

# Comparative study of different materials used for manufacturing of an automobile body

Abhijeet Maharnwar, Sarath Nair, Dr. Dhananjay Dolas

Department of Mechanical engineering, MGM's JNEC, Aurangabad, MS, India.

**Abstract**—The fast growing demand for more fuel-efficient vehicles to reduce energy consumption and air pollution is a challenge for the automotive industry. The weight reduction is considered as a leading key in upgrading the fuel economy. The Variety of different materials can be found within vehicle body including steel, magnesium alloys, plastics alloys and aluminium alloys .Aluminium alloy is more significant as compared to other material because of strength, weight and anti-corrosion as well as cost wise the aluminium alloy material cost is less than carbon fibre reinforced plastics. The objective of this paper is comparative study of different materials uses for manufacturing the automobile body and their performance. This study is useful to understand different materials performance in automobile body and their benefits. This study is an attempt to cover all variety of up-to date body materials, and highlight the most promising of them for volume production was committed on small scale industry.

**Keywords**— Steel, Aluminum, CFRP & Weight reduction.

## I. INTRODUCTION

In today's world it becomes necessary to find a alternative materials for manufacturing automobile and its components because of increase in emission levels and also to improve the efficiency of the vehicle. Further the automobile manufacturers are also keen on improving the productivity and for a cost efficient manufacturing. Although steel is normally used on a large scale for manufacturing of automobile components but new materials like Aluminium and composites are much lighter in weight as compared to steel. By replacing conventional materials by their new alternate helps in improving the performance and also reducing the carbon emissions. Also the resistance to corrosion and other properties gives them a upper edge in usage for manufacturing of Automobile components. Steel has been used for manufacturing of automobile for over decades and various types of the same has been developed, one of them normally used for manufacturing of automobile bodies is Ultra-light Steel Auto Body (ULSAB). Recently Aluminium has also gained popularity because of its

corrosion resistance properties, lighter density and other advantage over steel. Composite material like Carbon-fibre Reinforced Plastics is also considered as alternative material for manufacturing automobile components because of its light weight and good strength.

As far as automobile manufacturing is concerned, safeties, lightweight and cost are one of the important parameters for the manufacturers as well as to the customers. Thus optimizing of these parameters is an important aspect in Automobile sector.

## II. LITERATURE REVIEW

Davies [1] described the various materials for automobile bodies along with their machinability mechanical properties and their future trends in automobile industry. Ahmad [2] discussed the corrosion and mechanical properties study of car steel sheet and its manufacturing processes also the hardening procedure used for steel. Valerievich et. al. [3] analysed modern automobile manufacturing materials such as steel, aluminium, magnesium etc on the basis various parameters. Ghassemieh [4] has given the various material requirements for the manufacturing of the automobile along with the development and history of these materials. Application of these materials in different parts of a vehicle is also provided. Dr. Rathnakar. et. al. [5] provides a review on use of polymer composites and their application in Automotive Industry and also shows the scope of growth of these materials in the automobile industry. Salvi et al. [6] Presented the modal and structural analysis of ladder frame made of steel and carbon fibre and describes a comparative study of the both. Piyoosh et. al. [7] focused on advantage, disadvantage and application of composite materials used for production in the industries. Arun et. al. [8] carried out the analysis of vehicle chassis frame made of composite material and a comparative study of steel and carbon fibre plastic has been made. Musfirah et. al. [9] provides a general scope of aluminium and magnesium alloys in the automobile manufacturing sector. Miller et al. [10] provides the detail of the various aluminium alloys used in manufacturing in the Automobile industry.

### III. MATERIALS & METHOD

The comparative study of different materials likes steel, Composites, Aluminium and Magnesium Alloys are given below-

#### 3.1 STEEL

Even though development of various alternative materials for the manufacturing vehicle bodies steel is commonly used for manufacturing the automobiles bodies. It is not only used for manufacturing bodies but it is also used for manufacturing various engine components, wheels and several body parts. Steel is commonly used because it is cheaply available, it has formability, strength, weldability during assembling, fatigue resistance and it also absorbs shocks during crash providing safety to the passenger. In addition to these advantages it is necessary to have higher fuel efficiency and lower hydrocarbon emission (Ahmad, 2010). Steel has major disadvantage over the other alternative materials that it is heavy and corrodes easily if not coated. Over a year's lots of research is been done in order to minimize these disadvantages. Wide ranges of steels are now available with various properties to reduce the weight similarly corrosion is not a major issue as it was in early days zinc coated steel is now used know as electro-galvanized steel coating which is usually used in automobile industries.

