A COMPREHENSIVE REVIEW IN THE FIELD OF COMPOSITE DRIVE SHAFT

Abhishek patel[1], ShabanaNaz Siddique[2,*]

[1]Mechanical Engineering, Bhilai Institute of Technology, Durg 491001, India
[2]Mechanical Engineering, Bhilai Institute of Technology, Durg 491001, India
[1]abhipatel720@gmail.com, [2]shabananazsiddique@gmail.com

Abstract

The primary use of fibre-reinforced composites in automobiles, with the exception of a few specialized low volume vehicles, has been in semi-structural or decorative parts. Use of composites in primary structural areas of the vehicle, such as body structures, has been very limited to date. Such applications offer a tremendous opportunity for future expansion of composites in the automotive industry. In addition to materials cost, there are two over-riding criteria for significant application of FRP materials in automotive structures: (1)proof of structural functionality/durability; and (2) development of rapid, reproducible fabrication procedures to optimize manufacturing economics. This study deals with the replacement of conventional two-piece steel drive shafts with one-piece automotive hybrid aluminium /composite drive shaft & was developed with a new manufacturing method, in which a carbon fibre epoxy composite layer was co-cured on the inner surface of an aluminium tube rather than wrapping on the outer surface to prevent the composite layer from being damaged by external impact and absorption of moisture. Replacing composite structures with conventional metallic structures has many advantages because of higher specific stiffness and higher specific strength of composite materials. By considering the thermal residual stresses of the interface between the aluminium tube and the composite layer, the optimum stacking sequence is calculated with the help of Finite element analysis.

Keywords: *Composite shaft, FRP material, Epoxy, Finite element analysis*

1. Introduction

Composite materials may be outlined as a large combination of two or more materials having a recognizable interface between them. Composite materials usually have a fibre or particle phase that's stiffer and stronger than the continuous phase. Now day's people are using composite materials for many number of application in various fields, some of them are aerospace, automotive, construction etc. In automotive industry, the mass production economic constraints are different from speciality vehicles and aerospace industry especially in case of high-performance composite materials which have been applied in a cost-effective manner from cost-effective and fabrication point of view. The design of modern rotating machinery is toward the achievement of higher operating speeds. The conventional materials used for ordinary shaft are steel, generally 35C8, 45C8, 55C8 etc. When high strength is required alloy steel such as nickel, nickel-chromium or chrome-vanadium steel is used. The fundamental natural frequency of the carbon fibre composite propeller shaft may be double as high as that of steel or aluminium as a result of the carbon fibre composite material has four times more specific stiffness of steel or aluminium that makes it a potential to manufacture the propeller shaft of rider cars on one piece. The composite propeller shaft has several alternative edges like reduced weight and fewer noise and vibration.Therefore, studies of fibre-reinforced composite shafts, with high strength and stiffness ratios coupled with a low specific weight, had received abundant attention from engineering over the past decade.

Sheet moulded compounds materials are the highest performance composites used mainly in grill opening panels, hoods, doors and deck lids. In extension to this, the manufacturing of primary body structure which has to sustain major impact loads and this needs to be incorporated in such a manner that fibre orientation can be controlled with high production rates. Composite body structures are utilized in a range of speciality vehicles for the past six decades, the material used was glass fibre with polyester resin. A variety of production methods were used but primarily all processes were slow. Chassis is still made of steel which absorbed most of the road load and crash impact energy. The governing design guidelines for composites need to be further developed to ascertain i.e. a way to design with inexpensive composite materials and to determine allowable for stiffness in situations wherever major integration of components in composites eliminates a multiplicity of joints.

Rapid technological advances in engineering design field result in finding the alternate solution for the conventional materials. The design engineers brought to a point to finding the materials which are more reliable than conventional materials. Researchers and designers are constantly looking for the solutions to provide stronger and durable materials which will answer the needs of fellow engineers. Drive shafts are used as power transmission tubing in many applications, including cooling towers, pumping sets, aerospace, trucks and automobiles. In the design of metallic shaft, knowing the torque and the allowable shear stress for the material, the size of the shaft’s cross section can be determined. In the today’s days there is a heavy requirement for lightweight materials vehicle. The conventional steel material is replaceable by advanced composite materials. Composite materials are favoured by most of the scientist in the design of automobiles due to its higher specific strength and stiffness. Weeton et al. [1] stated the possibilities of replacing the conventional steel material by composites in the field of automobile. Weeton et al describe the possibilities of composites used to replace the steel leaf spring as well as steel drive shaft. The advanced composite materials such as graphite, carbon, Kevlar and glass with suitable resins are widely used because of their high specific strength (strength / density) and high specific modulus (modulus / density). The first application of composite drive shaft to automotive was the one developed by Spicer U-joint divisions of Dana Corporation for the Ford econoline van models in 1985. Drive shafts for power transmission are used in many applications, including cooling towers, pumping sets, aerospace, structures, and automobiles.

