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Static and dynamic analysis of composite leaf spring

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Abstract— Leaf springs are generally used for suspension in automobiles leaf springs are long and narrow plates attached to the above or below to the wheel axle leaf spring prevents the transmitting of road shocks to the vehicle components, helps for safe and comfortable riding to safeguard the occupants from road shocks it is necessary to determine the maximum safe stress and deflection. The objective is to find the optimum stresses and deformation of leaf spring by applying static and dynamic loads on it. Different materials with different mechanical properties are considered for the structural static analysis. In the present work they are designed by considering dynamic and static loads on automobiles. Leaf spring model was generated by using solid works 2016. With three different thickness 6mm 5mm 4mm and analysis was done using Ansys 16.0 workbench with three kinds of materials such as E-glass epoxy, Kevlar-49 and Al-Si-Mg composite. Static and dynamic analysis is carried out at 3342.5N stress, strain and total deformation was found. By the following results Kevlar-49 consist optimum frequency, stresses, total deformation, and weight reduction factor for 5mm thickness when compared to other materials such as E-glass epoxy and Al-Si-Mg composite.

Keywords: -leaf spring Solidworks 2016 Software. Static and dynamic analysis

I. INTRODUCTION

A leaf spring is generally used in suspension of automobiles. Originally called a laminated or cart spring, The leaf springs are arc shaped length. For heavy vehicles leas springs are piled with many layers with gradual and full length leaves .leaf springs are attached to the axle above or below. They serve damping as well as spring functions The friction between leafs provide damping action as it is not controlled well, manufacturers prefers mono leaf springs.

A leaf spring can be attached to the frame or one(front) end is attached to the frame and other(rare) end is attached to the shackle with a short swinging arm .and is fixed above or below the axle. The shackle takes the tendency of leaf spring to elongate when compressed .Leaf springs are in concave shape, called a spoon end. Leaf springs are commonly used in automobiles

II. LITERATURE SURVEY

[1] G.h. Goud and E. V. Goud explained analysis and modelling of leaf spring, used in vehicle suspension system. By modal and structural analysis determines safe stress and with stand loads study the behavior of the structures under required conditions. In the present work analyze the required safe loads of the leaf spring, this will indicate the safe drive and comfortable speeds is possible. In this Mahindra vehicle leaf spring is chosen to study. By finite element analysis safe stress and loads at which vehicle can with stand can be determined. Static and dynamic analysis is performed to find stress by using Ansys software and the results are compared with bending stresses calculated in mathematical analysis at required loads..It is observed that the inner eye end of lesf spring experienced more stresses the selected material should had good toughness, ductility and resilience to avoid from failure.

[2] Davood Rezaei and Mahmood M. Shokrieh a leaf spring used in the suspension of automobiles using Ansys 16,0 software. Theoretical results are compared with analytical results. Main consideration is to optimization of spring weight and thickness, capable of carrying given static and modal external forces with out failure.composite materials is made from E-glass epoxy, Kevlar-49 and Al-Si-Mg composite.

III. COMPOSITE LEAF SPRING

In automobiles leaf springs are widely used. A leaf spring should had good damping capacity, capacity to with stand loads. In automobiles leaf spring are used in suspension, Weight transfer is affected mainly by four factors: the centre distance between wheels, base of the wheels in braking, or width of the track in cornering.

Fig1leaf spring

Un-sprung weight transfer: is calculated by subtracting the sprung weight of the vehicle in gross weight. Un-sprung weight is the weight of all the components that are not supported to the leaf spring, they are wheels, brakes, spindles and other components. It is assumed that these components are connected to the automobile.

Sprung weight transfer: it is calculated by subtracting the Un-sprung weight in gross weight of the automobile. Sprung weight is the weight of the automobile components that are supported by leaf spring. Sprung weight transfer is the weight of the vehicle above (supported) on the leaf spring. In order to calculate sprung weight, requires the rear and front roll center heights and the sprung center of gravity.

JACKING FORCES: are the sum of the vertical force components experienced by the suspension links. More jacking force experienced due to the roll height center.

COMPOSITE MATERIALS: composite materials are formed by combining two or more materials in layers, in order to exhibit best qualities of both the materials they have good corrosion resistance, damping capacity, stiffness, strength, fatigue life, thermal insulation, wear resistance, thermal conductivity, acoustical insulation and weight. Reinforced materials are in the form of fibres, matrix materials may be continuous.

IV. SOLID WORKS 2016 Software

Solid works is a mechanical design automation software is a feature-based, can develop 3-d solid models with or without utilizing automatic or user defined relations to design. Parameters can be either numeric parameters, such as circle diameters or line lengths, or geometric parameters, such as vertical, tangent, parallel, concentric or horizontal. It had the advantage of familiar Microsoft Windows graphical user interface.

V. ANSYS 16.0 SOFTWARE

Static analysis: Static structural analysis is performed when the bodies are in rest position. A static structural analysis can be non-linear or linear. A static structural analysis calculates the effect of loading in steady conditions on the structure. A static analysis is used to determine stresses, strains, displacements, forces in components caused by loads that are not included damping and inertia.

Modal analysis: Modal analysis is performed when the structure or components are in motion. Modal analysis is used to determine mode shapes of structures and natural frequencies of automobile components or structure. The natural frequency depends on shaft diameter, hallow shaft thickness, specific stiffness and the length.

VI. CALCULATIONS OF DEFLECTION AND BENDING STRESS

Step (1): Material of leaf spring

Composition of materials: kevlar-49, Al-Si-Mg, E-glass epoxy

Step (2): Basic data of vehicle

Gross vehicle weight: 2150kg

Un sprung weight: 240 kg,

Factor of safety taken: 1.4,

Acceleration due to gravity: 10m/s^2,

Wheel track (L): 1346 mm.

