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Numerical Investigation Of Parabolic Leaf Spring For Composite Materials Using Ansys

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ABSTRACT
The purpose of the present investigation is to reduce the stress acting in the parabolic leaf spring in order to reduce the vibration of the vehicle. It can be achieved by choosing suitable composite materials e-glass/epoxy, carbon/epoxy, Kevlar/epoxy. Identification and solution provided through the various literatures, now the objective of the research work is to replace the existing conventional steel EN45 material through the composite material to reduce the weight and increase the strength. The solid modelling of leaf spring was done on CATIA and analysis using ANSYS software. Finally, standing from the static analysis result the study conclude that the newly designed carbon/epoxy mono composite leaf spring has better performance than that of the current conventional steel leaf spring of TATA 207. The aim of replacing leaf spring with carbon/epoxy composite is to obtain a leaf spring which is light weight and capable of carrying given static load by constraints limiting stresses and displacements. Moreover, the weight of the laminated carbon/epoxy composite mono leaf spring is reduced about 76.85%; this intern reduces the overall dead weight of the vehicle. Thus, applying the results of this research work will improve the efficiency and the fuel economy of the vehicle.

Keywords:- parabolic leaf, steel EN45, Kevlar/epoxy, e-glass/epoxy , TATA 207, carbon/epoxy composite

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I. INTRODUCTION

The responses of a vehicle are defined in terms of deflections, strains, and stresses, natural frequencies, random response functions, and fatigue life and so on. Evaluation of the above is what puts the basis on which robustness of a vehicle system or design is ascertained in terms of its mechanical behaviour. Simulation of vehicle responses largely concentrates on determination of the above. Different researches have been carried out regarding the performance, the response of components to static and dynamic loads, crashworthiness, safety and others by different institutions and automotive companies. Particularly, with the growing simulation capability using computers, researches are facilitated which are aimed to achieving better quality products.

The application of computer aided engineering (CAE) analysis to problems of this sort, in combination with prototype development and testing, enables to achieve structures having longer fatigue life, reduced cost, light weight and improved comfort. In light of this purpose, as stated earlier, advancements in the area are growing further. We can reduce the weight of the leaf spring without any reduction on load carrying capacity and stiffness due to the introduction of composite materials. Therefore composite materials are now used in automobile industries to replace metal parts. Elastic strain energy capacity is also high in composite materials. As compared to steel, they also have high strength-to-weight ratio. Composite materials offers opportunity for substantial weight saving. Spring are design to absorb and store energy and then release it hence strain energy of material and shape becomes major factors in designing the spring. The spring allows the movement of wheel over obstacles and then after, returns the wheel to its normal position. This work is mainly focused on the implementation of composite materials specially (FRP composites) by replacing steel in conventional parabolic leaf springs of a suspension system. Hou et al. [1] presented the design evolution process of a composite leaf spring for freight rail applications. The main concern associated with the first design was the delamina- tion 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 interlaminar 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 over- comes the problem by ending the fibres at the end of the eye section. Prakash E. J, et al, [2] study to suggest the best composite material for design and fabrication of complete mono composite leaf spring. The design constraints were stresses and displacement. It can be observed that Boron Aluminum is the best suitable material for replacing the steel in manufacturing of mono leaf spring. The saving in the weight is 90.3%.

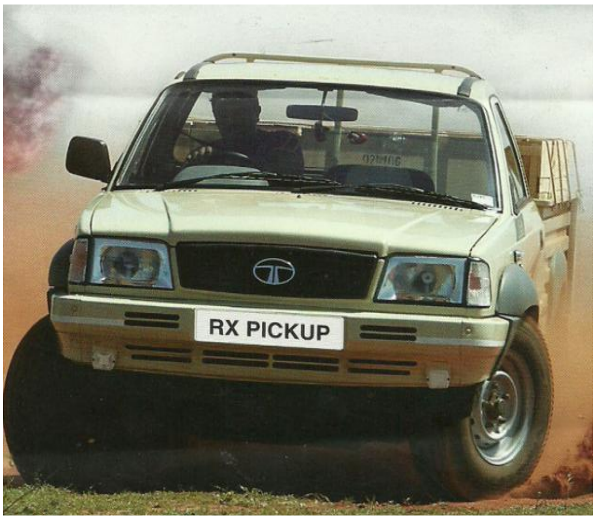
Putti Srinivasa R, et al, [3] study modal and harmonic analysis for a multi leaf spring for different materials using ANSYS 12.1 and compared with theoretical values. By using composite materials the weight of the multi leaf spring is reduced drastically. Finally the researcher state a conclusion for his work as: E-glass/epoxy and carbon/epoxy have high amplitude of response than other materials and Kevlar/epoxy, graphite/epoxy and steel have low amplitude of response. Malaga A, et al, [4] presented low cost leaf spring by replacing the multi-leaf steel spring to mono composite leaf spring for the same 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. It was possible to reduce the weight of the leaf spring without any reduction on load carrying capacity and stiffness. The design constraints were limiting stresses and displacement. Modeling and analysis of both the steel and composite leaf springs had been done using ANSYS software. Mahdi et al. [5] studied the influence of ellipticity ratio on spring rate and load carring capacity. In general, this study demonstrated that composites elliptical spring can be used for light and heavy trucks and meet the requirements, together with substantial weight saving. The results showed that the ellipticity ratio significantly influenced the spring rate and failure loads. Composite elliptic spring with ellipticity ratios of a/b=2.0 displayed the highest spring rate. Turan et al. [6] evaluated the effects of joint geometry and fiber orientation on the failure loads and failure modes, parametric studies were performed experimentally and numerically. A numerical study was performed by using 3D APDL codes with ANSYS fem software and Hashin Failure Criteria was used for predicted failure mode and failure load. The experimental and nu- merical results showed that the failure loads of composite plates were increased with increasing E/D and W/D ratios. Gebremeskel et al.[7] designed a single E-glass/Epoxy leaf spring and simulated following the design rules of the composite materials. And it was shown that the resulting design and simulation stresses are much below the strength properties of the material satisfying the maximum stress failure criterion. This particular design was made specifically for light weight three wheeler vehicles. Its prototype was also produced using hand lay-up method. Ekbote et al. [8] analyzed nine-leaf steel spring used in the rear suspension system of a light duty vehicle by finite element method using ANSYS software. The objective was to obtain a spring with minimum weight capable of carrying intended static external force without failure. The optimized spring will have its width decreasing and thickness increasing hyperbolically from the spring eye towards the axle seat. An approximate spring model was assumed and its analytical solution was also presented. Compared to steel spring, the optimized composite mono leaf spring has much lower stress and the spring weight without eye units is nearly 65% lower than steel spring. U. S. RAMAKANTH, et al, [9] study on ‘design and analysis of automotive multi-leaf springs using composite materials’. This work carried out on multi leaf springs having nine leaves used by a commercial vehicle. A Finite element approach for analysis of a multi leaf springs was performed using ANSYS software. Stresses in composite leaf spring is less as compared to the conventional steel leaf springs, also a new combination of steel and composite leaf springs (hybrid leaf springs) were given the same static loading and found to have values of stresses in between that of steel and composite leaf springs. Ritesh M. [10] study the finite element results showing stresses and deflection verified the existing analytical. Dynamic load analysis of leaf spring using ANSYS 14 software. In this study the researcher doesn’t consider the weight reduction of the leaf spring in details. Bhaumik A, et al, [11] compared the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring. The dimensions of an existing conventional steel leaf spring of a Light design calculations. Static analysis of a model of leaf spring was performed using ANSY S 11.0. The result of FEA also experimentally verified. The stress induced in the C-glass/Epoxy composite leaf spring 64% less than that of the steel spring nearly and the deformation induced in the C-glass/Epoxy composite leaf spring 57% less than that of the steel spring nearly . And finally the researcher conclude that the bending stress induced in the C-Glass/Epoxy composite leaf spring is 64% less than the conventional steel leaf spring for the same load carrying capacity.

