Fabrication and Testing of Bio-Composite Leaf Spring for Automobile Application

Vinoth R[1] Barathkmar K. J[2] Gokulnath K. S[3] Gokulprakash. E[4] Ahildarshan. K[5]
[1]Associate Professor [2,3,4,5]U.G Student
[1,2,3,4,5]Department of Mechanical Engineering
[1,2,3,4,5]Nandha Engineering College, Erode 52, India

Abstract— Automobile world has an increased interest in reduction of weight by the replacement of steel by natural fiber reinforced composites. Moreover, the composite materials have more elastic strain energy storage capacity and high strength capacity and high strength to weight ratio compared to steel. Natural fibers are emerging as low cost, lightweight and apparently environmentally superior alternatives. In present year's natural fiber composite material locale a major role in industries like aerospace and automobile. The natural fiber is amplified by hook up with plastics. The ample availability of natural fibers such as coir, Aleo Vera, Palm fiber ramie, sisal, jute, banana bagasse etc. Common matrix materials include Vinyl ester, phenolic, polyester, polyurethane vinyl ester etc. The composites formed by fibres gained attention due to their low cost, light weight, renewability, low density, high specific strength, non-abrasivity, non-toxicity and biodegradability etc. In this paper discussed the Composite leaf spring by using banana fiber with Vinyl ester composite and to evaluate the Mechanical properties of leaf spring (Tensile strength, Hardness, Toughness Examination).

Keywords: Bananafiber, Vinyl Ester, Tensile Strength, Hardness, Impact

I. INTRODUCTION

In the present scenario, to optimize the utilization of energy, weight reduction became one of the main focuses of automobile manufacturers. Weight reduction can be achieved by the introduction of better material. Leaf springs are mainly used in suspension systems to absorb shock loads in automobiles like light motor vehicles, heavy duty trucks and in rail systems. They carry lateral loads, brake torque, driving torque in addition to shock absorbing. Leaf springs are having an advantage that the ends of the spring may be guided along a definite path as it deflects. The use of composite materials for suspension leaf spring reduces the weight of conventional multi leaf steel leaf spring by nearly 75%.This achieves the vehicle with more fuel efficiency and improved riding qualities. For more compliant suspension system (i.e. energy storage capability), the leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of variations in the spring deflection so that the potential Energy is stored in spring as strain energy and then released slowly. A material with maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material for a leaf spring. The introduction of composite materials was made it possible to reduce the weight of leaf spring without any reduction on load carrying capacity and stiffness. The composite materials have more elastic strain energy storage capacity, excellent corrosion resistance, high strength to weight ratio as compared with those of steel. Conventional Multi-leaf steel springs are being replaced by mono-leaf composite springs.

Fatigue failure is the predominant mode of in-service failure of many automobile components. This is due to the fact that the automobile components are subjected to variety of fatigue loads like shocks caused due to road irregularities traced by the road wheels, the sudden loads due to the wheel traveling over the bumps etc. The leaf springs are more affected due to fatigue loads, as they are a part of the unstrung mass of the automobile. The fatigue behavior of Jute Glass Fiber Reinforced Composite materials has been studied. The fatigue strength at an arbitrary combination of frequency, stress ratio and temperature has been presented. In the present work, a multi-leaf steel spring used in Battery cars is replaced with a composite single leaf spring made of Banana fiber and Vinyl Ester composite. The stresses for both steel leaf spring and composite leaf springs are considered as same. The primary objective is to compare their load carrying capacity, stiffness and weight savings of composite leaf spring.

