature adjustments of resistance in contrast with materials consisting micro metered crystals. On controlling grain size, electronic properties can be tuned. Size-subordinate electrical and attractive properties fall under this usefulness.

3.4. Optical functionalities
Dispersion or nanoparticles of opaque materials can seem transparent because nanoparticles are very small as compared to the visible light. By fitting the size of nanoparticles, an exact color band can be balanced explicitly where the material absorbs or emits light, which property can be misused transparent dispersion of nanoparticles or in optical useful surfaces. This usefulness is related to color, fluorescence, and transparency.

3.5. Chemical functionalities
The chemical usefulness of nano-objects depends on its surface structure. Nanostructured materials have a high portion of surface atoms, which are profoundly reactive because of saturated bonding. The lattice strain prompts expanded surface energy, which can discover applications for surfaces with customized wetting conduct, for upgrading chemical reactivity and furthermore for chemical stability in assorted chemical procedures. Reactivity, selectivity, and surface properties are the functionalities under this class.

4. Applications of Nanotechnologies in Automobiles:
Possible application fields of nanotechnologies in automobiles may be classified broadly as under:

4.1. Car body shell exterior:
   Mechanical functionalities - Nano varnish and polymer glazing
   Optical functionalities - Electro-chromatic and Ultra thin layers
   Chemical functionalities - Sealing systems
Nanostructured surfaces offer improved paint adhesion. Scratch-resistant, dirt-repellent, and self-healing car paints are applications that might be sought after towards advancement. A flawless car body shell should be ensured much after a few car washes and quite a long while of activity. Contrasted with regular paint frameworks, nano varnishes take into account higher scratch resistance and paint brilliance. The reason for this technological impact is implanted ceramic particles in the varnish layer in the nanometer extend. During the drying and hardening process, they cross-connect with the molecular structure of the paint matrix, bringing about a thick and requested matrix on the paint surface which adds to a profoundly improved scratch resistance and paint brilliance. Nano paints comprise an organic binder with high elasticity and inorganic nanoparticles with high strength. The firmly packed nanoparticles make the paint scratch resistant.
For windshield majorly of a vehicle, glasses are processed largely. The substitution of mineral glass by polymer glass add-ons the capability of nanotechnology for lightweight construction. Acrylate paint coating have been used to impart scratch resistant property in which, during hardening process hard Al₂O₃ nanoparticles are introduced in substrate matrix, because of which solid impact strength with higher resistance to abrasion had been achieved. This coating is immensely transparent, accounting which of eminently small sized filler particles and having a fine distribution. New opportunities are created by “high strength scratch resistant plastics”. Which impart a broader aspect of use of plastics from “transparent roof tops and car body shell parts to whole car modules”. Thicknesses below 100nm of “ultra-thin reflecting layered Al₂O₃” are used to have superior optical quality of modern mirrors and headlights which is totally based on components of glass and plastic.

4.2. Car body

Mechanical functionalities - Nano steel
Chemical functionalities - Forming of high strength steel and corrosion protection

The safety of road users is a significant reason why we are developing materials and substance having nanostructures. Nanostructured car body parts with high strength that makes it supremely efficient crash absorbers. This would translate into reduction in weight and fuel consumption. For construction of car body steel is still the crucial material. Increasingly being used in bodies, given current weight reduction requirements, light metals and plastics are being considered as alternatives. High strength steel is now getting produced utilizing nanotechnology so as to get steel of high strength steel grades. Steel strength can be multiplied by embedded “metallic carbon nitride”. Process of dispersion hardening through use of fine particles currently in vogue, uniformly dispersed, may not be economical for production of large quantities of steel. The disadvantage can be set aside through nanoparticle addition of metallic carbon nitride. 5-10nm sized carbon nitride particles have the capability to do wonder. Manufacturability also can be quite cheaper.

On the issue of corrosion protection, chromium in hexavalent form is required to be discontinued due to health hazards and environmental perils arising out of it. The option lies in changing over to chromium in the trivalent form or chrome-free protection. The chrome-IV passivation that has a self healing effect whereas inferior protection is in chrome-III passivated surfaces. A long-term protection is missing in chrome-III as compared to chrome-IV. But this disadvantage can be eliminated by using “silica nanoparticles in the electrolyte”. A positive surface charge gets developed just because of exposure of zinc layer after damage. Negative charged SiO2 particles propagate towards damaged area. To prevent it, self-healing is done by covering it.

