iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** XII **Month of publication:** December 2021

DOI: https://doi.org/10.22214/ijraset.2021.39690

Modelling, FEA analysis and Optimization of Mono Composite Leaf Spring Using ANSYS

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Abstract: Conventional leaf spring made up of conventional materials like plain carbon steel are heavy and add weight to vehicle which reduces mileage. This necessitates new material which is light in weight and could provide adequate strength to leaf spring along with higher strain energy absorption to absorb shocks. The current research is intended to study the structural and vibrational characteristics of leaf spring made of P100/6061 Al, P100/AZ 91C Mg and structural steel materials. The investigation is carried out using ANSYS FEA software. The FEA results have shown that P100/AZ/ 91C generated lower stresses as compared to P100/6061 Al and structural steel material. The modal analysis of leaf spring aided to determine mass participation factor and mode shapes corresponding to each frequency.
Keywords: Leaf Spring, Energy Absorption, Structural Steel Materials, ANSYS FEA, Frequency.

I. INTRODUCTION

In today's automobile industry, the weight reduction is one of the primary concerns in the design of new motor vehicles which could aid in less wastage of raw materials and manufacturing costs. The leaf spring account 10%-20% of the unsprung weight [7]. The less weight of leaf spring could enable to achieve high fuel economy also. The conventional steel material leaf spring is heavy and can be substituted with light weight composite materials without much compromise in strength of leaf spring.

II. LITERATURE REVIEW

Mahmood M. shokrieh and DavoodRezaei[1] has conducted FE analysis on leaf spring and substituting steel material with composite material. The FEA analysis software used was Ansys. The stress and deformation are compared between the 2 materials and the results have shown that fiber epoxy composite leaf spring weighted lower than steel leaf spring with marginal increase in stress values.

Ajitabh Pateriya, Mudassir Khan [2] has conducted dynamic analysis of leaf spring using fluid solid interaction method in ANSYS software. The FEA results have shown that La2Zr2O7 is better material as compared to other conventional materials like aluminium alloy.

Pozhilarasu V. moreover, T ParameshwaranPillai [3] has conducted FE analysis of composite material leaf springs like Glass fiber fortified plastic – GFRP, glass epoxy using ANSYS software. The stress and deformation results have shown that conventional steel leaf springs can be replaced with composite leaf springs.

E. Mahdi an, O.M.S. Alkoles[4] has conducted experimental and numerical testing of leaf spring to determine the effect of ellipticity ratio(a/b) on spring rate and failure loads. The results have shown that highest spring rate is observed by ellipticity ratio of a/b 2.0. The effect of ellipticity is significantly high on spring rate.

Y. N. V. Santhosh Kumar, M. VimalTeja[5] has conducted numerical analysis on composite material leaf spring using ANSYS 9.0 software. The composite material used in the analysis is "fiber reinforced polymer (E-glass/epoxy), carbon epoxy and graphite epoxy are used against conventional steel". The CAD model of leaf spring was developed in AutoCAD 2012 and results have shown that "among the three composite leaf springs, only graphite/epoxy composite leaf spring has higher stresses than the steel leaf spring and composite mono leaf spring reduces the weight by 81.22% for E-Glass/Epoxy, 91.95% for Graphite/Epoxy, and 90.51 % for Carbon/Epoxy over conventional leaf spring" [5].

PankajSaini, AshishGoel, Dushyant Kumar [6] has conducted FE analysis of composite material leaf springs like Glass fiber fortified plastic – GFRP, glass epoxy using ANSYS software. The stress and deformation results have shown that conventional steel leaf springs can be replaced with composite leaf springs. The stress and deformation are compared between the 2 materials and the results have shown that fiber epoxy composite leaf spring weighted lower than steel leaf spring with marginal increase in stress values.

III. OBJECTIVE

Leaf spring made up of conventional materials like plain carbon steel are heavy and add weight to vehicle which reduces mileage. This necessitates new material which is light in weight and could provide adequate strength to leaf spring along with higher strain energy absorption to absorb shocks. New class of materials known as MMC's (Metal Matrix composites) which has been investigated in various other components is contemplated for leaf spring. The current research is intended to study the structural and vibrational characteristics of leaf spring made of P100/6061 Al, P100/AZ 91C Mg and structural steel materials. The investigation is carried out using ANSYS FEA software.