Step (3): Basic requirement of load

Total Weight (W) =1910*10*1.4 =26740N

Load is equally distributed to four wheels (each wheel consists one leaf spring)

So, load acting on each wheel = 26740/4 = 6685N.

Step (4): Calculation of dimensions of leaf spring

Thickness of Leafs (t) = 6mm, 5mm, 4mm

The effective length of leaf for this design is given by,

Wheel track of (L) = 1120/ (4) = 280 mm,

In this design there are no graduated leaves so (n_g)= 8,

No. Full length leafs (n_f) = 2,

Total Number of Leafs (n) =10

Width of leaf spring (b) = 50 mm.

Step (5): Calculation of the load and effective length of leaf spring

Consider the leaf spring. The load is acting on both eye ends of leaf spring; the load acting on the leaf spring is divided into two equal loads.

Load acting on leaf spring

W= 6685/2 = 3342.5N.

Step (6): Calculations of the stress generated in the leaf spring are as under Material of the leaf spring is

Bending stress generated in the leaf spring is as under:

Thickness:-6mm

σ_1=($6WL)/n\cdot b\cdot t^2$ =(6×3342.5×280)/10×50×6^2 = 311.96 N/mm^2

Thickness:-5mm

σ_2 = $(6WL)/n\cdot b\cdot t^2$ = (6×3342.5×280)/10×50×5^2 = 449.232 N/mm^2

Thickness:-4mm

σ_3= $(6WL)/ n\cdot b\cdot t^2$ =(6×3342.5×280)/10×50×4^2 =701.925 N/mm^2

As the stress generated on the leaf spring is lower than the allowable stress

Step (7): deflection of leaf spring are as under

Kevlar-49

Thickness:-6mm

$\delta k_1 = (4WL^3)/n\,E\cdot b\cdot t^3 \;=(4\times3342.5\times280)/10\times112400\times50\times6^3 \;=24.177\text{mm}$

Thickness:-5mm

$\delta k_2 = (4WL^3)/n\,E\cdot b\cdot t^3 \;=(4\times3342.5\times280)/10\times112400\times50\times5^3 \;=41.77\text{mm}$

Thickness:-4mm

$\delta k_3 = (4WL^3)/n\,E\cdot b\cdot t^3 \;=(4\times3342.5\times280)/10\times112400\times50\times4^3 \;=81.59\text{mm}$

Al-Si-Mg Composite:-

Thickness:-6mm

$\delta Al_1 = (4WL^3)/n\,E\cdot b\cdot t^3 =(4\times3342.5\times280)/10\times69000\times50\times6^3 \;=39.385\text{mm}$

Thickness:-5mm

$\delta\ Al_2 = (4WL^3)/n\,E\cdot b\cdot t^3 = 4\times3342.5\times280\ 10\times69000\times50\times5^3 \quad =68.05\text{mm}$

Thickness:-4mm

$\delta Al_3 = (4WL^3)/n\,E\cdot b\cdot t^3 \;= 4\times3342.5\times280\ 10\times69000\times50\times4^3 \quad =132.92\text{mm}$

E-glass epoxy:-

Thickness;-6mm

$\delta E_1 = (4WL^3)/n\,E\cdot b\cdot t^3 = (4\times3342.5\times280)/10\times76000\times50\times6^3 =35.757\text{mm}$

Thickness:-5mm

$\delta E_2 = (4WL^3)/n\,E\cdot b\cdot t^3 \;=(4\times3342.5\times280)/10\times76000\times50\times5^3 \;=61.78\text{mm}$

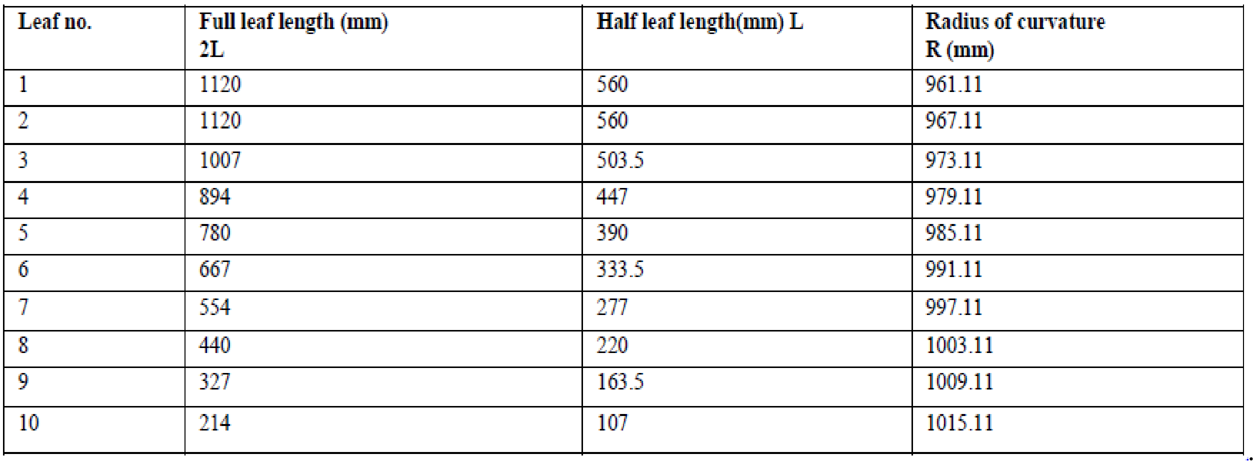
Thickness:-4mm

$\delta E_3 = (4WL^3)/\ n\,E\cdot b\cdot t^3 =(4\times3342.5\times280)/10\times76000\times50\times4^3 =120.681\text{mm}$

THICKNESS (mm)	TOTAL DEFORMATION(mm)			BENDING STRESS (σ) (N/mm^2)
	KEVLAR 49	AL-Si-Mg	E-GLASS EPOXY	
4 mm	81.59	132.92	120.68	701.92
5 mm	41.77	68.05	61.78	449.23
6 mm	24.17	39.38	35.75	311.96

