Investigation of combined leaf helix for profound credence automobile propose

NEELURI SURESH [1],
Assistant professor of Mechanical Dept.,
Gurunanak group of Institutions,
Hyderabad, Telangana, India

KONDURU ASHOK[2]
Assistant professor of Mechanical Dept.,
Gurunanak group of Institutions,

Hyderabad, Telangana, India

ABSTRACT

The aim of the paper is to design and model a leaf spring according to the loads applied. Presently used material for leaf spring is Mild steel. In this paper we are going to design leaf spring for the materials Mild Steel and GFRP. For validating this design we are conducting FEA Structural Analysis is done on the leaf spring by using two different materials Mild Steel and GFRP. Modal Analysis is also done. Pro/Engineer software is used for modeling and ANSYS is used for analysis. Modal analysis is also done on the leaf spring to determine the natural frequencies of the leaf spring. A leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. Leaf Springs are long and narrow plates attached to the frame of a trailer that rest above or below the trailer's axle. There are mono leaf springs**, or single-leaf springs, that consist of simply one plate of spring steel. These are usually thick in the middle and taper out toward the end, and they don't typically offer too much strength and suspension for towed vehicles. Drivers looking to tow heavier loads typically use** multi leaf springs**, which consist of several leaf springs of varying length stacked on top of each other. The shorter the leaf spring, the closer to the bottom it will be, giving it the same semielliptical shape a single leaf spring gets from being thicker in the middle.Springs will fail from fatigue caused by the repeated flexing of the spring.**

Keywords:*FEA[1],GFRP[2],strength[3],varying[4]*

1. INTRODUCTION

Originally 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 advantages of leaf spring over helical spring are that the end of the springs may be guided along a definite path.Sometimes referred to as a semi-elliptical spring or cart spring, it takes the form of a slender arc-shaped length of spring steel of rectangular cross-section. The center of the arc provides location for the axle, while tie holes are provided at either end for attaching to the vehicle body. For very heavy vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions. While the interleaf friction provides a damping action, it is not well controlled and results in stiction in the motion of the suspension. For this reason manufacturers have experimented with mono-leaf springs.

Fig: 1.A traditional leaf spring arrangement.

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.For the purpose of analysis, the leaves are divided into two groups namely master leaf along with graduated-length leaves forming one group and extra full-length leaves forming the other. The following notations are used in the analysis:

$n_{f=}$ number of extra full-length leaves

n_g =number of graduated-length leaves including master leaf

n= total number of leaves

b= width of each leaf (mm)

t= thickness of each leaf (mm)

L=length of the cantilever or half the length of semi- elliptic spring (mm)

F= force applied at the end of the spring (N)

F_f =portion of F taken by the extra full-length leaves (N)

F_g =portion of F taken by the graduated-length leaves (N)

2. INTRODUCTION TO COMPOSITES

A composite material is described in this chap-ter as a material composed of two or more distinct phases and the interfaces between them. At a macroscopic scale, the phases are indistinguishable, but at some microscopic scales, the phases are clearly separate, and each phase exhibits the characteristics of the pure material. In this chapter, we are only describing the characteristics, analysis, and processing of high-performance structural composite materials. This special class of composites always consists of are in forcing gphase and a matrix phase. There in forcing phase is typically a graphite, glass, ceramic, or polymer fiber, and the matrix is typically a polymer, but may also be ceramic or metal. The fibers provide strength and stiff-ness to the composite component, while the matrix serves to bind the reinforcements together, distribute mechani-cal loads through the part, provide a means to process the material into a net shape part, and provide the primary environmental resistance of the composite component. In Fig. 1, we can see the distinct cross section of graphite fibers in an epoxy matrix.

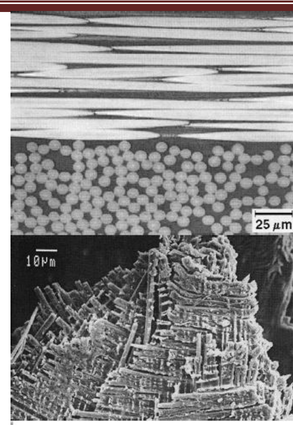


FIGURE 2 Cross Section Of A Graphite fiber–Reinforced Epoxypolymer.