IV. METHODOLOGY

The CAD model of leaf spring is modeled in ANSYS design modeler using extrude and sketch tools with the dimensions shown in table 1 below. The developed CAD model is shown in figure 1 below.

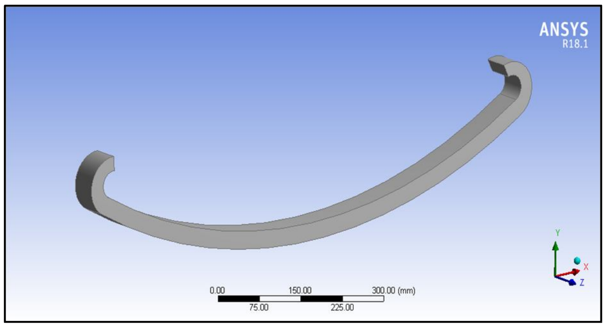

Figure 1: CAD model of mono leaf spring

The CAD model of leaf spring is discretized using hexahedral elements with growth rate 1.2 and smooth transition. The mesh sizing is set to fine and number of layers set to 4. The number of nodes generated is 3268 and number of elements generated is 474. The meshed model is shown in figure 2 below. Appropriate loads and boundary conditions are applied on leaf spring. The right cylindrical face of leaf spring is applied with displacement support and restricting displacement along all the three directions while on the left face the remote displacement is applied keeping the rotational degree of freedom free. The face is applied with different loads of 1000N, 1500N, 2000N, 2500N and 3000N.

Table 1: Specifications of leaf spring [8]

S No.	Specification	Value
1	Length of leaves (mm)	965
2	Number of full-length leaves	01
3	Width of all leaves (mm)	45
4	Thickness of all leaves (mm)	30
5	Inner radius of the eye(mm)	23
6	Outer radius of the eye(mm)	50
7	Camber (mm)	125
8	Young"s Modulus (MPa)	$2.1 *10^5$
9	Poisson"s Ratio	.33

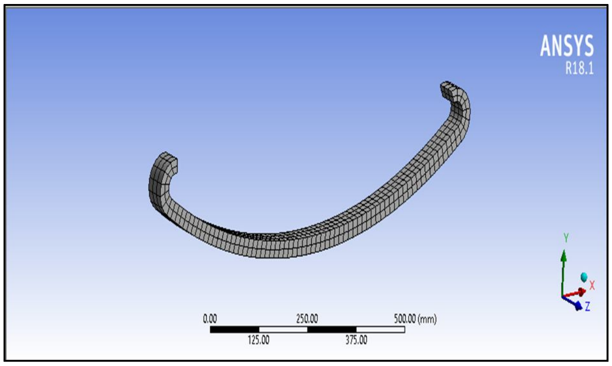

Figure 2: Meshed CAD model in ANSYS

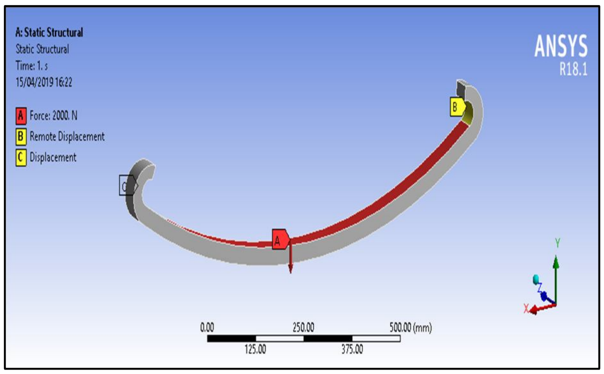

Figure 3: Loads and Boundary conditions

Subsequent modal analysis is conducted under same boundary conditions to determine natural frequency and mode shapes. The analysis is repeated for other MMC materials i.e. P100/6061 Al and P100/AZ 91C Mg.

V. RESULTS AND DISCUSSION

The FEA analysis conducted on leaf spring enabled to determine equivalent stress and total deformation.

