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RELIABILITY ANALYSIS ON DESIGN OF LEAF SPRING USING COMPOSITE MATERIAL

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ABSRACT:
The unique and diverse characteristics of composite materials have increased in many folds. From feather weight rods to high performance aircraft parts, the use fiber reinforced materials have become a compelling asset due to their high strength to weight ratio and high strength to stiffness ratio combined with easy manufacturing methods. The present endeavor is one such attempt to study the mechanical properties of glass fiber reinforced plastic (GFRP) by varying volume percentage. The mechanical properties involved in the study are tensile strength, bending strength and impact strength. The results are compared for different loading conditions and a suitable composition is selected for the fabrication of mono composite leaf spring. Reliability analysis for correlation R for composite and steel leaf spring in relation to the variation in loadings, and experimentally obtained static load data is analyzed using co-efficient of correlation. The study concluded that the composite leaf spring had induced stresses much lower than that of steel leaf spring and the spring weight was nearly 46% lower when compared to steel leaf spring.

Keywords: *Composite material E-Glass, Leaf Spring, Correlation Analysis .*

1. INTRODUCTION:

We require a lot of materials to process each thing with the unique qualities needed for the new technology. But these unique qualities, such a high strength to weight ratio, cannot be met by standard materials. By combining two or more insoluble materials, known as composites, we can create the new materials with these unique features. In today's engineering sectors, such as mechanical, electrical, automotive, aerospace, material science, and marine engineering, hybrid metal matrix materials are essential.

The improvement of mechanical and thermal qualities including tensile strength, hardness, wear resistance, thermal conductivity, and melting point was the primary goal of the preparation of HMMCs. Hybrid Metal Matrix Composites are getting ready to meet the engineering demands for the best possible price. Advanced composites have outperformed many other materials in a variety of applications, such as tennis racquets, industrial rollers, and space.

The suspension leaf spring is one of the potential elements for weight reduction in automobiles as it leads to the reduction of un-sprung weight of automobile. The reduction of un-sprung weight helps in achieving improved ride characteristics and increased fuel efficiency. To meet the need of natural resources conservation, automobile manufacturers are attempting to reduce the weight of vehicles in recent years. The interest in reducing the weight of automobile parts has necessitated the use of composite materials technology as a substitute in material design.

1.1 Characteristics of composites:

Futuredays will see an increase in the price of fuel, maintenance , materials, and the manufacturing of car parts. They will quickly increase their efficiency by losing weight. Steel and its alloys are used to prepare the body and nearly all of its components. Hybrid metal matrix composites, such as those made of E-glass are used to replace steel and its alloys to reduce the weight of the overall body.

In metal matrix composites, the matrix is made of metals, and the reinforcing components are made of natural materials, polymers, or ceramics. Cast aluminium alloys, iron, steel, titanium, copper, and nickel alloys are a few examples of MMCs. After composition, these will help to fully cover the needs in the appropriate location because they have greater mechanical, thermal, and electrical qualities than the base materials. When combined with ceramics such as silicon carbides, alumina, silica, boron carbides, or silicon, aluminium metal matrix composites have a lower density than the base material.

Through the various HMMC processing methods, carbide up to 40% weight of reinforcing material is combined with base material on a costeffective basis. Typically, the base material easily loses its density values during this procedure. Why? Because ceramics often have a lower density than metals. The process of choosing a material for a particular use is interesting. However, this mostly depends on factors like the requirements of the need, the fabrication processes, the cost, and the operating circumstances of the finished things. The matrix phaseThe initial phase, which is ongoing.The reinforcing phase is typically less rigid and more ductile.It transfers the strain while supporting the reinforcing phase.