2.1.Constituent materials

A composite can contain several chemical substances. There are additives, for example, to improve processability and serviceability. However, the two principal constituents that are always present in advanced composites are the ma-trix and the reinforcement. Generally, they are combined without chemical reaction and form separate and distinct phases. Ideally, the reinforcement is uniformly distributed throughout the matrix phase. The combination of the prop-erties of the reinforcement, the form of the reinforcement, the amount of reinforcement, and matrix properties gives the composite its characteristic properties. The matrix phase contributes to several characteristics of the composite. The matrix provides some protectionforthereinforcementfromdeleteriousenvironmentalcon-ditions such as harmful chemicals. The matrix plays an important role in determining the physical and thermo-physical properties of the composite. In continuous fila-ment, unidirectionally reinforced composites, the proper-ties transverse to the filaments are strongly influenced by the properties of the matrix. The distribution of the ap-plied load throughout the composite is influenced by the properties of the matrix. Table I shows typical values of selected properties of common matrix materials. The properties are tensile strength, F ^{tu}, Youngs modulus, E^{t}, total strain (or strain-to-failure), ε^{t} , coefficient of thermal expansion, α, and specific gravity. It can be seen that there is a wide varia-tion in these values between types of matrix materials.

TABLE I Matrix Materials

Property	Epoxy	Polyimide	Polyester	Polysulfone	Polyether ether ketone	Al 2024	Ti 6-4
E^{tu} (MPa)	6.2–103	90	21–69	69	69	414	924
E^{t} (GPa)	2.8–3.4	2.8	3.4–5.6	2.8	3.6	72	110
ε^{t} (%)	4.5	7–9	0.5–5.0	50–100	2.0	10	8
α (10^{-6} m m^{-1} K^{-1})	0.56	0.51	0.4–0.7	0.56	0.5	24	9.6
Specific gravity	1.20	1.43	1.1–1.4	1.24	1.2	2.77	4.43

2.2. properties

Physical Properties	**Metric**
Density	1.44 g/cc
Mechanical Properties	**Metric**
Tensile Strength, Ultimate	3000 MPa
	3620 MPa
Tenacity	2.08 N/tex
Elongation at Break	2.40 %

Tensile Modulus	112 GPa
Poissons Ratio	0.360

High-strength glass, carbon or other advanced fibers are used in applications requiring greater strength and lower weight. High-strength glass is generally known as S-type glass in the United States, R-glass in Europe and T-glass in Japan. S-glass was originally developed for military applications in the 1960s, and a lower cost version, S-2 glass, was later developed for commercial applications.High-strength glass has appreciably higher amounts of silica oxide, aluminum oxide and magnesium oxide than E-glass. S-2 glass is approximately 40-70% stronger than E-glass.

2.3.Thermal Properties

As temperatures increase, glass fibers lose tensile strength. C-glass performs poorly in high-temperature applications and should not be used for them. While E-glass and S-type glass lose about 50% of their tensile strength at 1000º F, their strength at high temperatures is still considered good.

Another temperature-related property to consider is the coefficient of thermal expansion (CTE). Fibers with a high CTE expand more as temperatures increase. S-type glass has a much lower CTE than either E-glass or C-glass. Having a similar CTE in both the fiber and resin prevents problems due to different thermal expansion rates.

2.4. Fiber Cost

Cost often is the deciding factor in choosing an appropriate glass type. It is priced based on quantity, filament diameter and other factors, bulk E-glass roving typically less expensive per pound, than C-glass. S-2 glass roving is typically more expensive. Product designers must weigh the benefits of advanced glass fibers against their higher cost in order to make the best selection for their application.

3. DESIGN OF LEAF SPRING CALCULATIONS FOR RADIUS AND LENGTHS OF LEAVES

Specifications of Viking

When n=10, Rear suspension

Number of leaf springs = 4

Overall length of the spring = $2L_1$ = 137.2cm = 1372mm

Width of leaves = 76.2 = 80mm

Number of full length leaves = 2 = n_f

Number of graduated leaves = 8 = N_g

Number of springs = 10 ($Ng+N_f$)

