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Automotive Materials: An Overview

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Abstract – *Automotive sector has evolved tremendously in past few decades and will going to do the same in the upcoming years. So, to support this evolution, materials used in this sector also evolved accordingly. A vehicle comprises of thousands of parts which are made from thousands of materials like steel, aluminium, plastics, rubber, copper, glass, magnesium, composites, etc. This paper will provide systematic information on the materials which are used for the production of automobiles to meet the future trends. Demand of higher fuel efficiency with light-weight and less emissions, leads to the development of advanced materials from traditional materials. Automobile industries are mainly emphasizing on the weight reduction without loss of strength which will enhance the performance and the fuel efficiency. This paper focuses on the current scenario as well as future scenario of the automotive materials. Elaborated content is provided on the current scene of the automobile industries. Then brief discussion is made on the advanced future materials which are going to be used in the nearby future or currently in use in the manufacturing of supercars which are very expensive. These materials are developing or inventing without compromising with the safety and comfort of the passengers or the person who are going to drive the vehicle.*

Key Words: Automotive Materials, Automobile Manufacturing, Automotive Sector, Automobiles, Advanced Materials.

1. INTRODUCTION

The automotive industries have undergone major changes over the past 50 years that move people and helps in the transportation of goods from one place to another and the main thing is the development of new materials and their manufacturing processes. Therefore, in this paper, we are going to concentrate on automobiles which consumes the most of the materials during their manufacturing.[1]

As materials play a decisive role in respect to the quality and cost of a automobile, selection of the correct materials at the earliest possible stage is very important.

The materials used in vehicles nowadays are selected on the basis to fulfill the specific requirements like light weight, high strength, etc. It is the job of the materials engineer in a car-manufacturing company to choose the materials so as to get optimum performance as well as considering the cost and external factors.

Newly developed materials in the market give competition for materials already in use. The application of such materials is dependent on how they will satisfy the requirements or the need of the automotive sector.[2]

1.1 How the materials evolved?

The growth of world population and global market has very good impact in the automotive business. In 1920, 12% of the world's population have vehicles and the composition of vehicles was ¾ of low-carbon steel except for the plastic for the replacement of wood, this materials distribution remains the same till 1975.[3]

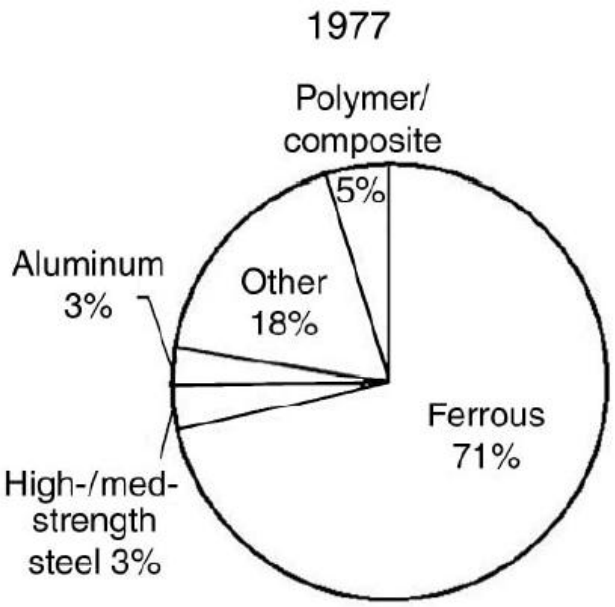


Fig-1: Use of different materials in automobile in 1977

1.2 Future in upcoming years

In the past few decades, vehicles have transformed a lot and become more safe, cooler, and more exciting to drive, with improved fuel efficiency and sustainability.

During this era of innovation, it is not noticeable that the use of plastics has increased to a greater extent. Today's cars contains about 50% of plastics because plastics are comparatively lighter than the other materials, and it comprise only 10% of the weight of the cars. Along with plastics, use of composites in automobile industries also increased by the good amount.

