Comparative Analysis of En 45 Steel & Thermoplastic Polyimide (30% Carbon Fibre Reinforced) Used In Mono Leaf Spring under Static Loading Condition Using ANSYS

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Abstract— This paper describes design and FEA analysis of mono leaf or single-leaf spring that consists of simply one plate of spring. The performance analysis of spring is under static loading condition. Due to the absorb and release property it becomes a major factor in designing the leaf spring which is showing the replacement of steel springs with composite leaf springs. A current leaf spring is made up of a steel material which is having high weight, high corrosion, more noise and the property of material is changing when the load is acting and gives low natural frequency. Therefore, composite materials become the predominant alternative material for replacing the spring steels. The objective of this paper is to compare the load carrying capacity, strength and weight saving of composite leaf spring with that of EN45 steel leaf spring. The design constraints are stress, deflection and weight saving for comfort riding and enhancing durability of spring. Dimensions of the composite leaf spring are to be taken as same as conventional EN45 steel leaf spring used in TATA SUMO GOLD for rear suspension. A Finite element approach for analysis of mono leaf springs using ANSYS R15 software is carried out. Using CATIA V5R20 for modelling the leaf spring. The results are compared with the properties of EN45 steel and thermoplastic polyimide with 30% carbon fibre composite material.

Key words: Mono Leaf spring, EN45 steel, thermoplastic polyimide with 30% carbon fibre composite, Stress, weight reduction, Deflection, FEA

I. INTRODUCTION

A leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles originally called a laminated or carriage spring, and sometimes referred to as a semi – elliptical spring or flat spring or flat plate. The design of leaf spring can be done in two ways one the mono leaf spring or the multi leaf spring. Mono leaf spring is used for the lighter vehicle which consists of a single plate. While in the multi leaf spring a leaf spring can made from the number of leaves called blades. The blades are varying in length. The blades are usually given an initial curvature or cambered so that they will tend to straighten under the load. The leaf spring is based on the theory of a beam of uniform strength. The lengthiest blade has eyes on its ends. This blade is called main or master leaf. When the vehicle comes across the projection on the road surface, the wheel moves up, this leads to deflecting the spring. A leaf spring takes the form of a cylinder 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.

Leaf springs can serve locating and to some extent damping as well as springing functions. While the interleaf friction provides a damping action, it is not well controlled and results in stiction in the motion of the suspension. For this reason manufacturers have experimented with mono-leaf springs.

In this present work, an attempt is made to replace the existing EN45 steel leaf spring with composite leaf spring used in light vehicle, made of composite materials of thermoplastic polyimide with 30% carbon fiber. Composite leaf spring is designed to analysis the behavior of bending stress, deflection and stress at various load is applied over the mono leaf spring. Weight reduction can achieve by the 80% after using thermoplastic polyimide with 30% carbon fiber composite material mono leaf spring.

In this present work, an attempt is made to replace the existing mono leaf spring used in light vehicle with composite mono steel leaf spring made of composite materials of thermoplastic with 30% carbon fiber. Composite leaf spring is designed to analysis stress and deflection at various loads is applied over the mono steel leaf spring.

II. SUSPENSION SYSTEM

Suspension = spring + shock absorber + linkage connecting vehicle to its wheel.

System = Assemblage or combinations of things or parts. Thus, Suspension system is a mechanical system which consists of springs and shock absorbers. The automobile chassis is mounted on the axles, not direct but some form of springs. This is done to isolate the vehicle body from the road shocks, which may be in the form of bounce, pitch, roll or sway. These tendencies give rise to an uncomfortable ride and also cause additional stress in the automobile frame and body. In suspension system the energy of road shock cause the spring oscillate. These oscillations are restricted to a reasonable level by damper which is more commonly called a shock absorber.

The purpose of the complete suspension system is to isolate the vehicle body from road shocks and vibrations which would otherwise be transferred to the passengers and load. It must also keep the tires in contact with the regardless of road surface. A basic suspension system consists of spring, axles, shock absorbers, arms, rods and ball joints.

A. Purpose of suspension

- To prevent the road shocks from being transmitted to vehicle components.
- To safeguard the occupants from road shocks.
To preserve the stability of the vehicle in pitting or rolling, while in motion.