Fig. 1: Traditional leaf spring arrangement

II. LITERATURE SURVEY

[1] Shiva Shankar, Vijayarangan (2006) Composites materials are now extensively used in the automobile industry instead of metal parts. Several papers were published on this topic; some of these papers are reviewed here for the further study of composites materials leaf spring application for automobile 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. The computer algorithm for design for variable with and variable thickness mono composite leaf spring is explained. Three-dimensional finite element analysis is used for verification of result obtained from experiment. In which the solid 45 element is used for steel leaf spring and solid layered 46 element is used

for composite leaf spring .For the fabrication of mono composite leaf spring of E-glass/epoxy hand lay- up technique is used. The experimental test are carried on both steel and composite leaf spring and compared the result .It is observed that composite leaf spring is more superior than steel with a large weight reduction.

[2]X.Y.Liu, G.C.Dai (2007)Composite leaf spring is design on basis of fatigue failure .Theoretical equation for prediction fatigue life is formulated using fatigue modulus and its degrading rate. The dimensions and number of leaves for both steel leaf spring and composite leaf spring are considered to be same. The stress analysis is performed using finite element method .The element selected for analysis is solid 45 which behave like a spring. For the fabrication of each leave the filament winding machine is used and assembled this leaves together with the help of center bolt and four side clamps. The testing of steel multi leaf spring and composite multi leaf spring are carried out with the help of an electro-hydraulic leaf spring test rig. Design and experimental fatigue analysis of composite multi leaf spring are carried out using data analysis. It is found that composite leaf spring has 67.35%lesser stress, 64.95% higher stiffness and 126.98% higher natural frequency and also 68.15% weight reduction is achieved.

[3] I. Rajendran, S. Vijayarangan (2001)In this paper a four-leaf steel spring used in the rear suspension system of light vehicles is analyzed using ANSYS V5.4 software. The finite element results showing stresses and deflections verified the existing analytical and experimental solutions. Using the results of the steel leaf spring, a composite one made from fiberglass with epoxy resin is designed and optimized using ANSYS. Main consideration is 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 design constraints were stresses (Tsai–Wu failure criterion) and displacements. The results showed that an optimum spring width decreases hyperbolically and the thickness increases linearly from the spring eyes towards the axle seat. Compared to the steel spring, the optimized composite spring has stresses that are much lower, the natural frequency is higher and the spring weight without eye units is nearly 80% lower.

[4]H.M.M.A. Rashid, M.A.Islam, F.B.Rizivi (2006)This paper presents the design evolution process of a composite leaf spring for freight rail applications. Three designs of eye-end attachment for composite leaf springs are described. The material used is glass fiber reinforced polyester. Static testing and finite element analysis have been carried out to obtain the characteristics of the spring. Load–deflection curves and strain measurement as a function of load for the three designs tested have been plotted for comparison with FEA predicted values. The main concern associated with the first design is the delamination failure at the interface of the fibers that have passed around the eye and the spring body, even though the design can withstand 150 KN static proof load and one million cycles fatigue load. FEA results confirmed that there is a high inter-laminar shear stress concentration in that region. The second design feature is an additional transverse bandage around the region prone to delamination. Delamination was contained but not completely prevented. The third design overcomes the problem by ending the fibers at the end of the eye section.

[5] Anthony Kelly (2008)A single leaf spring with variable thickness of glass fiber reinforced plastic (GFRP) with similar mechanical and geometrical properties to the multi leaf steel spring was designed, fabricated and tested. Glass fiber reinforced plastic (GFRP) presents advantages over graphite/epoxy such as lower sensitivity to cracks, impact and wear damage. The leaf spring model was considered to be a parabolic ally tapered, constant width beam carrying a concentrated load and assumed to be symmetrical with different cord lengths for the two limbs of the spring. A finite element program is used to model the behavior of leaf spring. In addition analytical analysis can be used to develop an expression which is a function of thickness and position along the spring. In present work the hand lay-up vacuum bag process was initially employed and mandrels (male and female) were made from plywood according to the desired profile and the glass fiber fabric was cut to the desired lengths, so that when deposited on the mandrel, would give the calculated thickness. The operation was simply performed by depositing impregnated glass fiber with epoxy resin over the rotating mandrel in a hoop pattern. The spring was subjected to a series of laboratory static loading tests. This study demonstrated that composite can be used for leaf spring for light trucks (jeeps) and meet the requirement, together with substantial weight saving.

