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Design and Analysis of Composite Leaf Spring

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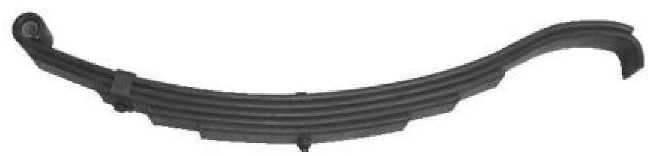
***Abstract* - Reducing weight while increasing or maintaining strength of products is getting to be highly important research issue in this modern world. Composite materials are one of the material families which are attracting researchers and being solutions of such issue. In this project we have done design and analysis of composite leaf spring. Current research in Automobile Industry undergoes the replacement of steel leaf spring with that of composite leaf spring, since the composite materials has high strength to weight ratio and good corrosion resistance. The material selected was glass fiber reinforced polymer (E-glass/epoxy) is used against conventional steel. In our project we have modeled the leaf spring in CREO 2.0 and the analysis was done using ANSYS 16.0 software.**

Key Words: Composite, Leaf Spring, E-glass, Creo, Ansys.

I. INTRODUCTION

Conventionally called laminated or carriage spring, a leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. It is also one of the oldest forms of springing, dating back to medieval times. The advantage of leaf spring over helical spring is that the end of the springs may be guided along a definite path. One of the purposes of the leaf springs is to bear the weight of the vehicle. Larger vehicles that must not only support their weight but also their heavier loads may have additional or heavy-duty leaf springs. For heavy vehicles, leaf springs have the advantage of spreading the load more widely over the vehicle's chassis. Hook down slipper leaf spring is being used in trailers. We have designed a Hook Down Slipper Leaf Spring in CREO and analyzed in ANSYS.



Hook Down Slipper Leaf Spring

Gulur Siddaramanna Shiva Shankar and Sambagam vijayarangan presented a paper in which a single leaf with variable thickness and width for constant cross sectional area of unidirectional glass fibre 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 the design of variable width 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 elements is used for steel leaf spring and solid layered 46 elements 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 is carried on both steel and composite leaf spring and compared with the result. It is observed that composite leaf spring is more superior than steel with a large weight reduction.

Mahmood M. Shokrieh, Davood Rezaei presented a paper in which 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.

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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.

J.P. Hou, J.Y. Cherruault, I. Nairne and G. Jeronimidis, R.M. Mayer presented a paper about 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 fibre 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 de-lamination failure at the interface of the fibres 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 de-lamination. De-lamination was contained but not completely prevented. The third design overcomes the problem by ending the fibres at the end of the eye section.

H.A. Al-Qureshi presented a paper about a single leaf spring with variable thickness of glass fibre reinforced plastic (GFRP) with similar mechanical and geometrical properties to the multi-leaf steel spring was designed, fabricated and tested. Glass fibre 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 parabolically 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 behaviour 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 fibre 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 fibre 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.

E. Mahdi,O.M.S. Alkoles , A.M.S. Hamouda , B.B. Sahari , R. Yonus and G. Goudah presented a paper where 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-nodded 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 behaviour than the conventional and composite leaf and coil spring.

Reaz A. Chaudhuri, K. Balaraman presented a paper about Hand lay-up technique for fabrication of fibre reinforced plastic (FRP) laminated plates, using glass fibres in the form of continuous roving. Fabricating the glass fibre 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 fibre orientation angles, can be fabricated. The impregnation method has the potential to fabricate FRP laminates, which will compare favourably 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.

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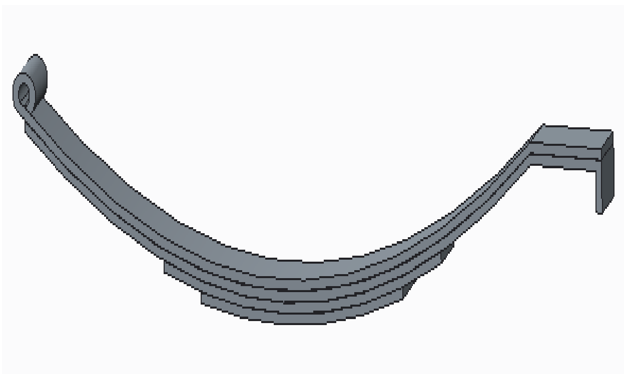
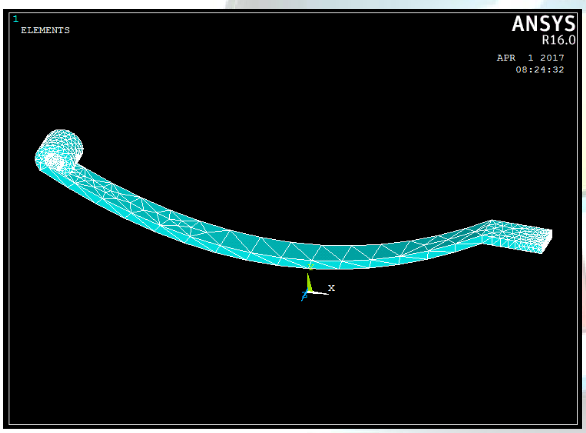
II. DESIGN OF HOOK DOWN SLIPPER LEAF SPRING