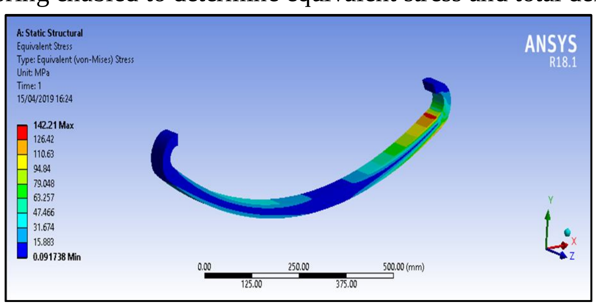

Figure 4: Equivalent stress using Steel at 2000N load

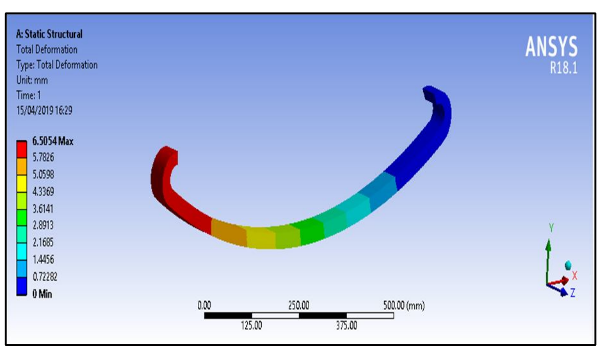

Figure 5: Deformation using Steel at 2000N load

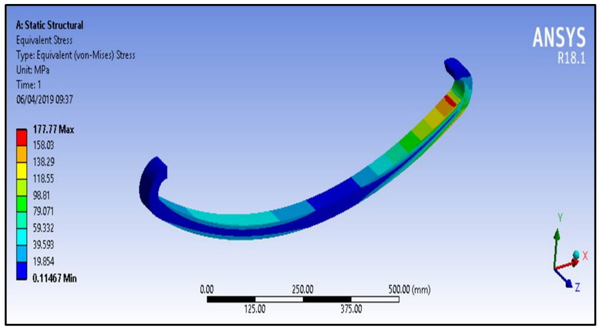

Figure 6: Equivalent stress using Steel at 2500N

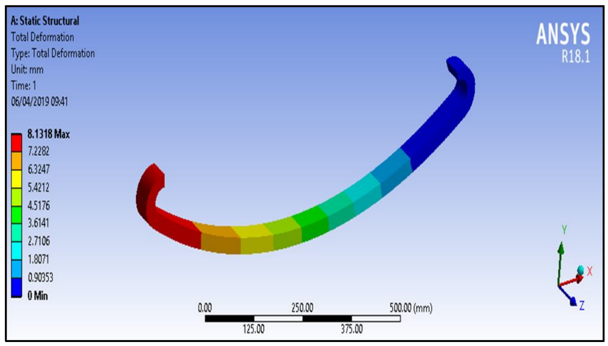

Figure 7: Deformation using Steel at 2500N

The equivalent stress plot obtained using steel material for 2000N and 2500N is shown in figure 4 and figure 6 respectively. The stress plot shows highest magnitude near the displacement support region as represented by red color region with magnitude of 142MPa nearly. The maximum deformation is obtained on remote displacement face of leaf spring as shown in figure 5 and figure 7. The maximum deformation obtained for 2000N load is 6.5054mm and maximum deformation obtained for 2500N load is 8.1318mm. Similar analysis is conducted with P100/6061 Al and P100/AZ 91C Mg material to determine equivalent stress and deformation.

