Material Optimization of Mono Leaf Spring using ANSYS

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Abstract: Leaf springs are used in heavy and medium motor vehicles to absorb shocks due to uneven road surface or bumps. The mono leaf spring is modeled using ANSYS design modeler and FEA analysis is performed using ANSYS static structural platform. Material optimization using MMC's (Metal Matrix Composites) is carried out to achieve mass reduction of mono leaf spring without much compromise in strength. Comparative studies are made on the basis of stresses and strain energy generated. Considerable reduction in weight along with good energy absorption characteristics is obtained with the application of MMC's on leaf spring.

Keywords: FEA, Material Optimization, Mono leaf spring

I. Introduction

Leaf spring are mostly used in suspension of light motor vehicles and heavy motor vehicles like truck, railway locomotives etc. The commonly used material in manufacturing of leaf spring is steel but researches have shown that composite materials perform better as compared to conventional leaf spring material. The function of leaf spring is to absorb energy when vehicle passes through bumps or uneven road surfaces and dissipate later. The energy stored in the form of strain energy. Leaf spring are attached to frame at both ends or at one end. The softness of leaf spring is dependent on length, more the length the softer is leaf spring and vice versa. In general practice the rear leaf spring lengths are longer than front leaf springs.

II. Literature Review

ManasPatnaik, NarendraYadav,[1] conducted FEA analysis on parabolic leaf spring validated with experimental results. The optimization paramters were eye distance and camber depth for design of experiments which is used in response surface method. The study was conducted on mini loader truck leaf spring and loading capacity of truck was 1 tonne. The CAD modelling was done using CATIA V5 software. They finished up with camber, normal measure of uprooting diminishes and normal measure of von mises pressure increments, with eye remove, normal measure of dislodging and von misses pressure increments. Optimum dimensions of leaf spring are determined from DOE.

Ashish V.Amrute, Edward Nikhil karlus[2] conducted study on TATA ACE vehicle using composite leaf spring and steel leaf spring. The evaluation parameters were stresses, loading capacity. With the use of composite leaf spring the bending stresses are decreased by 25.05% and stresses developed were comparatively less as with steel leaf spring. Leaf spring with steel weighted 3.26Kg and with E-glass/Epoxy weighted 3.26Kg. Weight reduction of 67.88% is obtained from analysis.

H.A.AI-Qureshi [3] conducted study on composite material leaf spring. They considered a composite car and focused their study on design, analysis and fabrication of its leaf spring. Fabrication, testing and design of mono composite leaf spring with varying thickness are studied with same geometrical properties. Initial field tests were conducted followed by experimental testing to check GFRP quality and found that adaptability of GFRP was more with less noise and harshness against steel leaf spring. Along with that the weight reduction obtained was nearly 80 %.

Rupesh N. Kalwaghe, K. R. Sontakke[4] conducted FEA analysis on semi-elliptical leaf spring using ANSYS software. Composite leaf spring used was E-glass/epoxy generated less stress and deformation as compared with steel leaf springs. The weight of E-Glass/Epoxy leaf spring was 67.88% less than steel leaf spring.

Manish Parwani1, Vaibhav Jain [5] conducted study on mono leaf spring using composite material using Jute/E-glass/Epoxy. Using this material weight of leaf spring is reduced by 80% without much compromise in strength of leaf spring.

Anil kumar et.al [6] conducted Finite Element analysis on leaf spring made from composite materials Graphite, Carbon, and E-Glass/Epoxy on 10 leaf springs having 2 full leaves and 8 graduated. The findings have shown composite leaf spring outperformed conventional leaf spring in terms of strength with 92.59mm deformation and 35.60mm stiffness.

Senthilkumar Mouleeswaran et.al [7] has reviewed Design, Manufacturing and Testing of Polymer Composite Multi-Leaf Spring for Light Passenger Automobile. A leaf spring put away a potential vitality as strain vitality and scattered gradually. So, because of this a support of leaf spring material is likewise an essential factor like limiting the modulus of flexibility longitudinal way and expanding the quality. The work done here comprises of investigation of exhaustion disappointment conduct of composite material under the utilization of burden. All the investigation here is performed with the assistance of exploratory and computational reproduction.

III. PROPOSED WORK

The current research is intended to change the existing material of mono leaf spring for mass reduction. FEA analysis of mono leaf spring using different materials is conducted using ANSYS software and comparative studies are made on the basis of equivalent stress, deformation. The comparative studies are made among structural steel, Boron/Al and SiC materials.

