Critical Review on Automobile Applications of Hybrid Fibre Reinforced Plastics

Lokesh K S[1], Dr.Shrinivasa Mayya.D*

[1]Assistant Professor, Department of Mechanical Engineering, Srinivas Institute of Technology, Valachil, Mangaluru

[2]Professor, Department of Mechanical Engineering, Srinivas Institute of Technology, Valachil, Mangaluru

Abstract;
Light weight structures designate the sustainable and suitable mechanical members for vehicle industry with the commercial findings and deposit remarkable materials with unique properties as well as exploring challenges. Composite structures retain the interest in the replacement of steel spring with leaf spring made of polymer composites which in includes the different fibers with proper resin ratio makes it possible to find best platform to perform as vehicle leaf blades serving the purpose of high strength and less weight. This review process clearly reveals about the replacement of steel springs with E-glass and silk hybrid fibers reinforced with epoxy polymer. The samples are prepared with the help of wooden die with the constant width and thickness. Tests to be conducted to assess the mechanical properties and fatigue strength of samples with the help of digital UTM and better proportion of hybrid fibres reinforced with polymers can be suggested.

Key words: leaf spring,Hybrid fibre,composite blades.

1.INTRODUCTION

Composites structures are derived from the properties, processability and characteristic results of two or more materials combined in a macroscopic scale to achieve the same among two materials in which one of the materials, called the reinforcing phase, is in the form of fibers, sheets or particles and are embedded in the other materials called matrix phase. The reinforcing and the matrix materials can be metal, ceramic, or polymer. Typically, reinforcing materials are strong with low densities while the matrix is usually a ductile or tough material. Fiber matrix interactions play a crucial role in determining the properties of their relative composites [1]. Humans have been using composite materials for thousands of years. For example, they have manufactured bricks out of mud which is thousand-year-old technology. In this modern era, we all depend on composite materials at some aspects of our lives. Fiberglass is one of the first modern composite which was developed in the late 1940s and is still the most common in our daily use. The use of composite materials in advanced engineering applications has been gradually increasing due to high strength and stable material characteristics. The composite materials, which have better light-weight, rigidity and several special characteristics, are preferred for aerospace, automotive and maritime vehicles [2].To meet the needs of natural resource conservation and energy economy, the automobile manufacturers have been attempting to reduce the weight of vehicles in recent years [3]. Fiber reinforced polymers are making inroad in many applications, principally because of the potential for weight saving. Other advantages of using fiber reinforced polymers instead of steel are the possibility of reducing noise, vibrations and ride harshness (NVH) due to their high damping factors the absence of corrosion problems, which means lower maintenance cost, and lower tooling cost, which has favorable impact on the part of manufacturing cost [4].The significance part of preparing a sample reflects the core properties and mechanical sustainability of material under various testing conditions.

1.1 Introduction to Springs

A spring is defined as an elastic machine element, which deflects under the action of the load & returns to its original shape when the load is removed [1]. Mechanical springs are used in machine designs to exert force, provide flexibility, and to store or absorb energy. Springs are manufactured for many different applications such as compression, extension, torsion, power, and constant force. Depending on the application, The fuel efficiency and emission gas regulations of automobiles are two important issue in these days. The best way to increase the fuel efficiency is to reduce the weight of the automobiles by employing composite materials in the structure of the automobiles. Metal springs can be can be replaced by composite springs because of weight reduction and corrosion resistance. Metal coil spring cannot withstand high temperature. At high temperature where it is required to operate composite springs are used. Metal springs are several advantages, they are very cheap to produce and can be produced in almost all kinds of and in a very broad range of stiffness. Since the composite materials are anisotropic in nature, the design and manufacture of composite springs are difficult. Therefore the application of composite materials in springs is not yet popular. For the purpose of saving energy and improving the performance of the shock absorbers, with light weight and high quality, composite materials have to be used for today's vehicles. With the more no of electric vehicles and hybrid vehicles are entering in to the market in the present scenario, it has become essential to go for the light components for improving the efficiency. Generally, simple replacement of steel parts by composite materials yields significant weight savings, but as with many new materials, design and manufacturing problems arises; for example the change from relatively isotropic-homogeneous steel alloys to anisotropic inhomogeneous fiber reinforcement plastic (FRP). As a result, it is not an easy task to replace steel by composite materials [5]. Engineers can design a metal suspension and to use composite spring only for its spring properties. This allows very refined mechanical suspension concept composite spring by vertical load control.