1.2 MATERIAL SELECTION:

The selection of reinforcement is influenced by the type of reinforcement, the manufacturing process, the matrix's chemical compatibility, as well as a number of characteristics of the reinforcement material, including size, shape, surface morphology, structural flaws, surface chemistry, and impurities. Even if a single kind is chosen, reinforcement will vary because of all the aforementioned considerations as well as potential feedstock and processing equipment contamination. Rohatgi and associates have investigated the use of mica, alumina, silicon carbide, clay, zircon, and graphite as composite reinforcements. Glass fiber reinforced polyester chopped strand mat is widely utilised in the chemical sector. For a chopped fiber glass vehicle structural composite, durability-based design criteria have been investigated. The flexibility content by weight in the matrix of E-GLASS chopped-strand mat/polyester composites was varied in the range (0– 50%) during monotonic and tension-tension fatigue testing. In this piece, hand layup is used to randomly arrange e glass fiber and crystal transparent epoxy resin.

1.3 GLASS FIBER

Among the most adaptable industrial materials currently available are glass fibers. They are easily made from raw resources, which are practically inexhaustible. All of the glass fibers discussed in this article are made from silicacontaining compositions. They display desired fiber features including strength, flexibility, and stiffness as well as practical bulk properties like hardness, transparency, chemical attack resistance, stability, and inertness. Glass fibers are utilized to create printed circuit boards, structural composites, and a variety of other products with unique uses. When silica-based or other glass formulations are extruded into many fibers with tiny diameters suited for textile production, glass fiber is created. Glass fibers made for textiles are made primarily of silica, or SiO_2. It exists as the polymer $(SiO_2)_n$ in its purest form. Although it has no actual melting point, it softens to 1200 °C before beginning to deteriorate. Most molecules can move around freely around 1713 °C. The glass won't be able to create an ordered structure if it is extruded and immediately cooled at this temperature. structure. With the silicon atom in the middle and four oxygen atoms at each of its four corners, SiO_4 groups are formed in the polymer. By sharing oxygen atoms, these atoms go on to build a network that is joined at the corners.

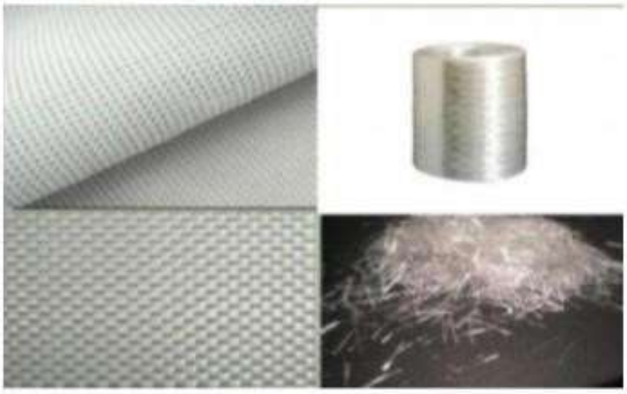


Fig 3.1: Different forms of glass fiber

E-glass/epoxy

1.4 EPOXY RESIGN :

Epoxy resins (monomers or oligomers) can come in the form of powders or thick liquids that are clear or yellow in colour. The diglycidyl ether of bisphenol A (DGEBA), novolac resins, cycloaliphatic epoxy resins, brominated resins, epoxidized olefins, and others are examples of common epoxy resins. Epoxy resins are offered in both liquid and solid forms, and a catalyst causes them to cure into the completed polymers.They are dried both at ambient temperatures and at higher temperatures of about 275°. The matrix material employed was resin grade LY-556, which has a density of 1.1–1.2 gm/cc at 298 k.

Hard resin is created when this and hardener 951 are combined. Low viscosity polyamine hardener 951. Combinations at 520 F and Hardener 951 are characterised by their excellent mechanical and electrical qualities.Faster curing at room temperature. Good chemical resistance properties Production of Fiber Melt spinning processes are typically used in the production of glass fibers. These entail melting the glass mixture into a platinum crown with tiny pores so the molten glass can flow through them. Short fibers can be made by spinning the crown, which pulls molten glass centrifugally through the holes, while continuous threads can be dragged out through the holes and wound onto spindles. Using mechanical tools or air jets, fibers are cut to the desired length.

