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A Review on Applications of Nanotechnology in Automotive Industry

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Abstract**—**Nanotechnology in pristine sense refers to building of structures at atomic and molecular scale. Meticulously nanotechnology encompasses the nanomaterials with at least one dimension size ranging from 1 to 100 nanometres. Unlike the literal meaning of its name, nanotechnology is a massive concept beyond imagination. This paper predominantly deals with relevance of nanotechnology in automotive industries. New generation of automotives looks at nanotechnology as an emerging trend of manufacturing revolution. Intricate shapes can be made out of fairly inexpensive raw materials instead of conventional fabrication process. Though the current era have enough technology to face competition, nanotechnology can give futuristic implications to pick up the modern pace. Nanotechnology intends to bridge the gap between automotives with superior technical performance and their cost fluctuation. Preliminarily, it is an area of great scientific interest and a major shaper of many new technologies. Nanotechnology can be an ideal building block for automotive industries, under constant evolution offering a very wide scope of activity. It possesses huge potential and is still in the embryonic form of research and development.

Keywords**—**Nanotechnology, nanomaterials, manufacturing, automotive industry**.**

I. Introduction

To gain an outline of this diverse technology, a brief literature has come to limelight in the automotive context. Public debates and economic and social reviews have already set a roadmap in the realms of nanotechnology. Nanotechnology is being heralded as a new technological revolution, thus modern industries are trying to be receptive towards nanotechnology within strict automotive standards. Nanotechnology originates from small dimensions, enabling high speed and high functional density, small and lightweight devices and sensors, high sensitivity and special surface effects offering superior efficiency in almost every facet of automotives [1]. Also, it has significant impact on a wide range of automotive components and is capable to meet firm legislations regarding emissions and security. Nanotechnology is rapidly changing the way cars are made, making it possible to build cars with extensive service life; lower component failure rate and smart materials for self-repairing. Materials at nanoscales exhibit unique properties different from their bulk state. Vehicles contrived with these materials can be manipulated to make their properties more advantageous [2]. Global automotive markets expect exponential positive returns, but they are hurdled by high initial investments and limited research and development. Although nanotechnology applications in automotive industry are manifold, many of the aspects of nanotechnology still remains untapped and unacknowledged.

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II. Literature Review

Today, Nanotechnology has opened new doors for automotive sectors. The entire product lifecycle management can be mounted on the automation of this technology. Besides being promisingly sustainable, safe, comfortable, and eco-friendly, it is also commercially economical technology. CO_2-free engines, safe driving, quiet cars, self-cleaning body, and windscreens etc. can be the key drivers for the idea of “nano in cars” to come alive [3].Nanotechnology explicitly presents new opportunities for worldwide accomplishments of automobiles. This technology is not only finding its way into every corner of car-world, but is also bringing great benefits. Fundamentally, two main approaches are used in nanotechnology. Firstly, the "bottom-up" approach, where nano-objects are created by assembling individual atoms together, thus is reducing the randomness in structural formation. Secondly, the "top-down" approach, where nano-objects are built from larger units without atomic level control. Reports show that nanotechnology is advancing as a core technology for automotive development. Many authors have emphasized on the use of nanocomposites in several domains like frames and body parts, engines, paints and coatings, suspension and breaking systems, lubrication, tires, exhaust systems, etc. Many anticipate that, certain materials like carbon nanotubes and carbon black that has enhanced mechanical, physical, and processing properties will render new functionalities. In addition, they may improve manufacturing speed and enhance environmental, thermal, and mechanical stability [4]. This means that car bodies will undergo less wear, better gliding, thinner coating, fewer lubrication, longer service intervals, and weight reduction. Lighter car bodies will use less material, without compromising the stiffness and crash resistance and will indirectly save fuel profoundly. This will also ensure greater safety and improved highway systems. Nowadays nanotechnology is blended with many pronounced disciplines to obtain exemplary products. One such technological breakthrough is the MEMS technology. In fact, automotive components need to be produced in very large volumes not only to meet the demand, but also to meet the necessity of recovering the initial investments. MEMS ought to be a crucial solution for this setback. Due to the progress made in batch manufacturing of MEMS, large volumes of highly uniform devices can be created at relatively low cost [5].Apart from this, nanotechnology contributes prominently in production of innovative materials, growth of income and employment. As yet, nanotechnology has influence the auto industry on a very small scale, but it is betting big on the applications that are unthinkable, provided; the company should generate sustainable revenue stream and healthy profit margin [6].Results from studies of various authors show that demand for increased power performance has turned the automakers to new technologies. For e.g. Cars powered by its own body panels is seen as next milestone especially in development of electric cars, and the concept of supercapacitor technology based on carbon nanotubes, seems the most lucrative idea. This is definitely going to be not only energy intensive but highly resource intensive too. It would trace behind significant impacts not only on environmental factors but also on financial factors. Therefore, nanoscience and nanotechnology ventures are counting big on commercial ramp-up [7]. Market continually demands better and more durable automotive coatings. Nanofillers for coatings may be inorganic or organic, like silicates, oxides, organo-clays, acrylics, urethanes, etc. The effect of coating properties varies inversely with the size of filler particles. Need of nanocoating is of paramount importance as they bring out the aesthetics of the product. Apart from the functionality, today's customers demand sublime surface smoothness, reflectivity, and high gloss appearance [8].