FARIS et al. [12] investigated the static and fatigue behaviors of steel and composite multi- leaf spring using the ANSYS V12 software. The dimensions of an existing conventional leaf spring of a light commercial vehicle were used. The same dimensions were used to design com- posite multi-leaf spring or the two materials-glass fiber/epoxy and E-glass fiber/vinyl ester, which are of great interest to the transportation industry. Main consideration was given to theeffects of material composition and its fiber orientation on the static and fatigue behaviors of leaf spring. The design constraints were bending stresses, deflection and fatigue life. Compared to the steel leaf spring, the designed composite spring has much lower bending stresses and deflections and higher fatigue life cycles.

Krishan et al. [13] designed a multi leaf spring made of steel and stress-deflection analysis was carried out by finite element approach using CAE tools i.e CATIA, ANSYS. When the leaf spring is fully loaded, a variation of 0.632 % in deflection is observed between the experimental and finite element analysis result, and same in case of half load, which validated the model and analysis. On the other hand, bending stress in both the cases was also close to the experimental results. The maximum value of equivalent stresses was below the Yield Stress of the material that the design was safe from failure. Raghavedra et al. [14] compared laminated composite leaf spring and steel leaf spring with respect to weight, stiffness and strength. By employing a composite leaf spring for the same load carrying capacity, there was a reduction in weight of 73%-80%, natural frequency of composite leaf springs are 27%~67% higher than steel leaf spring and 23~65% stiffer than the steel spring. Kothari et al. [15] studied static and fatigue life analysis of conventional leaf springs made of respectively SUP 9 & EN 45. Comparison for maximum stress, deflection and stiffness as well as fatigue life was done. The CAD models were prepared in CATIA and analyzed by using AN- SYS 12.1. Computer algorithm using C++ language had been used in calculating maximum stress, deflection and stiffness. Calculated results were compared with FEA result. SUP 9 springs has lower value of maximum stress, deflection and stiffness in compare to EN45 spring.
The purpose of the present investigation is to reduce the stress acting in the parabolic leaf spring in order to reduce the vibration of the vehicle. It can be achieved by choosing suitable composite materials e-glass/epoxy, carbon/epoxy, Kevlar/epoxy. Identification and solution provided through the various literatures, now the objective of the research work is to replace the existing conventional steel EN45 material through the composite material to reduce the weight and increase the strength.

II. DESIGN SELECTION

The leaf spring behaves like a simply supported beam. In this the flexural analysis is done. It is done by considering it as a simply supported beam. This beam is subjected to both bending stress and transverse shear stress. They both are important parameters in the leaf spring design. Here Weight and initial measurements of a Tata 207 Light commercial vehicle is taken-



SPECIFICATIONS

ENGINE		**FUEL TANK**	
Model	: TATA 497 SP	Capacity	: 60 liters
Type	: Water-cooled, Direct Injection, Diesel	**DIMENSIONS**	
Capacity	: 2956 cc	Wheel Base	: 3150 mm
Max.Output	: 65 HP @ 2800 rpm	Overall Length	: 5182 mm
Max Torque	: 18 mkg @1500-2000 rpm	Overall width	: 1860 mm
CLUTCH	: Single plate dry friction diaphragm type	Front Track	: 1537 mm
GEAR BOX	: GBS-76-514.1	Rear Track	: 1577 mm
Type	: Synchromesh on all gears	**MINIMUM GROUND**	
	: 5 forward and 1 reverse	**CLEARANCE**	: 210 mm Laden
STEERING	: Power steering	**LOADING AREA**	
BRAKES		**Load Body**	
Type	: Vacuum assisted independent Hydraulic	Length	: 2440 mm
	: with Tandem Master Cylinder	Width	: 1675 mm
Front Brakes	: Disc brake	Height	: 415 mm
Rear Brakes	: Drum brake	**WEIGHTS**	
SUSPENSION		Max GVW	: 2950 Kg
Front & Rear	: Reid Suspension with Semi-elliptical	Kerb Weight	: 1940 Kg
	: Leaf Spring	**SEATING CAPACITY**	: Driver + 1
WHEELS AND TYRES			
Tyres	: 7.00 x 16 12PR		

Figure 1 Tata 207 DI RX Specification [16]