Center load = 2W =115 tones = 11500kg

$$2W = 11500 \times 9.8 = 112700N$$

$$2W = 112700/4 = 28175N$$

$$2W = \frac{total\ load}{no\ of\ springs} = 28175N$$

$$W = 14087.5N$$

3.1 material used for leaf spring - mild steel

Bending stress σ_b = 21600 psi = 149 N/mm^2

Spring is simply supported beam

Width length = 2L

Central load =2W

Bending moment = M =W$\times L$ $= 9664025$

Section modulus Z = bt^2/6

b= width of leaves

t = thickness of leaves = $8Dt^2/6$

bending stress = $\sigma = \frac{M}{Z} = \frac{6wL}{nbt^2}$

n = no of full length leaves &graduated leaves

L = 686mm

σ = 149 N/mm²

n = 10

$$\sigma = \frac{6wL}{nbt^2}$$

$$149 = \frac{6\times14087.5\times686}{10\times80t^2} = \frac{57984150}{800t^2} = t^2 = 486.44; t = 20.133 = 22\text{mm}$$

Deflection for both full length and graduated leaves

$$\delta = \frac{4WL^3}{n\epsilon bt^3} = \frac{4\times14087.5\times686^3}{10\times210\times10^3\times80\times22^3} = \frac{18191406035600}{1788864000000} = 10.169 \text{ mm}$$

Deflection for graduated leafs

$$\delta_G = \frac{6WL^3}{N_G\epsilon bt^3} = \frac{6\times14087.5\times686^3}{8\times210\times10^3\times80\times22^3} \quad \frac{27287109053400}{1431091200000} = 19.06mm$$

For same deflection in stress in uniform x- section leaves

$$\sigma_f = \frac{3}{2}\sigma_G$$

Load for graduated leavers $W_G = (\frac{2n_G}{3n_F+2n_G})W$

W = total load on the spring

$W_G = load\ taken\ up\ by\ graduated\ leaves$

$W_F = load\ taken\ up\ by\ full\ length\ leaves$

$$w_G = \left(\frac{2\times8}{3\times2+2\times8}\right)14087.5 = \frac{16}{22}\times14087.5$$

$$w_G = 10245.45\text{N}$$

$$W = W_G + W_F$$

$$W_F = 3842.05\text{N}$$

3.1.1 Bending stress for full length leaves

$$\sigma_F = \frac{18WL}{bt^2(2n_G+3n_F)} = \frac{18\times14087.5\times686}{80\times22^2\times(2\times8+3\times2)} = \frac{173952450}{851840} = 204.20\text{N/mm}^2$$

$$\boldsymbol{\sigma_G} = \frac{\mathbf{12wL}}{\mathbf{bt^2(2n_G+3n_F)}} = \frac{\mathbf{12\times14087.5\times686}}{\mathbf{80\times22^2\times22}} = \frac{\mathbf{115968300}}{\mathbf{851840}} = \mathbf{136.13}\text{ N/mm}^2$$

$\boldsymbol{\delta_F}$ = Deflection of full length leaves

$$\boldsymbol{\delta_F} = \frac{\mathbf{12wL^3}}{\mathbf{\epsilon bt^3(2n_G+3n_F)}} = \frac{\mathbf{12\times14087.5\times686^3}}{\mathbf{210\times10^3\times80\times22^3\times22}} = \frac{\mathbf{54574218106800}}{\mathbf{3935500800000}} = 13.86\text{mm}$$

Equalized stress in spring leavers (nipping)

C = nip

C = $\delta_G - \delta_F = 19.06 - 13.86 = 5.2$mm

C = $\frac{2wL^3}{n\epsilon bt^3}$; $\delta_F \frac{4L^3}{n_F\epsilon bt^3}\times\frac{Wb}{2}$; $\delta_G = \frac{6L^3}{n_G\epsilon bt^3}\times\frac{Wb}{2}$

Load on clip bolts (wb) required to close the gap is determined by fact that gap is equal to intial deflection.

C = $\delta_G - \delta_F$

$$W_b = \frac{2n_F\times n_G\times W}{n(2n_{G+\_}3n_F)} = \frac{2\times2\times8\times14087.5}{10\times22} = \frac{450800}{220} = 2049.09\text{N/mm}^2$$

3.1.2 Length of Leaf Springs

$2L_1 = overall\ length\ of\ spring$

Ineffective length l = width of band/distance between centers of u-tubes

$n_F = no\ of\ full\ length\ leaves$

$n_G = no\ of\ graduated\ leaves = n_G + n_F$

Effective lengths 2L = $2L_1 - \frac{2}{3}l$ (when u bolts are used)