1.5 Composition

E-Glass is a low alkali glass with a typical nominal composition of SiO_2 54wt%, Al_2O_3 14wt%, CaO + MgO 22wt%, B_2O_3 10wt% and Na_2O+K_2O less than 2wt%. Some other materials may also be present at impurity levels. Carbon fiber is composition of about 90 to 99.9% by weight carbon fiber ,a total of 0.1% to 10% by weight at least one vinyl additional polymer having at least one oxidant ring said vinyl additional polymer being prepared by polymering one or more ethyl compounds.strength. To encourage wetting and adhesion of the matrix material to the fiber, further treatments might also be applied.

SPECIFICATION VALUES Material selected Eglass/Epoxy Tensile strength 800 N/mm2 Young’s modulus(E)

3.86x104 N/mm2 Design stress (σb) 328 N/mm2 Total length (2L) 960 mm Static loading (P) 1200 N spring width (w) 60 mm Spring weight 1.6kg Density (ρ) 2.6 kg/mm3.Because composite leaf springs provide significant advantages in terms of material design conception and production methods, the automotive industry has recently shown a greater interest in replacing steel springs with them. Applications for leaf springs are largely found in suspension systems in automobiles, such as light trucks and heavier cars, are used to absorb stress loads.

1.6 Uses Of Glass Fiber:

Glass Fiber Reinforced Epoxy Composites are the most widely used composites. Epoxy resin has excellent great mechanical and adhesive qualities, high electrical insulation, good chemical and water resistance, and resilience to environmental deterioration. Automobile fuel efficiency and emission gas regulation are two critical issues today. To address this issue, the automobile industry is developing new vehicles that are both efficient and affordable. The most effective way to improve fuel efficiency is to reduce the weight of the vehicle Weight reduction can be accomplished primarily through the use of better materials, design optimization, and improved manufacturing processes. The ability to reduce weight while improving mechanical properties has made composite a very good replacement material for conventional steel. One of the components of an automobile that can be easily replaced is the leaf spring. A leaf spring is a basic type of spring that is commonly used for suspension in wheeled vehicles. The suspension of leaf springs is the area that needs to be prioritized in order to improve the vehicle's suspensions for a more comfortable ride. The suspension leaf spring, which accounts for 10 to 20% of un spring weight in an automobile, is one of the potential items for weight reduction. Springs are well known for their ability to absorb shock. As a result, the strain energy of the material becomes an important factor in spring design. The use of composite materials will allow the leaf spring to be lighter without sacrificing load carrying capacity or stiffness .

1.7 Leaf spring composition :

the current study is an attempt to develop a physical and mechanical characterization of a class of composite material composed of an Epoxy-Resin polymer as the matrix and glass fibre as the reinforcing material.It is obvious that materials with lower density and modulus have a higher specific strain energy capacity. As a result, composite materials are both strong and light. The leaf spring of an automobile vehicle, Mahindra "Model-Commander 650di," is considered for further investigation in this work. The suspension quality can be improved by reducing vertical vibrations, impacts, and bumps caused by road irregularities, all of which contribute to a comfortable ride. The automobile industry is introducing a number of cars that are newly designed, modified, and have new parts replaced with advanced and composite materials for a more comfortable ride, lower weight, and better mechanical properties. The matrix material was medium Epoxy resin, which is widely used in industry due to its strong adhesive properties, chemical resistance, and toughness. The reinforcement material used was E-glass. other compounds. The hardener HY951 is used in a 1:15 ratio. The curing temperature and pot life govern the hardener selection. The experimentation includes the fabrication and testing of various percentages of EGlass/Epoxy. The composite leaf spring is made with the best E-glass/Epoxy mixture.

A spring is characterised as an elastic body that, when loaded, deforms and, upon removal of the load, returns to its original shape. Semi-elliptic leaf springs are virtually always utilised in both light and heavy commercial vehicles for suspension. They are prevalent.