[6]SairaTaj, Munawar Ali, hafiullah Khan (2009)In this paper, the influence of ellipticity ratio on performance of woven roving wrapped composite elliptical springs has been investigated both experimentally and numerically. A series of experiments was conducted for composite elliptical springs with ellipticity ratios (a/b) ranging from one to two. Mechanical performance and failure modes of composite elliptic spring elements under static load conditions are reported. Key design parameters, such as spring rate and failure load, are measured as a function of spring thickness. Parallel with the experimental work, numerical simulation for fatigue calculations was performed. The simulation was designed to calculate numerically spring constants of elliptic subjected to the compressive load along a major axis of the tubes and to calculate the cycle life of the elliptical composite spring. The simulation was performed using a commercial available finite element package (LUSAS). Eight noded QTS8 was used since they are expected to give an accurate stress and strain results. Composite elliptic spring with ellipticity ratios of a/b 2.0 displayed the highest spring rate. The present investigation verified that composites can be utilized for vehicle suspension and meet the requirements, together with substantial weight saving. It is also believed that hybrid composite elliptical springs have better fatigue behavior than the conventional and composite leaf and coil spring.

[7] J.P. Hou(2010)In this Paper hand lay-up technique for fabrication of fiber reinforced plastic (FRP) laminated plates, using glass fibers in the form of continuous roving, is presented. Fabricating the glass fiber roving reinforced epoxy (GFRRE) laminated plates, three sub-methods have been implemented in the present investigation: (a) resin flow method, (b) resin transfer method, and (c) impregnation method. Among the three techniques discussed

here, the impregnation method is the most effective, while the resin transfer method is quite satisfactory. In this study, a new hand lay-up method has been developed by which any plate having arbitrary number of layers with arbitrary fiber orientation angles, can be fabricated. The impregnation method has the potential to fabricate FRP laminates, which will compare favorably with most structural materials and, especially, with other types of FRP laminates as far as the strength-to-weight and modulus-to-weight ratios are concerned.

[8] A.Al-Qureshi (2006)In this investigation, a nonlinear elastic model of leaf springs is developed for use in the computer simulation of multibody vehicle systems. In the leaf spring model developed in this investigation, the distributed inertia and stiffness of the leaves of the spring are modeled using the finite element floating frame of reference formulation that accounts for the effect of the nonlinear dynamic coupling between the finite rotations and the leaf deformation. The leaf spring geometry and deformations are modeled using nodal degrees of freedom defined with respect to the spring body coordinate system. By assuming that the leaf deformation can be large but the leaf deformed shape remains simple, component mode synthesis techniques can be used to significantly reduce the number of deformation coordinates. The nonlinear stiffness matrix is first developed for the finite element of each leaf and is used to determine the overall leaf spring stiffness matrix. The pre-stresses, the contact and friction that characterize the nonlinear behavior of leaf springs are discussed. Using the nonlinear leaf spring formulation presented in this study, a detailed multibody model for a sport utility vehicle is developed. It is shown that the proposed leaf spring model that accounts for the effect of windup, contact and friction between the spring leaves can be effectively used for assessing the dynamic stability of sports utility vehicles.

[9] Mouleeswaran Senthil Kumar, SabapathyVijayarangan (2007)In the present work, a steel leaf spring was replaced by a composite leaf spring due to high strength to weight ratio for the same load carrying capacity and stiffness with same dimension as that of steel leaf spring. A semi-elliptical multi leaf spring is designed for a four wheel automobile and replaced with a composite multi leaf spring made of E-glass/epoxy composites. Under the same static load conditions the stresses and the deflection in leaf springs are found with great difference. Stresses and deflection in composite leaf springs is found out to be less as compared to the conventional steel leaf springs. All the FEA results are compared with the theoretical results and it is found that they are within the allowable limits and nearly equal to the theoretical results. A comparative study has been made between steel and composite leaf spring with respect to strength and weight. Composite leaf spring reduces the weight by 67.88% for E-Glass/Epoxy. E-glass/epoxy composite leaf spring can be suggested for replacing the steel leaf spring both from stiffness and stress point of view. Totally it is found that the composite leaf spring is the better that of steel leaf spring. Therefore, it is concluded that composite multi leaf spring is an effective replacement for the existing steel leaf spring in vehicles.