Table 1.theoretical calculations for leaf spring

DESIGN PARAMETERS OF LEAF SPRING:



Leaf no.	Full leaf length (mm) 2L	Half leaf length(mm) L	Radius of curvature R (mm)
1	1120	560	961.11
2	1120	560	967.11
3	1007	503.5	973.11
4	894	447	979.11
5	780	390	985.11
6	667	333.5	991.11
7	554	277	997.11
8	440	220	1003.11
9	327	163.5	1009.11
10	214	107	1015.11

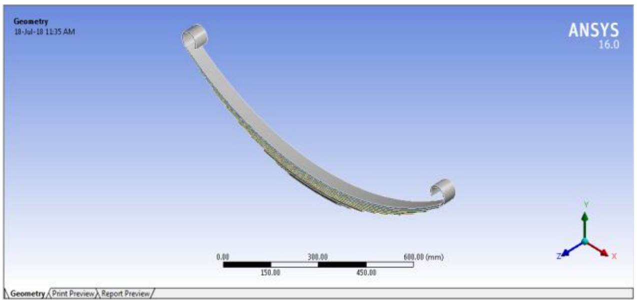
Table 2.design parameters of leaf spring

VII. ANALYSIS OF LEAF SPRING

STATIC STRUCTURAL ANALYSIS: For 5mm thickness

Leaf spring of 5mm thickness

Model


Geometry
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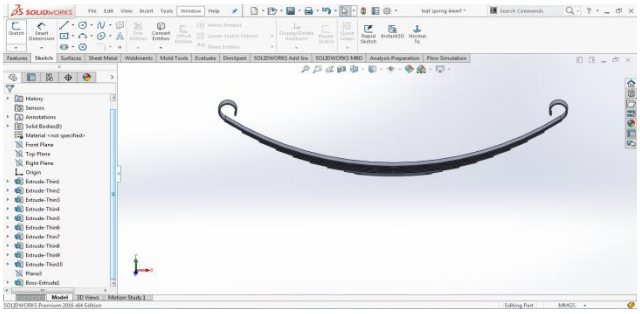
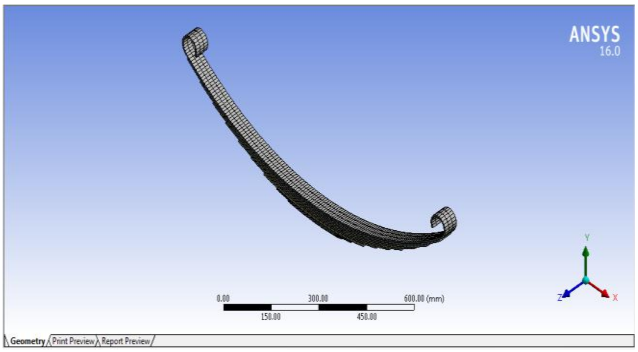
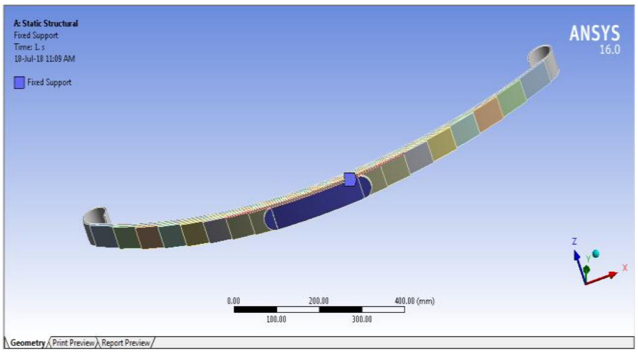


Mesh

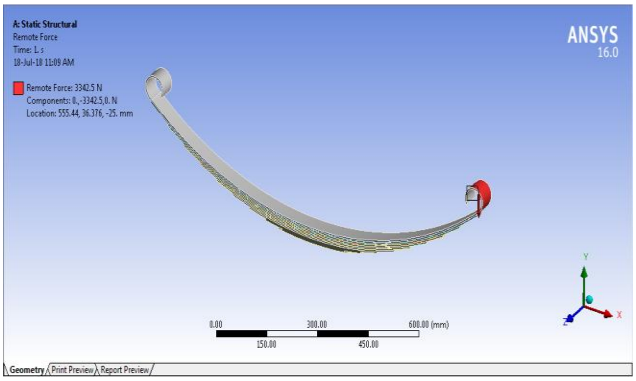
Fixed



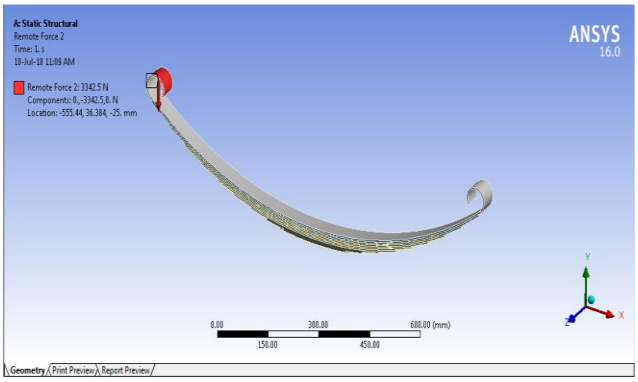

A: Static Structural
Fixed Support
Time: 1. s
18-Jul-18 11:09 AM

Fixed Support

Load force: 3342.5 N on each eye


A: Static Structural
Remote Force
Time: 1. s
18-Jul-18 11:09 AM

Remote Force: 3342.5 N
Components: 0.,-3342.5,0. N
Location: 555.44, 36.376, -25. mm