III. Applications

Nanotechnology has flooded the automotive hub with clusters of new-found technologies, which has together come up with classic applications in each and every part of automobiles. This has created new opportunities for encroachment of car engineering.

A. Tyres

Rubber fillers, like carbon black and silica as nano-structured materials have been cited as essence of automotive tyre sector for many years. But recently, research programs have been conducted to improvise these materials in order to provide lower rolling resistance, abrasion resistance, extended tyre life, and wet traction, safety, lower weight, superior performance, reduced friction and improved air retention.

B. Chassis

One of the automotive industry's most ambitious goals is the introduction of bodywork made of light alloys. Addition of new electronic components, safety technologies and increasing comfort features would have made the modern cars heavier. To relieve this, incorporation of nanoparticles has made it possible to reach the same mechanical resistance and lighter weights with less and lighter material. This can considerably improve the properties, like resistance, elasticity, or dimensional stability, as well as specific properties like fire resistance for interior parts and weather resistance for outer parts. Plastic bodywork is yet another option, provided; they undergo electrostatic painting together with metallic parts [9].

C. Coatings

Nanotechnology can be best used in automotives in the coatings. Parts of standard vehicles are treated with protective and decorative finishes. Coating has already made glass heat reflective. In addition, water and dust repellent coatings has already been applied to cars. However, there still remains a vast area where nanocoatings have to pave its way. Many coatings have been around for a long time and still continue to have use and function in the automotive marketplace. Hard coatings of ceramics, improves wear and friction characteristics of components, along with the specialty of detecting even fractional concentrations of gas in vehicle interiors. Self -repairing is yet another concept where materials can refine their original shape under the influence of external temperature. In addition, the electro-chromic coatings are prophetic of the enormous boon for future cars [10].

D. Nano-Fluids

The use of nanofluids has a clear advantage from the thermal performance viewpoint. The heat transfer coefficient of coolants can be increased by improving its specific properties. Nano-fluids can form vital component of fuel additives, coolants, brake fluids, lubricants and shock absorber systems, transmission fluids, engine oils and greases, etc. Nano-fluids have great potentials to improve automotive and heavy-duty engine cooling rates by increasing the efficiency, lowering the weight, and reducing the complexity of thermal management systems. The heat rejection requirements of automobiles can also be met in the same way [11]

E. Nano-Enabled Automotive Textiles

To enhance both the intrinsic and the perceived quality and comfort in a vehicles nanotextiles play an important role. Nanofibers can produce materials with reduced weight, proper insulation, and noise absorbents for accessories like cabin roof, boot carpets, safety belts, airbags, air filtrations, tyre cords, and trimmings. Moreover, these textiles can be recycled easily and can replace conventional hard-surface structures.

F. Sensors

Sensors are the detectors that are capable of monitoring the state of a number of aggregate moving systems. Types of sensors used in order to improve the reliability of the systems are rotational motion sensors that detect shaft rotational motion, pressure sensors that measure the pressure, linear position sensors that measure linear displacement, angular position sensors that measures revolutions, temperature sensors, etc.