III. DESIGN DATA FOR DESIGN PARABOLIC LEAF SPRING

Length of the main leaf (L)	852 mm
Length of the second leaf(L)	851.83 mm
Length of the third leaf(L)	758.1 mm
Length of the fourth leaf(L)	624.41
Length of the fifth leaf(L)	508.68
Length of the six leaf(L)	374.61
Length of the seven leaf(L)	239.87
Width of leaf (b)	76.2 mm
Camber height (C)	75.828 mm
Tip inserts	25 mm dia.
Thickness of leaves (t)	11.3mm

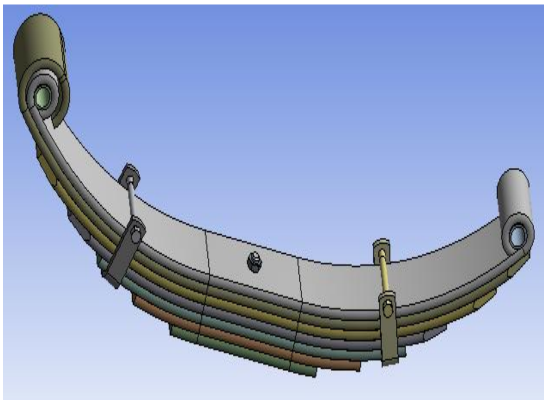
Tetrahedral elements are used for all the components of parabolic leaf spring. Tetrahedral elements better approximate the shape with minimum error as compared to brick elements. According to the mesh convergence test, the final Size of the tetrahedral elements for all the components of parabolic leaf spring and a total no. of 607575 nodes and 304886 elements are generated after the meshing which is almost more than 15 times of initial generated mesh

IV. SOLID MODELLING OF PARABOLIC LEAF SPRING

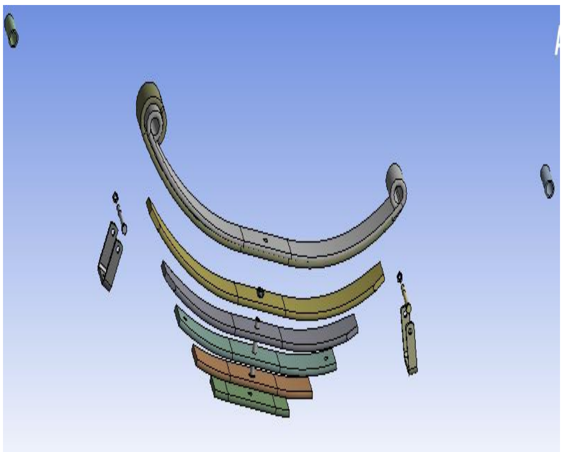
Computer aided design (CAD) is a powerful technique to create the design of products. CAD package has three components: Design, Analysis and Visualization. Design refers to geometric modelling, 2-D and 3-D modelling, including, drafting, part creation, creation of drawings with various views of the part, assemblies of the parts. In this section the process of solid modelling of parabolic leaf spring is presented. The solid models of the parabolic leaf spring are generated in a CAD system.

1.1Modelling of parabolic leaf spring

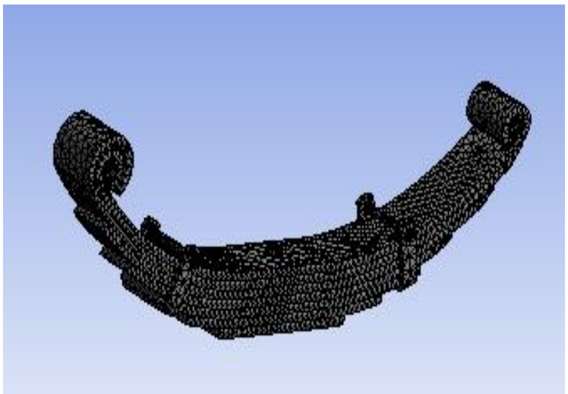
CREO is a feature-based, parametric solid modelling system with many extended design and manufacturing applications. Three dimensional model of parabolic leaf spring are prepared by using 3D modelling software CREO 3.0 after design and direction of load applied is presented in contour plot.



(a)



(b)



(C)

Figure 2 (a) CAD model of parabolic Leaf spring (b) Part Modelling of Leaf Spring (c) mesh element

Tetrahedral elements are used for all the components of parabolic leaf spring. Tetrahedral elements better approximate the shape with minimum error as compared to brick elements. According to the mesh convergence test, the final Size of the tetrahedral elements for all the components of parabolic leaf spring and a total no. of 607575 nodes and 304886 elements are generated after the meshing which is almost more than 15 times of initial generated mesh

I.1 Material Properties

There are four parabolic leaf springs on which the analyses are going to perform, one is conventional steel EN45 parabolic leaf spring and other three are composite parabolic leaf spring. The mechanical properties of the conventional steel material being used in this analysis are show in Table no-5.1 and the mechanical properties of composite material which can be taken as per ANSYS-16.1 standard material library are show in table no- 1,2,3 and 4.

Table no-1 Mechanical Properties of steelEN45

Material properties	**Value**
Density	7850 Kg/m^3
Young's modulus	200 GPa
Poisson's ratio	0.3
Shear modulus	7.6903E+10 Pa
Tensile yield strength	1500 Mpa
Tensile ultimate strength	1962 Mpa

Table no-2 shows the mechanical properties of composite (Carbon/Epoxy) material, which can be taken as per ANSYS-16.1 Standard material library.