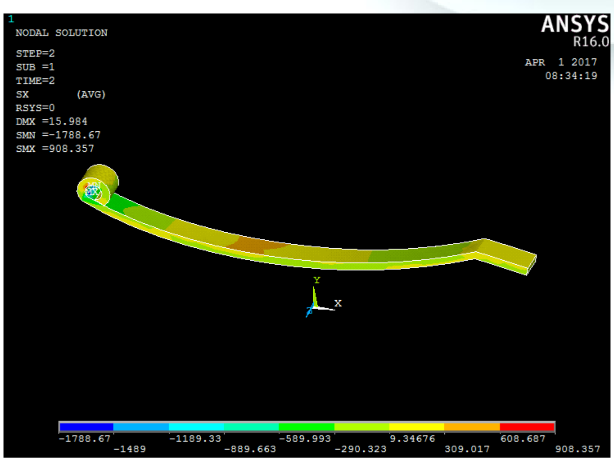
Model designed in CREO.

CREO is a 3D CAD modelling software used for solid modelling. We have designed our model using CREO. First, we have sketched the master leaf spring then we have sketched the graduated leaves.

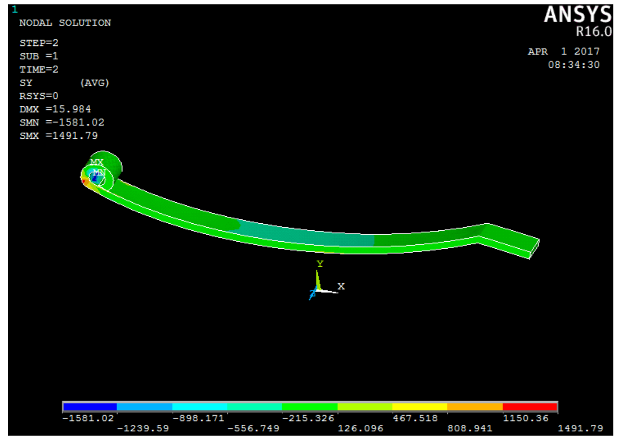
III. ANALYSIS OF HOOK DOWN SLIPPER LEAF SPRING



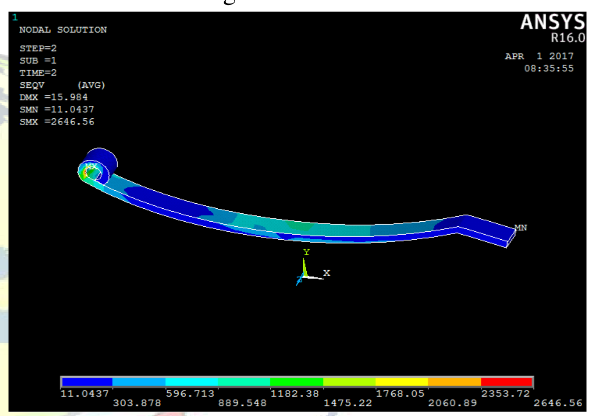
Meshed Model of Hook Down Slipper Leaf Spring