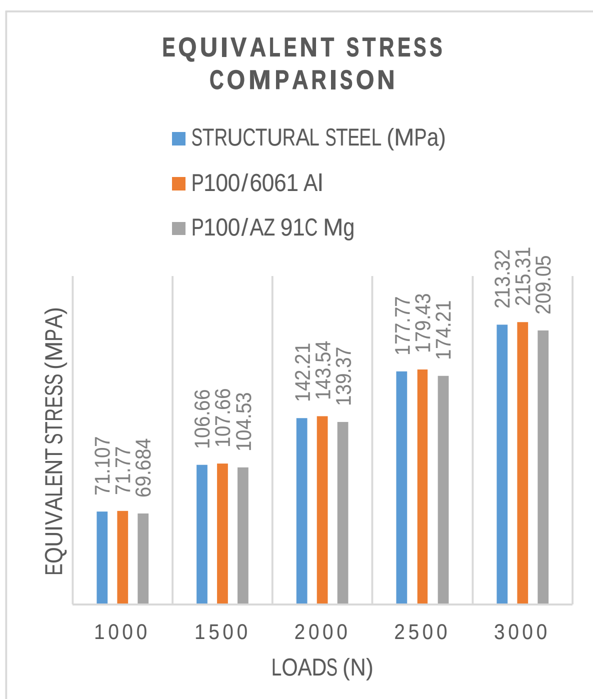

Figure 8: Equivalent stress comparison

The equivalent stress comparison plot is obtained for different materials is shown in figure 8 above. The plot shows under different loads the P100/AZ 91C Mg has lowest equivalent stress as compared to other materials. Out of all the three materials the leaf spring made of P100/AZ 91C Mg has lowest weight of 3.203Kg. The natural frequencies and mass participation factor of steel leaf spring is obtained for different materials. As it can be observed that mass participation is minimum for translational x axis with value of .2421 and maximum mass participation factor is observed for rotational x axis with value of .873. This signifies that any external excitation along rotational x direction would cause maximum amplitude build up and resonance.

***** PARTICIPATION FACTOR CALCULATION ***** X DIRECTION

MODE	FREQUENCY	PERIOD	PARTIC.FACTOR	RATIO	EFFECTIVE MASS	CUMULATIVE MASS FRACTION	RATIO EFF.MASS TO TOTAL MASS
1	28.1949	0.35467E-01	-0.11037E-01	0.214159	0.121824E-03	0.394145E-01	0.954257E-02
2	103.967	0.96185E-02	0.0000	0.000000	0.00000	0.394145E-01	0.00000
3	269.283	0.37136E-02	-0.51538E-01	1.000000	0.265620E-02	0.898789	0.208062
4	348.053	0.28731E-02	0.0000	0.000000	0.00000	0.898789	0.00000
5	502.037	0.19919E-02	0.17687E-01	0.343180	0.312827E-03	1.00000	0.245040E-01
6	657.723	0.15204E-02	0.0000	0.000000	0.00000	1.00000	0.00000
sum					0.309085E-02		0.242108

Figure **9**: Mass participation along x direction

***** PARTICIPATION FACTOR CALCULATION *****ROTX DIRECTION

MODE	FREQUENCY	PERIOD	PARTIC.FACTOR	RATIO	EFFECTIVE MASS	CUMULATIVE MASS FRACTION	RATIO EFF.MASS TO TOTAL MASS
1	28.1949	0.35467E-01	-2.0579	0.263831	4.23511	0.590248E-01	0.515382E-01
2	103.967	0.96185E-02	-7.8002	1.000000	60.8435	0.907001	0.740422
3	269.283	0.37136E-02	-0.66144	0.084797	0.437501	0.913099	0.532407E-02
4	348.053	0.28731E-02	2.3720	0.304100	5.62660	0.991517	0.684717E-01
5	502.037	0.19919E-02	0.11059E-01	0.001418	0.122299E-03	0.991519	0.148829E-05
6	657.723	0.15204E-02	-0.78009	0.100009	0.608547	1.00000	0.740558E-02
sum					71.7514		0.873163

Figure 10: Mass participation along rotational x direction

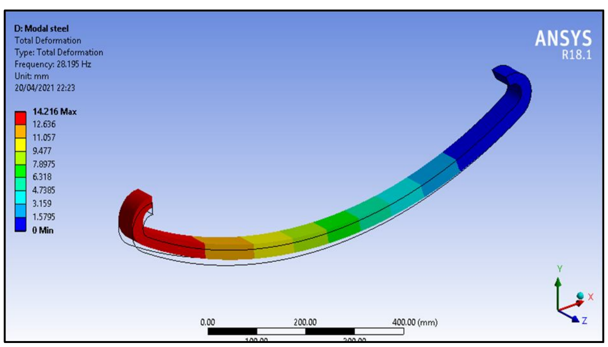

Figure 11: Mode shape and deformation at 1st natural frequency

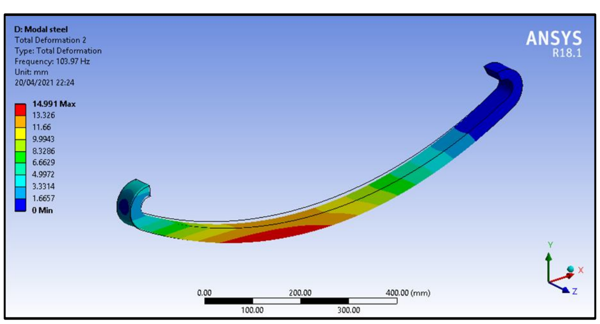

Figure 12: Mode shape and deformation at 2nd natural frequency

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 9 Issue XII Dec 2021- Available at www.ijraset.com

