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Composite Material for Modern Automobile Industry - A Review

*K Srinivas**

ABSTRACT

The various components where composites can replace conventional metals in automobiles have been discussed in the following paragraphs. The components discussed are the drive shaft, brake rotor, engine valves, body and suspension. Each component the composite used to replace is different from other components because of the specific work carried by each individual component. The final comparison of the composite to the conventional metal in each material showed evident weight reduction and improved efficiency.

Keywords: *Composite: Automobile: Weight Reduction: Efficiency.*

1.0 Introduction and literature Review

With the increase in demand for high efficiency and lightweight components, composites became one of the sources to accomplish this need. These composite parts directly or in combination with different materials are being used in different individual components of automobiles.

These components individually improving each component's efficiency, lead to the overall improvement of the whole automobile. There are different components in automobiles where composites are being used, and some of those areas are discussed here.

1. Driveshaft
2. Suspension
3. Brakes
4. Body
5. Engine valves

These above-mentioned components will be discussed in the further paper, where each component will be studied in the aspect of probable replacement with composite parts and outcome after the replacement.

1.1. Literature Review

Dai Gil Lee et al [1] replaced the conventional two-piece cast-iron drive shaft of the vehicle with a single unit aluminium drive shaft to transmit power. The hybrid aluminum composite drive shaft was fitted with press fit processing and the final assembly resulted in a reduced weight of 50% than the conventional one.

S.A. Mutasher et al [2] analysed the hybrid aluminium composite made drive shaft using finite element analysis. This work resulted that static torque capacity of drive shaft is affected by changing wind angle, stacking sequences and number of layers of composite. The maximum static torsion capacity of aluminium tube wound outside by six layers of carbon fibre/epoxy composite at a winding angle of 450 was 295 Nm.

H. Al-Qureshi et al [3] made automobile leaf springs with glass fibre composite materials and replaced them in the usage areas of conventional cast iron leaf springs. The composite springs were examined for stress conditions and delamination under loading. The work resulted in leaf springs having less weight than the conventional ones and suitable for usage in light vehicles like jeeps. Dai Gil Lee et al [4] made an enigne valve lifter with a hybrid of composite and steel. This is to reduce the mass of the lifter and to increase the fuel efficiency of the system. The lifter was examined under different loading conditions in laboratory and the test showed that the lifter was durable as of standard conditions. Gary Savage and Mark Oxley et al [5] The composites used in the F1 cars are discussed and the repairing methods employed for these cars were explained based on the type of damage and area of damage. The repairing techniques discussed were such that the damaged parts do not loose their efficiency after the repair. Y.G. Zhao et al [6] Investigated the frictional behaviour of composites of pure aluminium, modified aluminium and Mg2Si/Al, on a pin on disk setup.

**Department of Mechanical Engineering, Delhi Technological University, Delhi, India*
(E-mail: srinivaskrovvidi9@gmail.com)

The test showed that the wear rate increases with increasing load, but it varies from linear to rapid increase for all the test materials in the present work, with the increase of sliding velocity, the surface temperature of the materials increase, which leads to the rise of plastic flow of surface and subsurface, and therefore the wear rate increases.

A. Daoud et al [7] investigated the wear and friction behaviour of sand cast brake rotors made of A359-20 vol% SiC particle composite. This test was done with a pin on disk arrangement and compared with the conventional grey cast iron brake rotor. The test results showed that the wear rate decreased with load from 30-50N and increased from 50-100N at a speed range of 3-12m/s.

2.0 Driveshaft

Driveshaft's are used to transmit power from the engine to the wheels in the rear-wheel-drive systems. These are usually made of steel of different compositions, but to reduce the weight of the shaft, new areas are being explored where shafts are being made of composites. One example is the drive shaft through aluminum composite. The torque capacity of the drive shaft for normal cars should be larger than 2600Nm, and the bending natural frequency should be higher than 9200rpm to stop whirling, as the single unit drive shafts made of steel or aluminium with a length of 1.2 meters have bending natural frequency usually less than 5700rpm. To achieve this at low costs, a hybrid type aluminium/composite driveshaft is used, in which the aluminium has a role in transmitting the required torque, while the carbon fibre epoxy composite increases the bending natural frequency above 9200rpm.

This was manufactured as follows, two carbon fibre epoxy composite layers and one glass fibre epoxy composite layer were stacked on a mandrel, this was wrapped with composite layers and Insert into the aluminium tube. Stack the composite layers by rotating the mandrel with pressure on the inner surface of the aluminium tube. Insert a vacuum bag and fixing caps that have a vacuum line and O-rings. Apply an axial preload to the aluminium to eliminate the thermal residual stress between the aluminium tube and the composite layer. Cure the hybrid shaft by the autoclave vacuum bag degassing moulding method at 1250C for 3h. The mass of the manufactured hybrid aluminium/composite drive shaft was only 50% of the conventional two-piece steel drive shaft.

When this shaft is analysed for strength prediction, the outputs are as follows, increasing the number of layers can increase the static torque capacities of the hybrid shaft for both carbon fibre composite materials. A hybrid aluminium/composite wound with 450 layers can withstand higher static torsion compared to 900 in all cases. Shaft being laminated with stacking sequence of [90/+45/_45/ 90] and [+45/_45/90/90] gave the same behaviour of torque angle of twist relation.

3.0 Suspension

The suspension system in automobiles are used to take load by compressing and retracting between the force applications to facilitate to smooth ride in the vehicles. This is done by different types of suspension units, here we are to discuss about leaf springs In general. The materials normally used for these leaf springs are SAE-1080, 1095 etc. The general criteria is to absorb and release energy when required, so the strain energy is the main in designing these springs. These springs usually are in a pre-stressed position to increase carrying capacity. To replace the commonly used steel, the leaf springs were made using glass fibre reinforced composite.