Fig : Steel leaf spring

Fig4 : Composite Leaf Spring

2. METHODOLOGY :

2.1 Samples Preparation :

Several composite fabrication methods have been developed and can be categorised into four groups. Two of these are liquid metallurgy and powder metallurgical methods. Some of the liquid metallurgical techniques include unidirectional solidifications to produce directionally aligned MMCs, suspension of reinforcement in melts followed by solidification, compo casting, squeeze casting, spray casting, and pressure infiltration. Liquid metallurgical methods are the least expensive, however multi-step diffusion bonding processes might be. Diffusion bonding, vapour deposition, and powder mixing and consolidation are a few examples of solid state processing techniques. There are three advantages of using powder metallurgy for MMC production over liquid metallurgy. Lower temperatures can be employed for creating a PM-based composite than when creating a liquid metallurgy-based composite. There is less interaction between the matrix and the reinforcement when using the PM technique. Better mechanical by lowering undesirable interfacial reactions, characteristics are acquired. In other cases, PM techniques will make it possible to fabricate composites that would be difficult to do otherwise using liquid metallurgy. Liquid metallurgical methods can be challenging to employ because fibers or particles of silicon carbide, for instance, will dissolve in melts of many metals, including titanium.

1. The matrix material used was medium epoxy resign.
2. The reinforcement material employed was Eglass.
3. The hardener HY951 is used in the proportion 1:15.

The experimentation includes fabrication and testing of different percentages by volume of E-glass /Epoxy.

Matrix	Volume(%)	Reinforcement	Volume(%)
Epoxy	60	Glass fiber	40
Epoxy	50	Glass fiber	50
Epoxy	70	Glass fiber	30

Table 4.1.Details of samples prepared

2.1 Procedure for material test :

Step 1: The glass/epoxy composite is fabricated using simple hand layup technique.
Step 2: The fabrication involves different compositions of composite where the composite plates are cut down according to the ASTM standards in order carryout tensile, flexural, and impact test on each specimen.
Step 3: Then the fabrication of composite mono leaf spring will be done based on the best composition of E-glass/Epoxy.
Step 4: The steel and composite leaf springs will be tested according to standard procedures.
Step 5: The results will be compared for different loading conditions.
Step 6: The results are compared to measuring the strength of a correlation (R) between two variables (X and Y).

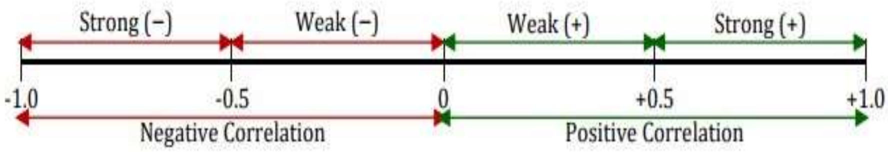
2.2 Hand Lay Up Process:

A variety of benefits that advanced composite materials can provide have made them appealing in many high performance applications. As a result, composites are increasingly used in lower cost, higher volume industries like the automotive as well as in applications for racing automobiles, aeroplane components, and sporting goods.The demand on the production processes to maintain high standards of quality while combining bigger volumes and cheaper prices has increased steadily as a result of this use's expansion. Layers of matched fibers are layered on top of a matrix material to create high-performance composites. These fibers give composites their remarkable structural qualities, but they also make them difficult to manufacture because they need to be constructed layer by layer, a type of reinforcement, is manually laid down in individual layers or "plies" during the production process known as "hand layup".

Composite material E-GLASS **Fabrication of composite material**

3.Correlation Analysis :

1. Correlation is a statistical technique for examining the closeness of a link between two variables.
2. Correlation Coefficient (R or r) is a scale to quantify the degree of the linear relationship between variables.
3. The coefficient of correlation R will range between -1 and+1.



i.e., $-1 \leq R \leq +1$.