[10] S.V.Joshi,L.T.Drzal,A..Mohanty, S.Arora (2001) Extant studies comparing life cycle environmental performance of natural fiber composites with glass fiber reinforced composites find that natural fiber composites are environmentally superior in the specific applications studied. We propose that NFR composites are likely to be environmentally superior to GFR composites in most applications also for the following reasons: (1) natural fiber production results in lower environmental impacts compared to glass fiber production; (2) NFR composites have higher fiber content for equivalent performance, which reduces the amount of more polluting base polymers; (3) lower weight of NFR composites improves fuel efficiency and reduces emissions during the use phase of the component, especially in auto applications; and (4) end of life incineration of natural fibers results in energy and carbon credits. A couple of caveats however are in order. First, fertilizer use in natural fiber cultivation results in higher nitrate and phosphate emissions, which can contribute to increased eutrophication in local water-bodies. One may have to tradeoff deterioration in local water quality against overall improvement in environmental quality. Second, the environmental superiority of NFR composites may vanish if NFR components have significantly lower operating life compared to GFR components. The future of natural fiber composites appears to be bright because they are cheaper, lighter and environmentally superior to glass fiber composites in general. Future research should hence focus on achieving equivalent or superior technical performance and component life.

[11] SanthoshKumarandVimalTeja (2012) Analyzed that 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. The leaf spring was modeled in Pro/E and the analysis was done using ANSYS Metaphysics software.

[12] Rghu Kumar, et al.(2013) Described that the composites are widely used in most of the industries in place of steel, due to low weight to strength ratio. In automobile industry, one can think of replacing parts with composites. The aim of this paper is to suggest the best composite material for design and fabrication of complete mono composite leaf spring. A single leaf with variable thickness and variable width for constant cross sectional area of different composite materials, with similar mechanical and geometrical properties to the multi leaf spring, were modeled and analyzed. The finite element results using ANSYS software showing stresses and deflections were verified with analytical results. The design constraints were stresses and displacement.

[13] GulurSiddaramanna,etal. (2006)Analyaed that 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. Therefore; the aim of this paper is to present a low cost fabrication of complete mono composite leaf spring and mono composite leaf spring with bonded end joints. Also, general study on the analysis and design. 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 multileaf spring, was designed, fabricated (hand-layup 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. 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.

[14] Jenarthanan,etal. (2018)Analyzed that a leaf Spring is one of the oldest components widely used in commercial vehicles due to easy manufacturing cost and better load carrying capacity. Due to heavy competitive market and strict rules from governments, automakers want to reduce pollution, fuel consumption etc. Further weight reduction is the most effective way of improving fuel economy without losing the performance of the vehicle. So, usage of Composite Materials is gradually increased in the Automobile Industry. In the beginning, Composites are used only for decorative purposes. But recently composites have been used in structural parts also. Some Sports car manufacturers even make an entire automobile body out of carbon fiber. Coming to Leaf Spring, Steel is still preferred due to its high strength and Energy Absorption Ratio etc. The applications of hybrid composite materials in various fields formerly cannot achieve using conventional materials. In this research article, Carbon/Glass Epoxy Composite is proposed as leaf spring material. The specimen is fabricated and mechanically tested for tensile strength, Impact Strength and Flexural Strength. Also, Solidmodelling of Leaf Spring is done using SolidWorks 2014 and FEA is done using ANSYS 16.2. Results are documented, compared and discussed.