Challenges in the coating market:
- Customer’s expectations
- Eco-efficiency & sustainability
- Innovation, change

Expectations for nanotechnology in coatings:
- Scratch resistance
4.3. Car interior

Geometric effects - Nano filter
Optical functionalities - Anti-glare coatings
Chemical functionalities - Dirt protection, fragrance in the cabin

In the vehicle interior, “dirt-repellent seats, air filters designed to filter particles and gas pollutants” play an important role. Auto OEMs have a responsibility to provide much more improved comfortability with keeping into consideration about the fuel economy and safety. Climate inside the vehicle is influenced by the air quality, which is guided by the filtration of particles and gaseous pollutants. The filter has to perform at “diverse temperatures under varying humidity conditions and endure vibrations, water and microbiological fouling”. Pressure loss is eliminated while transporting air and energy can be saved by minimizing air resistance, when the fibers in nanometer range are used in the filters which exhibits extremely fine filter properties. In passenger vehicles, soot filters are developed using nano-filtration technology to reduce pollutant emissions. Air supply and air conditioning is also another concern for the development, the air is being discharged on the roof with special foam which can be filtered using nanotechnology, so as to get foam material free from dirt particles because the particles will not adhere to the foam material. Another advantage is that it provides better heat insulation of foam.

If the fabric is made of such fabric and leather covering materials, the unwanted effects of dirt and water stains on the seats, when in rainy day, the water comes in as the door opens it makes the dirt stick to the seat covers can be reduced or somewhat eliminated. Use of nanotechnology is made to impart special fragrance on leather seats because of “aqueous micro capsule dispersion”. The thickness of the capsule is in small nanometer range which makes it to let the leather penetrate and adhere between fibers. And when seats are used film bursts, releasing fragrance in the car.

4.4. Chassis & tyres

Mechanical functionalities - Carbon black in tyres & Nano steel
Rubber mixtures play a prominent role in the property of tyres, as tyres are most technologically advanced product which decides the performance while contacting with road. Tyres possess contradictory requirements that are “good grip, lower rolling resistance, abrasion resistance, slip proof”. Chemical and physical interactions in the case of tyres are complex in between both rubber and filler material. Properties of natural rubber are significantly enhanced by using soot which increases durability and fuel efficiency. Reduced inner friction and rolling resistance is achieved by increased surface energy of nano-particles which improves interaction with molecules of natural rubber. At high speed, strain vibrations also get reduced within the material. On wet roads the most problematic area is superior traction.

Chassis designing is full of conflict theory in between making a balance between comfort and safety, on one hand, “soft chassis is comfortable” while on the other hand “hard chassis is safe”.

An automotive chassis is designed amidst a conflict between comfort and safety. A “soft” chassis is considered comfortable while a “hard” one safe. By the application of magnetic and electric field, magneto-rheological fluid used in damping systems can change the viscosity. This change must be a
rapid one, as such the fluid must transform into tenacious gel within few milliseconds. Nano particles used in as an additive can make this phase change transformation at much faster rate of 1500 times per sec from fluid and solid state. This shift is prominent as compared to modern hydraulics having rate close to 400-500 times per second.

4.5. Electrics & electronics

- Geometric effects - Fuel cell
- Electronic / magnetic functionalities - Solar cells

Electronics is the basic and most important stream when automation is considered as almost every part is controlled by electronic means. Super capacitors are made using nanotechnologies. In automation, electronics creates a driving assistance to the innovation which creates a wide variety of applications. A major issue in automobiles is power consumption. Electronics helped in the enhanced safety measures and comfort in addition to entertainment electronics which on the other hand increases power consumption of automobile. And as the fossil fuel reserves are depleting at a much faster rate the alternating energy are gaining the interest more significantly, for which fuel cells plays a crucial role. In the core of the fuel cell, chemical reactions between hydrogen and oxygen take place as a result of which heat and current is produced. Splitting of “hydrogen ions at anode”, and “electrons of oxygen at cathode”, between gas diffusion electrode with catalyst and membrane. A large surface catalyst is needed for membrane electrode unit operations and system performance, for which nanoscaled precious metal molecules is used. The challenge is to distribute these particles equally and avoid agglomeration during the operation.

In conventional solar cells difficulty arose is the efficiency reduction because of light reflection at glass pane, which is of around 10% in “high-quality glass pane” even. Reduction of reflection of light and improved solar system efficiency is obtained by glass coating which have been developed based on sol-gel technology. From a combination of 10-35nm diametric particles as a result of which the desired nano porous layer applies a “wide band anti-reflection coating”. Nano porous layer at 600-700°C is hardened with glass is formed of sol when the pains are dried by applying gel. Reduced reflection and increase solar transmission is caused by layer of low refractive index.