A mathematical expression of Pearson's method for measuring the strength of a correlation (R) between two variables
(X and Y) is as follows.

$$R = \frac{n(\sum XY) - (\sum X).(\sum Y)}{\sqrt{n(\sum X^2) - (\sum X)^2}\sqrt{n(\sum Y^2) - (\sum Y)^2}} \text{------ (1)}$$

Where,
N=number of observations
X=Measure of variable 1
Y=Measures of variable 2,
$\sum XY$ = sum of product of respective variable measures
$\sum X$ = Sum of measures of variable 1
$\sum y$ = Sum of measures of variable 2
$\sum x^2$ = Sum of squared values of the measures of variable 1
$\sum Y^2$ = Sum of squared values of the measures of variable 2

4. RESULTS

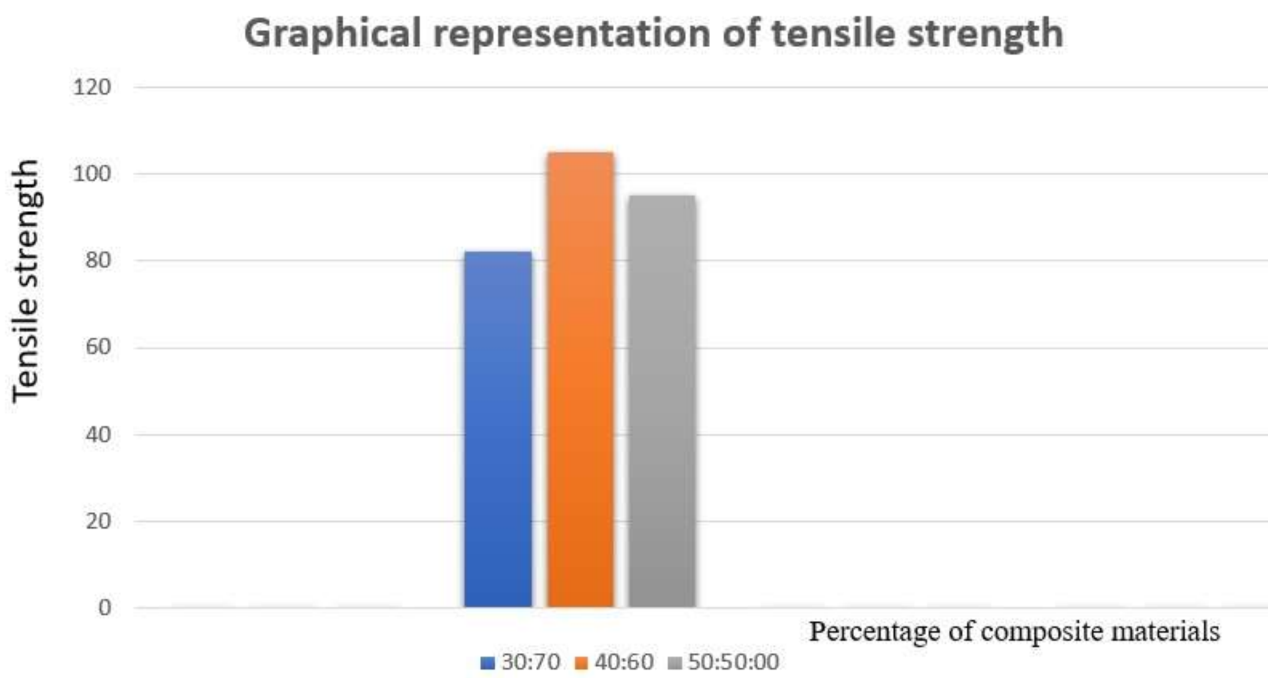
COMPOSITE MECHANICAL TESTINGS:

4.1 Tensile test:

A sample is subjected to a controlled tension until failure. for quality control, and to predict how a material will react under different forces. Tensile test specimens as per ASTM D3039 standards.The tensile test is carried out for three different cases.The test are carried out on universal testing machine.