$L_1 = 1372$mm

L = 300 mm (assume)

2L = 1372-$\frac{2}{3} \times 300 = 1172$mm

It may be noted that when there is only one full length leaf (master leaf only) then the no of leaves to be cut will be n and when there are two full length leaves (including one master leaf) then the no of leaves to be cut will be (n-1) if a leaf spring has has two full length leaves then the length of leaves is obtained as follows

Length of smallest leaf = $\frac{effective\ length}{n-1} + ineffective\ length$

n= 12

= $\frac{1172}{9} + 300$

= 430.22mm

Length of next leaf = $\frac{effective\ length}{n-1} \times 2 + ineffective\ length$

= $\frac{1172}{9} \times 2 + 300$

= 560.44mm

Length of 3rd leaf = $\frac{1172}{9} \times 3 + 300 = 690.66$mm

Length of 4th leaf = $\frac{1172}{9} \times 4 + 300 = 820.88$mm

Length of 5th leaf = $\frac{1172}{9} \times 5 + 300 = 951.1$mm

Length of 6th leaf = $\frac{1172}{9} \times 6 + 300 = 1081.32$mm

Length of 7th leaf = $\frac{1172}{9} \times 7 + 300 = 1211.54$mm

Length of 8th leaf = $\frac{1172}{9} \times 8 + 300 = 1341.76$mm

Length of 9th leaf = $\frac{1172}{9} \times 9 + 300 = 1471.98$mm

The nth leaf will be the master leaf and it is of full length since the master leaf has eyes on both sides therefore

Length of master leaf = $2L_1 + \pi(d + t) \times 2$

d = Inside diameter of eye

t = thickness of master leaf

d =22mm

t = 1372+π(22+22)$\times$ 2 = 1648.46mm

3.1.3 Radius of curvature

The approximate relation between the radius of curvature (R) and camber (Y) of spring is given by R = $\frac{{L_1}^2}{2y}$

$L_1 = half\ span\ of\ spring$

Y = δ (the maximum deflection of spring is equal to camber(y) of spring)

$L_1 = \frac{1372}{2} = 686mm\ ;\ \delta = 10.169mm$

$$R = \frac{686^2}{2\times 10.169} \quad \frac{470596}{20.338} = 23138.75\text{mm}$$

RADIUS VALUES OF LEAVES

1 =23336.75mm
2 = 23314.75mm
3 = 23292.75mm
4 = 23270.75mm
5 = 23248.75mm
6 = 23226.75mm
7 = 23204.75mm
8 = 23182.75mm
9 = 23160.75mm
10

4. 2D DRAWING

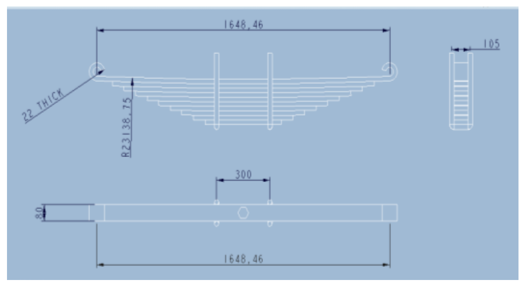


Fig:3.2d drawing

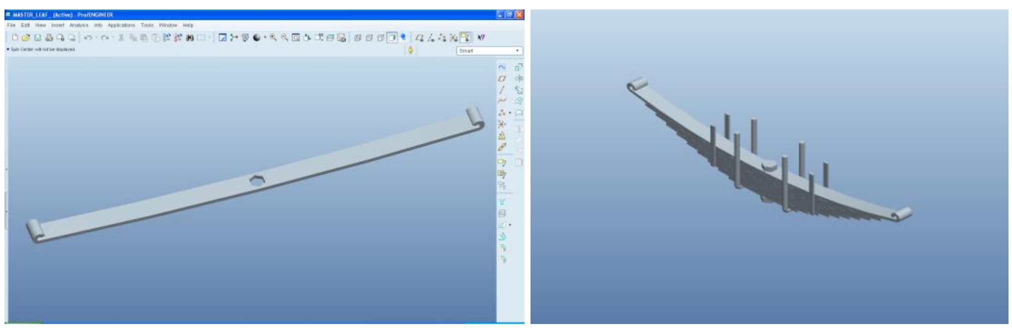


Fig: 4.model of leaf spring

CASE 1 – When thickness of leaves changes from 7 mm to 10mm with the interval of 1mm, the lengths, radius of curvatures, rotation angles are calculated.
Incase I, the thickness only varies, the remaining geometric properties are common

