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DESIGN AND ANALYSIS OF GLASS FIBER REINFORCED POLYMER (GFRP) LEAF

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ABSTRACT— The automotive industry's current focus is on finding ways to reduce weight. Improving materials, optimising designs, and streamlining production processes are the main ways to reduce weight. Composites are a great alternative to traditional steel because they may reduce weight while improving mechanical qualities to a sufficient degree. We consider the material's strength and price while making our selection. Many multi-leaf steel springs are giving way to mono-leaf composite springs because composites outperform steel in terms of strength-to-weight ratio and elastic strain energy storage capacity. A concise overview of the benefits and applications of composite leaf springs on cars is provided in this article. Building a mono composite leaf spring from the ground up is what this project is all about. Stress and deflections are the design restrictions. To create a composite leaf spring with mechanical and geometrical features comparable to those of a multileaf spring at a lower overall cost, glass fibre reinforced plastic (GFRP) and epoxy resin were chosen as the material of choice. The hand layup process is used to construct and test the composite leaf spring. Both analytical and experimental findings corroborated the stresses and deflections measured during the testing, which was carried out experimentally with the aid of UTM and by finite element analysis (FEA) using ANSYS software. Composite springs are more cost-effective than steel ones.

reduces tensions significantly and reduces spring weight by about 74%.

Keywords: Leaf spring, Composite material, FEM, GFRP

I. INTRODUCTION

A mechanical item that can withstand more elastic deformation than others is a spring. Various varieties of springs are often used in engineering. The leaf spring is one of the most common industrial uses for springs. Its use as a vehicle's suspension is extensive. A commonly used design for the rear suspension is a semielliptical beam with simple supports. It can withstand loads imposed at an angle. One such component that may be lightened in a car is the suspension leaf spring, which contributes about 10% to 20% of the vehicle's unsprung weight.

A more fuel-efficient and better ridding quality car is the result of using a composite leaf spring. Because to advancements in composite materials, the leaf spring may now be lighter without sacrificing stiffness or load bearing capability. Consequently, the automotive industry has begun to adopt composite materials in lieu of metal components. Due to the fact that, in comparison to steel, composites provide a high strength-to-weight ratio and a greater ability to store energy during elastic strain. A leaf spring, like any other spring, is a device for storing and releasing energy. It is equipped with an

benefits from acting as both a spring and a structural component of the suspension system. In most cars, there are two main types of suspension. The front suspension, which is cantilever-shaped, experiences both vertical and transverse loads.

A Suspension Object
in order to stop the beneficial shocks from reaching the car parts.
In order to protect the people inside from the impact of the road.
To prevent the vehicle from becoming unstable while in motion, whether it's pitching or rolling.
B. Suspension's Role Springs Placed between the wheels and the body, springs store energy when the wheels encounter road bumps by raising and deflecting the springs. The elasticity of the spring material causes it to rebound upon release, increasing the amount of energy stored. The spring will begin to vibrate in this manner, but the amplitude will decrease with time due to internal friction in the spring material and friction at the suspension joints, and the oscillations will eventually stop.

II. REVIEW OF LITERATURE

[1]Best wishes, Siddaramanna Vijayarangan Sambagam, Shiva Shankar The design, fabrication, and testing of a single leaf of unidirectional glass fibre reinforced plastic (GFRP) with variable thickness and breadth for a fixed cross sectional area exhibited mechanical and geometrical qualities comparable to those of a multileaf spring. The fabrication process was carried out using the hand-lay up approach. This article explains the computer method that is used to construct mono composite leaf springs with variable with and variable thickness. Results from experiments may be double-checked using three-dimensional finite element analysis. Wherein the steelleaf spring and solid layered 46 elements are used.