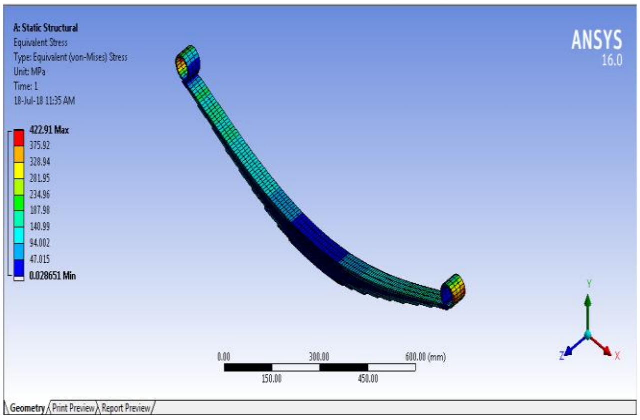

A: Static Structural
Remote Force 2
Time: 1. s
18-Jul-18 11:09 AM

Remote Force 2: 3342.5 N
Components: 0.,-3342.5,0. N
Location: -555.44, 36.384, -25. mm

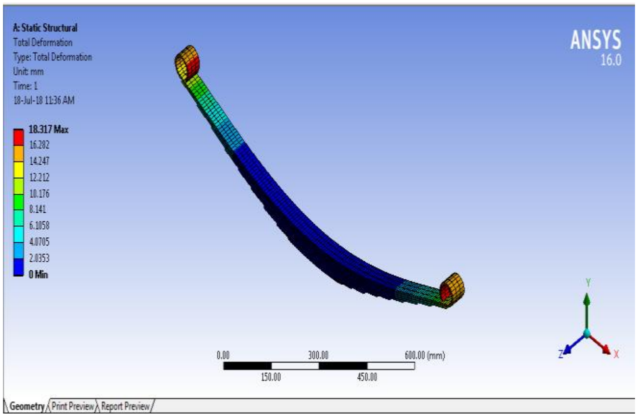
Material: E-glass epoxy

Maximum stress

Total deformation

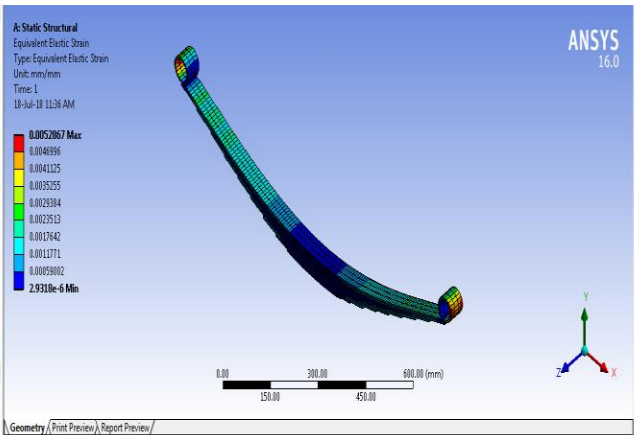

A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
18-Jul-18 11:35 AM

422.91 Max
375.92
328.94
281.95
234.96
187.98
140.99
94.002
47.015
0.028651 Min


A: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1
18-Jul-18 11:36 AM

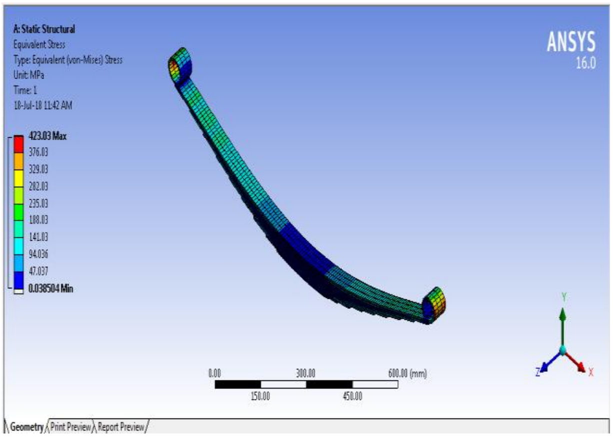
18.317 Max
16.282
14.247
12.212
10.176
8.141
6.1058
4.0705
2.0353
0 Min

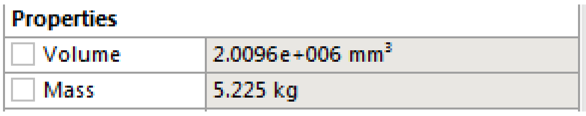
Maximum strain



Material kevlar-49

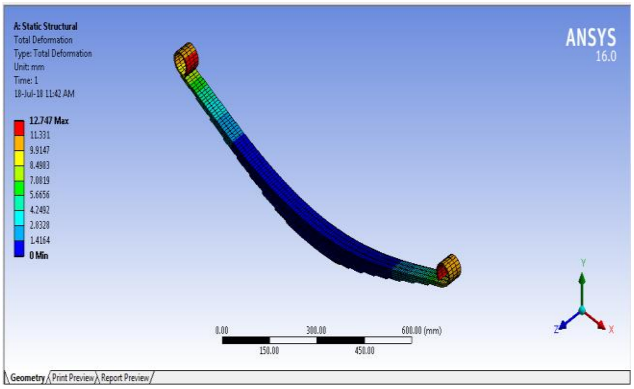
Max stress



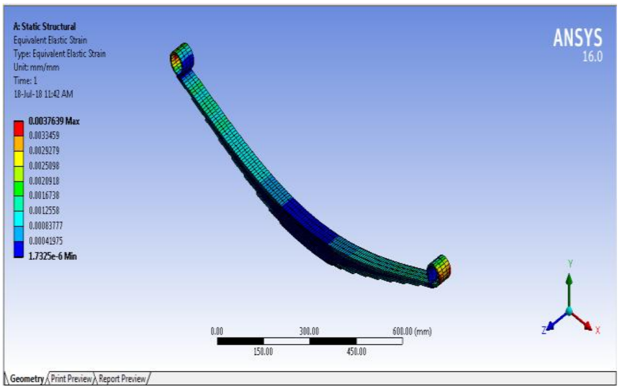


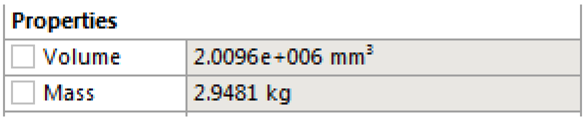
Properties	
☐ Volume	2.0096e+006 mm³
☐ Mass	5.225 kg

