Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 5, Issue 06, June -2018

A REVIEW: VIBRATION FREQUENCY OPTIMIZATION OF AUTOMOBILE LEAF SPRING USING DIFFERENT ANGLES OF ORIENTATION OF GLASS FIBER

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ABSTRACT: *Weight reduction with improved strength of design is an important research topic all around the globe. One very common solution for this issue now a days are composite material. Leaf springs are important for a suspension of sprung mass in the vehicle; it softens the effect of road vibrations on vehicle. The objective of this work is to find out the feasibility of GFRP as the material for replacement of steel in leaf spring application. The strength of the leaf spring using different angles of orientation of the fiber needs to be studied to find out the optimum angle of orientation for the vibration frequency optimization. It will include studying leaf with different fiber orientation angles and comparison of their vibration frequencies with the steel leaf spring used conventionally.*

Keywords -: *Leaf spring, ANSYS 16.2, GFRP*

I. INTRODUCTION

Conventional leaf springs used in automobiles are made of spring steel, which is heavy in weight. A leaf spring of reduced weight, without compromising stiffness can increase the efficiency of vehicle. Hence, composites can be used as an alternative to traditional engineering materials for leaf spring. Advantageous use of fiber reinforced plastics (FRP) has made it possible to reduce the weight of an element without affecting the load carrying capacity. Since FRP materials high elastic strain energy storage capacity and high strength to-weight ratio compared with those of steel, multi-leaf steel springs are being replaced by GFRP leaf springs. Newly invented composite leaf spring failed to yield the production facility in the early 1960s because of inconsistent performance in fatigue and absence of strong willingness for mass reduction. Particularly the automobile manufacturers and parts makers have been attempting to reduce the weight of the vehicles in recent years. Studies are made to demonstrate viability and potential of FRP in automotive structural application. [3]

Composite materials consist of two or more physically dissimilar and instinctively separable components called reinforcement and matrix. These two components can be mixed in a restricted way to achieve optimum properties, which are superior to the properties of each individual component. Composite materials have been widely used in automobile industry because of its high strength and modulus to weight ratio, low cost and flexibility in material and structure design. The conventional leaf spring used in suspension is one of the products for weight reduction in automobile since it accounts for huge amount of the unsprung weight. This helps in achieving the vehicle with improved riding qualities. Since the strain energy is

inversely proportional to density and modulus of elasticity of the material, it is recommended that the material for leaf spring must have low density and modulus of elasticity. Many researchers have been carried out in the direction to replace conventional steel leaf spring by composites [4]

Leaf springs are one of the oldest suspension components they are still commonly used, especially in commercial vehicles. The past literature survey shows that leaf springs are designed as generalized force elements where the position, velocity and orientation of the axle mounting gives the reaction forces in the chassis attachment positions. Another part has to be focused, is the automobile industry has shown increased interest in the replacement of steel spring with composite leaf spring due to high strength to weight ratio. Hence, FEA of the composite material becomes critical to study the behavior of Composite Leaf Spring. [6]

COMPOSITE MATERIALS:

Composite material is a material made up of two or more constituents combined together by mechanical or chemical bonds. In composite materials constituents tend to retain their original physical properties. Generally components of the composite material can be identified as separate entities physically, and interface between them can be also be seen.

Many composite materials are known to have superior structural performance when compared with the conventional materials. They are generally superior when it comes to strength to weight ratio and so are sought as a replacement of the steel in many applications. Many physical properties can be tailored by adding components with different qualities to make superior composite material Composites can be used to manufacture leaf springs, drive shafts, road wheels and many other chassis components.

The metal matrix composite generally contain discontinuous or continuous fibers as reinforcements of the size 0.1-0.5 µm in diameter and have a length to diameter ratio up to 200.Glass fiber reinforced polymer (GFRP) and carbon fiber reinforced polymer (CFRP) are the examples of the metal matrix composites which are generally used in the manufacturing of the leaf springs for F1 racing cars. Today, bodies of the aircrafts, kayaks and boats are made up of

GFRP. Different manufacturing processes like hand layup, spray layup three dimensional printing, compression molding can be used to manufacture the composite materials.