1.1.1 Different Types of springs;

a. Helical springs

Helical springs are wide-spread elastic elements and are very often used in machines construction. Usually helical springs are produced by coiling steel wire of circular or rectangular section. Wires with small diameter are mostly cold-coiled after heat treatment. After forming springs are usually tempered in order to reduce residual stresses. Springs with bigger sections as well as springs with liable applications are hot-coiled and subsequently heat treated in order to increase mechanical properties. Because of different applications and followed by them different requirements related to characteristic, ratio between maximum load and transversal dimensions, mounting solution etc. many different constructions of helical springs are used. The construction that is relatively new among others is spring machined from cylindrical sleeve. Springs of such type made with high precision without introducing residual stresses distinguish themselves with high accuracy of characteristic and possibility of various mounting ways with co-operating elements. The ways of spring mounting shown above enable their application in many-directions loaded systems. Such springs can therefore work both for stretching and compressing. These springs can be applied in systems where because of certain reasons very small tolerance of positioning is demanded like e.g. in elastic seat of deflecting segments in slide thrust bearings of high overall dimensions. Important advantage of such springs is also possibility of gaining very high stiffness, not possible in case of springs coiled from wire.

Figure.1 Coil spring

b. Leaf spring

Originally Leaf spring called laminated or carriage spring, a leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. It is also one of the oldest forms of springing, dating back to medieval times.

Sometimes referred to as a semi-elliptical spring or cart spring, it takes the form of a slender arc-shaped length of spring steel of rectangular cross-section. The center of the arc provides location for the axle, while tie holes are provided at either end for attaching to the vehicle body. For very heavy vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions.

A leaf spring can either be attached directly to the frame at both ends or attached directly at one end, usually the front, with the other end attached through a shackle, a short swinging arm. The shackle takes up the tendency of the leaf spring to elongate when compressed and thus makes for softer springiness.

Figure.2 Leaf blades

c. Disc spring

Conical disc springs are axial compression spring . They are used machines where large forces are required and small deflections are desired. Also machines transmitting mechanic power, turbines, jet motors and space applications are other areas to use disc springs. Disc springs have several advantages distinguishing them from standard springs. These are having the advantages of Offers high load in small spaces, Offers any desired spring length or spring characteristics by adding or removing any number in a Stack, longer service life under dynamic loads with a suitable sizing, and various application opportunities due to load / deflection characteristics. Therefore the application of composite materials in springs is not yet popular. For the purpose of saving energy and improving the performance of the shock absorbers, with light weight and high quality, composite materials have to be used for today's vehicles. With the more no of electric vehicles and hybrid vehicles are entering in to the market in the present scenario, it has become essential to go for the light components for improving the efficiency.

Figure.3 Disc spring

2. LITERATURE REVIEW

Thorough knowledge of composite structure response to variety of testing conditions correlated to structure integrity and load tolerable conditions when moulded properly with considerable composition of different fibers and resin mixture demands concluded work which has been conducted earlier. In this view, review of literature part clearly configures the sufficient amount of experimental possibility of conducting the same. Ramakrishna et al. describes the recent developments of natural fiber reinforced polypropylene (PP) composites. Natural fibers are low-cost, recyclable, and eco-friendly materials. Due to eco-friendly and bio-degradability characteristics of these natural fibers, they are considered as strong candidates to replace the conventional glass and carbon fibers. The chemical, mechanical, and physical properties of natural fibers have distinct properties; depending upon the cellulosic content of the fibers which varies from fiber to fiber. The mechanical properties of composites are influenced mainly by the adhesion between matrix and fibers. Chemical and physical modification methods were incorporated to improve the fiber–matrix adhesion resulting in the enhancement of mechanical properties of the composites. The chemical, mechanical, and physical properties of natural fibers have distinct properties; cellulose content of these fibers varies from fiber to fiber. The moisture content lowers the mechanical properties. The mechanical properties of composites are influenced mainly by the adhesion between matrix and fibers. As in the case of glass-fibers, the adhesion properties can be changed by pre-treating the fibers [6].