E-glass/Epoxy	Tensile strength
40:60	105Mpa
50:50	95Mpa
30:70	82Mpa

Table 6.1: Values of Tensile Test

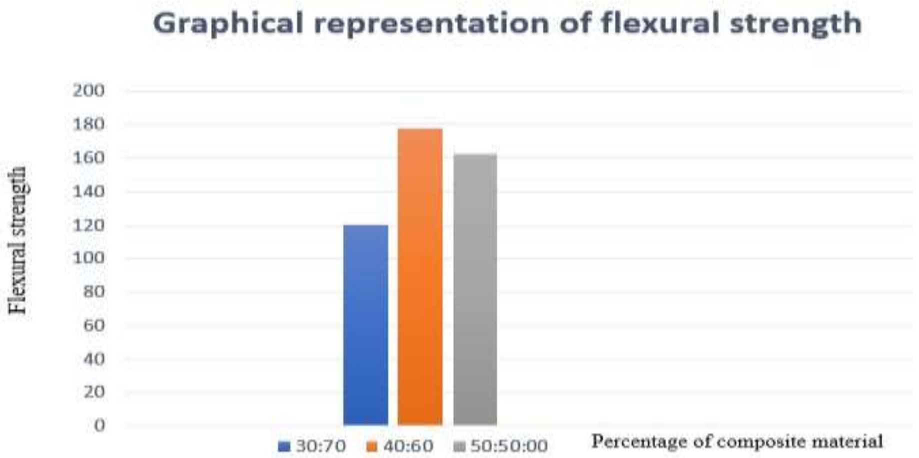


From the graph, it is clear that 40:60% by volume of E-glass/Epoxy has maximum yield stress and even ultimate stress and also tensile strength for 40:60% of E-glass/Epoxy is higher as compared to other two volume percentages.

4.2 Flexural test :

Flexural strength is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. The bending test is carried out for different volume percentage of E-glass/Epoxy composites.Flexural test specimens as per ASTM E32 standards.

E-glass/Epoxy	Flexural value
40:60	178
50:50	163
30:70	121



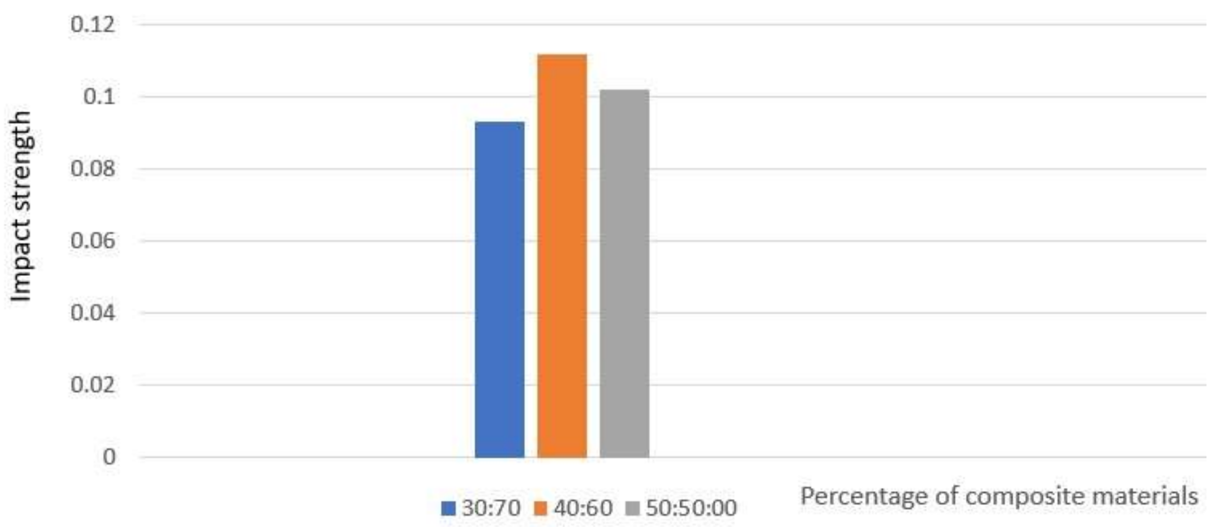
From the graph, it is clear that, volume percentage of 40:60% of E-glass/Epoxy has the highest bending strength as compared to other two volume percentages.