The manufacturing techniques used were vacuum bag moulding to project a shape of a parabolic structure. The reinforcements in the composite were woven glass fibre combined with epoxy. The final leaf spring was tested in a series of tests under static loading and intactness, these results were then compared to the actual leaf spring of steel made. The comparison gave results as the thickness of the new leaf spring is reduced while the width remaining the same, and also there is a significant reduction in the weight of the system. These springs had high nominal shear stress and better fatigue behaviour under loading compared to steel springs.

4.0 Brakes

The brake systems are used to decelerate or stop the moving systems in automobiles. The brake system comprises of rotors made of metals or steel combinations, this rotor unit takes the load to create deceleration motion. Here we are going to see the comparison between the rotor made of cast iron and the rotor made of composite. The composite used for the study will be of mmc of aluminium with 20% silicon carbide. Wear pattern on the composite and the cast iron are examined on the arrangement of a pin on disk. These tests were conducted on the force arrangements of 0.3-1Mpa for a time period of 30min at ambient room conditions. The final result comparison gave output that, the wear rate of composite decreases with increasing the applied load from 30 to 50N and increases with increasing the load from 50 to 100 N. The wear rate of the composite decreases as the speed increases. At a speed range of 3–9 m/s, the wear rate of the composite is higher than that of the cast iron at a load of 30 N, slightly higher at a load of 50N, and again significantly higher at a load of 100 N. The wear rate of the friction material sliding against the composite decreases as the applied load increases from 30 to 50N and increases with increasing the load from 50 to 100 N. However, it decreases with increasing the sliding speed, indicating improved wear resistance at the higher speeds. For all sliding speeds, the friction coefficient of the composite and friction material couple decreases with increasing the applied load. Increasing the sliding speed at the applied load range of 50–100N does not have a significant effect on the friction coefficient of the composite. The composite disc shows a stable and higher friction coefficient in comparison to cast iron, which is essential for brake rotor applications. The frictional heating parameter of the cast iron disc is about 3 times higher than that of the composite, indicating that the composite disc runs much cooler.

At a load of 50N and speed range of 3–12 m/s, the worn surface of a composite disc shows a dark adherent layer, which mostly consists of constituents of the friction material. This layer acts as a protective coating and lubricant, resulting in an improvement in the wear resistance of the composite. The use of a composite brake rotor is a result of the combination of its wear resistance, higher thermal conductivity, lighter weight and more uniform friction coefficient compared to cast iron brake rotor. These properties provide reduced braking distance and brake noise.

5.0 Body

The body panels of automobiles are usually made from thin sheets of steel and aluminium alloys, but these body panels do not carry any structural integrity and are only used for aesthetics. These body panels are now a days replaced with composites to get weight reduction in the system. This usage can be seen widely where automobiles are used for completions. In the competitive usage to achieve maximum performance from a vehicle, the weight of the vehicle is reduced by using composite materials in different areas of bodywork. The composites used can range from glass fibres, carbon fibres to lightweight metal matrix alloys. These units not only have to serve the requirement of weight reduction but also need to be accessible to easy repair. The repairs of the body made of composites are done in different ways depending upon the area of damage.If the damage occurred is revealing in the internal components initially, the area is covered with a resin plug to prevent contamination, then the damaged area will be filled with the resin infection covering the damaged part. If the damage occurs in the surface area, then the damage is covered using the pre-cured composite patches in the affected areas. If the surface damage is severe, then the surface regions of the damage are removed and the larger patch of the pre-cured composite is attached.

6.0 Engine valves

The valves of the engine provide fuel to the system by the sequential motion of opening and closing. This motion is facilitated by synchronisation of various moving components. These components are usually made of steel and the weight of these components affects the sequential opening and closing motion. One of the components that are used in the valve system is the valve lifter. The valve lifter generally lifts the value for fuel intake. This unit can be replaced with the hybrid system of composite and steel to reduce the weight of the unit. The construction of this unit will be such a way that the contact region will be of steel while the rest of the body will be made of a composite of lighter glass fibres. Thus made system is subjected to load under the circumstances of 300-500 Rpm for 40000 cycles to asses' durability. The hybrid valve lifter is 35% lighter in comparison to the conventional steel valve lifter. This helps to improve the efficiency of the engine.

7.0 Summary

I The drive shaft is replaced with a single unit aluminium composite drive shaft, which resulted in a weight reduction of 50% to that of the conventional type and shear strength bearing capability 3.5 times more than that of the conventional unit.

ii The cast iron suspension systems of a leaf spring suspension, when replaced with the glass fibre composite the results showed a reduction in weight and suitable usage for lighter locomotives like jeeps.

iii Brake rotors of automobiles are replaced with the mmc of aluminium and silicon carbide system. This proved to have better wear resistance in comparison to the conventional cast iron system in compared under loading conditions ranged from 0.3-1Mpa.

iv The body of the automobile, when replaced with the composites, resulted in weight reduction and added feasibility of various repair methods to attend under deformed conditions.

v The Engine valve components, when replaced with the hybrid steel composite unit, this resulted in reduced weight and increased engine efficiency and fuel economy.

8.0 Conclusions

In this study, various components of the automobile are discussed where composite of different combinations can replace the conventional materials used with an added improvement in the respective fields of usage. These composites are aluminium matrix composite for the drive shaft, glass fibre matrix for leaf spring, aluminium silicon carbide system for brake rotors, fibre plastic components in the body and hybrid of steel combined with fibre composite for valve lifter.

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