Material properties	**Value**
Tensile modulus along X-direction (E_x), Pa	2.09E+11
Tensile modulus along Y-direction (E_y), Pa	9.45E+09
Tensile modulus along Z-direction (E_z), Pa	9.45E+09

Shear modulus along XY-direction (G_{xy}), Pa	5.5E+09
Shear modulus along YZ-direction (G_{yz}), Pa	3.9E+09
Shear modulus along ZX-direction (G_{zx}), Pa	5.5E+09
Poisson ratio along XY-direction (NU_{xy})	0.27
Poisson ratio along YZ-direction (NU_{yz})	0.4
Poisson ratio along ZX-direction (NU_{zx})	0.27
Mass density of the material (ρ), kg/mm^3	1540

Table no-3 Mechanical Properties of E-Glass/Epoxy

Material properties	Value
Tensile modulus along X-direction (E_x), Pa	4.5E+10
Tensile modulus along Y-direction (E_y), Pa	1E+10
Tensile modulus along Z-direction (E_z), Pa	1E+10
Shear modulus along XY-direction (G_{xy}), Pa	5E+09
Shear modulus along YZ-direction (G_{yz}), Pa	3.8462E+09
Shear modulus along ZX-direction (G_{zx}), Pa	5E+09
Poisson ratio along XY-direction (NU_{xy})	0.3
Poisson ratio along YZ-direction (NU_{yz})	0.4
Poisson ratio along ZX-direction (NU_{zx})	0.3
Mass density of the material (ρ), kg/mm3	2000

Table no- 4 shows the mechanical properties of composite (Kevlar/Epoxy) material, which can be taken as per ANSYS-16.1 Standard material library.

Table no- 4 mechanical properties of Kevlar/epoxy

Material properties	Value
Tensile modulus along X-direction (E_x), Pa	9.571E+10
Tensile modulus along Y-direction (E_y), Pa	1.045E+10
Tensile modulus along Z-direction (E_z), Pa	1.045E+10
Shear modulus along XY-direction (G_{xy}), Pa	2.508E+10
Shear modulus along YZ-direction (G_{yz}), Pa	2.508E+10
Shear modulus along ZX-direction (G_{zx}), Pa	2.508E+10
Poisson ratio along XY-direction (NU_{xy})	0.34
Poisson ratio along YZ-direction (NU_{yz})	0.37
Poisson ratio along ZX-direction (NU_{zx})	0.34
Mass density of the material (ρ), kg/mm3	1402

The above mentioned three composite materials are used to perform the finite element analysis and compared with the conventional steel EN45 material for better improved mass and low stress and low total deformation. This can be remedied by introducing composite material, in place of steel in the conventional parabolic leaf spring.

I.2 Mesh convergence test

By using mesh convergence test a check point is tested on the assembly. This is done in order to simplify and justify the analysis result. In this process the von- misses stress level is tested on assembly by taking different size of element during meshing. With the assistance of ANSYS-16.1 software, the respective mesh sizes with corresponding Total deformation are presented below. The load value is same for each mesh size 3617.5 N. here it is observed that in figure 3 mess are not so fine the number of node and element are 37181 and 15655 respectively. So mess refining test are required to check whether the final value are independent are not hence grid independence test were performed to get the final result of the parabolic leaf spring.

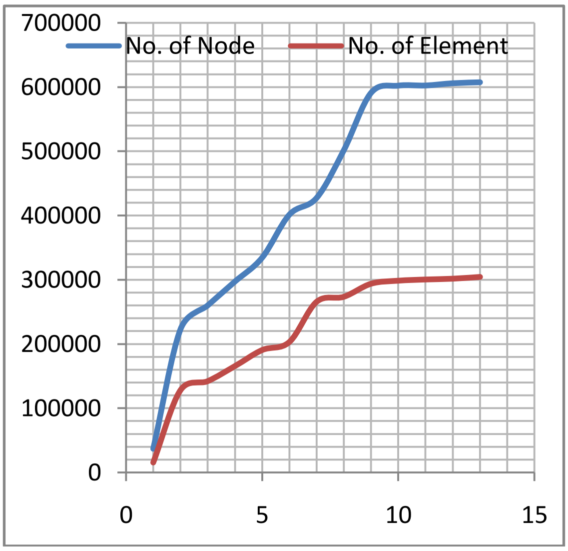


Fig.3 Grid Independence Test with respect to Total Deformation

I.3 Loading and boundary condition

The parabolic leaf spring is placed on the axle of the vehicle; the frame of the vehicle is attached to the ends (by eyes) of the leaf spring. The ends of the parabolic leaf spring are produced in the form of an eye. The front eye of the parabolic leaf spring is attached straightly with a pin to the frame so that the eye can revolve without restraint about the pin but no translation is takes place. The backside eye of the spring is assembled with to the shackle which is a flexible link the next end of the shackle is linked to the frame of the vehicle. One eye of the leaf spring is reserved fixed. This leaf spring is being provided a cylindrical support. Whereas the other eye is given certain degree of rotation. This is done to allow the leaf spring to deflect by some amount along its length to meet the actual conditions for both the parabolic leaf spring (steel EN45 and composite) which is shown in Fig.5.1 (b).After load is applied of magnitude 2500 N to 4856 N in the upward direction at the centre of the parabolic leaf spring. This specific computation of load to be applied has been completed on the basis of Gross Vehicle Weight (GVW). This has been clearly shown the Fig.1

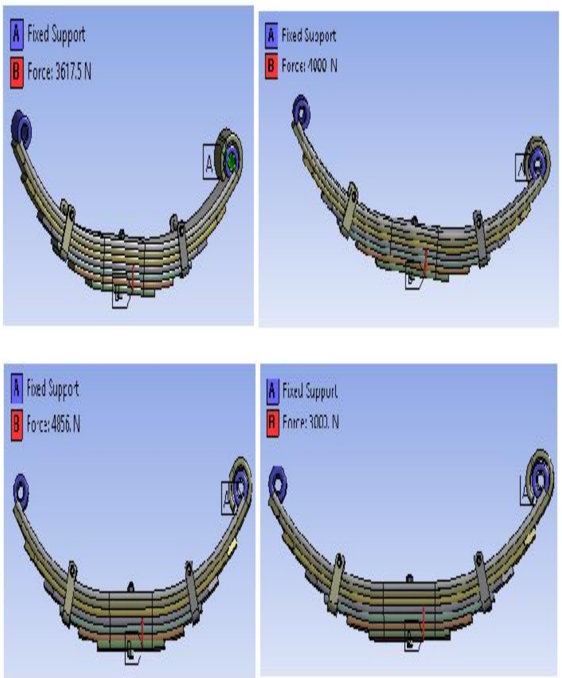


Fig 4 show loading and boundary condition of parabolic leaf spring

Partial Overload Condition (4000 N)
Equivalent Von-mises stress-
Equivalent (Von Misses) stress, computed from equation based on distortion energy failure theory, this criteria has been shown to be particularly effective in the prediction of failure for ductile materials and widely used by designers to check whether their design will withstand a given load condition. Using the ANSYS 16 Workbench software, the values of equivalent (Von-Misses) stress found along with the given boundary conditions and applied load of 4000 N.