II. LITERATURE REVIEW

Sorathiya Mehul et. al. conducted "Analysis of Composite Leaf Spring Using FEA for Light Vehicle Mini Truck". This work shows FEA analysis on steel leaf spring and composite Multi leaf spring. Sought to compare stiffness, weight, load carrying capacity and weight save. While designing full bump loading in kg is considered. When composite leaf spring design is compared with the steel design of the same load carrying capacity and same number of leaves total of 70.6% weight reduction can be achieved while opting for composite material. Mono leaf spring design of the composite material on the other hand save 90.09% weight of the conventional leaf spring. [1]

Syambabu Nutalapati have presented the "Design and Analysis of Leaf Spring by Using Composite Material for Light Vehicles" Automobile sector is keen on replacing conventional materials with the composites due to their better strength to weight ration and corrosion resistance properties. From variety of composite available as an option author have chosen GFRP (Glass fiber reinforced polymer) as potential replacement for the steel in the design of leaf spring for light commercial vehicle application. This study compares stress and deflection of the GFRP leaf spring for similar design loading. Also weights of the GFRP and steel design are compared. Comparison of weight has shown that 85% weight reduction is possible when GFRP replaces steel. While performing this study author focused his study around the stiffness of the spring. [2]

Akhil Mehndiratta et.al. Presented the analysis on GFRP Leaf Spring. In this paper static analysis is performed on the steel leaf spring and GFRP laminated leaf spring. Parameters like load taking capacity, stiffness, stress, deflection and weight of the designs are compared from theoretical, analytical and experimental results. Technique used for manufacturing of the composite material is hand layup technique which is followed by vacuum pressing. Plywood has been used as a material for mould using which composite leaf spring is fabricated according to the design dimensions. Cutting is performed on the glass fibres as per the requirements from design which then afterwards used to stack up in the mould ply wise to create design GFRP component. After manufacturing of composite leaf spring they perform the experimental work and found the following results:-
Laminated composite leaf spring & steel spring are compared for 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. [3]

Manjunath H. N et. al. studied "Static Analysis and Fatigue Life prediction of Composite Leaf Spring for a Light Commercial Vehicle (TATA ACE)". Authors conducted FEA static analysis using ANSYS on various leaf springs also the fatigue life of those springs is calculated using Hwang and Han relation. Results say that:

- Different composites and steel is compared for stress, deflection and fatigue life and outcome is studied.
- FEA results are matching with the theoretical values.
- Boron/Aluminium has least stress and deformation, and shows' high stiffness when compared with other composites.

Graphite/Epoxy and Boron/Aluminium has good performance in fatigue as compared to conventional steel spring with similar design specifications. [4]

Jeevan Herekar et. al. presented paper to analyze theoretically "Experimental Analysis of Epoxy- Glass Fiber composite Leaf Spring for Natural Frequency of Leaf Spring to Reduce the Vibration". Experimentally and by finite element method the mechanical behaviour of GFRP material used for leaf spring.

1. Experimental results of loading & deflection are matching with the FEM results hence we can replace glass fiber leaf at steel leaf spring due to advantage of reduction of weight by 67 %.
2. Stress level is same in both the springs of steel & glass leaf; as cross section area is same.
3. Reduction in mass of glass fiber leaf, suspension performance will be greater than leaf spring.
4. This glass leaf spring will be corrosion free hence friction noise problem will be no more and no need of greasing the leaf springs as in steel leaf case.
5. Loading deflection - ANSYS results of steel leaf & glass fiber leaf are compared and found similar with 7 % of acceptable range of difference. [5]

Mr.Nisar S. Shaikh et. al. performed "Modeling and Analysis of Suspension System of TATA SUMO by using Composite Material under the Static Load Condition by using FEA In this study carbon fibre and steel designs for the leaf spring are compared for static and fatigue analysis. Results parameters of interest for the author are spring rate, stresses and load taking capacity of the designs. IN suspensions soft springs take us for better ride comfort, at the same

time they might fail due to stresses caused by the loading conditions. In carbon fiber design FEA results author observed that spring rates are lower when compared with the steel leaf spring. Which means for the same design loading conditions carbon fibre leaf spring design is softer than the steel and is prone to have better ride comforts on the plain roads. But in bad road conditions stone hitting from below may damage the epoxy layer on the CFRP spring which might result in loosing resilience. Also ANSYS FEA results are in conformance with the practical testing results of the CFRP spring at the lower loading conditions when loading goes towards the higher end the results do not match. [6]