Case 1 (a): Thickness of leaves = 7mm

The below geometric properties are common to case 1 (b) case 1 (c) Case 1 (d) camber = 80mm
Span = 1372mm
Thickness of leaves = 16mm
Number of leaves = 10
Number of full length leaves n_F = 2
Number of graduated length leaves n_G = 8
Width = 80mm
Ineffective length = 300mm
Eye Diameter = 22mm

Bolt Diameter = 10mm

By using above formulae the following table is resulted

TABLE 3. LENGTH OF LEAVES WHEN FOR STEEL

Leaf Number	Full Leaf length (mm)	Half leaf Length (mm)	Radius of Curvature (mm)
10	1648.46	824.23	23138.75
9	1471.98	735.99	23160.75
8	1341.76	670.88	23182.75
7	1211.54	605.77	23204.75
6	1081.32	540.66	23226.75
5	951.1	475.55	23248.75
4	820.88	410.44	23270.75
3	690.66	345.33	23292.75
2	560.44	280.22	23314.75
1	430.22	215.11	23336.75

Model Calculation for leaf number 10

Span $2L_I$ = 1372mm

Number of leaver = n = 10

Ineffective length = 1 = 30mm

Effective length = E.L = 2 L_I – (2/3)1

So effective length = 1372 – (2/3) 300 = 1672 mm

So length of leaf number 10 = $\frac{\text{Effective length}}{\text{n-1}}$ X (n-1) + Ineffective length

$\frac{1672}{9}$ X 9 + 300 = 1471.98mm

TABLE 4. LENGTH OF LEAVES FOR KEVLOR

Leaf Number	Full Leaf length (mm)	Half leaf Length (mm)	Radius of Curvature (mm)
10	1648.46	824.23	3198.91
9	1471.98	735.99	3214.91
8	1341.76	670.88	3230.91
7	1211.54	605.77	3246.91
6	1081.32	540.66	3262.91
5	951.1	475.55	3278.91
4	820.88	410.44	3294.91
3	690.66	345.33	3310.91
2	560.44	280.22	3326.91
1	430.22	215.11	3342.91

TABLE 5. LENGTH OF LEAVES FOR S2-GLASS

Leaf Number	Full Leaf length (mm)	Half leaf Length (mm)	Radius of Curvature (mm)
10	1648.46	824.23	2500.91
9	1471.98	735.99	2516.91
8	1341.76	670.88	2532.91
7	1211.54	605.77	2548.91
6	1081.32	540.66	2564.91
5	951.1	475.55	2580.91
4	820.88	410.44	2596.91
3	690.66	345.33	2612.91
2	560.44	280.22	2628.91
1	430.22	215.11	2644.91

5. STRUCTURAL AND FREQUENCY ANALYSIS OF LEAF SPRING PRESSURE – 1.08N/mm^2 5.1 mild steel

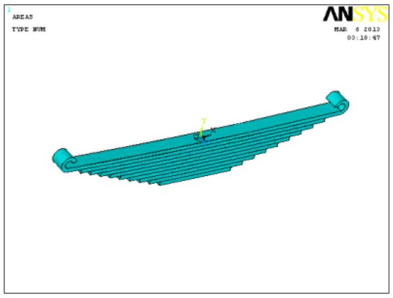


Fig:5.Imported Model from Pro/Engineer

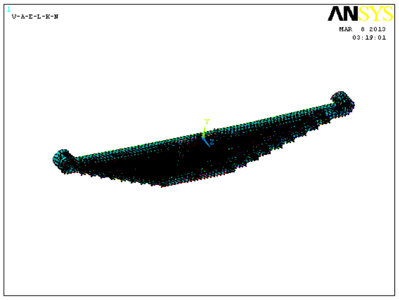


Fig:6.Meshed Model

Element Type: Solid 20 node 95
Material Properties: Youngs Modulus (EX) : 205000N/mm^2
Poissons Ratio (PRXY) : 0.29
Density : 0.000007850 kg/mm^3