IV. METHODOLOGY

The CAD model of mono leaf spring is modelled using dimensions as shown in figure 1 below. The CAD model is developed in ANSYS design modeler using sketch and extrude tools as shown in figure 1 below.

Table 1: Dimensions and Material Specifications [7]

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

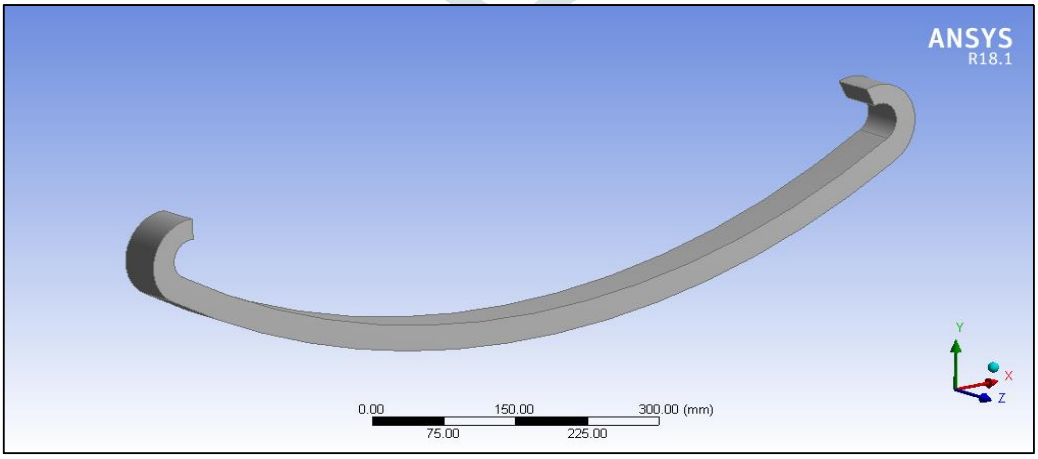

Figure 1: CAD model of mono leaf spring

After CAD modeling the model is meshed using brick elements. The total number of elements generated is 474 and number of nodes generated is 3268. The meshed model is shown in figure 2 below.

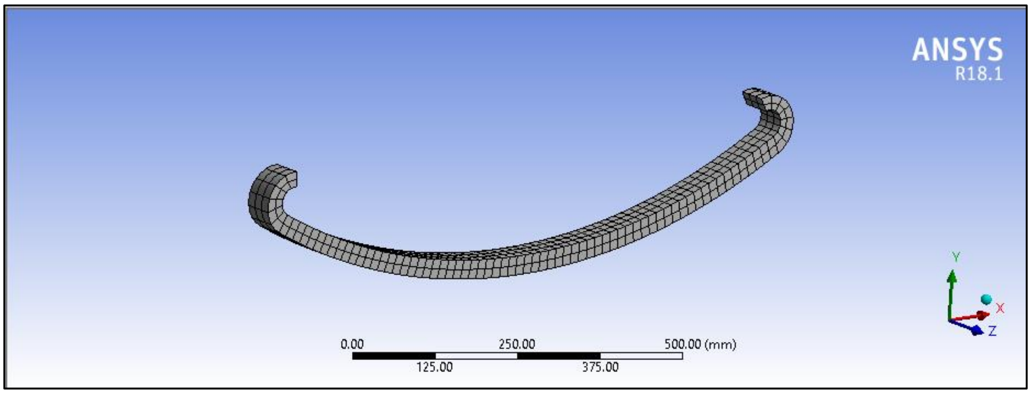

Figure 2: Meshed model of Mono Leaf spring

After meshing the CAD model is applied with appropriated loads and boundary conditions as shown in figure 3 below. The left end is applied with displacement support and right end of mono leaf spring is applied with remote displacement keeping Rot_z degree of freedom free and other degree of freedom restricted. The load is applied in mid face of mono leaf spring.