that is used in composite leaf springs.We employ the hand lay up approach to fabricate mono composite leaf springs out of E-glass and epoxy. The results of the experimental tests were compared between the steel and composite leaf springs.With a significant weight decrease, composite leaf springs are shown to be superior than steel ones. Both of these Mouleeswaran said Sabapathy Vijayarangan, Senthil Kumar The design of composite leaf springs is based on fatigue failure in this research.Fatigue life prediction equations are derived from fatigue modulus and degradation rate. Steel and composite leaf springs are thought to be identical in terms of size and number of leaves. The finite element technique is used to do the stress analysis.Solid 45, which exhibits spring-like behaviour, is chosen for the study. The filament winding machine is used for the manufacture of each leaf, which is then joined using a centre bolt and four side clamps. A hydraulic electro-leaf spring testing apparatus is used to test both steel and composite multi-leaf springs. We use data analysis to design and conduct experimental fatigue tests on composite multi-leaf springs. The results show that composite leaf springs reduce stress by 67.35%, increase stiffness by 64.95%, increase natural frequency by 122.98%, and reduce weight by 68.15%. the thirdthe third Shahrokh Shokrieh *, Davood Rezaei, This article uses ANSYS V5.4 software to analyse a four-leaf steel spring that is utilised in the rear suspension system of light cars. The current analytical and experimental answers were confirmed by the finite element findings that displayed stresses and deflections. Building on the findings of the steel leaf spring, a fiberglass-reinforced composite epoxy resin is developed and fine-tuned with the help of ANSYS. The spring geometry optimisation is the primary focus. The goal was to find a lightweight spring that could withstand static external stresses without breaking. Design limitations included displacements and stresses, as defined by the Tsai-Wu failure criteria. Findings demonstrated a hyperbolic decline in ideal spring width and a linear rise in thickness from spring eyes to axle seat. Reduced stresses, increased natural frequency, and about 80% lighter without eye units characterise the optimised composite spring in comparison to the steel spring. [4][4] R.M. Mayer, G. Jeronimidis, I. Nairne, J.P. Hou, J.Y. Cherruault, A composite leaf spring developed for use in goods train applications is detailed in this study. Composite leaf springs with three different eye-end attachment designs are detailed. Glass fibre reinforced polyester is the substance used. In order to determine the spring's properties, static testing and finite element analysis were performed. We compared the three tested designs' load-deflection curves and strain measurements as a function of load to the values predicted by the finite element analysis. The delamination failure at is the primary issue with the initial design. the point where the fibres that have wrapped around the eye meet the spring body, despite the fact that the design can endure a static proof load of 150 KN and a fatigue load of one million cycles. The presence of a significant concentration of interlaminar shear stress in that area was verified by the FEA findings. A second design element is an extra transverse bandage that is wrapped around the area that is likely to delaminate.

Contamination was achieved, albeit not entirely eradicated. The third concept gets around the issue by cutting the fibres short at the eye section's end. [5] Written by H.A. Al-Qureshi, this article details the design, fabrication, and testing of a single-leaf spring made of glassfiber reinforced plastic (GFRP) that exhibits mechanical and geometrical features comparable to those of a multileaf steel spring. Lower susceptibility to fractures, impact, and wear damage are some of the benefits of glass fibre reinforced plastic (GFRP) versus graphite/epoxy. The leaf spring concept was originally thought of as a symmetrical, parabolically tapered beam with a constant width that carried a focused load; the two spring limbs were supposed to have varied cord lengths. To simulate how a leaf spring works, a finite element software is used. An equation that depends on both the thickness and the location along the spring may also be derived via analytical analysis. At the beginning of the current operation, the hand lay-up vacuum bag method was used. Mandrels, both male and female, were constructed from plywood in accordance with the required profile. The measured lengths of glass fibre fabric were then applied to the mandrel in order to achieve the computed thickness. The process was carried out by hooping epoxy resin-impregnated glassfiber over the spinning mandrel. A battery of static loading tests were conducted on the spring in the lab. This research shown that light vehicles (jeeps) may satisfy the requirements for leaf springs made of composite material while also significantly reducing their weight.

In the study conducted by E. Mahdi, O.M.S. Alkoles, A.M.S. Hamouda, B.B. Sahari, R. Yonus, and G. Goudah, [...] The effect of ellipticity ratio on the functionality of composites encased in woven roving is discussed in this research.