Girisha et al investigate the tensile properties of composites made by reinforcing sisal, coconut spathe and ridge gourd as the new natural fibers into epoxy resin matrix. The natural fibers extracted by retting and manual processes were subjected to alkali treatment. The composites fabricated consist of reinforcement in the hybrid combination like sisal-coconut spathe, sisal-ridge gourd and coconut spathe-ridge gourd with the weight fraction of fibers varying from 5% to 30%. It has been observed that the tensile properties increase with the increase in the weight fraction of fibers to certain extent and then decreases. The hybridization of the reinforcement in the composite shows greater tensile strength when compared to individual type of natural fibers reinforced. The incorporation of natural fibers such as Sisal (in the form of fibers), Ridge gourd (in the form of natural woven mat), and Coconut leaf sheath (in the form of natural woven mat) in to the Epoxy matrix shows the moderate improvement in the tensile properties of the composites [7]. Mahmood M.et al used four-leaf steel spring in the rear suspension system of light vehicles is analyzed using ANSYS software. Using the results of the steel leaf spring, a composite one made from fiberglass with epoxy resin is designed and optimized using ANSYS. Main considerations given to the optimization of the spring geometry. The objective was to obtain a spring with minimum weight that is capable of carrying given static external forces without failure. The stresses in the composite leaf spring are much lower than that of the steel spring. Compared to the steel leaf spring the optimized composite leaf spring without eye units weights nearly 80% less than the steel spring. The natural frequency of composite leaf spring is higher than that of the steel leaf spring and is far enough from the road frequency to avoid the resonance[8]. Gulur Siddaramanna investigated a single leaf with variable thickness and width for constant cross sectional area of unidirectional glass fiber reinforced plastic (GFRP) with similar mechanical and geometrical properties to the multi leaf spring, was designed, fabricated (hand-lay up technique) and tested. Computer algorithm using C-language has been used for the design of constant cross-section leaf spring. The results showed that an spring width decreases hyperbolically and

