iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** VII **Month of publication:** July 2016

DOI:

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

www.ijraset.com
IC Value: 13.98

Volume 4 Issue VII, July 2016
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Design Optimization and Analysis of Leaf Spring Using Static Load Conditions

Mahesh Dasgaonkar[1], Abhishek Hambar[2], P Baskar[3]

School of Mechanical Engineering, Vellore Institute of Technology (VIT University), Vellore, Tamilnadu

Abstract - A leaf spring is the simplest type of suspension system, widely used in heavy commercial vehicles. The leaf spring is a structural member and acts as an energy absorbing system on the virtue of its deflection. In this research work leaf springs are analyzed using finite element methods considering different parameters. Parameters considered in the analysis are the material of the leaf spring and two different model geometries. This paper includes the study of deflection and stress distribution of leaf spring for heavy duty vehicles, considering various recent materials and change in the thickness of the leaf springs. The results highlight the best suitable material for leaf spring and its design optimization.

Keywords - Leaf spring, Heavy commercial vehicle, Finite element method, Static structural analysis

I. INTRODUCTION

A leaf spring is an elastic energy absorbing body, used as suspension system in heavy duty vehicles. The important function of the leaf spring is to deflect when loaded and come back to its original position when the load is removed. Leaf spring generally takes care of the load and vibration induced due to road surface irregularities. Leaf springs are generally monitored on the basis of its deflection attributes and ability to store and absorb the strain energy. Leaf spring used in automotive vehicles is generally of semi-elliptic form. In the construction of leaf spring, it is generally composed of number of curved plates, called leaf of the spring. The leaves of the spring are reducing in its length. The largest leaf is called master leaf; other leaves are called graduated leaves. All the leaves are assembled together with the help of the steel straps, nut and bolt. The leaf spring is on the Axle of the vehicle with its ends attached to chassis frame. One of its ends is rigidly attached to the frame and other one is connected to chassis frame by shackle. The main purpose of shackle is to adjust the spring length when the road wheel comes across the road irregularities. That generally means, front end of the leaf spring is fixed and constrained in all directions while the rear end is constrained only in Y and Z directions and not in X-direction.

Structural steel is the conventional material used for leaf spring. EN45, EN47 and steel-chromium alloy etc. these materials are generally used for conventional leaf spring. In the present scenario, composite materials are widely used in case of multi-leaf spring. Due to the use of composite materials weight reduction of leaf spring is possible without changing its load carrying capacity and stiffness. Some of the non-ferrous metals such as titanium alloys are also used to manufacture leaf spring, basically to improve its corrosion resistance. In the present work, multi-leaf spring has been analyzed for static loading using finite element analysis with four different materials and two different model geometries. SOLIDWORKS 2013 has been used to create three-dimensional leaf spring model. ANSYS 16.0 has been used for static structural analysis to find stress distribution and deflection of spring when subjected to constant vertical load.

©IJRASET: All Rights are Reserved

Fig.1. Leaf spring

II. PROBLEM IDENTIFICATION

A. Weight of the structural steel leaf spring is comparably high.
B. Deflection attributes are poor in case of structural steel.
C. Poor ride properties due to the noise and friction.

III. OBJECTIVE

A. To reduce weight of structural steel leaf spring by using other alloys and composite material.
B. To improve the deflection attributes of leaf spring.
C. To improve the ride properties and passenger comfort.

IV. CORRELATION PARAMETERS

A. Spring stiffness

Stiffness is generally expressed as ratio of force to deflection. As,
K = force / deflection
Spring stiffness is important parameter to monitor spring deflection and its attributes.

B. Equivalent stress

Stress is the second important element for leaf springs. Equivalent Stress generally co-relate with durability of leaf springs.

C. Strain Energy

Strain energy is the energy stored in the elastic body under loading condition. Strain energy is the third co-relation parameter to compare the leaf springs with different materials.

V. LOAD CALCULATION

Vehicle Name : Tata SFC 407

For Rated Load Condition,

Gross Vehicle Weight : 5000kg

Total Weight (N) : 5000*10=50000

No. of leaf springs : 4

Load on each spring : 50000/4=12500 N

For Over Load Condition,

Gross Vehicle Weight : 5000kg

Load carried : 3000kg

Total Weight (N) : 8000*10=80000

No. of leaf springs : 4

Load on each spring : 80000/4=20000 N

VI. MATERIAL SELECTION

Structural steel is the conventional material used for leaf spring. This research paper compares the result of structural steel with titanium alloy (Ti-6Al-4V) and composite materials. The composite materials used are E-Glass fiber and S-glass fiber. The properties of the materials used in the present work are as mentioned in table 1.

©IJRASET: All Rights Reserved

Volume 4 Issue VII, July 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

TABLE.I. MECHANICAL PROPERTIES OF MATERIALS

Properties	Structural Steel	Titanium Alloy	E-Glass fiber composite	S-Glass fiber composite
Density(g/cc)	7.85	4.43	2.57	2.48
Modulus of Elasticity(Mpa)	200000	113800	73500	86900
Poisson's Ratio	0.3	0.342	0.22	0.22
Tensile Yield Strength(Mpa)	250	880	2050	--

VII. MODELING AND ANALYSIS

In the present work leaf spring of heavy duty commercial vehicles is taken for modeling and analysis, to compute and compare results. The 3D modeling of leaf spring is carried out using SOLIDWORKS 2013. Figures given below show one of the models of leaf spring used in analysis.

