MODELING AND ANALYSIS Laminated Composite Leaf Spring under the Static Load Condition by Using F E A

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Abstract-**The paper work is carried out on a multi leaf spring having eight leaves used by a commercial vehicle. In order to reduce the cost and weight of leaf spring, the Automobile sector is replacing steel leaf spring with fiber composite leaf spring, the objective of study was to replace steel material for leaf spring, the material selected was glass fiber reinforced plastic. A spring with constant width and thickness with different arrangements of composite leaves was used for analysis. In this study all models are designed for factor of safety 2.5 and analysis is done using ANSYS software. Deflection and Stresses results were verified for analytical results. Result shows that, the composite spring has stresses much lower than steel leaf spring and weight of composite spring was reduced. By capturing the fundamentals of combining dissimilar materials and thus its equivalent modulus affects the overall stiffness characteristics of multi-leaf design.**

Index Terms- **Leaf spring, finite element analysis and composite materials, composite leaf springs.**

I. INTRODUCTION

Ever increasing demands of high performance together with long life and light weight necessitate consistent development of almost every part of automobile. Increasing competition and innovations in automobile sector tends to modify the existing products or replacing old products by new and advanced material products. A suspension system of vehicle is also an area where these innovations are carried out regularly. 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 . The suspension leaf spring is one of the potential items for weight reduction in automobiles un-sprung weight. This achieves the vehicle with more fuel efficiency and improved riding qualities. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The study demonstrated that composites can be used for leaf springs for light weight vehicles and meet the requirements, together with substantial weight savings. 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. Since, the composite materials have more elastic strain energy storage capacity and high strength-to-weight ratio as compared to those of steel .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. Upon those products leaf spring is the focus of this project for which researches are running to get the best composite material, which meets the current requirement of strength and weight reduction in one, to replace the existing steel leaf spring.

II. LITERATURE SURVEY

A leaf spring is a long, flat, thin, and flexible piece of spring steel or composite material that resists bending. The basic principles of leaf spring design and assembly are relatively simple, and leafs have been used in various capacities since medieval times. Most heavy duty vehicles today use two sets of leaf springs per solid axle, mounted perpendicularly to support the weight of the vehicle. This Hotchkiss system requires that each leaf set act as both a spring and a horizontally stable link. Because leaf sets lack rigidity, such a dual-role is only suited for applications where load-bearing capability is more important than precision in suspension response.

Increasing competition and innovations in automobile sector tends to modify the existing products or replacing old products by new and advanced material products. Also to meet the needs of the natural resource conservation and energy and economy, the automobile manufacturers have been attempting to reduce the weight of the vehicle in recent years. A suspension system of a vehicle is also an area where these innovations are carried out regularly. More efforts are taken in order to increase the comfort of the user. Appropriate balance of comfort riding qualities and economy in the manufacturing of leaf springs becomes an obvious necessity. Many past recorded data shows that steel leaf springs are manufactured by EN45, EN45A, 60Si7, EN47,and 50CrMoCV etc these materials are widely used for the manufacture of the conventional multi leaf springs. The introduction of the composite materials made it possible to reduce the weight of the leaf springs without any reduction of load carrying capacity and stiffness. Studies were conducted on the application of the composite materials for automobile suspension system (leaf springs) Compared to steel spring, the composite leaf spring is found to have 64.95% higher stiffness and 126.98% higher natural frequency than that of existing steel leaf springs Multi leaf springs used in the automotive vehicles normally consist of full length leaves and graduated length leaves. The specimen under this research work consists of nine leaves. Finite element analysis using ANSYS software has been carried on conventional leaf springs to determine the safe stress and pay loads and it is observed that inner side of eye sections .Composite mono leaf springs were manufactured with integral eye and tested under static loading condition. Also fatigue life prediction was done to ensure a reliable number of life cycles . Leaf springs were modelled in conventional way and simulated for the kinematic and dynamic comparatives . An artificial genetics approach for the design optimisation of the composite leaf springs were conducted . Static testing and finite element analysis have been conducted to obtain the characteristics of the spring. Load – deflection curves and strain measurement as a function of loads for the three design tested have been plotted for the comparison with the FEA predicted values . Fatigue strength of shot peening leaf spring from laboratory samples of EN45 steel spring is calculated. A lot of research has been done to improve fatigue strength of material by creating compressive residual stress field in there surfaces through shot peening . A double tapered beam for automotive suspension leaf springs has been designed and optimized .Demonstration of the feasibility of using the program as a tool in establishing the initial design consideration s and in developing of preliminary design was done . Investigation of the fundamental properties of the dimensioning of the FRP leaf spring made from GFRP to replace four steel springs . The fatigue strength of 65Si7 spring steel has been evaluated experimentally as a function of shot penning parameters for the application in automotive vehicles . The main objective of this work is to perform finite element analysis of multi leaf springs of three different combinations and to find the bending stresses, to perform static analysis of the three combinations.