Thickness increases linearly from the spring eyes towards the axle seat. The finite element results using ANSYS software showing stresses and deflections were verified with analytical and experimental results. The design constraints were stresses (Tsai-Wu failure criterion) and displacement. Compared to the steel spring, the composite spring has stresses that are much lower, the natural frequency is higher and the spring weight is nearly 85 % lower with bonded end joint and with complete eye unit. The development of a composite mono leaf spring having constant cross sectional area, where the stress level at any station in the leaf spring is considered constant due to the parabolic type of the thickness of the spring, has proved to be very effective[9]. Santhosh Kumar et al worked on Composite structures for conventional metallic structures have many advantages because of higher specific stiffness and strength of composite materials is discussed. The automobile industry has shown increased interest in the replacement of steel spring with fiberglass composite leaf spring due to high strength to weight ratio. This work deals with the replacement of conventional steel leaf spring with a Mono Composite leaf spring using E-Glass/Epoxy. The design parameters were selected and analyzed with the objective of minimizing weight of the composite leaf spring as compared to the steel leaf spring. It was observed that the deflection in the composite leaf spring was almost equal so we can say that composite spring had the same stiffness as that of steel spring [10]. Chang-HsuanChiu focused on four different types of helical composite springs were made of structures including unidirectional laminates (AU),rubber core unidirectional laminates (UR), unidirectional laminates with a braided outer layer (BU), and rubber core unidirectional laminates with a braided outer layer (BUR), respectively. It aims to investigate the effects of rubber core and braided outer layer on the mechanical properties of the aforementioned four helical springs. According to the experimental results, the helical composite spring with a rubber core can increase its failure load in compression by about 12%; while the spring with a braided outer layer cannot only increase its failure load in compression by about 18%, but also improve the spring constant by approximately 16%. The helical spring with a BUR structure has the highest mechanical properties among those considered herein, its failure load in compression approximately equals 336.2 kgf, and the spring constant is almost 16.27 kgf/mm. The four kinds of helical composite springs have been developed in this study, and they are lighter and stiffer than the spring made of a commonly used spring steel (both its spring constant and weight are about 7.8 kgf/ mm and 498.59 g, respectively, of the same volume as the helical composite springs designed in this study)[11]. Afyon kharisar studied the effectiveness of composite disc springs with different cross-section and hybrid type are determined by taking into account load capacities, masses, hybridization characteristics and costs of composite disc springs. The disc springs are analyzed with finite elements program by compressing between two rigid plates. The load-deflection characteristics obtained as a result of the analysis are compared with the analytic and experimental studies. Then different cross-section and hybrid composite disc springs were modeled. The trapeze A disc spring were confirmed to be more advantageous in terms of load capacity and mass by investigating the modeled disc springs. The effect of hybridization on hybrid disc springs with standard cross-section was investigated and optimum hybrid disc spring was determined according to cost and maximum loading capacity. Consequently, it is determined that carbon/epoxy plies used for outer layers are more advantageous. But the outer ply subjected to force was damaged this layer should be particularly reinforced [12]. Gajendra Singh Rathore provides the information about the fatigue stress for the helical compression spring. Springs are mechanical shock absorber system. The researchers throughout the years had given various research methods such as Theoretical, Numerical and Experimental. Researchers employ the Theoretical, Numerical and FEM methods. This study shows that shear stress and deflection equation is used for calculating the number of active turns and mean diameter in helical compression springs. Comparison of the theoretical obtained result by the shear stress equation to the Finite Element Analysis result of helical compression springs is the mode of our present work, by this analysis it will possible in future to provide help to designers for design of spring against fatigue condition[13]. Bruno Kaiser et al found the results of fatigue tests on a variety of helical springs up to a number of 107 cycles. These results were obtained in a research project which extensively investigated the fatigue properties of helical springs with five different wire diameters (1, 2, 3, 5 and 8 mm) up to 107 cycles. The test springs for this project were made out of six different spring materials, two patented cold drawn unalloyed spring steel wires, two oil hardened and tempered spring steel wires and two stainless spring steel wires. After having completed these fatigue investigations limited at 107 cycles, some long term fatigue tests on shot peened helical compression springs were operated, in one case up to a maximum number of 1,5 x 109 cycles. The fatigue range of shot peened helical compression springs made of oil hardened and tempered Cr-Si-alloyed spring steel wires shows a significant decrease in the extremely high cycle region. Further investigations are necessary to better understand and possibly prevent these failures [14].

3. MATERIALS AND METHODS

3.1 Hybrid composition of Material Structures

Hybrid composites, the plies can include fibers of two, or may be more types, e.g., carbon and glass, glass and aramid and so on. Hybrid composites provide wider possibilities to control material stiffness, strength and cost. Promising application of these materials is associated with the so-called thermo stable structures that do not change their dimensions under heating or cooling. The foregoing sections of this chapter concern the properties of unidirectional plies reinforced with fibers of a certain type - glass, carbon, aramid, etc. In hybrid composites, the plies can include fibers of two, or may be more types, e.g., carbon and glass, glass and aramid and so on. Hybrid composites provide wider possibilities to control material stiffness, strength and cost.