Total deformation



Maximum strain

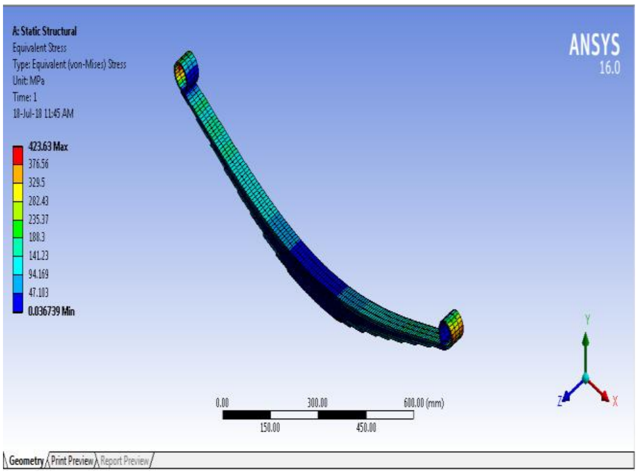




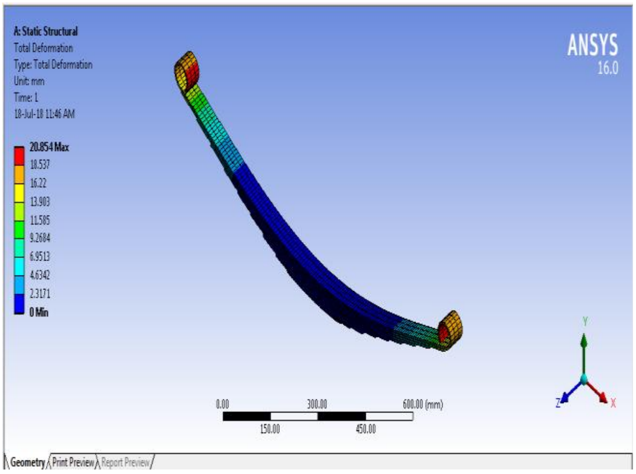
Properties	
☐ Volume	2.0096e+006 mm³
☐ Mass	2.9481 kg