T. N. V. Ashok Kumar et. al. Presented "Design and Material Optimization of Heavy Vehicle Leaf Spring". Paper illustrates vibration analysis and static structural analysis of steel and composite leaf spring. Aim of the study is comparison of weight, stress, deflection and frequencies for steel and composite designs of leaf spring. The dimensions are calculated for current steel design using conventional design formulae. 3 D model is created for the given dimensions of steel leaf spring. Static as well as modal analysis is performed on the steel leaf spring model. With same dimensions GFRP and Kevlar epoxy models are created and they are also analyzed for static and modal analysis to find out stresses, deflections and frequencies of the design. Various analyses are performed on the composite designs by changing the stacking number from 3 to 11. Results for the frequency, deformation and stress are observed and compared. Weight of the composite leaf spring designs are compared with the steel leaf spring weight. Total of 27.5 % weight reduction achieved by changing the design material for the leaf spring from steel to composite. [7]

Ghodake A. P et. al. performed the "Analysis of Steel and Composite Leaf Spring for Vehicle". This study describes that design and finite element analysis of GFRP composite leaf spring. Dimensions are measured from the field for conventional design of leaf spring, application is chosen as light commercial vehicles. From the results they conclude that GFRP can be used to fabricate the leaf spring for light vehicles and can be an effective replacement for steel. When we replace the steel leaf spring with mono leaf spring designed from GFRP they have observed that weight reduction up to 85 % is achieved. This weight saving is achieved without losing any load carrying capacity of the spring. GFRP has high strength to weight ratio, strain energy storage capacity when compared with steel. [8]

Mouleeswaran Senthil Kumar et. al. presented "Analytical and Experimental Studies on Fatigue Life Prediction of Steel and Composite Multi-leaf Spring for Light Passenger Vehicles Using Life Data Analysis". In this thesis LVC's leaf spring is measured directly for conventional steel design dimensions and is verified by checking it trough design formulae. Dimensional analysis is performed on the model of the leaf spring by creating plane elements. Conventional design analysis results are then compared with the practical field testing. Same dimensions are used to create composite model of leaf spring. E glass epoxy uni directional laminates are used to model the leaf spring. Analysis is performed on the composite design and load carrying capacity, stiffness, stresses, frequencies are compared with the conventional results. Composite leaf spring is found to have 70 % less stress, 65% higher stiffness, 127% higher natural frequencies when compared with its steel counterpart. Fatigue life for the GFRP design is also calculated and GFRP has to be found out higher fatigue life when compared to the steel. [9]

Gulur Siddaramanna, SambagamVijayarangan presented "Mono Composite Leaf Spring for Light Weight Vehicle – Design, End Joint Analysis and Testing" This work aims to provide low cost fabrication for mono composite leaf spring and composite leaf spring with bonded ends. General design and analysis study is also performed. UD GFRP leaf spring design is created, width and thickness of the leaf spring is varied to find out best suited combination for calculated cross section from the design, where mechanical properties of the cross section are similar to multi leaf spring. This design is fabricated using hand layup technique. C programming is used to find out designs of the spring of constant cross section. It shows width of the model decreases hyperbolically but thickness decreases linearly when moving towards axle seats from eye. FEA is performed on this design using ANSYS with criteria of acceptance being stress and deflections. Results shows that 85 % less weight is observed in the bonded end design of the spring when compared with the steel eyes at the end. [10]

Smita C. Sadhu, Vikas V. Shinde performs "Modelling and Analysis of Composite as an Alternative Material for Leaf Spring." It is very important in automobile industry today to reduce the weight while retaining strength similar for product. Also it is common for automobile sector replacing conventional metals with the high performing composite material. Composites which use unidirectional fibres as suspended particles in the polymers matrices are creating revolutionary change in the way industry performs. High performance segment of the automobile has already switched towards light weight composites. Steel when compared with the composites have low corrosion resistance, lower frequencies and low strength to weight ration. So current multi leaf spring design which uses steel as a material is needed to be replaced with the GFRP composite design of lower weight and higher frequencies. In this paper analysis is performed on the both conventional and new proposed designs. Results of them are compared with the actual manufactured component test results. [11]