Experimental and numerical investigations of elliptical springs have been conducted. The composite elliptical springs were tested in a number of ways with ellipticity ratios (a/b) between one and two. Composite elliptic spring components' mechanical performance and failure mechanisms under static load circumstances are presented. The relationship between spring thickness and important design parameters like failure load and spring rate is well-established. Numerical simulations for fatigue calculations were carried out in tandem with the experimental investigation. The purpose of the simulation was to determine the elliptical composite spring's cycle life and the spring constants of an ellipse exposed to a compressive stress along the tubes' main axis. A commercially available finite element program (LUSAS) was used to conduct the simulation. Because of their reputation for producing reliable stress and strain data, eight-nodded QTS8 were chosen. The spring rate was maximum for composite elliptic springs with an ellipticity ratio of 2.0. Results from this study show that composites are indeed used for car suspension and fulfil the criteria, while also significantly reducing weight. Additionally, compared to traditional and composite coil and leaf springs, hybrid composite elliptical springs are thought to have superior fatigue behaviour [6].Chaudhuri, Reaz A., Balaraman, K., Using continuous roving of glass fibres, this paper presents a hand lay-up process for fabricating fibre reinforced plastic (FRP) laminated plates. The current study incorporates three sub-methods for fabricating the GFRRE laminated plates: (a) resin flow method, (b) resin transfer technique, and (c) impregnation technique. The impregnation method outperforms the other two approaches, although the resin transfer method is also quite good. This research presents a novel hand lay-up technique that allows for the fabrication of plates with an unlimited number of layers and fibre orientation angles. The impregnation approach may produce FRP laminates that outperform other FRP laminates in terms of strength-to-weight and modulus-to-weight ratios, in addition to most structural materials.

III. SELECTION OF MATERIAL

Materials constitute nearly 60 to70% of vehicle cost and contribute to the qualityand performance of vehicle even a smallamount in weight reduction of vehicle,may have a wider economic impact. Thestrain energy of the material becomes amajor factor in designing the springs.The relationship of the specific strainenergy can be expressed as,

$$U = \frac{\sigma^2}{\rho E}$$

Find out where the spring material's strength, density, and Young's modulus are located. The maximum permissible stress squared and the modulus of elasticity in both the longitudinal and transverse directions are the direct and inverse variables that affect the stored elastic strain energy in a leaf spring. In comparison to steel, composites provide a high strength-to-weight ratio and a greater ability to store energy in the event of elastic strain. Because of their shown suitability as steel alternatives, composite materials have been chosen for the leaf spring. A. FRP, or Fibre Reinforced Plastic Material combinations Because they meet the requirements and transmit strength to the matrix, fibres are the most crucial kind of reinforcement.

component that affects and improves their qualities as needed. The first fibrils known to have been employed for reinforcing materials were glass fibres. Composites became much more robust and heat-resistant with the discovery and widespread usage of ceramic and metal fibres. Several circumstances cause fibres to not operate up to par. The mechanical characteristics of the matrix and the fibres' length, shape, orientation, and composition determine the fibre composite's performance.

C. Glass Fiber Glass is the most common fiber used in polymer matrix composites. Its Advantages include its high strength, low cost, high chemical resistance. The main types are E-glass (also called “fiberglass”) and S-glass. The “E” in E-glass stands for electrical because it was designed for electrical applications. However, it is used for many other purposes now, such as decorations and structural applications. The “S” in S-glass stands for higher content of silica. It retains its strength at high temperatures compared to E-glass and has higher fatigue strength.

C. Functions of a Matrix In a composite material, the matrix material serves the following functions: Holds the fibres together. Protects the fibres from environment. Distributes the loads evenly between fibres so that all fibres are subjected to the same amount of strain. Enhances transverse properties ofa laminate. Improves impact and fracture resistance of a component. Helps to avoid propagation of crack growth through the fibres by providing alternate failure path along the interface between the fibres and the matrix.

D. D. Characteristics of Fibre Reinforced Polymer (FRP) Composites. Many factors must be considered when designing a fiberreinforced composite, including length, diameter, orientation, amount and properties of the fiber; the properties of matrix; and the bonding between the fibers and matrix. 1) Fiber Length and Diameter Fibers can be short, long even continuous. Their dimensions are often characterized by aspect ratio l/d, where l is the fiber length and d is the diameter. Typical fiber have diameter varying from 10µm (10 x 104 cm) to 150µm (150 x 104 cm)