Application of nano-structured materials on the other hand assures the safety of car and its passengers. Apart from this,

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flexibility, weight reduction, and strength of nanostructures are to be taken care of, so as to increase the performance, reducing fuel consumption and economy of operation.

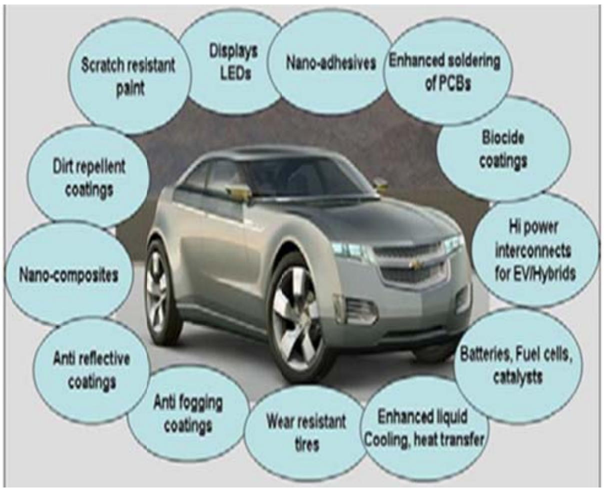

Fig. 1 Automotive applications of nanotechnology [12]

IV. MEMS in Automotive Mainstream

Micro-Electro-Mechanical Systems (MEMS) is a new buzzword in nanotechnology. It is an integration of miniaturized electrical and mechanical systems. This kind of micro fabrication has proliferated the use of MEMS in various sensors, actuators, and electronics on a common silicon substrate. Provision of moving parts in MEMS, which can sense or manipulate the physical environment, makes vehicles far more interactive. MEMS devices senses, think, act, and communicate. They offer a route to low-cost and low-power sensors for a wide range of applications. They can convey light, fluids and detect matter, pressure, heat, or motion. Hence, MEMS sensors are used in automotive industry as prime elements of airbag systems, vehicle security systems, electronic stability control systems or roll-over detectors, inertial brake lights, headlight leveling, automatic door locks, active suspension, etc. [13]. Automotive engineers are challenged by a host of rigorous requirements. MEMS has not only contributed to the downsizing of devices but has also maintained their lower price to performance ratio in particular. Thus, a fair economy is maintained due to batch processing, together with miniaturization and integration of electronic intelligence. Simply, MEMS promise to make more beneficial and high performance sensors available for automotive applications by replacing conventional sensors which would have been otherwise several times more expensive [14]. Nowadays, modern technologies like bus communication, digital gauges, and electric power assist steering and navigation systems are becoming a necessity in modern vehicles. Therefore, to maintain the lower cost of automotive sensors used in these technologies, wire connections are limited [15]. MEMS are most popular in the automotive industry and are on the verge of becoming a general-purpose technology. Although, looked at as separate and distinct technologies, there exists a mutual dependence between MEMS and Nanotechnology.

V. Advantages

Nanomaterials are characterized by some especially advantageous mechanical properties unattainable for conventional materials. It has found its wider applications in technological driving aids like anti-lock braking system, power-steering, airbags, etc. The dashboards and body panels made out of these materials are highly resistant to scratching and surface damaging. Apparently, this makes the car parts look brand new even after many years. Moreover, the enhanced barrier properties of nanocomposites make them profitable for building fuel tanks. In addition, these type of tanks ensures that the full energy is harnessed from the fuel in automobile combustion, thus reducing environmental pollution [16]. Nanomaterials can be modified as compared to other materials due to increased relative surface area, and quantum effects. Depending upon the diameter of the nanomaterials, they can have very high electrical and thermal conductivity as well as mechanical properties due to minimum defects in the atomic structure. This makes car bodies robust and at the same time provides generous crumple zones in case of accidents. Using nanotechnology in car tires could save millions of gallons of gas a year caused by under inflated tires and would lower accident rates [17]. This technology benefits automotive industry, at various levels both, in terms of passenger needs and environmental impact. In addition, polymer nanocomposites that are manufactured commercially for diverse structural vehicles applications, and nanofillers for exterior vehicle panels, increase the modulus of materials. Carbon nanofibres used in automotive exterior panels reduces weight in bumpers and fenders. Some applications provide improved colourability and mar resistance [18]. Product ranges in automotive industries are accompanied by risk management.