These advanced materials like plastics, composites, carbon fibre, 3-D printed parts, etc. are helping in improvements in terms of safety, design, and performance and taking the whole world to the new era of vehicle manufacturing and sustainability.[4]

2. OVERVIEW OF MATERIALS

Very large number of materials is used to make cars. The main materials which are used for making cars, and their parts & components, are steel, aluminium, glass, plastics, rubber, magnesium, copper and carbon fiber. The factors which are kept in mind while selecting the material, for the body especially, include resistivity to heat, chemical and mechanical shocks, easy to manufacture and also their durability. Apart from these, affordability is also an important factor in vehicle manufacturing.

Now a days, composite materials have more advantages over the steel in automobile manufacturing. They are considered to be safer and lighter which leads to more fuel efficiency. They do not corrode just like steel or aluminium. The problem is that the cost of composites are at least 20 times higher than that of steel which increases the cost of vehicle a lot. Hence, steel is our first choice.

Iron and steel in the past few decades become more lightweight and stronger. Applications of steel not only include body, but also includes engine, wheels and many other parts. With its low cost and capability to absorb impacts in a crash, iron and steel are ruling the automobile industries.

Aluminium usage increases within past years in automotive industry due to its low density, high strength and high energy absorption. Also aluminium can reduce the weight of the body of vehicle by 50% as compare to steel. It is used for body, chassis, exterior attachments such as doors, bonnets etc.

Magnesium demand in automobile industries is increasing rapidly as it is 33% lighter than aluminium and 75% lighter than steel. Also magnesium has faster solidification and higher machinability.

Titanium is also used where the temperature is high, and also high strength is required, like exhaust, valves, etc.

But now a days, automobile manufacturers are trying to develop cheap carbon fibre to make structural and non-structural in order to have high performance at affordable cost.[5]

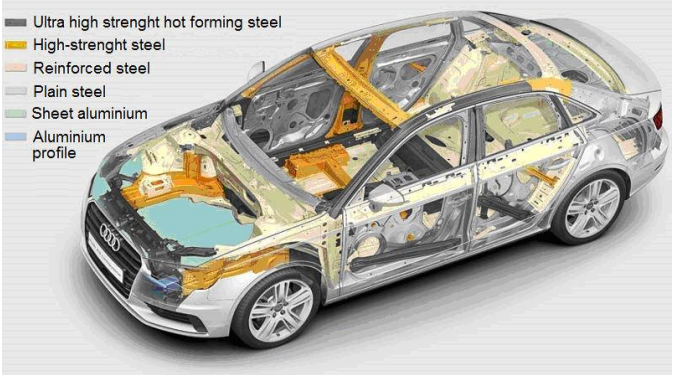


Fig-2: Car made up of various materials

3. CURRENT SCENARIO OF MATERIALS

The performance of vehicles has increased so as to meet their requirements materials should also be upgraded. In order to use these upgraded materials in mass-production of vehicles they must have a number of qualities, such as affordable cost, easy to machine, etc.[6] There is huge variety of materials which are used by the car manufacturers according to their suitability for manufacturing, some of them are listed here:

3.1 Steel

Use of steel in automobile manufacturing has greatly changed in few decades, but now automobile industries uses different types of steel for different parts of the vehicle. The main body parts of the car generally made with steel. Moreover, low-carbon sheet steel of thickness of (0.65–2) mm is preferably used as it reduces the overall weight of the car and increases the rigidity. The use of steel in automotive has its own pros and cons. Most car bodies are made of sheet steel as it has high strength, deformability, ability to weld, colouring, enough service life with proper anticorrosion treatment, and most important its less cost [7].

Today most car parts are made with steel like underlying chassis or cage beneath the body that forms the structure of the cars and protects us in the crash. Even the exhausts are made with stainless steel. Other parts like door beams, roofs and body panels are also manufactured with steel. Steel is used to made various parts of a car in order to accommodate the engine or other parts [8].