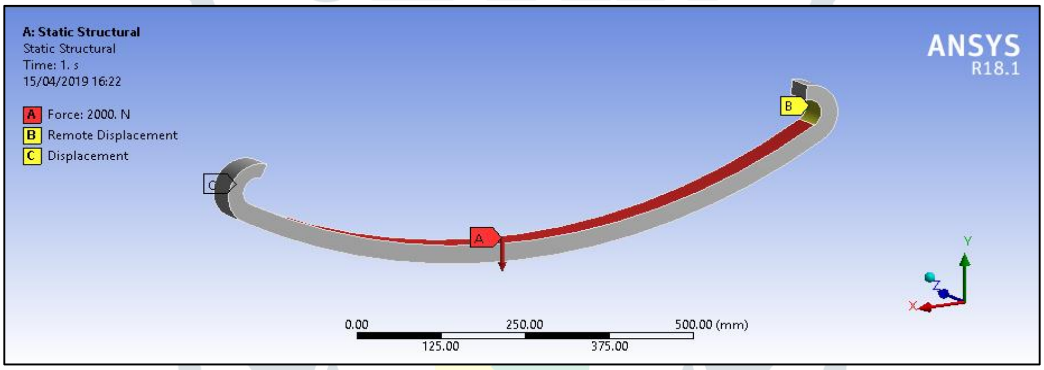

Figure 3: Loads and Boundary conditions of Mono Leaf spring

The next stage is solution stage where software carries out matrix formulations, multiplications and inversions, assemblage of global stiffness matrix and calculations are made at nodes while results are interpolated along entire element edge length. After solving the results of equivalent stress, deformation are generated as shown in subsequent figures. The properties of materials used for analysis of leaf spring is shown in table 2 below.

Table 2: Material Properties

Material Name	**SiC**	**Boron/Al**	**Structural Steel**
Modulus of Elasticity (N/m²)	$3.3 * 10^{11}$	$1.38*10^{11}$	$2*10^{11}$
Poisson's Ratio	.33	.23	.33
Density (Kg/m³)	3020	2700	7800

V. RESULTS AND DISCUSSION

FEA analysis using different materials is conducted using ANSYS software and contour plots of results are plotted for equivalent stress and deformation. The results below shows equivalent stress and strain energy plot of mono leaf spring using structural steel material.

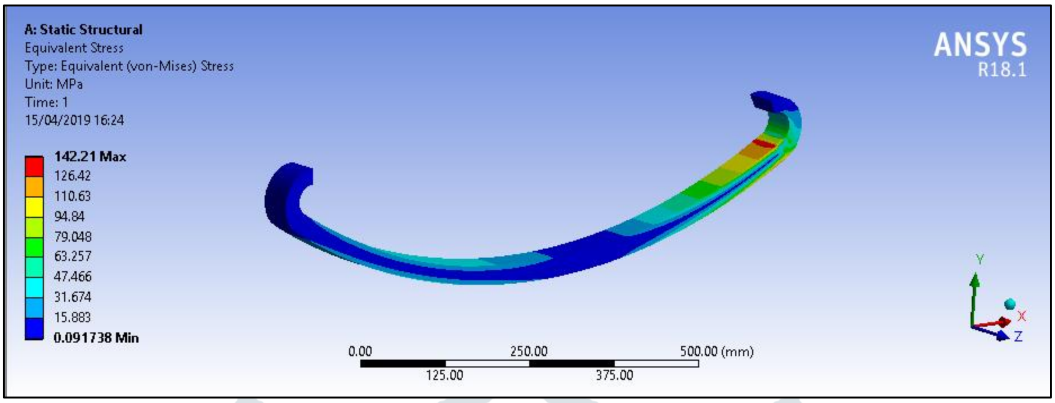

Figure 4: Equivalent stress plot using structural steel

The equivalent stress plot generated is shown in figure 4 above. The stress plot shows maximum values of equivalent stress near remote displacement support portion of leaf spring with magnitude of 142.21MPa and maximum value of strain energy is seen near displacement support with magnitude of 68.06mJ as shown in figure 5 below.

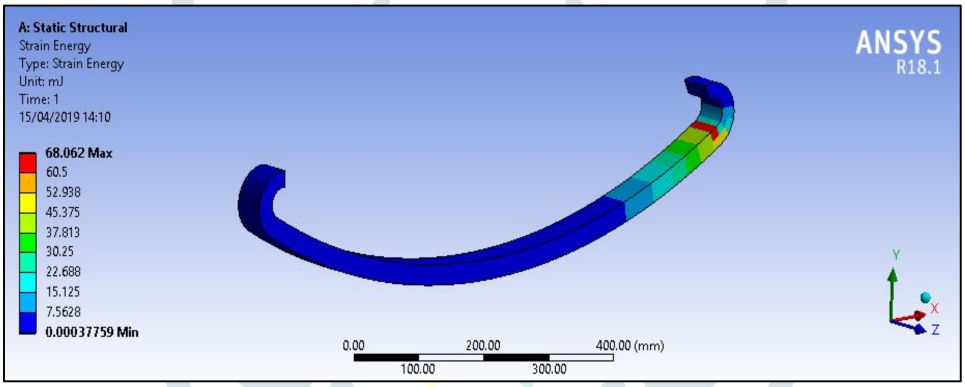

Figure 5: Strain energy plot using structural steel

The equivalent stress plot generated for SiC material is shown in figure 6 below. The stress plot shows maximum values of equivalent stress near remote displacement support portion of leaf spring with magnitude of 143.54MPa and maximum value of strain energy is seen near displacement support with magnitude of 40.24mJ as shown in figure 7 below.