Ashish V. Amrute et. al. Performed "Design and assessment of multi leaf spring" Since 1805 leaf springs are part of the suspension system for automobile. Today automobile industry is leading towards better, lighter components to replace the old components. With introduction of composites automobile industry been replacing steel with composite materials

which are better with their high strength to weight ratio. This work analyzes multi leaf spring which has 3 full leaves and design replacement is sought for the same with GFRP composites. Same dimensions are used for both the springs. Aim of the study is to find out weight saved by the replacement of steel with GFRP in this particular design. CAE analysis is performed on the both the designs. Results are compared with the theoretical outputs. [12]

Mahmood M. Shokrieh performs "Analysis and optimization of a composite leaf spring." A multi-leaf system used at the rear suspension of LCV is analysed using ANSYS software. Stress and deflection results from the analysis are compared with the actual testing. Also design for composite replacement for the application is created and analyzed. GFRP design is then optimized using shape optimization techniques to find out optimum cross section for the mono leaf spring design. GFRP mono leaf spring with width reducing hyperbolically when moving from eye to axle support and thickness increasing linearly is selected as the optimum solution for the constant cross section mono leaf design. Stresses are observed to be low in the optimized design for the same loading conditions and high natural frequencies are observed. Analysis results are also compared with the actual manufactured optimized model. Weight study of the designs shows that GFRP optimized model has 80 % less weight when compared with the conventional multi leaf spring design, without considering weight of the eyes. [13]

Achamyeleh a kassie performs "Design of single composite leaf spring for light weight vehicle." As leaf spring comprises of around 20 % of the unsprung mass it has always fascinated engineers for weight optimization studies. GFRP mono leaf spring design calculations are performed in this work to get dimensions for the composite light weight leaf spring by following composite design rules. Spring of constant cross section is design for the ease of manufacturing. CAE analysis is performed on the leaf spring design to find out stresses and deflections. Stresses are observed to be well within the acceptance criteria of static as well as fatigue stress limit for the GFRP material. Design is suitable to be used for LCVs. [14]

N. AnuRadha, C. Sailaja et. al. presented "The modelling, stress analysis and material optimization of master leaf spring and comparison of deformation and stress results between steel leaf spring and composite leaf springs under same conditions." They used Pro/E (Wild Fire) for modelling and analysis is done using ANSYS for theoretical analysis. In this paper authors focused on the modelling, static structural analysis and optimization of leaf spring and comparing stress and deformation results of steel and composite leaf springs at similar loading conditions. After the performing the theoretical & practical analysis they conclude that composite leaf spring can replace conventional spring.[15]

Kaveri A. Katake, Sham H. Mankar, Sandip A. Kale performed "Numerical and Experimental Stress Analysis of a Composite Leaf Spring." Vehicle companies now days are putting continuous effort to increase fuel economy, riding comfort and safety. Reduction in the weight of the vehicle by replacing old materials with the better strength to weight ration composite materials just the solution needed for them to achieve their goal. This work focuses on creation of alternative design solution for LMV leaf spring by replacing conventional steel multi leaf spring with composite design. GFRP and CFRP are the composite materials selected for this study. These material strengths are affected by the ply angle orientations, ratio of the epoxy to reinforcements by volume to volume and length to depth ratio of the composite composites. With the help of analysis, theoretical and practical testing of the leaf spring manufactured and created by varying all these parameters are studied and results are compared. Comparison shows that composite materials can be effectively used for replacement of steel leaf spring in the application of LMV. [16]

III. CONCLUSION

It can be observed from the literature survey that almost all researchers have performed the study of mono composite leaf spring in regards to stress analysis only. Only static structural analysis is considered for the research. There is very little work on the modal frequency optimization and the fiber orientation angle optimization. This indicates the gap in the previous studies. With respect to above points we can bring forward the following studies -

- Vibration frequencies of the leaf spring for at least 6 mode shapes can be optimized.
- The fiber orientation angles can be varied to optimize the orientation angle for optimizing the natural frequencies.

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