4.6. Engine & Drive train

- Mechanical functionalities - Low friction components
- Chemical functionalities – Catalysts, Fuel additives

Reduction of friction by nano layer systems can result in fuel savings. Fuel consumption is influenced by engine friction due to the friction loss at the moving mechanical parts. Apart from the piston aggregate comprising the cylinder wall and the piston, elements of the crank drive and valve drive, including the camshaft and valves for part of the mechanical parts, friction of the piston aggregate causes a major part of the friction losses. Nanotechnologies can help reduce fuel consumption by reducing friction through application of nanocrystalline coatings onto the cylinder wall. Exhaust-cleaning automotive catalysts comprise a mix of platinum (Pt), rhodium (Rh) and palladium (Pd). Within the catalyst, the chemical reaction between the precious metals and exhaust gases contributes to the chemical reaction of nitrogen oxide (NOX), Carbon monoxide (CO) and hydrocarbons (HC) - into non-toxic compounds such as nitrogen (N\textsubscript{2}), water (H\textsubscript{2}O), and carbon dioxide (CO\textsubscript{2}).

In conventional catalysts, the high temperatures within the catalyst cause the precious metals to cluster-up, reducing the exposed metal surface area, leading to less-effective cleaning of the gases. To compensate this problem, existing converters contain a higher amount of precious metals in order to maintain an efficient level of cleaning. For the reduction of exhaust emissions in automobiles, catalysts are necessary. Catalysts include catalytically active materials for the red-ox reactions to convert the pollutants to nitrogen, steam and carbon dioxide. For exhaust cleaning, systems based on three-way catalysts are used. During conversion of toxic to non-toxic gases, nanotechnologies play a crucial role. Impact of the catalysts depends on the surface. If the material used for the catalytic function is scaled to the nanometer range, the specific surface area increases drastically.
Engine coolant:
Thermal conductivity was enhanced by using nanofluids that are the suspended nanoparticles in conventional fluids. Such enhancement cannot be achieved be achieved by micrometer sized particle fluid suspensions. Following potential exists for nanotechnology in engine coolants:

- Coolant life increase
- Downsize cooling system
- Increase compression ratio & downsize engine
- Improved heat transfer

Auto OEM's concern:
- Increased guarantee period with no coolant change i coolant topping
- Provision to be made for field abuse in case of dilution, mixture with other fluids, leakage etc.
- Toxicity, if any
- Coolant cost vis-a-vis increase in fuel efficiency
- Compatibility of nano-based coolant with existing coolants
- The coolant has to be non amine & free from borates, silicates, phosphates, chlorides, Sulphates Metal ions like Ca, Al, Fe, Zn, Cu, Pb is not permitted.

Engine modifications can be effected only after the nanofluid application technology matures with time. [6]

5. Conclusion
A full research on the economical ability of nanotechnologies needs to be done for automotive industries. Nanotechnology has a potential to open up new markets for the auto industry. There appears a decisive advantage through use of nanotechnology. Nanotechnologies, with their numerous application possibilities and significant impact on materials and substances, could give an impetus to innovations, especially in the auto sector. The functional properties in the field of chemistry and materials lie in improved “material properties” and “surface functionalisation” followed by “protective and optical functions”, applied in automobiles.

Industrial product enhancement with an innovative research can be attained by acquiring a driving force. These portray the characteristic qualities of automotive industry based on its technological capacity. To gain a competitive edge, nanotechnology provides an add-on in terms of automotive industry. Regarding its possibility of future enhancements, analysis of on-going developments needs to be done.

In automotive industry, nanotechnologies have a vital position. Nanomaterial examples are “Electrochromic mirrors avoid the blinding of the driver - anti-glare instruments and heat absorbing panes”. On different roads tyres made of nanomaterial composition, adheres better. Futuristic cars can be seen more intelligent in response to environmental stimuli. Aesthetic functional properties using nanotechnologies is also significant. For the vehicle, “Body-in-white, engine and chassis, lightweight construction composites” with new properties can be explored that have superior crash resistance. For drive units, nanotechnologies offer an optimization potential as regards enhanced fuel efficiency and emission reduction. Nanotechnology finds useful application in catalytic converters. New potentials may be explored by nano tribology because the functional property of vehicle gets influenced by abrasion of parts. Diffusion membranes can be optimized with the help of nano technological products.

Automotive industry market competition and an increase in profitability is the result of nano technological applications. Automotive industries when collaborating their knowledge and research with the academic and research organizations can do wonders in the field of nanotechnologies.

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