Material: Al-Si-Mg composite

Maximum stress



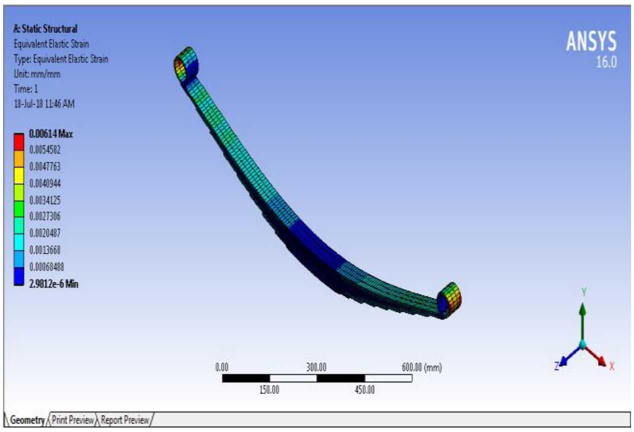
Total deformation

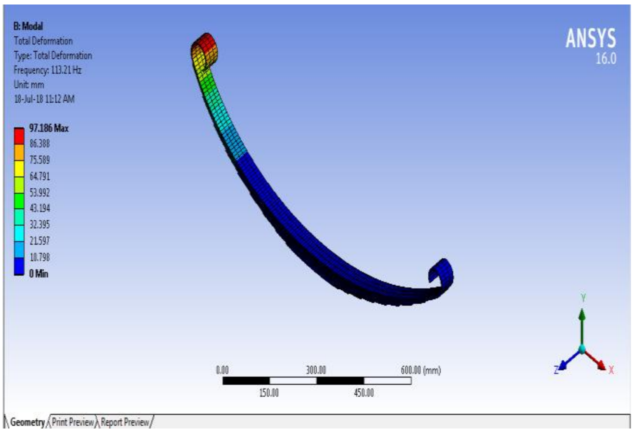


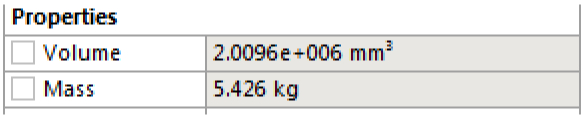
MODAL ANALYSIS::FOR 4 mm

Material: E-glass epoxy

Maximum strain



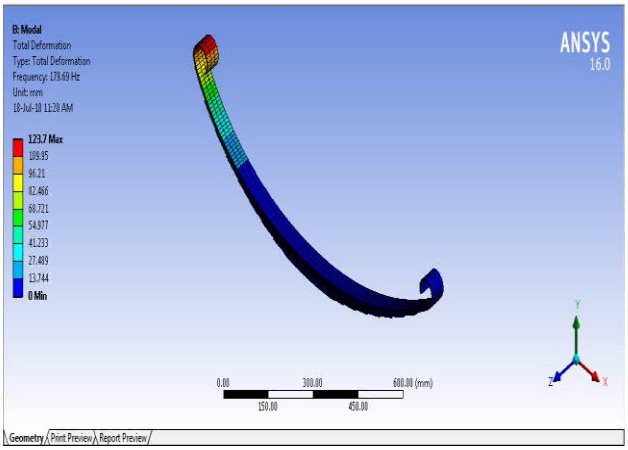


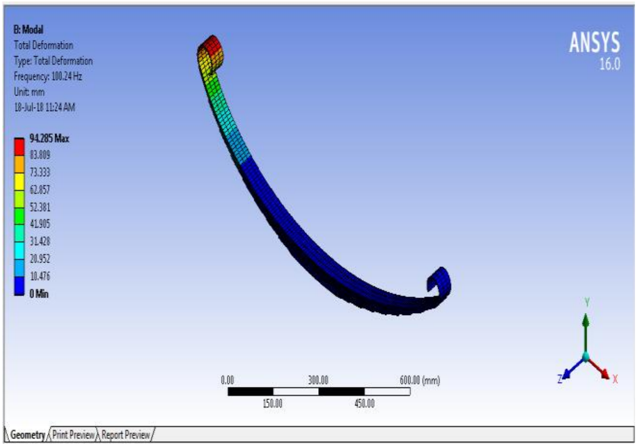


Properties	
☐ Volume	2.0096e+006 mm³
☐ Mass	5.426 kg

Material: kevlar-49

Material: Al-Si-Mg composite

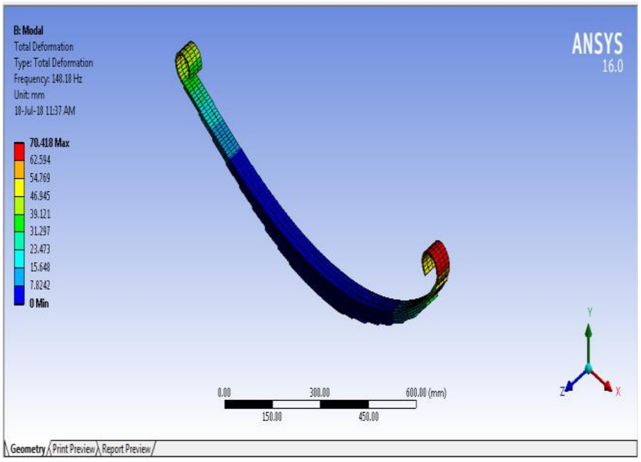


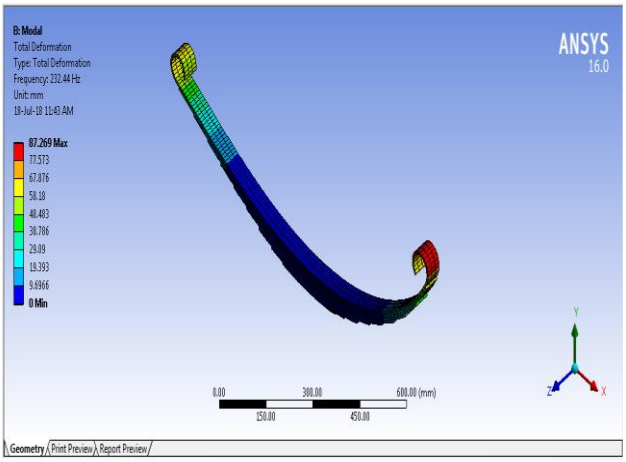


FOR 5mm

Material: E-glass epoxy

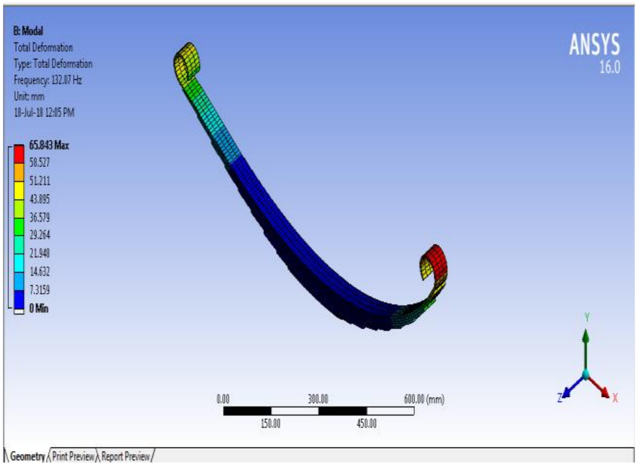
kevlar-49



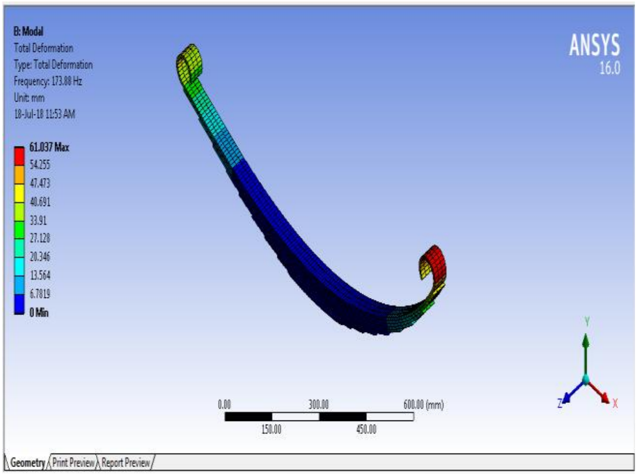


FOR 6mm

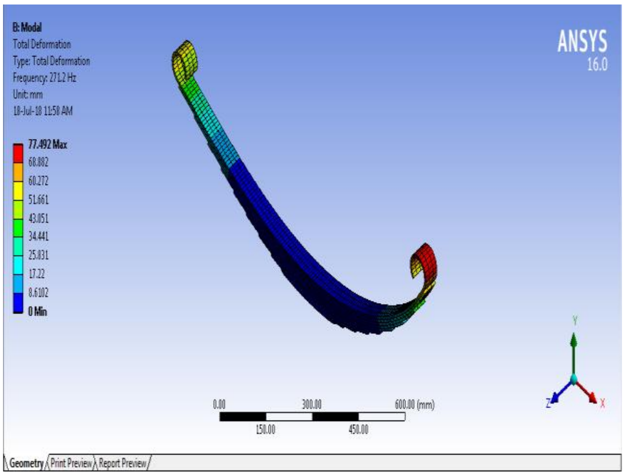
Al-Si-Mg composite



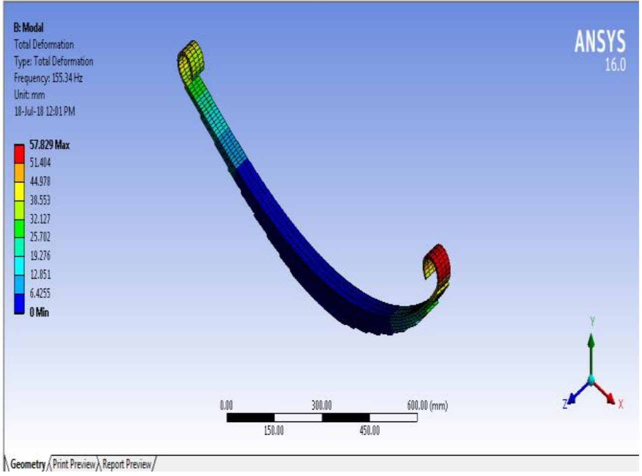
E-glass epoxy



Kevlar-49



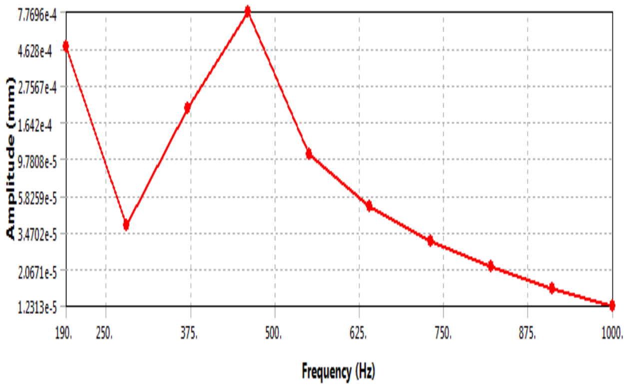
Al-Si-Mg composite



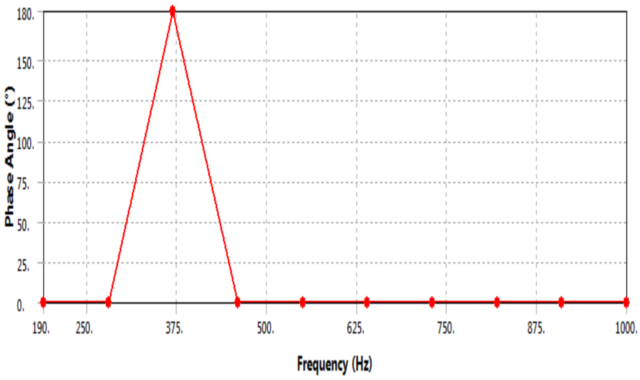
HORMONIC ANALYSIS: For 5mm

Kelvar-49

Frequency Vs Amplitude

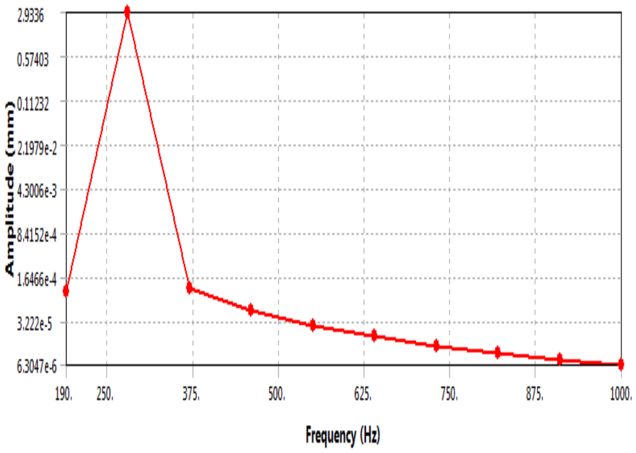


Phase angle Vs Frequency

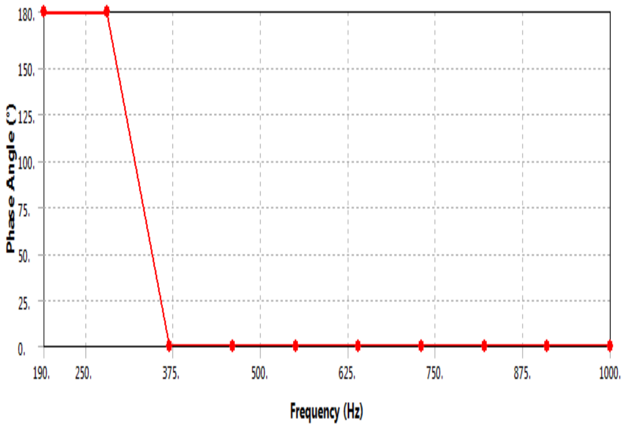


E-glass epoxy

Frequency Vs Amplitude

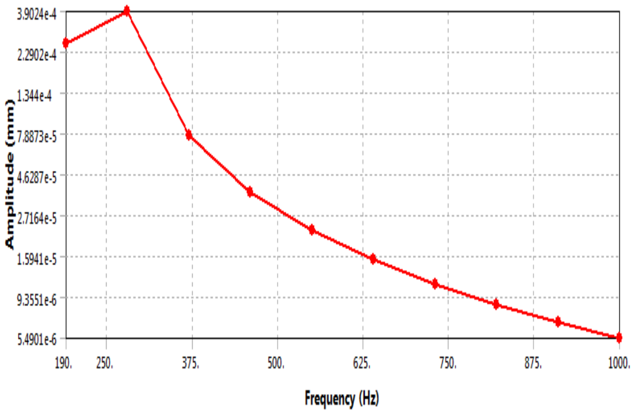


Phase angle Vs Frequency

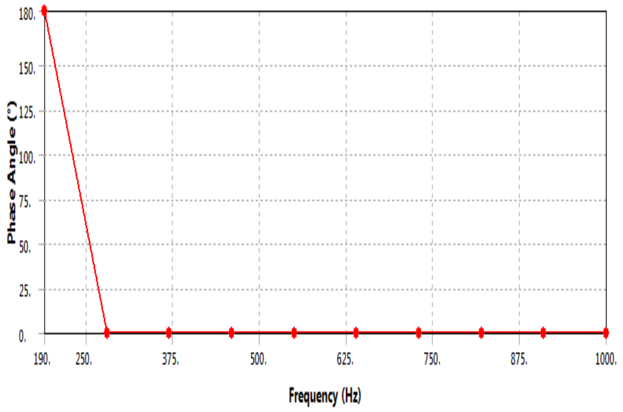


Al-Si-Mg composite

Frequency Vs Amplitude



Phase angle Vs Frequency



VIII. RESULTS AND DISCUSSIONS

STATIC ANALYSIS:

For 4mm thickness

Material	Max stress (MPa)	Total deformation (mm)	Max strain	Mass (Kg)
E-glass epoxy	642.76	35.795	0.008035	3.8835
Kevlar-49	637.23	24.896	0.0056702	2.2788
Al-Si-Mg composite	639.14	40.733	0.0092644	4.1942

Table 3.static analysis results for 4mm leaf spring

For 5mm thickness

Material	Max stress (MPa)	Total deformation (mm)	Max strain	Mass (Kg)