4.3 IMPACT TEST:

Impact tests are used for studying the toughness of material. Charpy impact test specimens as per ASTM E32Standards using impact test machine, the impact values at different compositions on leaf spring samples the values are mentioned below table:

E-glass/Epoxy	Impact value
40:60	0.112 j
50:50	0.105 j
30:70	0.093 j

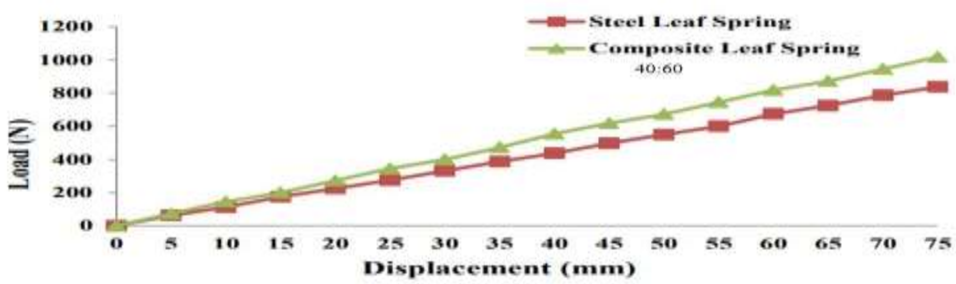
Graphical representation of impact test



From the above graph, it is clear that 40:60% by volume of E-glass/Epoxy has maximum strength.

The above tests characterize the fact that E-glass/Epoxy of 40:60 % composite material has high Tensile, Flexural and Impact strength thus in implementing the same composition for the fabrication of the mono composite leaf spring.

4.4 Static load test:
The primary concern behind conducting a Static load test lies in determining the performance characteristics of a Steel leaf spring and a composite leaf spring. The performance characters include load carrying capacity and weight comparison.
The static load test involves direct pile head displacement in the response to a physically applied test load. It is the most fundamental form of pile load test and is considered as the bench-mark of pile performance. Static load test is carried out for both Steel and composite leaf spring. The load is applied at the center of spring and the vertical deflection of the spring center is recorded with gradually varying load. The spring is loaded from zero to prescribed maximum deflection and back to zero,which gives load v/s displacement curve.



Steel vs composite leaf spring load deflection curve

From above graph shows a variation with increase in load with increasing displacemenet But the difference lies in the load carrying capacity which is close to 850(N) in steel leaf and 1050 (N) in composite leaf spring.

4.5 Correlation Analysis

Correlation is a statistical technique for examining the closeness of a link between two variables. Their correlation coefficient quantifies the degree to which two variables are related. The steel leaf displacement values consider as x variables and composite displacement consider as y variables.

Load	X	Y	X^2	Y^2	XY
0	0	0	0	0	0
200	14.8	14.9	219.04	222.01	220.52
400	31.6	33.5	5877.6	1122.25	1058.6
600	55.3	60.3	3058.09	3636.09	3334.59
800	62.4	72.6	3893.76	5270.76	4530.24
1000	70.2	81.3	4928.04	6609.69	5707.26

The coefficient of correlation R is 0.9985. It is lies between -1 to 1. So it is positive corelated and its safe.

4.6 COMPARISON BETWEEN STEEL AND COMPOSITE:

Load difference :

Leaf spring	Steel	Composite
Static load	850.3	1050.2

Weight of materials

Leaf spring	Steel	Composite
Weight	4.85	1.60

From the above results discussion it can be clearly defined that leaf spring can bear more static load when it is made of composite rather than steel, and weight also reduced for the composition.

5. CONCLUSION:

The Reliability analysis for compositions of 30:70%, 40:60%, 50:50% of Eglass/Epoxy, 40:60% composition yielded maximum tensile strength, impact strength and flexural strength. The entire fabrication of composite leaf spring was done with 40:60% of E-Glass/Epoxy composition. By using reliability analysis for composite and steel leaf springs with respect to weight and strength showed that composite leaf spring has more load carrying capacity and is lighter compared to Steel leaf spring. The composites can be used for leaf springs in light weight vehicles which meet the requirements together with substantial weight savings .

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