III. LITRATURE SURVEY

Senthil kumar and Vijayarangan [1] has introduce leaf spring absorbs the vehicles vibrations, shocks and bump loads(induced due to road irregularities) by means of spring deflections, so that the potential energy is stored in the leaf spring and then relived slowly. Efforts were taken for finite element Analysis for multi leaf springs. Static and fatigue analysis of steel leaf springs and composite multi leaf spring made up of glass fibre reinforced polymer using life data analysis. The dimensions of existing conventional steel leaf springs of a light commercial vehicle are taken and are verified by design calculations. Static analysis of 2-D model of conventional leaf spring is also performed using ANSYS 7.1 and compared with experimental results.

Smita C. Saddu, Vikas V. Shinde [2] has describe the analysis of steel and composite material leaf spring. Then these results are compared with that of the experimental results. The results is concluded that stresses developed in the composite material leaf spring is less as compared with that of the steel material leaf spring, so it proves that composite material is more effective and economical than the conventional leaf spring with similar design specification. The analysis is done through CATIA V5R19.

Pankaj Saini et al. [3] the composite material were they used was glass fiber reinforced polymer (E-glass/epoxy), carbon epoxy and graphite epoxy is used against conventional spring. The design parameters were selected and analyzed with the objective of minimizing of the composite leaf spring as compared to the steel leaf spring.

Shishay Amare Gebremeskel [4] In this a single E-glass/Epoxylle spring is designed and simulated following the design rules of the composite materials considering static loading only. It is shown that the resulting design and simulation stresses are much below the strength properties of the material, satisfying the maximum stress failure criterion. The designed composite leaf spring has also achieved its acceptable fatigue life. This particular design is made specifically for light weight three wheeler vehicles.

M. M. Patunkar and D. R. Dolas [5] they have done study Design, manufacturing, testing and analysis of mono composite leaf spring under static loading condition. The material selected for the study was glass fiber reinforced plastics. A spring with constant width and thickness was fabricated by hand layup technique. The experiments were conducted on load testing machine (in various load condition) and numerical analysis was done via (FEA) using ANSYS software. Result shows that, the stresses and deflection of analytical data will lower when compare with manufacturing and analyzed data.

Amrita Srivastava and Sanjay Choudhary [6] Comparative analysis between steel leaf spring and Jute/E glass reinforced Epoxylle spring. The hybrid composite leaf spring is found to have lesser weight, lesser cost, lesser stresses and higher stiffness. The CAD models of Leaf spring are prepared in Unigraphics NX6 and imported in static structural analysis workbench of Ansys 14.5 where finite element analysis (FEA) is performed. The design constraints are stresses and deflections.

Ashish V. Amrute et al. [7] Deals with replacement of conventional steel (65Si7) leaf spring of a light commercial vehicle with composite leaf spring using E-glass/Epoxy. Dimensions of the composite leaf spring are to be taken as same dimensions of the conventional leaf spring. The objective is to compare the load carrying capacity, stresses and weight savings of composite leaf spring with that of steel leaf spring. The finite element modelling and analysis of a multi leaf spring has been carried out. The CAE analysis of the multi leaf spring is performed for the deflection and stresses under defined loading conditions. The theoretical and CAE results are compared for validation.

Minoru Iwata et al. [8] Introduced bent and rotationally hindered structure into polyimide chain using asymmetric dianhydride and obtained newly developed polyimide having a good thermo plasticity. For the evaluation of the newly developed polyimide on radiation durability, they irradiated the polyimide with proton beam, evaluated its durability by using mechanical properties, and compared with conventional commercial polyimide. From the experimental results, they could confirm the high radiation resistivity of newly developed thermoplastic polyimide.

Parkhe Ravindra and Sanjay Belkar [9] Describes design and analysis of composite mono leaf spring with Carbon/Epoxy composite materials is modelled and subjected to the same load as that of a steel spring. The design constraints were stresses and deflections. The composite mono leaf springs have been modelled by considering Varying cross-section, with unidirectional fibre orientation angle for each lamina of a laminate. Static analysis of a 3-D model has been performed using ANSYS 12.0. In project work comparative analysis of Carbon/epoxy composite leaf spring and steel leaf spring is done by analytical, FEA using ANSYS 12. The result of FEA is also experimentally verified. Compared to mono steel leaf spring the laminated composite mono leaf spring is found lesser stresses and weight reduction of 22.15% is achieved.