III.SPECIFICATION OF THE PROBLEM

Multi leaf structure creates problems such as producing squeaking sound, fretting corrosion thereby decreasing the fatigue life. The objective of the present work is to design and analyze mono leaf natural composite leaf spring. For this purpose, Glass Fiber/Epoxy & Natural fiber Glass composite leaf springs we remanufactured using hand-layup technique. Then they are experimentally tested for static load conditions and the results are compared with FEA results. The fatigue factors and natural frequencies are computed for the NFRC leaf spring.

Considering several types of vehicles that have leaf springs and different loads on them, various kinds of composite leaf spring have been developed. The following cross-sections of mono-leaf spring for manufacturing easiness are considered.

¾ Constant thickness, constant width design
¾ Constant thickness, varying width design
¾ Varying width, varying width design.

In the present work, only a mono leaf spring with constant thickness, constant width design is analyzed

IV. DESIGN OF LEAF SPRING

Conventional steel leaf springs are manufactured by EN45, EN45A, 60Si7, EN47, 50Cr4V2, 55SiCr7 and 50CrMoCV4 etc. These materials are widely used for production of the parabolic leaf springs and conventional multi leaf springs. In general terms higher alloy content is mandatory to ensure adequate harden ability when the thick leaf sections are used. Plain carbon steel, Chromium vanadium steel, Chromium- Nickel- Molybdenum steel, Silicon-manganese steel, are the typical materials that are used in the design of leaf springs. The material used for this work is 65Si7.

The relationship of the specific strain energy can be expressed as it is well known that springs, are designed to absorb and store energy and then release it slowly. Ability to store and absorb more amount of strain energy ensures the comfortable suspension system. The relationship of the specific strain energy can be expressed as

Where ı is the strength, ḓ is the density

E is Young's Modulus of the spring material

From the above equation, the material which is having low density and low Young's modulus will have high strain energy storage capacity. This purpose will be served by composites.

A. Conventional Steel multi-leaf spring

The basic requirements of a leaf spring steel is that the selected grade of steel must have sufficient harden ability for the size involved to ensure a full martensitic structure throughout the entire leaf section. In general terms higher alloy content is mandatory to ensure adequate harden ability when the thick leaf sections are used.

The material used for the experimental work is 55Si2Mn90. Its chemical compositions are given below in Table 1.

Mechanical properties of existing leaf spring

PARAMETERS	VALUE
MATERIAL OF SPRING	65Si7
YOUNG'S MODULUS,E	2.1×10^{5} MPa
POISSON'S RATIO	0.266
Tensile Strength Ultimate	1272 MPa
Tensile Yield Strength	1158 MPa
Tensile Yield Strength	7.86×10^{-6} Kg/mm^3

DESIGN PARAMETERS OF LEAF SPRING

Leaf span	860MM
Free Camber	90MM
Width of all leaves	60MM
Thickness of the spring	8MM

Manufacturing of Composite leaf spring

The hand layup is one of the oldest and most commonly used methods for manufacture of the composite parts.

Hand layup composite are a case of continuous fiber reinforced composite. Layers of unidirectional or woven composite are combined to result in a material exhibiting desirable properties in one or more directions. Each layers oriented to achieve the maximum utilization of its properties. Layers of different material (different fiber in different directions) can be combined to further enhance the overall performance of the laminated composite material. Resins are impregnated by hand into fibers, which are in the form of woven, knitted, stitched or bonded fabrics. This is usually accomplished by rollers or brushes, with an increase use of nip–roller type impregnators for forcing resin into fabrics by means of rotating rollers and a bath of resin. Laminates are left to cure under standard atmospheric conditions.