3.1.1 E-glass Fabric

Glass fibres are the primary members to explore the load bearing capability with considerable straining when reinforced with thermo set matrix which highlights the significant performance and mechanically compatible for normal operating temperature conditions considered. Glass fibres are manufactured by drawing molten glass into very fine threads and then immediately protecting them from contact with the atmosphere or with hard surfaces in order to preserve the defect free structure that is created by the drawing process. Glass fibres are as strong as any of the newer inorganic fibres but they lack rigidity on account of their molecular structure. The properties of glasses can be modified to a limited extent by changing the chemical composition of the glass, but the only glass used to any great extent in composite materials is ordinary borosilicate glass, known as E-glass. The largest volume usage of composite materials involves E-glass as the reinforcement. S-glass (called Rglass in France) has somewhat better properties than E-glass, including higher thermal stability, but its higher cost has limited the extent of its use.

3.1.2 Silk fiber

Silk is a naturally available fibre which delivers some important properties when it is used as a reinforcing material. Silk is a proteinfibre, some forms of which can be woven into textiles. The protein fibre of silk is composed mainly of fibroin and produced by certain insect larvae to form cocoons. The best-known type of silk is obtained from the cocoons of the larvae of the mulberry silkworm Bomby xmori reared in captivity (sericultu re). The shimmering appearance of silk is due to the triangular prism-like structure of the silk fibre, which allows silk cloth to refract incoming light at different angles, thus producing different colors Silks are produced by several other insects, but generally only the silk of moth caterpillars has been used for textile manufacturing. There has been some research into other silks, which differ at the molecular level. Many silks are mainly produced by the larvae of insects undergoing complete metamorphosis, but some adult insects such as web spinners produce silk, and some insects such as raspy crickets produce silk throughout their lives. Silk production also occurs in Hymenoptera (bees, wasps, and ants), silverfish, mayflies, thrips, leafhoppers, beetles, lacewings, fleas, flies and midges.Other types of arthropod produce silk, most notably various arachnids such as spiders.

Table 1.Specifications of existing steel leaf spring

Parameters	Values
Total length (eye-to-eye), mm	1150
Arc height at axle seat(Camber), mm	70
Spring rate, N/mm	20
Width of the leaves, mm	50
Thickness of the leaves, mm	06

Table.2 Design parameters of composite leaf spring

Parameters	Values
Thickness, mm	06
Width, mm	50
Thickness of fibre, mm	0.2
Width of fibre, mm	50
Thickness of silk, mm	0.05
Width of silk, mm	50
Volume fraction, Epoxy:GF:Silk	40:45:15, 40:30:30, 40:15:45, 50:50, 50:50silk

The fibers chosen for the spring design are Silk, E-glass in the form of mat due to their high extensibility, In order to facilitate the wetting of fibers, epoxy resin with 2 h pot life is selected. L-12/K-6 epoxy system for laminating applications is used. Fabrication the constant cross section design is selected due to its capability for mass production, and to accommodate continuous reinforcement of fibers and also it is quite suitable for hand lay-up technique. Many techniques can

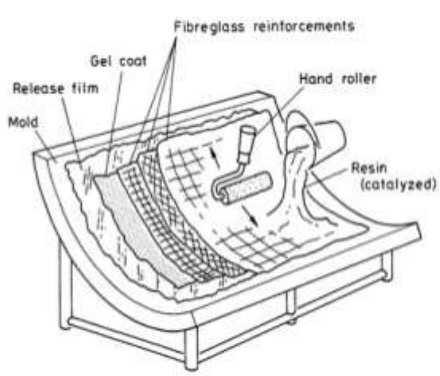

Figure.6 Hand lay-up technique

Fig.5 Composite Leaf blade

be suggested for the fabrication of composite leaf spring from unidirectional GERP. Composite leaf spring was fabricated using wet filament winding technique [15].To assess the tensile behavior of hybrid fibre laminates to justify the overall behavior of hybrid laminates under various loading conditions, two types of laminates (360 GSM woven & 200 GSM chopped) composite specimens were tensile tested. The load-deflection curve was evaluated. It is observed from the results, compare to chopped fibre woven glass fibre/Epoxy composites yields high strength [16]. In the present work, the hand lay-up process was employed. The templates (mould die) were made from wood according to the desired profile which is as shown in figure.4. The glass fibers and silk were cut to the desired lengths, so that they can be deposited on the template layer by layer during fabrication. In the conventional hand lay-up technique, a releasing agent (PVA) was applied uniformly to the mould which had good surface finish. This is followed by the uniform application of epoxy resin over glass fiber. Another layer is layered and epoxy resin is applied and a roller is using for removing all the trapped air. the prepared leaf blade with proper volume fraction of both Glass fibre and silk fibre and limited to experimental dimension of the sample which is as shown in figure.5.