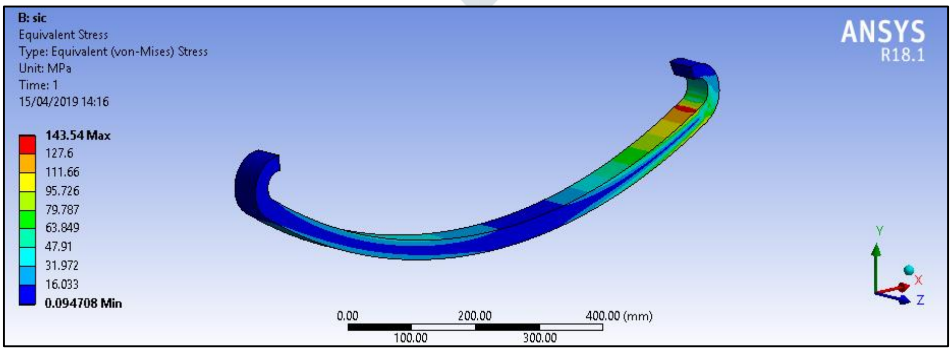

Figure 6: Equivalent stress plot using SiC material

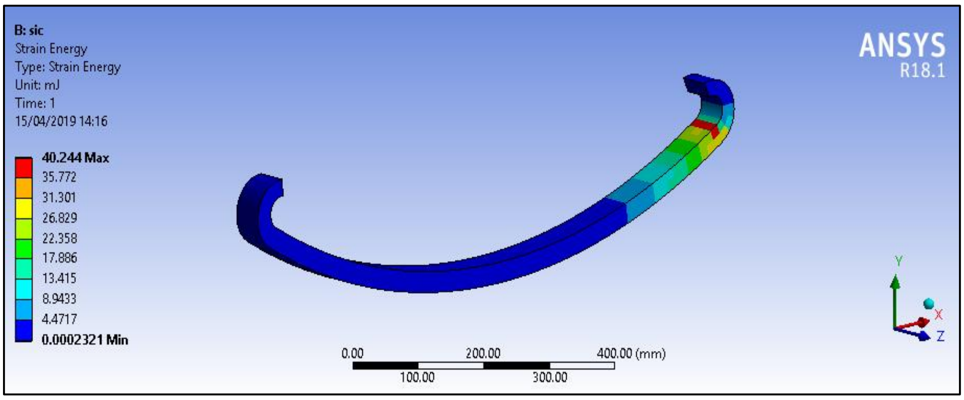

Figure 7: Strain energy plot using SiC material

The equivalent stress plot generated for Boron/Al material is shown in figure 8 below. The stress plot shows maximum values of equivalent stress near remote displacement support portion of leaf spring with magnitude of 139.37MPa and maximum value of strain energy is seen near displacement support with magnitude of 103.3mJ as shown in figure 9 below.