The results of this static structural analysis shows that the equivalent (Von-Misses) stress of the laminated carbon/epoxy composite material leaf spring is the smallest one as compared to that of the E-glass/epoxy leaf spring under the same load and boundary conditions where as compared to steel it is little bit higher. This implies that laminated carbon/epoxy composite material leaf spring is less stressed, light weight and has a better performance.

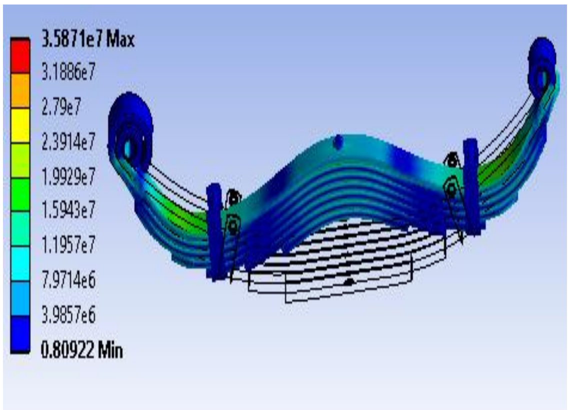


Figure 5 Steel EN 45 Parabolic leaf spring

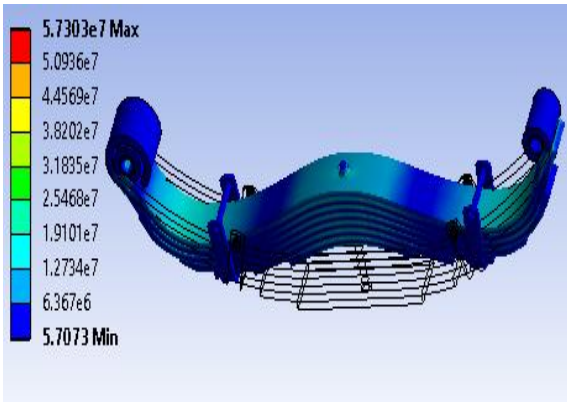


Figure 6 E-glass/epoxy parabolic leaf spring

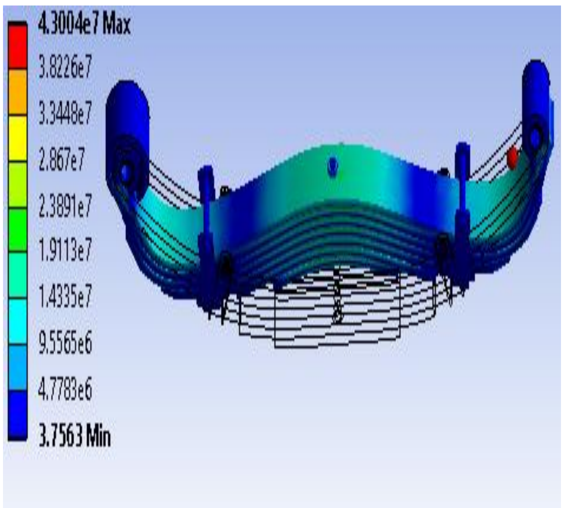


Figure 7 carbon/epoxy parabolic leaf spring

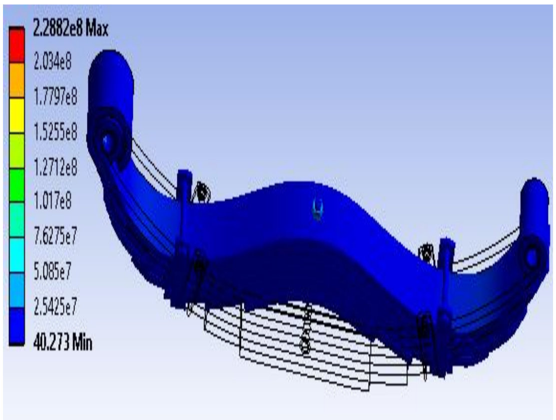


Figure 8 kevlar/epoxy parabolic leaf spring

Total deformation

From this static structural analysis ANSYS 16 workbench software, we show that, the maximum displacements of the laminated carbon/epoxy composite material leaf spring has the lowest deformation value compare with that of the current conventional steel leaf spring. When external loads applied to an elastic body, the body may deform or elongate according to the nature of the applied load. Then stress is defined as the average load per unit area that some particle of a body exerts on an adjacent particle, across an imaginary surface that separates them.