Loads
Pressure – 1.809 N/mm^2

Solution

Solution – Solve – Current LS – ok

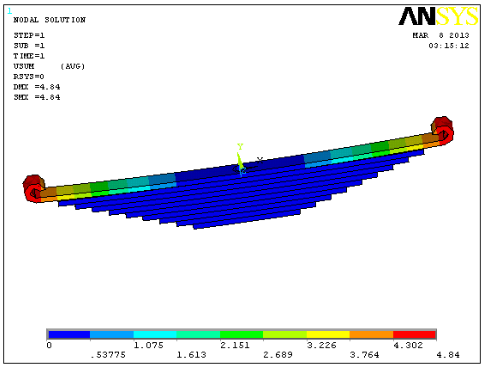


Fig:7.Displacement Vector Sum

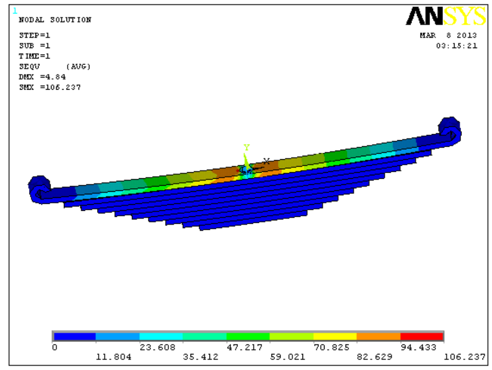


Fig:8.Von Mises Stress

GFRP

Element Type: Solid 20 node 95

Material Properties: Youngs Modulus (EX) : 35000N/mm^2

Poissons Ratio (PRXY) : 0.3

Density : 0.000002 kg/mm^3

Solution

Solution – Solve – Current LS – ok

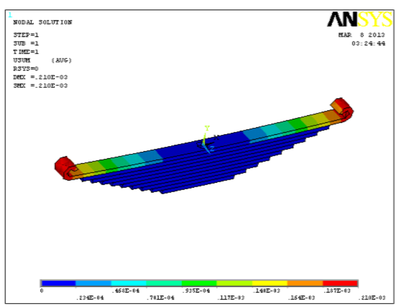


Fig:9.Displacement Vector Sum

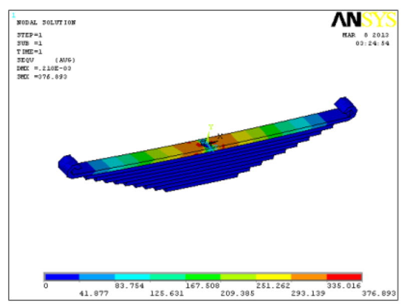


Fig:10.von Mises Stress

PRESSURE – 0.45 N/mm^2 MILD STEEL

Loads

Pressure – 0.45 N/mm^2

Solution

Solution – Solve – Current LS – ok

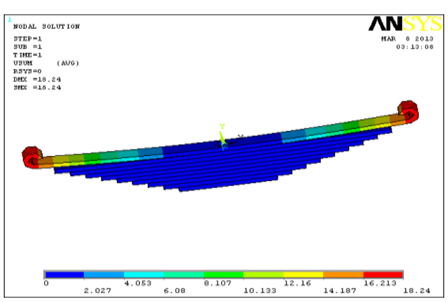


Fig: 11.Displacement Vector Sum

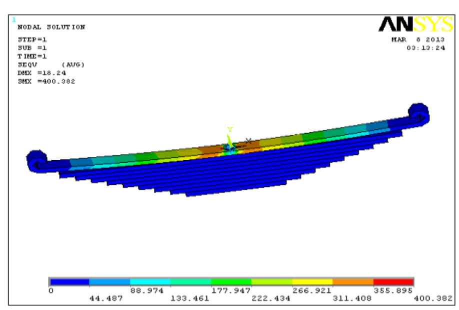
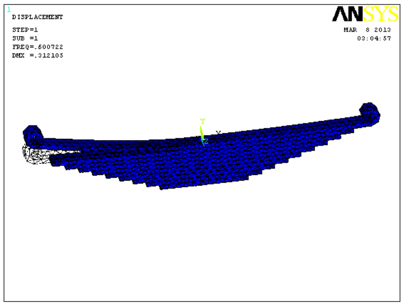
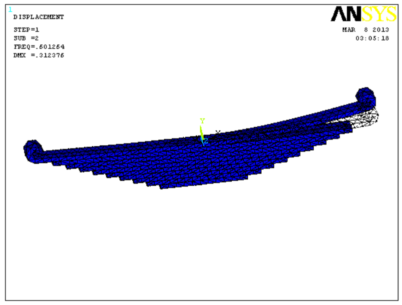
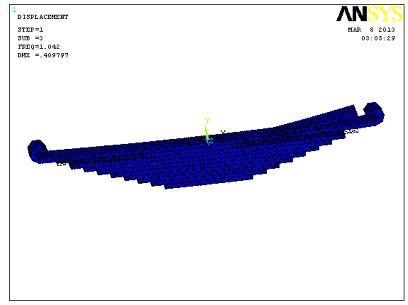