There are lot of improvement seen in the steel in automobile industries but the main thing is the mass reduction through advanced use of iron and steel as they are the dominant material (86% of total weight of the automobile).The use of high-strength steels (HSS) or high-strength low-alloy (HSLA) steels in the past decades increases dramatically in the automobile industries. A form of HSLA steels is Ultra-light Steel Auto Body (ULSAB) which is 19% lighter and has good strength and structural performance with less cost of manufacturing compared with conventional steel body. High-strength steel has a yield strength in between 210 MPa and

550 MPa whereas ultra-high strength steel (UHSS) has a yield strength more than 550 MPa but high strength steel can cost more than 50% of traditional steel but on the other hand they provide lesser thickness[5].

Table-1: Types of steel with properties and applications

Steel	Properties	Applications
Thin sheet, cold-rolled killed (RRST 1405)	Strength 270–350 MPa, elongation is more than 36 %, thickness 0.6–0.9 mm	Roof, hood, door, sidewalls, etc.
Thin sheet, boiling steel (UST 1203, UST 1303)	Strength 270–410 MPa, elongation is 28–32 %, thickness 0.6-0.9 mm	Painted external panels, floor parts, inner frame, floor panels, etc.
Hot-rolled steel tape (ST 4)	Strength 280–380 MPa, elongation is more than 38 %, thickness 1.5-2.5 mm	For parts located under the car body and for parts having large thickness

3.2 Aluminium

Aluminium is used by the automotive sector from a very long period of time and is evolved greatly. Various things are done in order to improve the hardness, corrosion resistivity, plasticity, durability and other mechanical and physical properties of aluminium. There is a lot modification which has been down in production method of aluminium alloys like various additives are introduced. Titanium and vanadium are added in aluminium to form refractory inter-metallic TiAl3 and VAl6, surfactants or elements of group (Li, Na, K, Rb, Cs), sulphur and phosphorus are also added to have high efficiency of complex modifiers and to have effective grinding, aluminium titanium- boron (AlTiB) and aluminium-titanium-carbon (AlTiC) crystals are added. Adding these things lead to improved mechanical properties and reduced gas porosity. Apart from these elements, there are lot of experiments are performed to have better aluminium for the automobile production with affordable price[7].

Aluminium is widely used in automotive industries. Its composites are used in manufacturing of pistons of engine. But traditionally pistons are made with aluminium silicone, then in 1982 Toyota Motor Company introduced piston of aluminium composite and this material leads in the increase of working life of combustion engine pistons. But now new generation of engine frames are made up of aluminium alloys reinforced with silicon particles having certain size. LOKASIL used to manufacture such cylinder liners of 3-mm thickness and are used in Porsche sports car. These composite materials are also used to manufacture brake disc and drums. Moreover, chrome plating is also used to increase service life and this technology is used by big car manufacturers like BMW, Mercedes-Benz and Porsche. Also nickel matrix coating is used by NIKASIL in BMW and Jaguar cylinder liners. This coating also contains silicon carbide particles of size range between 2–5 μm and for their fabrication electrolytic deposition is used. After surface finish honing process, depth of such nickel coating on liner is 0.06–0.08 mm[9].

3.3 Plastics

The implementation of lightweight material in automotive industry is our need to have better efficiency and the plastics industry plays a major role in this. It was begun in 1950 with the entry of thermoplastics in automotive sectors. The various researches on advanced, high-performance plastics or polymers have dramatically changed the scenario. Earlier plastics were used as they offered good mechanical properties, excellent appearance, self-colouring, etc. Nowadays, the plastics are used mainly in cars for reducing weight with durability, toughness, design flexibility, corrosion resistance, and high performance at minimum cost. Currently plastics weigh approximately 10-15 % of total weight of the vehicle. Various types of polymers are used in more than thousand different parts of car of different dimensions. Plastics are used in exterior as well as interior of the vehicle. There are 13 different polymers which may be used in a single car model from which polypropylene (32 %), polyurethane (17 %) and PVC (16 %) constitute 66% of total plastic used in a car.