Fabrication Procedure

A plywood mould was prepared with required dimensions of leaf spring. Wax polish (Manson) was applied with the help of cloth on mould for better surface finish & for easy removal of leaf spring after curing. Number of layers of E-glass, Jute and epoxy are laminated simultaneously for required thickness of leaf spring. Then it is cured for 24 hours before removal.

V. EXPERIMENTAL TESTING

After fabrication of both (E-glass/epoxy & Natural fiber E-glass epoxy) leaf springs are experimentally tested on UTM machine at load intervals of 5kgs. The experimental data of deflection against load was recorded.

PARAMETER	VALUE
Material selected-steel	65Si7
Young's modulus, E	2.1*10 N/mm2
Poisson's Ratio	0.266
BHN	400-425
Ultimate tensile strength	460 MPA
Tensile strength Yield	250 MPA
Spring stiffness	221.5 N/mm2
Mass	58.758 kg
Normal static load	35000N

Material properties

Material properties of E glass/ Epoxy (GFRP): The different parameters related to GFRP leaf springs are tabulated in the table below:

PARAMETER	VALUE
Tensile modulus along X-Direction	3400 MPA
Tensile modulus along Y-Direction	6530 MPA
Tensile modulus along Z-Direction	900 MPA
Tensile strength	450 MPA
Compressive strength	2433 MPA
Shear modulus along XY Direction	1698 MPA
Shear modulus along YZ Direction	2433MPA
Shear modulus along ZX Direction	58.758 kg
Poisons ratio along XY Direction	0.217
Poisons ratio along XY Direction	0.366
Poisons ratio along XY Direction	0.217
Density of material	26*10 Kg/mm3
Behaviour	Orthotropic

V .FINITE ELEMENT ANALYSIS

Finite Element Analysis (FEA) is a computer-based numerical technique for calculating the strength and behaviour of engineering structures. It can be used to calculate deflection, stress, vibration, buckling behaviour and many other phenomena. The power and low cost of modern computers has made Finite Element Analysis available to many disciplines and companies.

In the finite element method, a structure is broken down into many small simple blocks or elements. The behaviour of an individual element can be described with a relatively simple set of equations. Just as the set of elements would be joined together to build the whole structure, the equations describing the behaviours of the individual elements are joined into an extremely large set of equations that describe the behaviour of the whole structure. The computer can solve this large set of simultaneous equations. From the solution, the computer extracts the behaviour of the individual elements. From this, it can get the stress and deflection of all the parts of the structure.