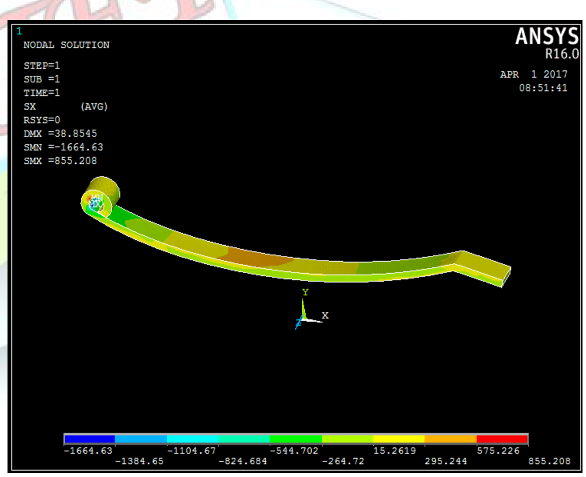
Stress acting in X -direction for Steel



Stress acting in Y – direction for Steel



Von Mises Stress of Steel Leaf Spring



Stress acting in X – direction for Epoxy

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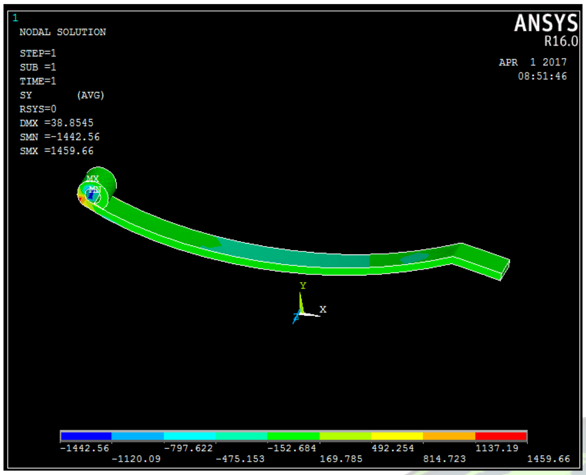
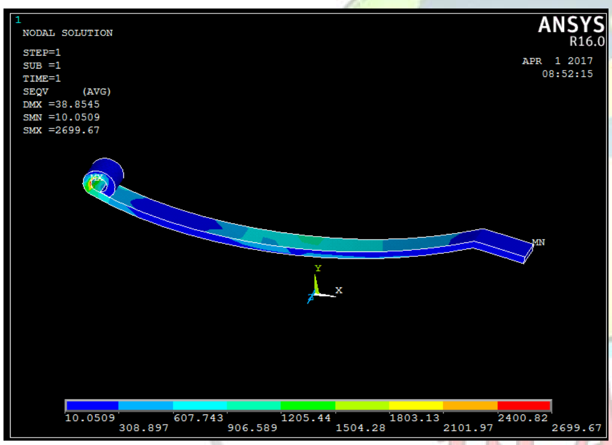


Stress acting in Y – direction for Epoxy



Von Mises Stress of Composite Leaf Spring

Von Mises stress is used to check whether the design made of isotropic or ductile will withstand a given load condition. We can say whether the design will fail or not using von mises stress.

The general purpose of finite element analysis software ANSYS version 16.0 is used for the present study. Using the advantage of symmetry in geometry and loading, only one-half of the leaf spring is modelled and analyzed. The three-dimensional structure of the leaf spring is divided into a number eight-nodded 3D brick elements in order to get accurate results, more number of elements are to be created. Hence, an aspect ratio of three is maintained in the finite element model. We have analyzed the leaf spring using module APDL in ANSYS 16.0.

Composites materials, often shortened to composites or called composition materials, are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct at the macroscopic or microscopic scale within the finished structure. Composite is the fastest growing "materials" market segment. Sporting goods, Aircraft, automobile, shipbuilding, Boeing 777, disc brake pads, which consist of hard ceramic particles embedded in soft metal matrix, in shower stalls and bath tubs which are made of fiber glass are a few examples. Materials constitute nearly 60%-70% of the vehicle cost and contribute to the quality and the performance of the vehicle. Even a small amount in weight reduction of the vehicle, may have a wider economic impact. Composite materials are proved as suitable substitutes for steel in connection with weight reduction of the vehicle. Since, the composite materials have more elastic strain energy storage capacity and high strength to weight ratio as compared with those of steel, multi-leaf steel springs are being replaced by mono-leaf composite springs. Christo Ananth et al.[2] discussed about E-plane and H-plane patterns which forms the basis of Microwave Engineering principles.

The E-glass fiber is a high quality glass, which is used as standard reinforcement fiber for all the present systems well complying with mechanical property requirements, so we selected this composite.Composite leaf springs are not new to the automotive industry. In fact, the leaf spring itself dates back to the horse-drawn carriage. By design, leaf springs absorb vertical vibrations caused by irregularities in the road. Variations in the spring deflection allow potential energy to be stored as strain energy and then released more gradually over time. Composites are well suited for leaf-spring applications due to their high strength-to-weight ratio, fatigue resistance and natural frequency. Internal damping in the composite material leads to better vibration energy absorption within the material, resulting in reduced transmission of vibration noise to neighboring structures.

Weight reduction has been the main focus of automobile manufacturers in the present scenario. The replacement of steel with optimally designed composite leaf spring can provide 92% weight reduction. Moreover the composite leaf spring has lower stresses compared to steel spring. All these will result in fuel saving which will make countries energy independent because fuel saved is fuel produced.

In comparison to common materials used today such as metals, composites can give a distinct advantage. The main advantage in the adoption of composites is the lightweight properties. In transportation, less weight equates to more fuel

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savings and improved performance. Besides weight savings, the most important benefits of composites include:

1.) Non-corrosive
2.) Non-conductive
3.) Flexible, will not dent
4.) Low maintenance
5.) Long life
6.) Design flexibility

IV. CONCLUSION

1. The composite leaf spring is designed according to constant cross-section area method.
2. The 3-D model of the composite leaf spring is analyzed using finite element analysis.
3. A comparison chart on stress and displacement has been created based on the analysis results of the steel and composite leaf spring.
4. A comparative study has been made between composite and steel leaf springs with respect to weight, riding quality.

From the study and analysis results, it is seen that the composite leaf spring are lighter and more economical than that of conventional steel leaf springs for similar performance. Hence, the composite leaf springs are the suitable replacements to the conventional leaf springs.

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