PP (polypropylene: chemical resistant and UV resistant), **PUR** (polyurethane), **PVC** (poly-vinyl-chloride: good resistance to chemical and solvent attack), **ABS** (acrylonitrile-butadiene-styrene: resistant to weather and some chemicals), **PA** (polyamide or nylon 6.6 or nylon 6: high resistance to abrasion, low friction characteristics and good chemical resistance), **PS** (polystyrene: ease to manufacture), **PE** (polyethylene: good chemical resistance),**POM** (polyoxymethylene or polyacetal or polyformaldehyde: big stiffness, rigidity and excellent yield), **PC** (polycarbonate: has good weather and UV resistance, with transparency), **PMMA** (acrylic: more transparent than glass, has reasonable tensile strength),**PBT** (polybutylene terephthalate: good chemical resistance and electrical properties), **PET** (polyethylene terephthalate: good thermal stability, good electrical properties), and **ASA** (acrylonitrile styrene acrylate: great toughness and rigidity) [10].

Table-2: Plastic parts in vehicles

Parts of vehicle	Type of plastic
Bumpers	PS, ABS, PC/PBT
Seating	PUR, PP, PVC, ABS, PA
Dashboard	PP, ABS, SMA, PPE, PC
Fuel systems	HDPE, POM, PA, PP, PBT
Body	PP, PPE, UP
Under-bonnet components	PA, PP, PBT
Interior trim	PP, ABS, PET, POM, PVC
Electrical components	PP, PE, PBT, PA, PVC ABS,
Exterior trim	PA, PBT, POM, ASA, PP PC, PBT, ABS, PMMA, UP
Lighting	PVC, PUR, PP, PE
Upholstery	PP, PE, PA
Liquid reservoirs	

3.4 Glass

Glass has various types of applications depending upon the requirement. There is a lot of difference between our windows glass and windshields. A car's windshield is manufactured in such a way to resist under harsh conditions and also acts as a support to the roof of the car. There are 2 types of glass used for automobiles:

Laminated Glass

Laminated glass is a sandwich of two sheets of glass that are stuck together with a layer of plastic named poly-vinyl buytrl (PVB), at high temperatures which have higher strength and it doesn't shatter in case of an accident, but it may break upon impact, this layer don't allow the sharp pieces to fly around. Laminated glass acts as a cushion when a passenger might be thrown on windshield. It is used in manufacturing of the front and rear windshield of the car. When rocks or pebbles hit the windshield, they don't damage the whole glass but only exterior which can be repair.

Tempered Glass

Tempered glass is manufacture by heating the curved glass to high temperature and then cooling. It is used in the manufacturing of side windows of vehicle as it is 10 times stronger than the regular glass. It shatters into small pieces that can harm the passenger on collision and it cannot be repaired as it breaks entirely [11].

Windows are made with tempered glass which is made in float glass furnaces with nitrogen and hydrogen gas and with new oxygen-burner technology which melt glass more efficiently with lesser emissions. Windshields are made with laminated glass with nitrogen gas between the two sheets that will lead to blunt pieces if it breaks.[12].

3.5 Rubber

Without tires a vehicle is just a box of steel, in order to move it we need to provide tires in it. And without rubber, we are not able to make tires. Rubber industry is a huge supplier to automotive manufacturing, about 75% of the world's natural rubber is used to make tires for the automobiles. The rubber tire protects the wheel or alloy from wearing down, which improves the fuel efficiency and road safety[8].

Simple rubber is not used in the manufacturing of tires. Silicone rubber is used which has strength, resistance and durability required for tires applications. To increase the power of vehicles, more load or more heat came on the tires which results in the wear and ultimately tire worn out. To overcome this temperature effect, silicone rubber are used to have better temperature resistance from -60°C to 230°C and replaces the EPDM (Ethylene Propylene Diene Monomer) whose temperature resistance is 140°C max. With mind blowing temperature resistance, outstanding weathering properties and resistance to rain, wind, abrasion, UV radiation and chemicals make silicone the material of tires in the automotive industries[13].