[15] Harmeet Singh and Gurinder Singh Brar (2018) Characterized that the mechanical properties of composite materials that can be used for the leaf spring. Aluminum based metal matrix and carbon epoxy composite materials have been used in various industries including automobile industry because of their light weight and good strength. In this present study rear leaf spring of Tata Ace (mini truck) made of EN45A spring steel has been considered. Metal Matrix Composite (MMC) leaf spring with Aluminum and 25% boron carbide manufactured by stir casting technique and carbon epoxy based leaf spring manufactured by hand layup fabrication technique were investigated for use in leaf spring. Both composite based leaf spring were examined under tensile stress and hardness test as per the standards - IS 1135: 1995 (Laminated Springs Assembly for Automobiles) and SAE (HS - J788 - Manual on Design and Application of Laminated Springs). The evaluation of EN45 steel and both composite based leaf spring shows that the composite spring has the low density, low weight and high strength.

[16] Mahmood M. Shokreih, Davood Rezaei (2006) Experimental results from testing the leaf spring under static loading condition the stresses and deflections are calculated. These results are compared with FEA. Mono composite leaf springs for the vehicular suspension system was designed using E-Glass/Epoxy, Natural fiber epoxy with the objective of minimization of weight of the leaf spring subjected to constraints such as type of loading and laminate thickness and ply orientation angle. By analyzing the design, it was found that all the stresses in the leaf spring were well within the allowable limits. GFRC and Jute glass epoxy composite are considered to be almost equal in vehicle stability and both are manufactured with same dimensions. The major disadvantage of GFRC and Jute Glass Epoxy composite leaf spring are chipping resistance. The objective was to fabricate and analyze the springs with minimum weight which is capable of carrying given static external forces by constraints limiting stresses and displacement. The weight of the leaf spring is reduced considerably about 75% by replacing steel and GFRP and Jute-E-Glass-Epoxy composite leaf spring thus, the objective of reducing the un-sprung mass is achieved to a larger extent.

[17] Yu WJ, Kim HC (1988)A Comparison has been made between laminated composite leaf spring & steel spring having same design and same load carrying capacity Leaf spring made of GFRP and mild steel have: Same deflection under same load. Similar bending stress. GFRP leaf spring is 86.424 % lighter than leaf spring of mild steel. GFRP blades are 56.66 % cheaper than mild steel blades.

[18] James Holbery and Dan Houstan (2001)The automobile industry has shown increased interest in the replacement of steel springs with fiberglass reinforced composite leaf springs. Therefore, the aim of this paper is to present a general study on the analysis, design and fabrication of composite springs. From this viewpoint, the suspension spring of a compact car, “a jeep” was selected as a prototype. A single leaf, variable thickness spring of glassfiber reinforced plastic (GFRP) with similar mechanical and geometrical properties to the multileaf steel spring, was designed, fabricated (molded and hoop wound) and tested. The testing was performed experimentally in the laboratory and was followed by the road test. Comparison between the performance of the GFRP and the multileaf steel springs is presented. In addition, other relevant parameters will be discussed.

[19] Hiroyuki Sugiyama(2003)A steel leaf spring is replaced with two types of composite mono leaf springs. They are experimentally tested and the results are verified with FEA. Main consideration was given to the jute E-glass epoxy composite leaf spring. The objective was to obtain a natural fiber composite leaf spring that is capable of carrying given static external forces by constraints limiting stresses and displacements. The results showed that the maximum stress and displacements are within the limit (Tensile stress 850N/mm², compressive stress 450N/mm², deflection 130mm) for both composite materials. Compared to the weight of steel leaf spring (9.35Kgs), 62% and 72% weight reduction is possible for E-glass epoxy and natural fiber mono leaf composite springs respectively without affecting the load carrying capacity. Natural fiber composite is having equal strengths as e-glass epoxy with further weight reduction by 28%. The natural frequency of composite leaf spring is higher than enough from the road frequency to avoid the resonance.