One of the commonly used steel types is Ultra-light Steel Auto Body (ULSAB) it is light in weight also has better mechanical properties as compared to conventional steel. Development of ULSAB also includes research of ULSAB – AVC which is Ultra-light Steel Auto Body advanced vehicle concept. It was proved that for the production of 100000 units per year, bodyweight could be reduced by 25 % to 203 kg, static torsion rigidity enhanced by 80 %, static bending by 52 % first body mode increased by 58 per cent. The part count was reduced from 200 to 94 stampings and a total of 158 parts (Davies, 2003). Because of its light in weight it also helps in increasing fuel economy, reducing carbon emissions. As far as cost is concerned is slightly more than that of the steel. Hence now a day's ULSAB can be a better replacement for the steel.



Fig. 1: Steel body frame

#### 3.2 COMPOSITE MATERIALS

The use of polymer based composites has increased in the past few years. This is mainly because the improvement in the knowledge and technology related to these materials which give us a better strength to weight ratio, improved fatigue resistance, good magnetic and optical properties, higher resistance to corrosion and thermal conductivity. A composite material is basically a combination of two or more different materials attached together with a separate distinct layer separating the two layers. Carbon or aramid are rarely considered because of their higher cost, thus Glass reinforced plastics (GRP) is usually applied for manufacturing using composite materials in automotive industry. Although steel is much cheaper than GRP, but the latter provides us much optimized vehicle weight, reducing corrosion and a good vehicle economy. Body-in-white (BIW) accounts to almost 25% of the total weight of an automobile. Using alternate Materials for BIW like Fibre reinforced composites helps in reduction of total automobile weight. For example, the production team of Jaguar have reported a weight saving up to 45% and stiffness increase up to 60% when compared to its traditionally used rival, steel metal. They also reported that replacing the conventional steel with aluminium gave a weight reduction up to 40% and stiffness up to 60%, but when replaced by a suitable composite material gave a much better statistics. Carbon fibre reinforced composites are the best, but due to its high cost are mostly used for aerospace application and seldom used for automotive application. As compared to steel, a weight saving of 50-70% can be achieved and 20-40% as compared to aluminium. (Dr. Rathnakar, 2015).



Fig. 2: CFRP body frame.

Also for manufacturing of ladder frame, studies have shown that using carbon fibre instead of steel reduces the weight tremendously also increasing the stiffness. (Mass of steel chassis-170.45Kg and mass of carbon fibre chassis- 54.28Kg) (Salvi, 2014).

Fibre reinforced composites has also gained the trend as automotive manufacturers are turning towards Fibre Reinforced plastics (FRP) for manufacturing of body

panels, suspensions, brakes. The only problem pertaining with FRP is of Recycling. Researchers are working on this issue so that FRP can replace all the other conventionally used materials in automobile industry. (Dr. Rathnakar, 2015).

### 3.3 ALUMINIUM AND MAGNESIUM ALLOYS

Steel has been used widely in manufacturing of automobile since the 1920s. But the need to find a better alternative for efficient weight reduction, lower manufacturing cost and also to reduce the emissions gave rise to use of aluminium alloys in the automobile sector. Weight reduction has a direct effect on reducing the emissions. (10% weight reduction equals 5.5% improvement in vehicle mileage) (Miller, 2000). The use of aluminium has increased to more than 80% in the last 5 years. We can see that aluminium sheet metals are used for manufacturing of the Body-in-white and panels, whereas aluminium engine blocks and piston manufacturing has been made possible due to the very good casting properties of aluminium just as cast iron. Wrought aluminium is also finding applications in manufacturing of many components instead of casting. Forged wheels can be used in application where better mechanical properties are needed. Also wrought aluminium finds application in side impact panels, seat frames, air bag housings and others. Aluminum alloys has also been used for manufacturing of heat exchangers. The Body-in-white (BIW) offers the greatest scope for weight reduction with almost 50% reduced weight when steel metal is replaced with much lighter aluminium alloys. For outer panel the formability and surface quality is an important factor, thus aluminium alloy of series 6xxx are used. For inner panels stretch behaviour and drawing properties are important thus aluminium alloy of series 5xxx are used extensively. For structural application both 5xxx and 6xxx can be used but care has to be taken because higher quantity on Mg content can lead to intergranular corrosion deformation (Miller, 2000).

Another material which is finding application in today's modern world manufacturing is Magnesium and its alloys. Magnesium is lighter than aluminium and thus can be used for reducing the power train mass and thereby improving the efficiency. But the metal also has certain disadvantages like its creep resistance is low so cannot be used for manufacturing of engine block and piston head. Also its use is limited in the field of car body manufacturing because of the price stability aluminium has over magnesium. (Musfira, 2012).

Further research is required for making magnesium more suitable for large scale production of automobile components and given the properties the metal shows it

has great future scope in the Automobile manufacturing industry.



Fig. 3: Aluminium body frame.

We can see that carbon fibre has a better Youngs modulus as compared to aluminium and close to that of mild steel. Also it gives the lowest body weight of all thereby reducing the overall body weight.