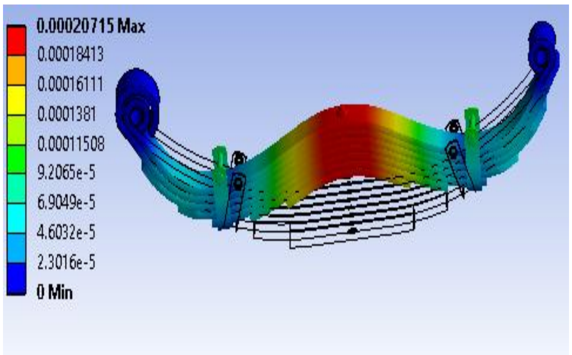


Figure 9 Steel EN 45 Parabolic leaf spring

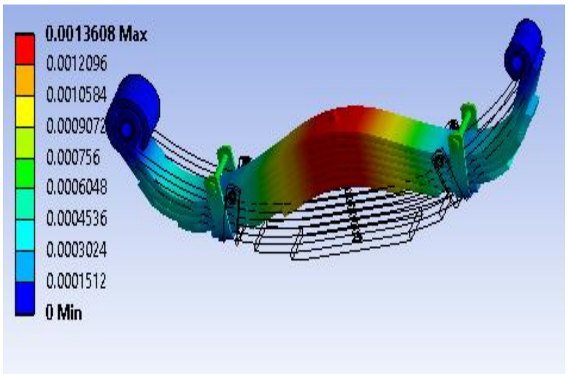


Figure 10 E-glass/epoxy parabolic leaf spring

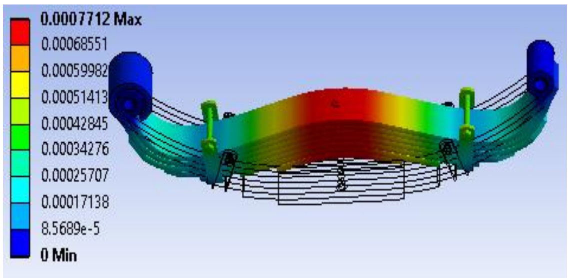


Figure 11 carbon/epoxy parabolic leaf spring

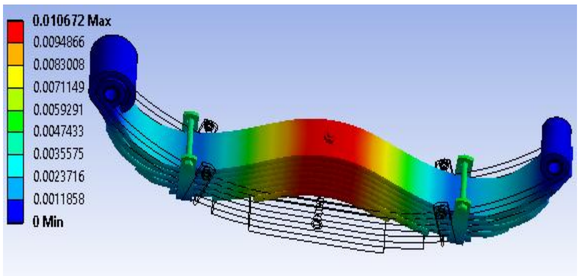


Figure 12 kevlar/epoxy parabolic leaf spring

Maximum principal stress

As expected from our theoretical calculations, it is observed that the Maximum principal stresses are lowest at the top and bottom faces and maximum at the center . To illustrate more clearly, a mid-section view at 22° angle from the (Fig. 13 and 14) is given below (Fig. 5.31 and 5.32.).

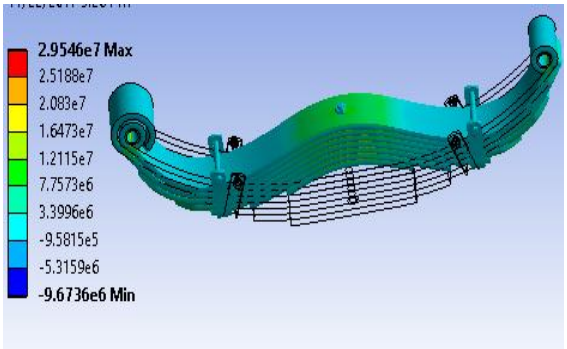


Figure 13 Steel EN 45 Parabolic leaf spring

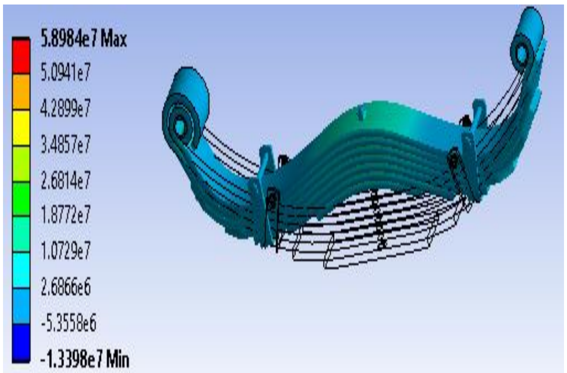


Figure 14 E-glass/epoxy parabolic leaf spring

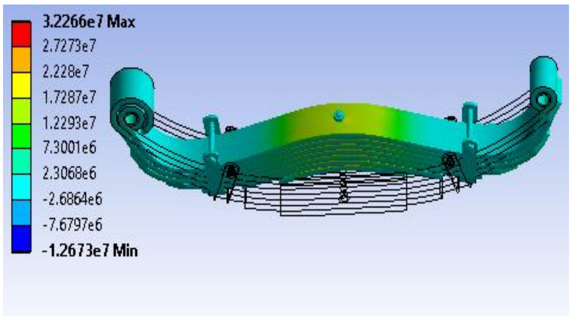


Figure 15 carbon/epoxy parabolic leaf spring

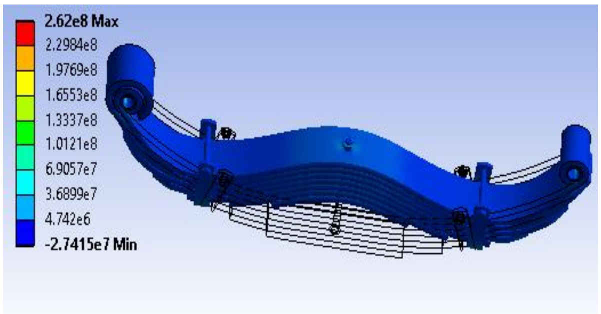


Figure 16 kevlar/epoxy parabolic leaf spring

Equivalent elastic strain

The results of this static structural analysis shows that the equivalent elastic strain of the laminated carbon/epoxy composite material leaf spring is the smallest one as compared to that of current steel EN 45 and the E-glass/epoxy leaf spring under the same load and boundary conditions. This implies that laminated carbon/epoxy composite material leaf spring has a better performance