[20] Reyes Baeza Rubio, et al. (2017)Described that the unidirectional and woven carbon or glass fibers are the most common reinforcements used in these automotive composites. To take full advantage of these materials, it is of importance to evaluate the different processes to manufacture

them. The purpose of this research work is to characterize, optimize and manufacture fiber reinforced thermoset composites using the compression molding process for the application of producing improved automotive leaf springs. An epoxy resin matrix that is reinforced with E-glass fiber is the material of interest. These thermoset-based composites are evaluated to substitute the currently used steel parts in order to reduce the weight and accordingly improve fuel efficiency. The material used is a pre-impregnated or “pre-preg” containing 68% by weight E-glass fiber with Epoxy resin. The superior mechanical properties of glass fibers and the high stiffness and thermal properties of the epoxy matrix are the main elements that make this type of composites suitable for replacing the steel leaf spring suspension system. By characterizing the epoxy glass fiber reinforced composite mechanical and thermal properties; a baseline reference is obtained to optimize the processing parameters (time and temperature) without altering in a faulty way the properties. After full characterization and process optimization, a finite element model was created to predict the performance of the material in the suggested application and under a common test setup for the actual steel parts.

III. Selection of Materials

Fiber-reinforced polymer composites have played a dominant role for a long time in a variety of applications for their high specific strength and modulus. The manufacture, use and removal of traditional fiber–reinforced plastic, usually made of glass, carbon or aramid fibers–reinforced thermoplastic and thermo set resins are considered critically because of environmental problems. By natural fiber composites we mean a composite material that is reinforced with fibers, particles or platelets from natural or renewable resources, in contrast to for example carbon or aramide fibers that have to be synthesized

IV. Properties of Composite Material

VALUE OF MILD STEEL	VALUE OF BANANA FIBER
Tensile Strength 841N/mm^2	Tensile Strength 425.44N/mm^2
Yield Strength 425.3N/mm^2	Yield Strength 284.36N/mm^2

Table 1: Properties of Fibers

V. Material Separation

The Banana fiber which is taken as reinforcement in this study is collected from local sources. The vinyl resin and the hardener are supplied.

The composite samples of different composition are prepared in the ratio of banana fiber 45% with mixing of Vinyl resin 55%.

If the ratio of banana fiber 60% with mixing of Vinyl resin 40% is prepared, the material when preparing will break.

VI. Mixing Process

The Vinyl resin and hardener are mixed in the ratio of 2:1 and stirred thoroughly. The fibers are washed with fresh water thoroughly. The fibers are then soaked in NaOH solution for 8 hours. The fibres were then washed several times with fresh water to remove the residual NaOH sticking to the fibre surface and neutralized by Acetic acid finally washed again with water. The fibers were then dried at room temperature for 10 hours.

Minimum 8 hours the fibers should be soaked in NaOH and the maximum is 1 day.

VII. Fabrication

Aluminium mould was prepared with required dimensions of leaf spring. Wax polish applied on mould for better surface finish Number of layers of Banana fiber and vinyl are laminated Mould kept 24 hours for curing.