VI. Challenges Faced by Nanotechnology in Automotive Industries

Despite being a field full of ambitious ideas, nanotechnologies face many arguments. These arguments may question the future of nanotechnology in automotive industries if not resolved with deliberation. As compared to the other well-established branches of applied science, nanotechnology is still in the under-developed stage. In contrast to the benefits; there are concerns about potential substantial risks that nanotechnology might hold. There are number of other challenges and an approach has to be made for safe nanotechnology. Even engineered nanomaterials can behave uncertainly, disrupting health and environment. Therefore, automotive manufacturers and suppliers must continue the daunting task of keeping themselves aware of the on-going developments in nanomaterial hazard and risk assessment [19]. Nanotechnology anyways, has to face social challenges, as mass production of vehicles will make the market more cost competitive. Despite its huge advantages, making nanotechnology commercially viable is yet another challenge. Clearly, the unrestricted availability of advanced nanotechnology may pose severe risks for automotive industries, which may finely outweigh the benefits of clean, cheap, convenient, and self-contained manufacturing [20]. For e.g., nanofluids face limitations, due to its poor chemical and physical stability in suspensions, lower specific heat, high cost, undesirably increased pressure drop and pumping power. Environmental compatibility is another impending challenge. Holistic approach of nanotechnology can lead to superior cars but at the same time, it can facilitate disruption in an international market arena putting intense pressure on the competitive capabilities [21]. Some automotive firms see nanotechnology as a great help, while the conformist ones see it patronizing. Much of the discussion on the need, regulation, development, & applications of nanotechnology is still inconclusive. Ultimately, it is consumer's interest to approve nanotechnology favorably.

VII. Conclusion

Nanotechnology is about to explode as a major shaper of automotive industries. It has brought tremendous innovation in transforming industrial outlook. Automobile industry is set to be influenced by the development-taking place in the field of nanotechnology. This review paper sheds light on the evolution of nano-engineered automobiles and provides an up-to-date overview of current and emerging state of the art of automotive technologies. Spin off effects of invasion of nanotechnology in automobiles has been a trendsetter for modernization of cars. Significant usage of nanotechnology in the automotive industry has increased the production scale. Lastly, by the end of this decade, nanotechnology is expected to be a generic technology accepted worldwide.

VIII. The Future Scope

Nanotechnology awaits a boom in the car industry. Growing desire to optimize cars can be very well influenced by this technology. The entire spectrum of nanotechnology will set numerous future trends for smart cars. One of the changing traits of modern cars is that, progressively more parts there in are controlled electronically. For e.g. electronically controlled fuel injection, exhaust emission, anti-lock braking system, automatic air conditioning, headlight brightness control, automatic adjustment of driver's seat, steering control, electronically controlled hanging, etc. [22]. It should also be noted that it will also be safer, as it will incorporate a level of artificial intelligence that enables it to compensate for driver errors. The car of the future will be networked with other vehicles in the vicinity, and this will extend its range of perception. However, this is not where the vision ends. In future automotive engineering, nanotechnological competence will be one of the fundamental capabilities required to remain universally competitive. All the automotive subsystems will be a creation of nanotechnology. It includes using advanced nanoparticles as a filler in car tyres, anti-reflective coatings for displays and mirrors, nanoparticle-reinforced polymers and metals, modified adhesive technologies and adhesive primers, improved fuel cell technology and hydrogen storage, catalytic nanoparticles as a fuel additive, etc. [23]. The high-tech cars will comprise of headlights that will automatically follow the road, radar and heat sensors that will recognize humans, animals, and objects on roadways and assist in parking. Acutely, this is a work of engineering endeavor and the manufacturers are keen to bring their ultra-modern cars off the assembly line and meet the burgeoning demand.

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