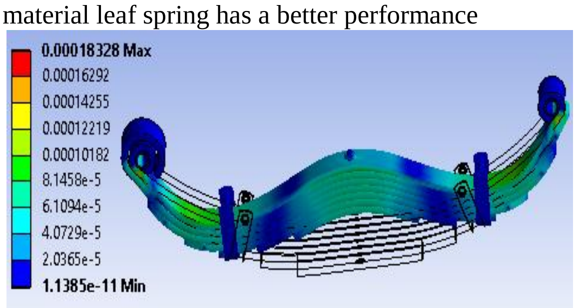


Figure 17 Steel EN 45 Parabolic leaf spring

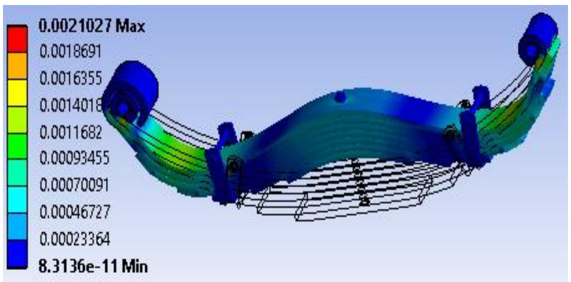


Figure 18 E-glass/epoxy parabolic leaf spring

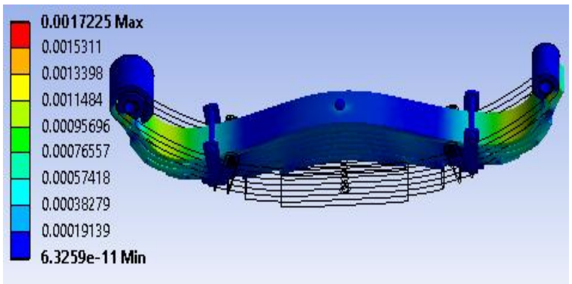


Figure 19 carbon/epoxy parabolic leaf spring

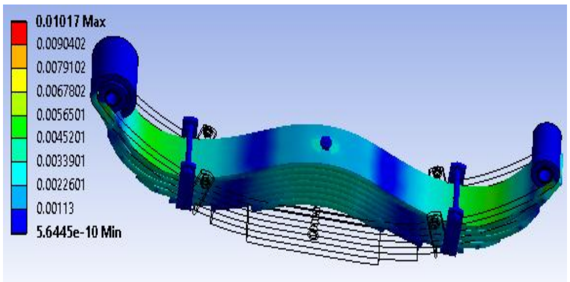


Figure 20 kevlar/epoxy parabolic leaf spring

II. STATIC ANALYSIS RESULTS

II.1 Load Verses Stress

In analysis process we can see that von-mises stress is at maximum towards the fixed end of the parabolic leaf spring, and the value is less than yield point value of steel EN45 and composites. So the design of parabolic leaf spring is safe. Figure no-6.1 shows the comparison of load verses stress of both steel and composite leaf springs. It shows the load is taken on the x-axis. Whereas the stress for steel and composite material is taken on y-axis. Observation of the graph indicates the difference level of stress of four different materials. The variation of stress against the load applied for the material under consideration. It is observed that the stresses linearly increase with the applied load maximum.

Table 6.1 Load vs Von-mises stress for various materials

VON MISES STRESS					
S. NO.	LOAD (N)	STEEL EN 45 (MPa)	E-GLASS/EPOXY (MPa)	CARBON/EPOXY (MPa)	KEVLAR/EPOXY (MPa)
1	2500	22.42	35.815	26.878	6.215
2	3000	26.9	42.977	32.253	7.16
3	3617.5	32.441	51.824	38.892	7.3
4	4000	35.871	57.3	43	8.11

5	4856	43.548	69.556	52.2	9.12

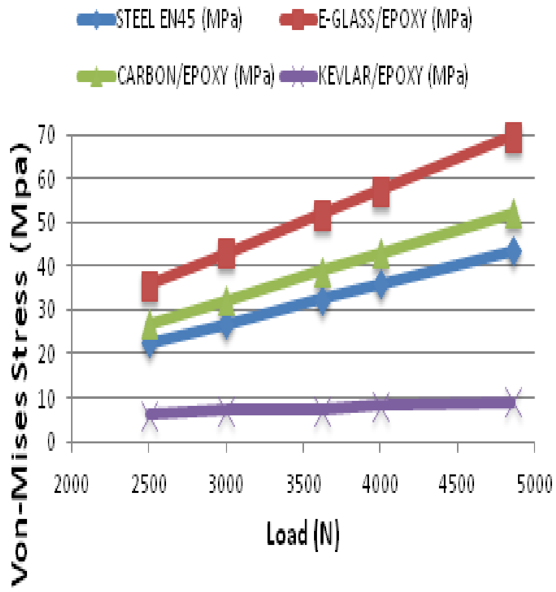


Figure 6.1 Load vs Von-mises Stresses graph for various materials

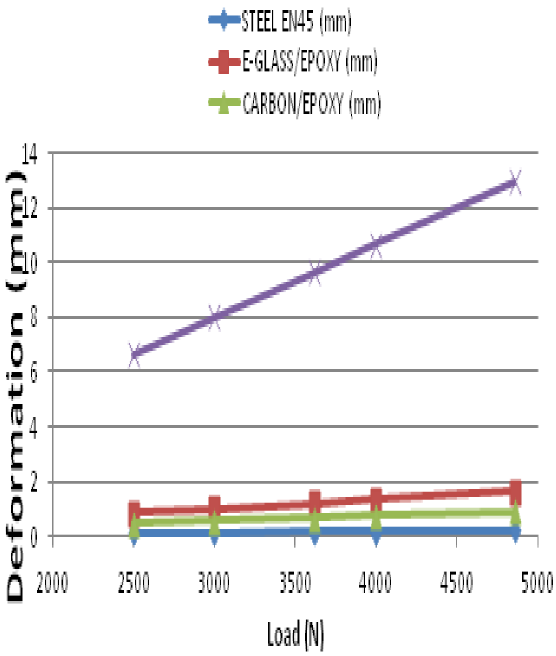


Figure- 6.2 Load vs Displacement graph for various materials

II.2 **Load Verses Deformation**

The rate of deformation is a function of the material properties, and the applied load depending on the magnitude of the applied stress and its duration. Figure-6.2 shows the comparison of applied load verses deformation of both conventional steel and composite leaf springs. It is found that the deformation in composite leaf springs is higher than steel leaf spring for the given loading conditions.

Table 6.2 Load vs Displacement for various materials

Deformation					
S. No.	Load (N)	Steel En 45 (Mm)	E-Glass /Epoxy (Mm)	Carbon /Epoxy (Mm)	Kevlar/Epoxy (Mm)
1	2500	0.129	0.85	0.482	6.67
2	3000	0.155	1.02	0.578	8.004
3	3617.5	0.187	1.23	0.698	9.652
4	4000	0.21	1.36	0.771	10.67
5	4856	0.25	1.65	0.936	12.956

II.3 Load verses maximum principal stress

According to maximum principal stress criterion theory, the ultimate tensile strength of the material is greater than maximum principal stress then the material of the parabolic leaf spring is safe. Figure-6.3 shows the deviation of principal stress is very low at minimum load condition and the deviation of principal stress increases when the magnitude of applied load increases.