An automotive drive shaft transmits power from the engine to the differential gear of a rear wheel drive vehicle. The torque capability of the drive shaft for passenger cars should be larger than 3500 Nm and the fundamental bending natural frequency should be higher than 9200 rpm [1] to avoid whirling vibration. Since the fundamental bending natural frequency of a one-piece drive shafts made of steel or aluminium is normally lower than 5700 rpm when the length of the drive shaft is around 1.5 m [1], the steel drive shaft is usually manufactured in two pieces to increase the fundamental bending natural frequency because the bending natural frequency of a shaft is inversely proportional to the square of beam length and proportional to the square root of specific modulus. The two-piece steel drive shaft consists of three universal joints, a centre supporting bearing and a bracket, which increases the total weight of an automotive vehicle and decreases fuel efficiency. Since carbon fibre epoxy composite materials have more than four times specific stiffness

($E= \rho$) of steel or aluminium materials, it is possible to manufacture composite drive shafts in one-piece without whirling vibration over 9200 rpm[1].
The composite drive shaft has many benefits such as reduced weight and less noise and vibration. However, because of the high material cost of carbon fibre epoxy composite materials, rather cheap aluminium materials may be used partly with composite materials such as in a hybrid type of aluminium/composite drive shaft, in which the aluminium has a role to transmit the required torque, while the carbon fibre epoxy composite increases the bending natural frequency above 9200 rpm.
Composite body structures have been used in a variety of speciality vehicles for the past three decades, Lotus cars, which began production in 1956, being a particularly well-known example. The composite material used was invariably glass fibres in, typically, a polyester resin. A variety of production methods have been used but perhaps the only common thread is that all the processes were slow, primarily because a very low production rate was required (typically, a maximum of 5000 per annum). The other common factor among these vehicles was the general use of some type of steel backbone or chassis which absorbed most of the road loads and crash impact energy. Thus, while the FRP body can be considered structural, the major structural loads were not imposed on the FRP materials. High FRP content vehicles in existence today were initially designed to use FRP materials. Consequently, there is no direct comparison available between an FRP vehicle and an identical steel vehicle to relate baseline characteristics. Perhaps the best comparison is the prototype Graphite LTD built by Ford to afford a direct comparison between a production steel vehicle and a 'high-tech' FR P vehicle, l Although graphite fibres were used and the vehicle was fabricated by hand lay-up procedures, several interesting features were evaluated.
While the thermoset matrix composites will probably constitute the bulk of the structural applications, thermoplastic-based composites formed by a stamping process may well have a significant, but comparatively minor, role to play. Most of the thermoplastic matrices in commercial use today tend to concentrate on polypropylene or Nylon as the base resin. The reason is simply the economic fact that these materials tend to be the most inexpensive of the engineering thermoplastics and are easily processed. Both of these materials are somewhat deficient in either heat resistance and/or environmental sensitivity relative to vehicle requirements for high-performance structures. Other thermoplastic matrices for stampable glass-fibre-reinforced composites are under development, and materials such as polyethylene terephthalate (PET) hold significant promise for the future.

2. Fabrication of Composite Materials

The successful application of structural composites to automotive structures is more dependent on the ability to use rapid, economic fabrication processes than on any other single factor. The fabrication processes must also be capable of close control of composite properties to achieve lightweight, efficient structures. Currently, the only commercial process which comes close to satisfying these requirements is compression moulding of sheet moulding compounds (SMC) or some variant on the process. There are, however, several developing processes which hold distinct potential for the future in that these techniques combine high rates of production, precise fibre control and high degrees of part integration. The evolving processes are thermoplastic stamping and high speed resin transfer moulding~ a variation on 'preform moulding' (e.g. resin transfer moulding, structural resin injection moulding). Each of these processes is summarized separately below with some comments relative to its merits and potential disadvantages.

3. Compression molding

A schematic illustration of the sheet moulding compound (SMC) process, depicting both the fabrication of the SMC material and the subsequent compression moulding into a component. This technology is widely used in the automobile industry for the fabrication of grill opening panels on virtually all car lines, and for some exterior panels on selected vehicles. The process consists of placing sheets of leathery textured SMC (1-2 inch chopped glass fibres in chemically thickened thermoset resin) into a heated mould (typically at 150 °C) and closing the mould under pressures of 1000psi (7 MPa) for about 2 minutes to cure the material. Approximately 80 % of the mould surface is covered by the SMC charge and the material flows to fill the remaining mould cavity as the mold closes.
The above description of the SMC process delineates material primarily used for semi-structural applications rather than high-load bearing segments of the structure which must satisfy severe durability andenergy absorption requirements. To sustain the more stringent structural demands, it is normally necessary to incorporate appreciable amounts of continuous fibres in pre-designated locations and orientations.The same basic SMC operation can be utilized to incorporate such material modifications either by formulating the material to include the continuous fibres along with the chopped fibres or by using separate charge patterns of two different types of material. The complexity of shape and degree of flow possible are governed by the amount and location of the continuous glass material.

4. High-speed resin transfer moulding

Fabrication processes allowing precise fibre control with rapid processability would overcome many of the deficiencies outlined above. The use of some kind of preform of oriented glass fibres preplaced in the mould cavity followed by the introduction of a resin with no resultant fibre movement would satisfy these requirements. The basic concepts required for this process are practised fairly widely today in the boat building and speciality car business. Without exception the glass preform is hand constructed and the resin injection and cure times are of the order of tens of minutes at the fastest. Major time contractions and automation of all phases of the process are necessary to generate automotive production rates.

5. Thermoplastic stamping

The process of thermoplastic stamping is attractive to the automotive industry because of the rapid cycle time and the potential utilization of some existing stamping equipment. Thermoplastic stamping at its current level of development achieves cycle times of one minute for large components. Typically a sheet of pre-manufactured thermoplastic and reinforcement is preheated above the melting point of the matrix material and then rapidly transferred to the mould. The mould is quickly closed until the point where the material is contacted and then the closing rate is slowed. The material is formed to shape and flows to fill the mould cavity much the same as compression moulded SMC. The material is cooled in the mould for a short period of time and then the mould opens and the component is removed.Thermoplastic stamping is currently used in automobiles to form low cost semi-structural components such as bumper backup beams, seats, and load floors.

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