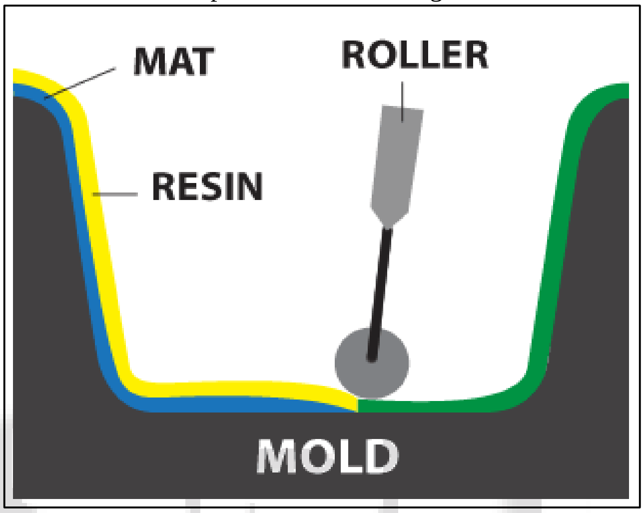


Fig. 2: Hand Layup Method

VIII. Photograph

Fig. 3: Fabrication


AR-TECH SPECTRO METALLURGICAL
LABORATORY TRICHY
TEST REPORT

Fig. 4: Test Report

IX. MECHANICAL PROPERTY TESTS

A. *Tensile Test*

A tensile test, also known as a tension test, is one of the most fundamental and common types of mechanical testing.
Tensile test applies tensile (pulling) force to a material and measures the specimen's response to the stress.

B. *Hardness Test*

Hardness is a characteristic of a material, not a fundamental physical property. It is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation. The Rockwell test is generally easier to perform, and more accurate than other types of hardness testing methods.

C. *Impact Test*

The impact test is a method for evaluating the toughness and notch sensitivity of engineering materials. It is usually used to test the toughness of metals, but similar tests are used for polymers, ceramics and composites.

X. CALCULATIONS

Weight of Vehicle = 1200kg (MODEL: TATA ACE)
Maximum Load Caring
Capacity = 1000kgS
Total weight = 1200+1000
= 2200kg
Gravity (g) = 9.81m/s^2
Taking factor of safety = 2
Total Weight ^{x} Gravity = 2200^{x}9.81
= 21582 N
Load on each wheel (W) = 21582/4
2F = 5395.5N
F = 5395.5/2
F = 2697.75 N
So, Load on each eye of spring is 2697.75 N
Span length 2L=1072 mm.
L=1072/2
L=536mm.
Conventional Leaf Spring
Maximum Induced Bending Stress,

$\sigma = \frac{6WL}{bt^2}$

= 6^{x}2697.75^{x}536
3^{x}60^{x}8^2
=753.12N/mm^2

Total Deflection, $\delta = \frac{6\times f\times l^3}{E\times n\times b\times t^3}$

= 6x2697.75x536^3
2.1x10^{5}x3x60x3^3
=128.79mm
Young's Modulus of Banana Fibre = 32GPa
Young's Modulus of Vinyl Ester = 3.5GPa
Whereas the composite of banana fibre with vinyl ester leaf spring in the ratio of 45:55 respectively.
By test report
Young's modules = Tensile strength / percentage of elongation
= 425.44/0.0596
=7138N/mm^2
To Find:
t=?
Assume:
b=125mm
n=6

$$\delta = \frac{6\times f\times l^3}{E\times n\times b\times t^3}$$

128.79 =6^{x}2697.75^{x}536^3
7138^{x}6^{x}125^{x}t^3
t^3 = 3604mm
t = 16mm
Given Data:
L=536mm
b=125mm (by std. value)
t=16mm
F=2697.75N
Maximum Induced bending stress of composite leaf spring

Formula, $\sigma = \frac{6WL}{bt^2}$

= 6^{x}2697.75^{x}536
6^{x}125^{x}16^2
= 45.17N/mm^2
Total deflection of composite leaf spring

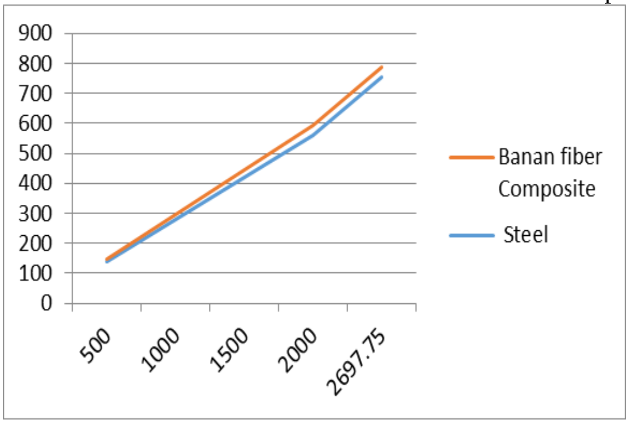
$$\delta = \frac{6\times f\times l^3}{E\times n\times b\times t^3}$$