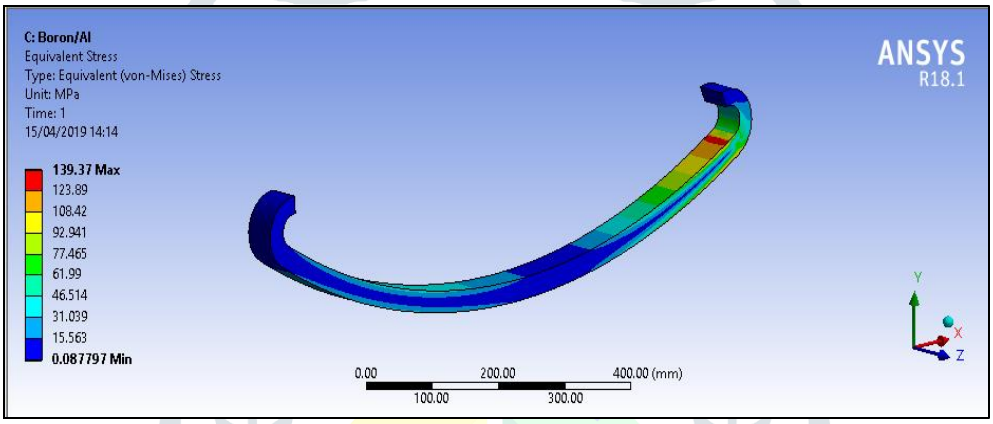

Figure 8: Equivalent stress plot using Boron/Al material

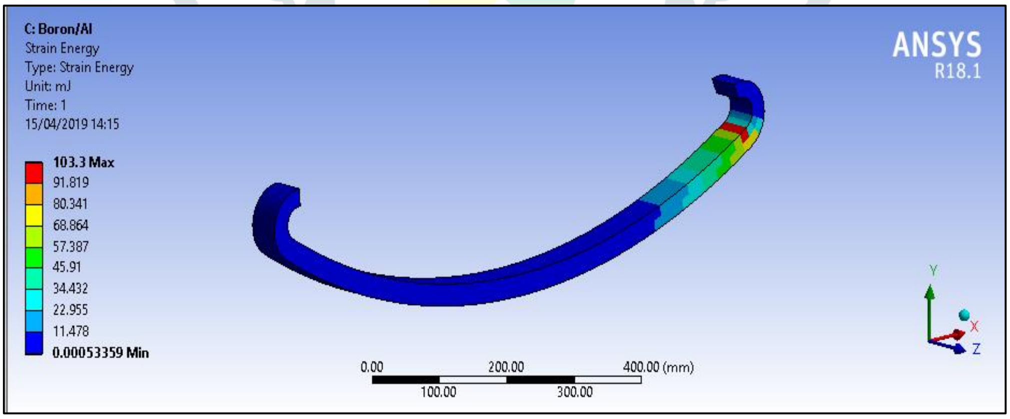

Figure 9: Strain energy plot using Boron/Al material

Table 3: Equivalent stress table for different materials

LOADS	STRUCTURAL STEEL	SiC	Boron/AL
1000	71.107	71.77	69.68
1500	106.66	107.66	104.53
2000	142.21	143.54	139.37
2500	177.77	179.43	174.21
3000	213.32	215.31	209.05