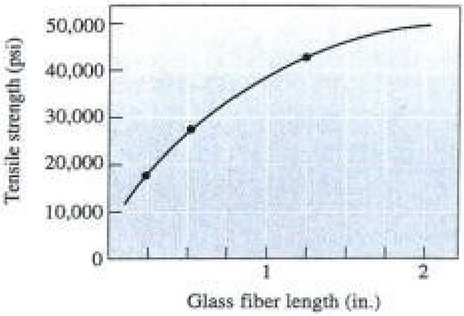
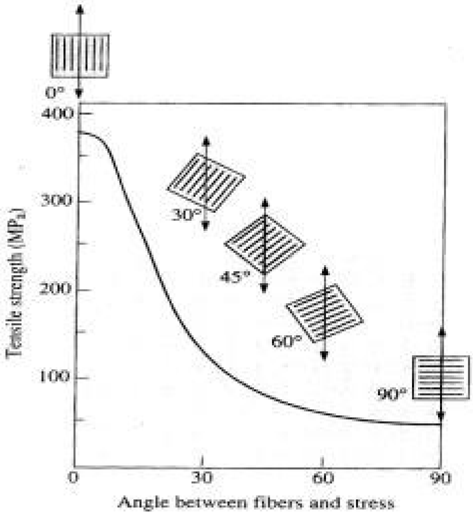


Fig. 2 Increasing the length of chopped E-glass fiber in an epoxy matrix increases the strength of composite. 2) Amount of Fiber A greater volume fraction of fiber increases the strength and stiffness of the composite, as we would expect from the rule of matrix. However, the maximum volume fraction is about 80%, beyond which fiber can no longer be completely surrounded by matrix. 3) Orientation of Fiber The orientation of the fiber in the matrix is an indication of the strength of the composite and the strength is greatest along the longitudinal directional of fiber. This doesn’t mean the longitudinal fibers can take the same quantum of load irrespective of the direction in which it is applied. Optimum performance from

longitudinal fibers can be obtained if the load is applied along its direction. The slightest shift in the angle of loading may drastically reduce the strength of the composite. Unidirectional loading is found in few structures and hence it is prudent to give a mix of orientations for fibers in composites particularly where the load is expected to be the heaviest.



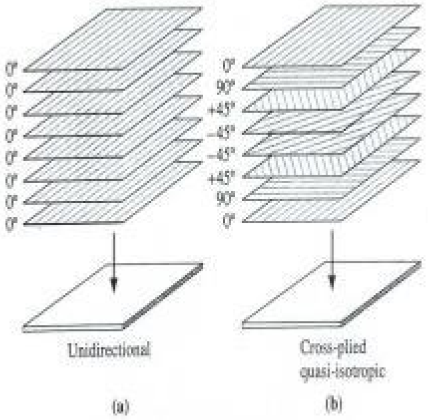


Fig. 3 Effect of Fiber Orientation on the tensile strength of Eglass fiber reinforced epoxy composite 4) Fiber Properties In most fiber-reinforced composite, the fibers are strong, stiff, and lightweight. If the composite is be used at elevated temperature, the fiber should also have a high melting temperature. Thus specific strength and specific modulus of the fiber the specific modulus fiber are important characteristics. Specific Strength = TS/ Specific Modulus = E/ Where TS is the tensile strength, is the density, and E is the modulus of elasticity

Properties of E-Glass/Epoxy Table 1 Typical Properties of Glass Fibers (SI System of Units)

Property	Units	E-Glass
Axial modulus	GPa	85
Transverse modulus	GPa	85
Axial Poisson's ratio	—	0.20
Transverse Poisson's ratio	—	0.20
Axial shear modulus	GPa	35.42
Axial coefficient of thermal expansion	μ m/m/°C	5
Transverse coefficient of thermal expansion	μ m/m/°C	5
Axial tensile strength	MPa	1550
Axial compressive strength	MPa	1550
Transverse tensile strength	MPa	1550
Transverse compressive strength	MPa	1550
Shear strength	MPa	35
Specific gravity	MPa	2.5

Table 2 Typical Properties of Matrices (SI System of Units)

Property	Units	Epoxy
Axial modulus	GPa	3.4
Transverse modulus	GPa	3.4
Axial Poisson's ratio	—	0.30
Transverse Poisson's ratio	—	0.30
Axial shear modulus	GPa	1.308
Coefficient of thermal expansion	μ m/m/°C	63
Coefficient of moisture expansion	m/m/kg/kg	0.33
Axial tensile strength	MPa	72
Axial compressive strength	MPa	102
Transverse tensile strength	MPa	72
Transverse compressive strength	MPa	102
Shear strength	MPa	34
Specific gravity	MPa	1.2

Table 3 Chemical Composition of E-Glass

Material	% Weight
Silicon oxide	54
Aluminum oxide	15
Calcium oxide	17
Magnesium oxide	4.5
Boron oxide	8
Other	1.5

Table 4 Properties of E/glass epoxy

Property	Units	Eglass/epoxy
Longitudinal elastic modulus E_1	GPa	60.52
Transverse Young's modulus, E_2	GPa	11
Major Poisson's ratio, ν_{12}		0.230
Minor Poisson's ratio ν_{21}		0.03941
In-plane shear modulus, G_{12}	GPa	4.014

V. FEM Analysis of GFRP Leaf spring

The models made up of GFRP materials are not directly developed for the composite materials; we feed the data in the matrix form or layered form. GFRP analysis SOLID46 element is used.