IV. OBJECTIVES

- The objective of this research work is to investigate the best suitable reinforced plastic fiber for composite material in automobile leaf spring application.
- To compare the load carrying capacity, stresses, deflection and weight saving at same load applied to composite leaf spring with that of EN45 steel leaf spring.
- The focused on the implementation of composite material by replacing steel in conventional leaf springs of a suspension system to reduce weight, improving safety, comfort and durability.
- To design and analyzed composite leaf spring for suspension system of automobile, under static loading.
- To testing the conventional steel mono leaf spring on compression machine. And comparing the result with the FEA results of steel spring.
– Find out the variation between composite material and steel material leaf spring, after finite element analysis.
– To find out the weight ratio of EN 45 steel and thermoplastic polyimide with 30% carbon fiber composite material leaf spring.

V. DESCRIPTION OF THE PROBLEM

As weight plays an important role in deciding the efficiency of an automobile. The leaf spring used generally is made of steel which are quite bulky and one of the potential items for weight reduction in automobiles because it accounts 10-20% spring weight carried by its own. To avoid this disadvantage and comfort riding qualities an attempt is to be made in replacing the material with advanced materials like composite materials. This work is mainly focused on the implementation of thermoplastic polyimide with 30% carbon fiber composite materials by replacing excising conventional EN45 steel material leaf spring of a suspension system to reduce product weight, improving the safety, comfort and durability.

VI. SPECIFICATION OF THE CONVENTIONAL LEAF SPRING

Generally leaf springs are made of various fine grade alloy steel. The test steel leaf spring used for experimentation purpose is made up of EN 45. The composition of material is 0.60 C%, 2.00 Si%, 1.00 Mn%, 0.05 P%, 0.05 S% [29]. The parabolic leaf spring is used in the TATA SUMO GOLD vehicle, for Rear Suspension. Following are the parameters for the EN 45 steel.

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total Length of the spring (Centres of Eye to Eye)</td>
<td>1183 mm</td>
</tr>
<tr>
<td>2</td>
<td>Free Camber (At no load condition)</td>
<td>130 mm</td>
</tr>
<tr>
<td>3</td>
<td>No. of full length leave (Master Leaf)</td>
<td>01</td>
</tr>
<tr>
<td>4</td>
<td>Thickness of leaf spring</td>
<td>7.75 mm</td>
</tr>
<tr>
<td>5</td>
<td>Width of leaf spring</td>
<td>61.5 mm</td>
</tr>
<tr>
<td>6</td>
<td>Internal Diameter of Berlin Eye</td>
<td>35.75 mm</td>
</tr>
<tr>
<td>7</td>
<td>Young’s Modulus of the spring</td>
<td>204 x 10^3 N/mm²</td>
</tr>
<tr>
<td>8</td>
<td>Weight of the leaf spring</td>
<td>5.445 Kg</td>
</tr>
</tbody>
</table>

Table I. Specification of Existing Steel Leaf Spring

VII. MATERIAL FOR LEAF SPRING

The commonly used material for leaf spring is plain carbon steel having 0.90 to 1.0% carbon. The leaves are heat treated from forming process. After the heat treatment steel spring gets high strength and higher load capacity, high range of deflection and better fatigue properties.

A. Composite Material

A composite material is the combination of two or more materials that produce a synergistic effect so that the combination produces aggregate properties that are different from any of those of its constituents attain independently. This is intentionally being done today to get different design, manufacturing as well as service advantages of products. Composite materials offer a chance to reduce the weight of the spring but it is not as cost effective as its steel counterparts [10]. Advanced composite materials seem ideally suited for suspension (leaf spring) applications.

An important consideration in the use of composites is lightweight. Research studies of specific components have shown that using all composite structures a saving of 20 to 45% can be achieved while selectively reinforced metal structures offer about 10 to 25% only [16].

Modern composites using fiber-reinforced matrices of various types have created a revolution in high-performance structure in recent years. Advanced composite materials offer significant advantages in strength and stiffness coupled with light weight, relative to conventional materials.