Fig:12.Von Mises Stress

Mode 1 **Mode 2** **Mode 3**

GFRP

Solution

Solution – Solve – Current LS – ok

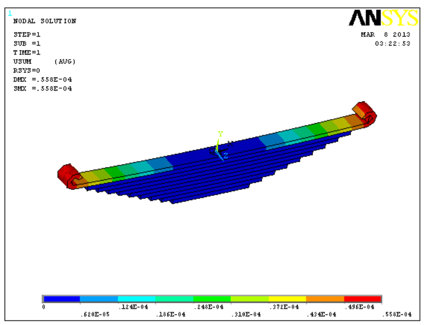


Fig:13.Displacement Vector Sum

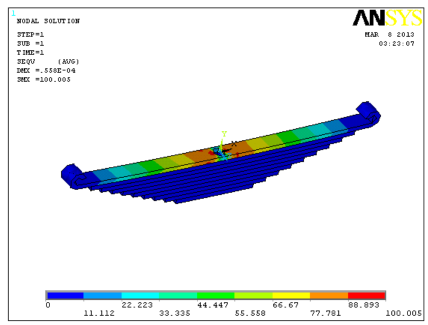


Fig:14.von Mises Stress

6. RESULTS AND DISCUSSIONS WEIGHT COMPARISON

	WEIGHT (Kg)
MILD STEEL	141.225
GFRP	35.98

PRESSURE – 1.809N/mm² STRUCTURAL ANALYSIS

	STEEL	GFRP
DISPLACEMENT (mm)	18.24	$0.21e^{-3}$
STRESS (N/mm²)	400.382	376.893

MODAL ANALYSIS

		STEEL	GFRP
MODE1	**Hz**	0.6	538.949
	Deflection (mm)	0.3121	0.951104
MODE 2	**Hz**	0.6012	539.413
	Deflection (mm)	0.3123	0.951
MODE 3	**Hz**	1.042	935.354
	Deflection (mm)	0.409	1.254

PRESSURE – 0.45 N/mm² STRUCTURAL ANALYSIS

	STEEL	GFRP
DISPLACEMENT (mm)	4.84	$0.558e^{-4}$
STRESS (N/mm²)	106.237	100.005

MODAL ANALYSIS

		STEEL	GFRP
MODE1	Hz	0.6	538.949
	Deflection (mm)	0.3121	0.951104
MODE 2	Hz	0.6012	539.413
	Deflection (mm)	0.3123	0.951
MODE 3	Hz	1.042	935.354
	Deflection (mm)	0.409	1.258

7. CONCLUSION

In this paper, a leaf spring is designed for Viking vehicle. The data is collected from net for the specifications of the model. The leaf spring is designed for the load of 14087.5N. Theoretical calculations have been calculated for leaf spring dimensions at different cases like varying thickness, camber, span and no. of leaves by mathematical approach. In this paper, analysis has been done by taking materials steel and GFRP. Structural and modal analysis is conducted on total assembly of leaf. The results show: The stresses in the composite leaf spring of design are much lower than that of the allowable stress.

1. The strength to weight ratio is higher for composite leaf spring than conventional steel spring with similar design.
2. Weight of the composite spring by GFRP is very less than steel. For less weight of the spring mechanical efficiency will be increased.

In this paper it can be concluded that using composite GFRP is advantageous.

8. BIBILOGRAPHY

1 MARK'S Calculations for mechanical design by Thomas H. Brown
2 Machine Design by R.S. KHURMI, J.K. GUPTA
3 Mechanical Engineering Design by Budynas–Nisbett.
4 Mechanics of Solids by T.J.Prabhu.
5 Fundamentals of Materials Science and Engineering by William D. Callister
6 www.google.com