4. CONCLUSION

Critical review on composite leaf blades with the best prediction by recommending the use of of hybrid fibres which are more convenient to use as light weight structure which is still undefined to fit as dynamic set as well as to serve the commercial industrial aspects for leaf blades which is evaluated more successfully. It is concluded that developing light weight members offers huge market for experiencing fluctuating loads and demands for these structures increasing gradually to overcome the usage of steels to get maximum benefit of light weight, non-corrodible less cost, easy to prepare and avoid machining operation. The replacement of steel springs with E-glass and silk hybrid fibers reinforced with epoxy polymer has to be prepared with the help of suitable die usually made of wood with the constant width and thickness.

Mechanical tests has to be done with the help of digital UTM and fatigue test will be conducting to assess the material behavior against fluctating loads and best proportion of hybrid fibres reinforced with polymers can be recommended purely to bear fatigue loading as well as mechanical strength of the samples prepared.

REFERENCES

[1] R.M. Rowell H.P. Stout, "Hand book of fiber Chemistry", Marcel Dekker Inc. Newyork, 2nd edition, p. 456-460 (1998).

[2] M. EnamulHossai Journal of Composite Materials 45(20) 2133–2144

[3]K.Tanabe.,T.Seino.,andYKajioCharacteristicsofcarbon/glas fiber reinforced plastic leaf spring. Society of Automotive Engineers, Inc..(1982)

[4]P. K. MallickComposite Engineering Hand Book, New York .Marcel Dekker.(1997)

[5] M.Shokrieh, and D.Rezaei. Analysis andoptimization of compositeleaf spring. Composite,Structures.**60**: 317-325(2003)

[6] Ramakrishna Malkapuram, Vivek kumar and Yuvraj Singh Negi

[7] C.Girisha., Sanjeevamurthy, Gunti Rangasrinivas…Vol.2, Issue.2, Mar-.Apr 2012

[8] M Mahmood. Shokrieh,Davood Rezaei… Composite Structures 60 (2003) .317–325

[9] GulurSiddaramanna, SambagamVijayarangan*ISSN 1392–1320 MATERIALS SCIENCE (MEDŽIAGOTYRA).Vol. 12, No. 3. 2006*

[10] Y. N. V. Santhosh Kumar & M. VimalTeja.

[11] Chang-Hsuan Chiu , Chung-Li Hwan.

[12]AfyonKocatepe University, Technical Education Faculty, ANS Campus, .Afyonkarahisar, Turkey, No. 12-CSME-62, E.I.C. Accession 3382

[13]Gajendra Singh Rathore1, Upendra Kumar Joshi2… Issue 3, Vol.2 (May 2013)

[14] Bruno Kaiser and Christina Berger

[15]I. Rajendran., S.Vijayarangan,.Optimal Design of a Composite Leaf Spring using Genetic Algorithms *Int. Jr of Computer and Structures* 79 2001: pp. 1121 – 1129.

[16] KS Lokesh, , SM Ravi, 2017/6 ,Evaluation of Mechanical Properties and Wear Characterization of Polymer Composites under Varying Temperature Conditions: A Review, IJEAIS,Volume-1,Issue-4, Pages;64-68

[17] Lokesh KS,Chetan A,2015/2, Experimental Evaluation of effect of filler on tensile behavior of E- glass/epoxy composites ,International Journal of Research in Engineering and Science (IJRES), Volume 3, Issue 2.

[18]Lokesh KS Effect of E-waste Rubber on Wear Behaviour of Glass fibre Reinforced with Epoxy Composites, IJASRE – Volume-4,Issue-3,March-2018,
DOI: 10.7324/IJASRE.2018.32624