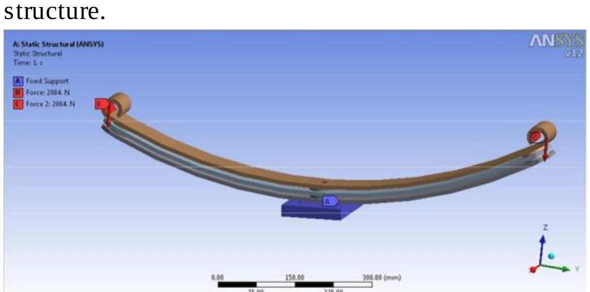

Fig.1 *Meshed Model of Steel Leaf Spring with Boundary Conditions*

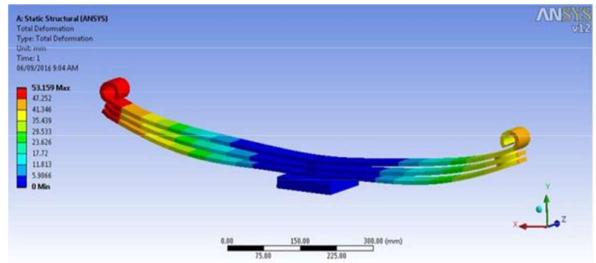

Fig.2 *Total Deformation of Steel Leaf spring*

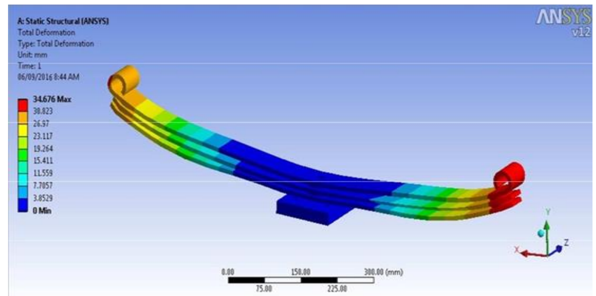

Fig3 *Complete Deformation of Composite Leaf Spring*

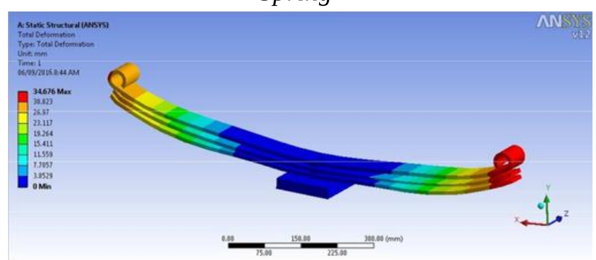

Fig.4 *Total Deformation of Composite Leaf Spring*

VI. SPECIFIC DESIGN DATA

Here Weight and initial measurements of four wheeler "TATA ACE" Light commercial vehicle is taken

Weight of vehicle= 700 kg

Maximum load carrying capacity=1000 kg

Total Weight=700+1000=1700 kg

Taking Factor of Safety=2

Acceleration due to gravity(g)=9.81 m/s^2

Therefore; Total Weight = 1700*9.81 = 16677

Since the vehicle is 4-wheeler, a single leaf spring corresponding to one of the wheels takes up one 4th of the total weight.

∴ 16677/4 = 4169 N,

But 2F = 4169 N.

∴ F = 2084 N.

Span length, 2L = 860 mm,

∴ L= 430mm.

Now the Maximum Bending stress of a leaf spring is given by the formula

Bending Stress, $\sigma_b = 6FL / nbt^2 = (6*2084*430) / (3*60*8^2) = 466.84$ MPa

The Total Deflection of the leaf spring is given by

$\delta max = 6FL^3 / Enbt^3$

$= (6*2084*430^3) / (2.1*10^5*3*60*8^3)$

$= 51.38$ mm.

OUTPUT

From the results of static analysis of steel leaf spring, it is seen the displacement of leaf spring is 53.159 mm which is well below the camber length of leaf spring shown in fig.4. It is seen that the maximum bending stress is about 450.73MPa, which is less than the yield strength of the material shown in fig.3. The FEA results are compared with the theoretical results and found that the theoretical result and FEA result are nearer to each other.

Table No.5 Comparison between theoretical and ANSYS results of conventional steel leaf spring

Parameter	Theoretical Results for steel leaf spring	FEA Results for steel leaf spring	Variation
Load, N	4169	4169	NIL
Bending Stress, MPa	466.84	450.73	3.04 %
Total Deflection, mm	51.24	53.159	3.06 %

After that the multi leaf spring with E-Glass/Epoxy material is analyzed in ANSYS-12 with same dimension and same boundary condition as that of conventional leaf spring.

The comparison between steel leaf spring and composite leaf spring for deflection and bending stress results from the ANSYS is shown in the Table-VI.FEA results comparison between steel and composite leaf spring.

Parameter	FEA Results for steel leaf spring	FEA Results for composite leaf spring	Variation
Load, N	4169	4169	NIL
Bending Stress, MPa	450.73	338.03	- 25.05 %
Total Deflection, mm	53.159	34.676	- 34.76 %

By the comparison of results between steel leaf spring and the composite leaf spring from ANSYS-12 the deflection is decreased by 34.76 % in composite leaf spring that is within the camber range. The bending stresses are decreased by 25.05% in composite leaf spring means less stress induced with same load carrying conditions. The conventional multi leaf spring weights about 10.27kg whereas the E-glass/Epoxy multi leaf spring weighs only 3.26 kg. Thus the weight reduction of 67.88% is achieved. By the reduction of weight and the less stresses, the fatigue life of composite leaf spring is to be higher than that of steel leaf spring. Totally it is found that the composite leaf spring is the better that of steel leaf spring. Table No.07 Percent saving of weight by using composites

Materials	Weights	%weight saving
Conventional steel	10.27 kg	-
E-glass/epoxy	3.26 kg	67.88%

VII. CONCLUSION

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.

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