= 6^{x}2697.75^{x}536^3
7138^{x}6^{x}125^{x}16^3
=113.63mm

XI. RESULTS AND DISCUSSION

S.NO	Load (N)	Steel σ N/mm²	Banana fiber / vinyl ester σ N/mm²					
			Leaf 1	Leaf 2	Leaf 3	Leaf 4	Leaf 5	Leaf 6
1	500	139.5	50.25	25.1	16.	12.2	10	8.37
2	1000	297.1	100.5	50.2	33.	25.2	20.	16.66
3	1500	418.7	150.7	75.3	50.	37.7	30	25.20
4	2000	558.3	201.3	135.	67	50.2	40.	33.50
5	2697	753.1	271.4	100	90	67.2	54	45.17

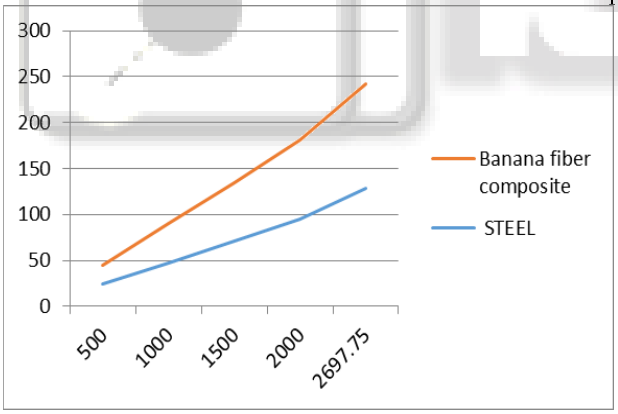
Table 1: Comparison of bending stress



Graph 1: Comparison of bending stress

S.NO	Load (N)	Steel δ mm	Banana fiber / vinyl ester δ mm					
			Leaf 1	Leaf 2	Leaf 3	Leaf 4	Leaf 5	Leaf 6
1	500	139.5	23.87	126.	63	42.1	31.6	25.8
2	1000	297.1	47.74	252	126	84.2	63.4	50.40
3	1500	418.7	71.61	379	189	126	94.75	75.80
4	2000	558.3	95.48	513	256	171	128.4	102.6
5	2697	753.1	128.7	681	341	227	170.5	136.4

Table 2: Comparison of deformation



Graph 2: Comparison of defection

The above table shows the comparison of maximum induced bending stress and deflection of the composite leaf spring with conventional steel leaf spring. Although the maximum induced bending stress is lower than the conventional steel leaf spring the deflection is higher than the current conventional leaf spring thus further calculations have been carried out to select the suitable number of leaf spring for any particular application. Upon increasing the numbers to 6, the deflection of the spring becomes lower than the conventional leaf spring. Thus 6 composite leaf spring can be used in place of a conventional leaf spring without any change in the overall comfort and load capacity of the vehicle.

XII. Conclusion

After obtaining of the result it is found that weight reduction can be easily achieved by using composite materials instead of conventional steel, here we have used banana fiber and vinyl ester for the natural fiber leaf spring, it can observed from the comparison that the maximum bending stress induced in the Banana fiber/Vinyl ester composite leaf spring is 72% lesser than conventional steel leaf spring for the same load carrying capacity. The deflection of the composite leaf spring when compared with the conventional leaf spring is higher while using the same number of leaf spring as the conventional one. But upon increasing the number of composite leaf spring to 6, the deflection is lower than the conventional leaf spring, also the increase in the number of composite leaf spring has actually reduced the overall weight of the leaf spring assembly by 32% compared to conventional leaf spring .Thus the main objective of the project which is weight reduction has been achieved without any trade-off in the performance of the leaf spring.

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