Table 6.3 Load vs Maximum Principal Stresses for various materials

Maximum Principal Stress					
S. No.	Load (N)	Steel En45 (MPa)	E-Glass/Epoxy (MPa)	Carbon/Epoxy (MPa)	Kevlar/Epoxy (MPa)
1	2500	18.46	36.86	20.16	163.75
2	3000	22.159	44.238	24.2	196.5
3	3617.5	26.721	53.344	29.18	236.95
4	4000	29.54	58.98	32.67	262
5	4856	35.86	71.6	39.17	318.07

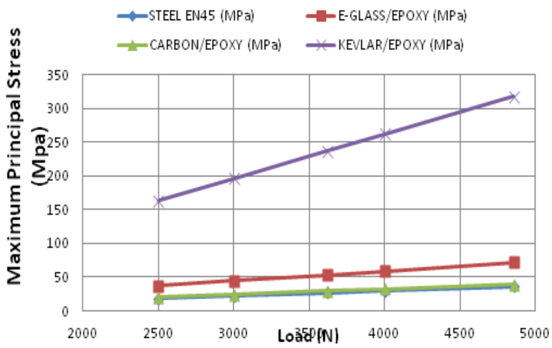


Figure- 6.3 Load vs Maximum Principal Stresses graph for various materials

II.4 Load verses Equivalent Elastic Strain

When a load is applies on an elastic body it leads to change the sape and size of the body. This deformation of a body depends upon the property of material. After removal of the load the body gets its original shape and size. This phenomena is knows as elastic strain. It is a kind of strain. The figure 6.5 shows the change in elastic strain while changing the load on different materials.

Table 6.4 Load vs Elastic Strain for various materials

Equivalent Elastic Strian					
S. No.	Load (N)	Steel En45	E-Glass/Epoxy	Carbon/Epoxy	Kevlar/Epoxy
1	2500	0.114	1.314	1.076	6.356
2	3000	0.137	1.577	1.291	7.627
3	3617.5	0.1657	1.9	1.5578	9.197
4	4000	0.1832	2.1	1.723	10.17
5	4856	0.222	2.55	2.09	12.374

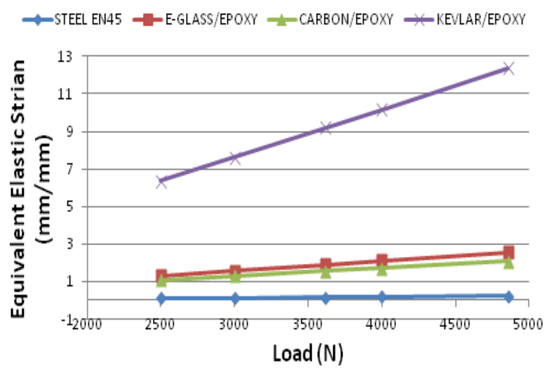


Figure- 6.4 Load vs Elastic Strain graph for various materials

2.5Comparison of weights

The bar chart have made below, which shows the comparisons in parabolic leaf spring weight in Kg by considering steel and composite material. Red bar is the weight of steel leaf spring and composite leaf springs. From the comparison of bar chart, it is clearly observed that by using the different composite material, weight is reduced in parabolic leaf spring. For steel leaf spring, weight is 8.828 kg and for composite leaf spring it is E-glass/epoxy weight is 3.7 kg, carbon epoxy weight is 2.37 kg, and Kevlar epoxy weight is 2.15 kg. Table 6.5 shows that using composites material instead off steel EN45 weight is saving.

Table 6.5 Percentage of weight savings for various materials

S. No.	Material	Weight	% weight saving
1	Steel EN45	32.6 kg	-
2	E-glass/epoxy	9.1673 kg	71.87%
3	Carbon epoxy	7.1245 kg	78.14%
4	Kevlar epoxy	5.8086 kg	82.18%

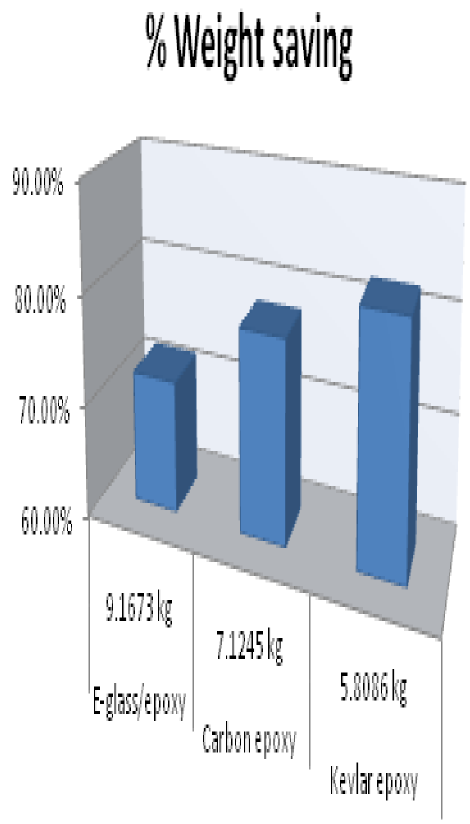


Figure- 6.5 Percentage of weight saving graph for various materials

III. CONCLUSION

A comparative study has been made between composites and steel EN45 parabolic leaf spring for deflection, strain energy and stresses. From the results, of static analysis we observed that the composite parabolic leaf spring is lighter and more economical than the conventional steel EN45 spring with similar design specifications. We observed that the weight of the composite parabolic leaf spring made of Kevlar/epoxy fibre, is reduced by 82.18% compared to spring made of steel EN45, by using material E-glass/epoxy Fibre it is reduced by 71.87% compared to spring made of steelEN45.by using material carbon/epoxy fibre it is reduced by 78.14% compared to spring made of steelEN45. Without any reduction on load carrying capacity and stiffness the weight of the parabolic spring was being reduced because of introduction of composite material.

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