TABLE 1- Material properties of steel, aluminium and carbon fibre composites. (Dr. Rathnakar, 2015) (Antony, 2015).

Material	Youngs Modulus Gpa	Density g/cm <sup>3</sup>	Body Weight Kg
Aluminium	70	2.7	260
Steel	190-210	7.8	750
Carbon Fibre Reinforced Plastics	125-150	1.6	155

In spite giving us the best weight reduction, good corrosion resistance and very high durability these advanced composites find a very little use in modern day manufacturing primarily because of its very high cost. (piyoosh, 2013).

Research and advancement in this field is thus required for making these advanced composites more cost efficient for automobile manufacturers also taking into consideration the recycling issues involved with the same. The above study shows us the different materials that are mostly used for manufacturing in automotive sector. From the productivity point of view the selection of the right material according to their different properties is important and thus the following parameters are discussed below.

## IV. MATERIALS PARAMETERS

### 4.1 LIGHTWEIGHT

Increase in global pollution due to automobiles constantly efforts are been taken to reduce the pollution by automobile industries. One of the ways is to reduce the weight of automobile by replacing existing material by lightweight materials for manufacturing. From early days steel is used to manufacture the vehicles. Around 80% of the vehicles on road today are made of steel. But in order to reduce the hydrocarbon emission it is necessary to use

light weight materials such as aluminium, CFRP (carbon fibres reinforced plastic), magnesium, composite materials etc. despite of their high cost than steel has become necessary to use these materials for manufacturing the automobiles. It has been found that for every 10% reduction in weight of automobile, fuel economy is increased by 7%. This states that for each kilogram decrease in weight of the vehicle, there is about 20 kg decreases in carbon dioxide emission.(Ghassemieh, 2011)

Light weight materials especially carbon fibre is used for manufacturing high speed sports cars. In sports cars where there is speed is a governing factor weight of vehicle plays important role so as to reduce the overall weight of the vehicle it is necessary to use lightweight materials.

#### 4.2 COST

Cost plays important role in the sales of the vehicle as it is directly related to the buying power of the consumer. Hence it is necessary for the manufacturer to select the material which is best situated from the customer's point of view. Steel is most commonly used in manufacturing because it is easily available at low cost. Machining cost required for steel is also less as compared to other materials. Replacement of steel by different materials is highly depend on its cost of raw material, machining cost, availability, ease in manufacturing and its overall effect on the performance of the vehicle. Low volumes production is susceptible to investment cost and high volumes are related to material cost. Higher investment, high production rate and cheap material cost represent steel bodies. Lower investment, lower production rate and expensive material is represents aluminium, CFRP, composite materials etc bodies. (Valerievich,2014)These are costly as compared to steel and its machining cost is relatively high hence using such these materials for the manufacturing of the vehicle increases the cost of the vehicle. But use of such materials is highly depending on the requirement of the customer.

If customer is interested in more efficient, green or high speed vehicle then use of such material is highly recommended. Cost is also includes the maintaining and repairing cost. Body parts made up of steel can be easily replaced at low cost, aluminium requires moderate repairing cost but body parts made of CFRP and composite materials are expensive when there are to be replaced. CFRP have major concern. CFRP wreckage spreads over after impact and left over the street it is serious problem for road users. Repair and regain of original shape is very expensive. If part is unrecoverable, many plastic parts cannot be recycled and turn down to repair increases environmental pollution (Davies, 2012).

#### 4.3 SAFTY

As far as automobiles are considered safety is major aspect for the passengers. Safety of the vehicle is highly dependent on the type of materials used for manufacturing the vehicle. Absorption of energy during crash is important factor for material used in manufacturing the vehicle. Parameters on which it depends are strength of material, plasticity, design and dimensional aspects. In today's automobile industry parts made of conventional materials are being replaced by composite materials in order to increase fuel economy and decrease the weighty of the vehicle. Most of composite materials give brittle response than ductile response, while the conventional metals used for manufacturing the vehicle are collapse during crush by buckling or folding. Aluminium alloys can absorb more energy during crushing as compared to conventional steels.

### V. CONCLUSION

From the above study we found that by selecting appropriate material for manufacturing automobile components optimization of weight, cost and safety can be achieved. Steel is the cheapest of all materials and has been widely used but it is comparatively heavier than the other materials. Aluminium can be used for manufacturing of engine blocks, piston head along with steel for the best weight optimization and increasing the efficiency. Magnesium can be used for manufacturing but further research for the material is required as it has certain drawbacks. Similarly Composite materials like Carbon-Fibre Reinforced plastics provides the lightest weight of all and is mainly used for manufacturing of components in sports and racing vehicles to reduce the weight but the cost of these materials remains a constraint. thus selection of the material is based on suitability as well as certain parameters such as cost, safety, availability, machinability and weight of the material.

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