E-glass epoxy	422.91	10.317	0.0052867	5.225
Kevlar-49	423.03	12.747	0.0037639	2.9481
Al-Si-Mg composite	423.63	20.854	0.00614	5.426

Table 4.static analysis results for 5mm leaf spring

For 6mm thickness

Material	Max stress (MPa)	Total deformation (mm)	Max strain	Mass (Kg)
E-glass epoxy	300.88	11.137	0.0037612	5.839
Kevlar-49	302.73	7.762	0.0026935	3.4263
Al-Si-Mg composite	302.85	12.694	0.0043893	6.3061

Table 5.static analysis results for 6mm leaf spring

MODAL ANALYSIS:

For 4mm thickness

Materials		E-glass epoxy	Kelvar-49	Al-Si-Mg composite
Mode 1	Frequency (Hz)	113.21	179.69	100.24
	Total deformation (mm)	97.186	123.7	94.285
Mode 2	Frequency (Hz)	113.25	179.78	100.29
	Total deformation (mm)	97.215	123.74	94.317
Mode 3	Frequency (Hz)	209.79	322.41	185.03
	Total deformation (mm)	110.78	147.75	111.65
Mode 4	Frequency (Hz)	209.85	322.51	184.08
	Total deformation (mm)	110.83	147.83	11.7
Mode 5	Frequency (Hz)	229.59	373.09	205.76
	Total deformation (mm)	153.74	199.86	146.51
Mode 6	Frequency (Hz)	229.62	373.14	205.79
	Total deformation (mm)	153.76	199.91	146.54

Table 6.dynamic analysis results for 4mm leaf spring

For 5mm thickness

Materials		E-glass epoxy	Kelvar-49	Al-Si-Mg composite
Mode 1	Frequency (Hz)	148.18	232.44	132.07
	Total deformation (mm)	70.418	87.269	65.843
Mode 2	Frequency (Hz)	148.23	232.54	132.13
	Total deformation (mm)	70.441	87.306	65.869
Mode 3	Frequency (Hz)	217.35	334.65	197.35
	Total deformation (mm)	71.457	94.551	70.637
Mode 4	Frequency (Hz)	217.4	334.76	192.41
	Total deformation (mm)	71.476	94.59	70.664
Mode 5	Frequency (Hz)	279.88	448.11	252.13
	Total deformation (mm)	112.3	140.08	103.77
Mode 6	Frequency (Hz)	279.91	448.17	252.16