The commonly used fibers are carbon, glass, Kevlar, aramide, thermoplastics etc. Among these, the selection of thermoplastic polyimide with 30% of reinforced fiber were it used in aircraft, road bridges, house boat, car body etc. And gives strength, fatigue life and good corrosion resistance.

VIII. MODELLING OF LEAF SPRING IN CATIA

Leaf spring with dimension is first modelled in the CATIA V5R20 then imported in ANSYS R15.

A. Element Type

8 Node Brick 185: SOLID185 is used for the 3-D modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions.

B. Boundary Condition

– The front end of the leaf spring is coupled with a pin to the frame so that the eye can rotate freely about the pin.

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Young’s Modulus E In Mpa</th>
<th>Poisson’s Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>En 45 Steel Leaf Spring</td>
<td>204 X 10^3</td>
<td>0.29</td>
</tr>
<tr>
<td>Thermoplastic Polyimide</td>
<td>20.7 X 10^3</td>
<td>0.3</td>
</tr>
<tr>
<td>With 30% Carbon Fibre</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Material Property of Leaf Spring
Comparative Analysis of En 45 Steel & Thermoplastic Polyimide (30% Carbon Fibre Reinforced) Used In Mono Leaf Spring under Static Loading Condition Using ANSYS

**IX. RESULT AND DISCUSSION**

From the result of static analysis of EN 45 steel and TPI with 30% CF composite material leaf spring, it is seen that the maximum bending stress in EN45 steel about 450.73N/mm² when gives 2645N load on leaf spring shown in fig.4. were in TPI with 30% CF have bending stress is 79.51N/mm².

The result of deflection in EN45 steel shown 59.34 mm in fig.5, were the TPI with 30% CF is deflected about 584.70 mm In fig.6. The deflection variation in TPI with 30% CF material is because the young’s modulus of TPI material is 10 times less than EN45 steel.

The results of EN45 steel and Thermoplastic polyimide with 30% carbon fiber composite material analyzed in ANSYS R15 with same dimension and same boundary condition as that of conventional EN45 steel leaf spring. With their material property is different.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>FEA result of EN45 steel</th>
<th>FEA result of TPI with 30% CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load, N</td>
<td>2645</td>
<td>2645</td>
</tr>
<tr>
<td>Bending Stress, N/mm²</td>
<td>450.73</td>
<td>79.51</td>
</tr>
<tr>
<td>Total Deflection, mm</td>
<td>59.34</td>
<td>584.70</td>
</tr>
</tbody>
</table>

Table 3. Comparison ANSYS result of steel & composite material leaf spring

The conventional EN45 steel leaf spring weight about 5.445kg whereas the thermoplastic polyimide with 30% carbon fiber composite material leaf spring weight only 1.06kg. Thus the weight reduction of 80.53% achieved. By reduction of weight and the less stresses, the fatigue life of composite leaf spring is higher than that of EN45 steel leaf spring.

<table>
<thead>
<tr>
<th>Material</th>
<th>Weights</th>
<th>% weight saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional EN45 steel</td>
<td>5.445 kg</td>
<td></td>
</tr>
<tr>
<td>Thermoplastic polyimide with 30% carbon fiber</td>
<td>1.06 kg</td>
<td>80.53 %</td>
</tr>
</tbody>
</table>

Table 4: Percentage saving of weight by using composite

**X. CONCLUSION**

As reducing weight increasing strength of products are high in the world, composite material are getting to be up to the mark of satisfying these demand. In this present work the thermoplastic polyimide with 30% carbon fiber composite material reduce weight of vehicles and increase the strength of their spare parts is considered. The deflection is more in...
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results of thermoplastic polyimide when compared with EN45 steel material, so increasing weight of thermoplastic polyimide material leaf spring is further work of this research, to see the behavior of deflection. Static analysis result shows the greater difference in bending stress and deflection.

A comparative study has been made between steel and composite leaf spring with respect to strength and weight. Thermoplastic polyimide with 30% carbon fiber composite material mono leaf spring reduces the weight by 80.53% over EN45 conventional steel leaf spring.

ACKNOWLEDGEMENT

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