SOLID46 is a layered version of the 8-node, 3-D solid element. It is designed to model thick layered shells or layered solids and allows up to 250 uniformthickness layers per element. An advantage with this element type is that you can stack several elements to model more than 250 layers to allow through-the-thickness deformation slope discontinuities. The user-input constitutive matrix option is also available. The deformation result of the GFRP is 97 mm at 3000N load and the Vonmises Stress 247 MPa.

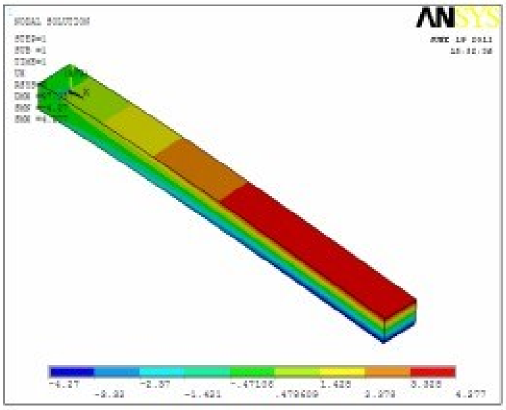


Fig. 4 Total Deformation

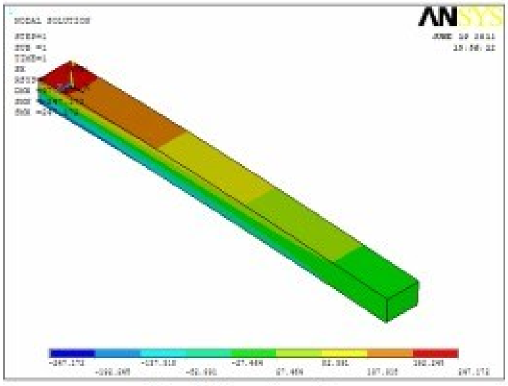
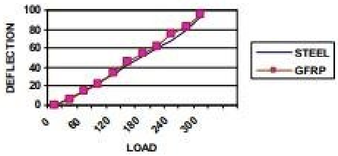


Fig. 5 Vonmises Stress

For Fabrication of GFRP leaf spring Hand Lay-up Technique is used The hand (wet) lay-up is one of the oldest and most commonly used methods for manufacture of composite parts. Hand lay-up composites are a case of continuous fibre reinforced composites. Layers of unidirectional or woven composites are combined to result in a material exhibiting desirable properties in one or more directions

In the experimental analysis the comparative testing of GFRP leaf spring and the steel leaf spring are taken. The deflection or bending tests of both the spring for comparative study is taken on the universal testing machine (UTM).The load is gradually applied on steel and GFRP leaf spring and the following graph are obtain from the testing.



Graph Load Vs Deflection

For steel leaf spring the deflection come for the load of 3000N is 93 mm and for the same loading condition the GFRP leaf spring deflection is 97 mm.

Fig. 6 Load applying on GFRP Leaf spring

VIII. CONCLUSION

CONCLUSION

Calculated are the experimental findings of stress and deflection tests performed on the leaf springs under static loading. Comparing these findings with FEA is also done. So yet, only GFRP leaf springs made of unidirectional E-Glass/Epoxy have undergone testing. From a strength perspective, there is also no problem with replacing the GFRP leaf spring since it can endure the static stress.

replaces traditional leaf springs with GFRP ones. Both the steel and GFRP leaf springs are almost equivalent in terms of vehicle stability since they are both built for the same level of rigidity. We set out to get a lightest possible spring that can withstand static external forces within the limits of the stresses and displacements that it can withstand. Swapping out the steel leaf spring with a FRP one reduces the weight of the spring by a significant margin of about 74%. In addition to being lighter, composite leaf springs are expected to have a sufficient fatigue life. The goal of lowering the unsprung mass is therefore partially met. The GFRP leaf spring experiences much less stress than the steel spring.

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