4. ADVANCED MATERIALS

The advanced materials or lightweight materials are necessity to the industry of automobiles. It is calculated that if there is 10% reduction in vehicle weight then it leads to 5% to 7% of fuel saving. Hence for every kilogram of vehicle weight reduction, there is chances to reduce the carbon dioxide emissions in the atmosphere by 20kg. Apart from the above, there is lot of things that can lead to the development of advanced materials. Various advanced materials are discussed below:

Thermoplastic Olefin

Thermoplastic olefin enables the car manufacturers to easily style the exterior parts with good designs and with low cost. But it lacks in weight, strength and quality. In order to get over this riddle General Motor uses nanotechnology treatment to overcome the above mentioned riddles[3].

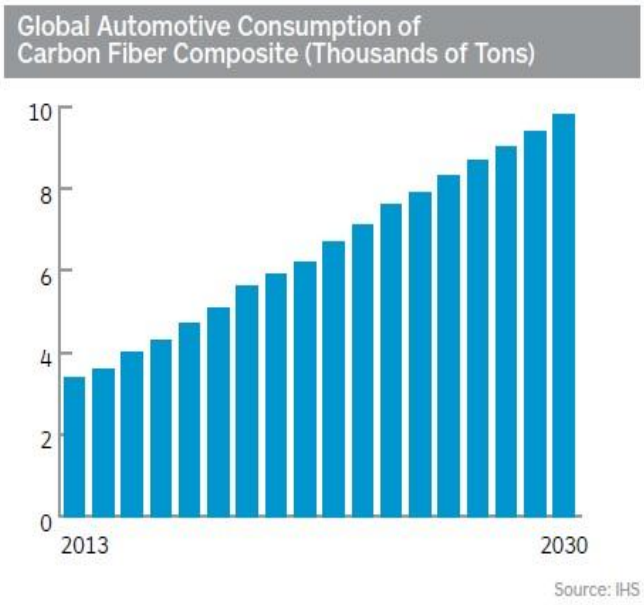
Magnesium

Among all the engineering metals, magnesium is the lightest one with the density of 1.74 g/cm3 and it is 33% lighter than aluminium and 75% lighter than steel. Other than this, magnesium alloys are more resistive to corrosion. But on the other hand magnesium has certain disadvantages of mechanical and physical properties like it cannot work where unique design application is required, low tensile strength, etc. However, these disadvantages are overcome by some treatment and improved magnesium is used in the various parts of a vehicle[5].

Carbon Fiber Composites

Carbon fiber composites have high strength, stiffness, half weight as compared to steel and four times stronger than steel. Earlier it was used only in the high-performance cars due to its very high cost[14]. But now this technology is also getting its place in the standard vehicle for the weight reduction in order to have high fuel economy. This is only possible because of the new technologies that are evolving continuously and help in the reduction in the cost of these expensive materials. But even now it is not so common to see the regular cars[15].

CHART-1: Carbon fiber usage



5. CONCLUSIONS

Thus, from the above discussion, we can conclude that the materials are evolving on the basis of their needs in the automotive sector. Mainly automobile sector is moving to the new era of reduced weight, high performance and higher fuel efficiency but without compromising with the quality, comfort and safety. This leads to the meet of the needs of the current situation of the market. This sector has rapidly evolved in the past decades and predicted to continue this evolution in the future and we will have high performance vehicles with affordable cost in the upcoming years.

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BIOGRAPHY

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Third year student of B.Tech of Dayalbagh Educational Institute. He is pursuing his B.Tech in mechanical stream. He did his internship at GEE KAY MOULDS (June-2019) where he acquired the knowledge of moulds and materials. Automobiles and material science are his areas of interest.