	Total deformation (mm)	112.32	140.11	103.8

Table 7.dynamic analysis results for 5mm leaf spring

For 6mm thickness

Materials		E-glass epoxy	Kelvar-49	Al-Si-Mg composite
Mode 1	Frequency (Hz)	173.88	271.2	155.34
	Total deformation (mm)	61.037	77.492	57.829
Mode 2	Frequency (Hz)	174.03	271.48	155.5
	Total deformation (mm)	61.08	77.558	57.877
Mode 3	Frequency (Hz)	214.73	331.37	190.92
	Total deformation (mm)	62.356	78.089	58.343
Mode 4	Frequency (Hz)	214.85	331.63	191.06
	Total deformation (mm)	62.382	78.151	58.387
Mode 5	Frequency (Hz)	341.83	542.1	308.43
	Total deformation (mm)	109.01	138.35	102.17
Mode 6	Frequency (Hz)	341.9	542.24	308.51
	Total deformation (mm)	109.06	138.43	102.22

Table 8.dynamic analysis results for 6mm leaf spring

IX. CONCLUSION

The selection of materials for leaf spring based on mechanical properties was considered for performing the structural, modal analysis; such materials are E –glass epoxy, kevlar-49 and Al-Si Mg composite. By performing the structural and model analysis the following results are drawn.

From the above results it was concluded that by varying thickness of 6mm and 5mm of Kevlar-49 material had similar optimum solutions. Instead of 6mm thickness of Kevlar-49 material, 5mm thickness was used because of weight reduction as shown above table-5.As the Kevlar-49 stiffness was more than two other materials. Therefore the frequency of Kevlar-49 was more compare to two other materials.

It was concluded that Kevlar-49 material with 5mm thickness gives the optimum stresses, total deformation and optimum frequency.Kevlar-49 material with 5mm thickness had optimum reduction weight when compared to other materials.

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