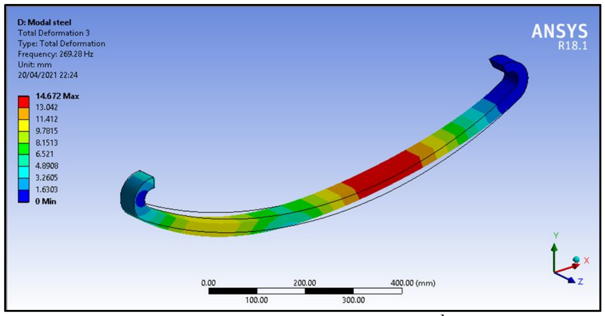

Figure 13: Mode shape and deformation at 3^{rd} natural frequency

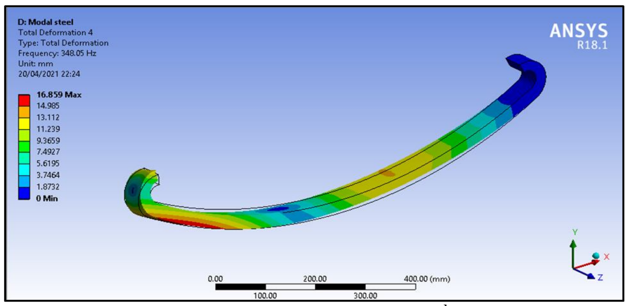

Figure 14: Mode shape and deformation at 4^{th} natural frequency

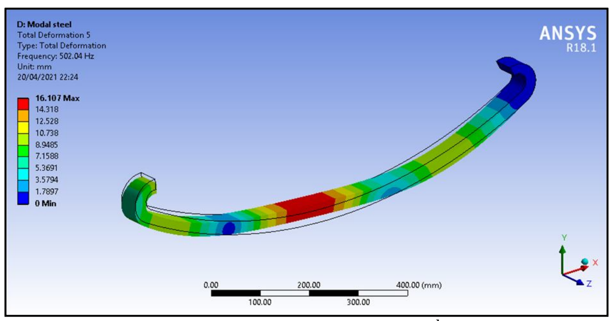

Figure 15: Mode shape and deformation at 5^{th} natural frequency

The minimum deformation is observed for 1^{st} natural frequency mode shape with magnitude of 14.216mm and maximum deformation is observed for 4^{th} natural frequency with magnitude of 16.859mm. The 3^{rd} and 5^{th} natural frequency shows mode shapes along lateral direction. The 1^{st} and 2^{nd} natural frequency shows mode shape deformation along y direction.

VI. CONCLUSION

The structural and vibration analysis of leaf spring is conducted using ANSYS FEA software to determine equivalent stress and natural frequencies using P100/6061 Al composite material and P100/AZ 91C Mg composite material. The detailed results are:

A. FEA results of P100/6061 Al composite material has shown good feasibility to be used as material for manufacturing of mono leaf spring with 72% weight reduction. FEA results of P100/AZ 91C Mg composite material has also shown good feasibility to be used as material for manufacturing of mono leaf spring with 74% weight reduction.

B. For all the three materials i.e. structural steel, P100/6061 Al and P100/AZ 91C Mg composite material it can be observed that mass participation is minimum for translational x axis with value of .24 and maximum mass participation factor is observed for rotational x axis with value of .87. This signifies that any external excitation along rotational x direction would cause maximum amplitude build up and resonance.

C. The modal analysis results have shown that mass participation factor along longitudinal direction is minimum for all the materials i.e. structural steel, P100/6061 Al and P100/AZ 91C Mg composite material. Therefore, any external excitation in this direction doesn't cause resonance.

D. For P100/AZ 91C Mg, the minimum deformation is observed for 1st natural frequency mode shape with magnitude of 28.376mm and maximum deformation is observed for 4th natural frequency with magnitude of 33.478mm.

E. For P100/6061 Al**,** the minimum deformation is observed for 1st natural frequency mode shape with magnitude of 25.19mm and maximum deformation is observed for 4th natural frequency with magnitude of 29.94mm.

F. For steel material leaf spring, the minimum deformation is observed for 1st natural frequency mode shape with magnitude of 14.216mm and maximum deformation is observed for 4th natural frequency with magnitude of 16.859mm.

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