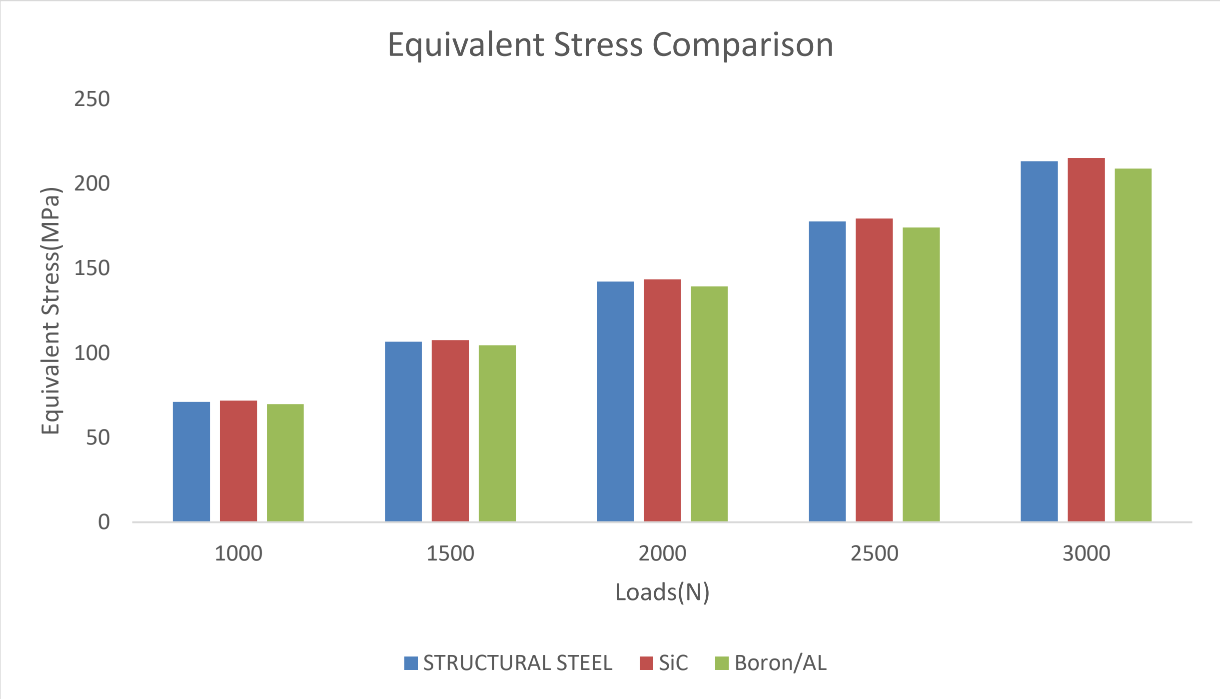

Figure 10: Equivalent stress comparison

As can be seen from figure 10 equivalent stress generated for SiC and structural steel material are almost same for all loading conditions and minimum equivalent stress is generated for Boron/Al material.

Table 4: Strain energy table for different materials

LOADS	STRUCTURAL STEEL	SiC	Boron/AL
1000	17.016	10.061	25.824
1500	38.285	22.637	58.104
2000	68.062	40.244	103.3
2500	106.35	62.881	161.4
3000	153.14	90.549	232.42

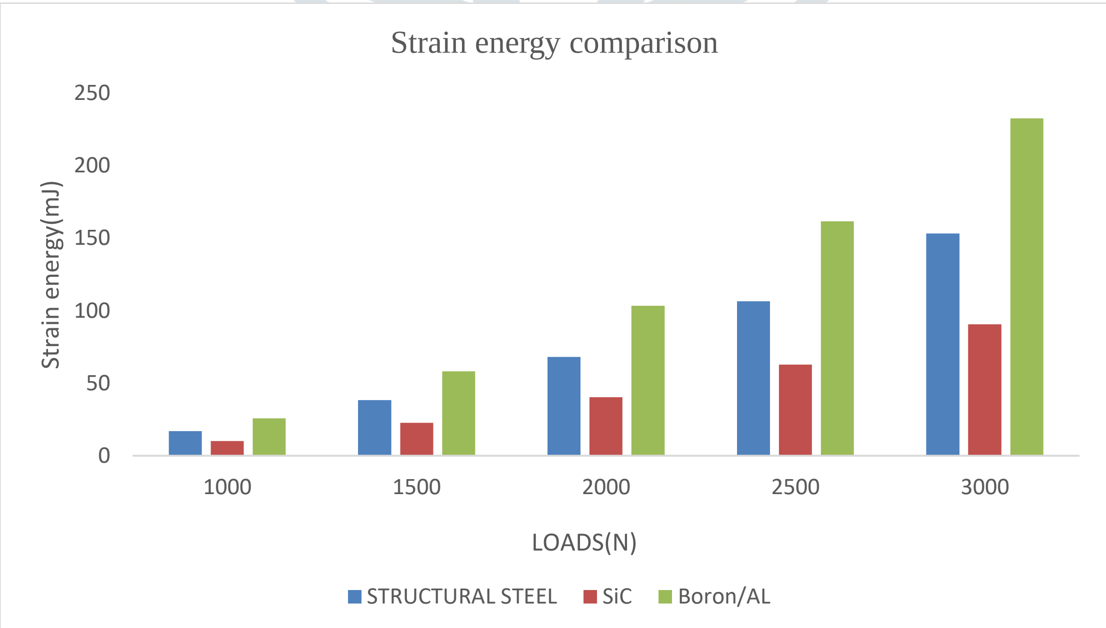

Figure 11: Strain energy comparison

The figure 11 shows strain energy comparison for different material. The comparative chart shows that energy absorption characteristics is highest for Boron/Al material for all loading conditions while SiC is having lowest strain energy absorption characteristics for all loading conditions.

Table 5: Mass of mono leaf springs using different materials

STRUCTURAL STEEL (Kg)	**SiC (Kg)**	**Boron/AL (Kg)**
12.76	4.9115	4.391

VI. CONCLUSION

The FEA analysis is conducted to predict the equivalent stresses and strain energy at specified load applied to mono leaf spring. Considerable weight reduction is obtained with the use of composite materials in manufacturing of mono leaf spring. From the analysis it may be concluded that application of metal matrix composites has led to considerable reduction in weight of mono leaf spring. FEA results of SiC composite material has shown good feasibility to be used as material for manufacturing of mono leaf spring with 61.5% weight reduction. FEA results of Boron/Al composite material has also shown good feasibility to be used as material for manufacturing of mono leaf spring with 65.5% weight reduction.

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