TABLE.II. DIMENSION OF THE LEAF SPRING

Parameters	Dimensions for Model-1	Dimensions for Model-2
Total span of leaf spring(mm)	1180	1180
Width of each leaf(mm)	50	50
Thickness of master leaf(mm)	6	8
Thickness of graduated leaves(mm)	5,5.22,5.63,5.75,5.87	7,7.33,7.75,7.89,7.94,7.98
No. of leaves	7	7
Rated load (N)	12500	12500
Over load(N)	20000	20000

A. Finite Element Analysis

Multi-leaf spring, with seven leaves used for heavy commercial vehicles, has been analyzed using finite element methods. The analysis is carried out in ANSYS 16.0 workbench to evaluate the stress distribution and deflection attributes. Each model is analyzed statically with same loading conditions for four different materials viz. structural steel, Titanium alloy (Ti-6Al-4V), E-Glass epoxy fiber, S-Glass epoxy fiber. The basic steps followed in finite element analysis are shown in the following flowchart (fig.4).

B. Boundary Conditions

Figure 2 and Figure 3 show boundary conditions employed in front and rear ends of leaf spring. The front end is fixed to the frame and allowed to displace only in Z-direction (rotation). The rear end is connected to the frame with shackle and allowed to displace in X-direction (translation) and in Z-direction (rotation).

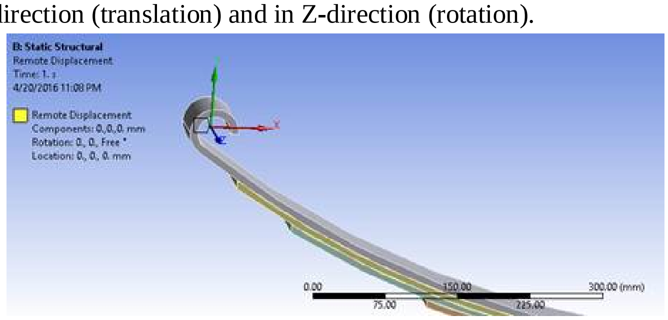


Fig.2. Boundary Conditions at front end

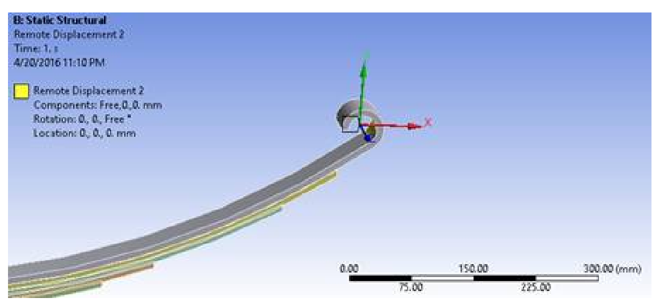


Fig.3. Boundary Conditions at rear end

©IJRASET: All Rights are Reserved

Volume 4 Issue VII, July 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

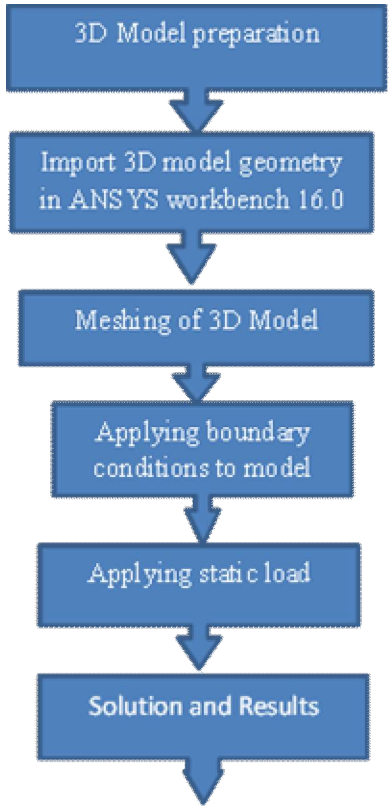


Fig.4. Flow chart of FEA Analysis

C. Meshing

Mesh generation process is one of the important processes in finite element analysis. Meshing discretize entire model into very small elements. In this work "fine mesh" is selected for meshing the 3D model of the leaf spring.

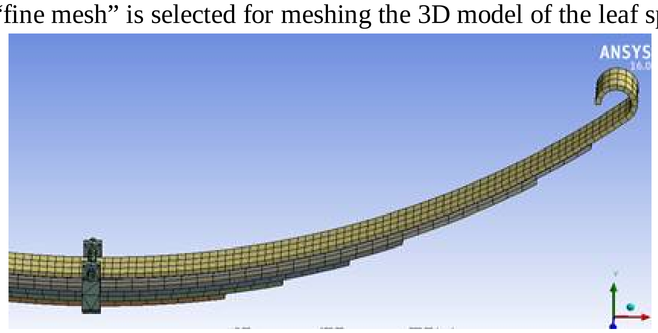


Fig.5. Meshing of 3D Model-1

The results shows deflection attributes of four different materials for model-1 and rated load conditions of leaf spring.

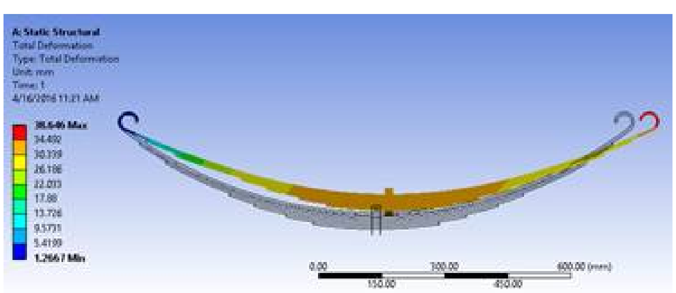


Fig.6.Deflection in Structural steel

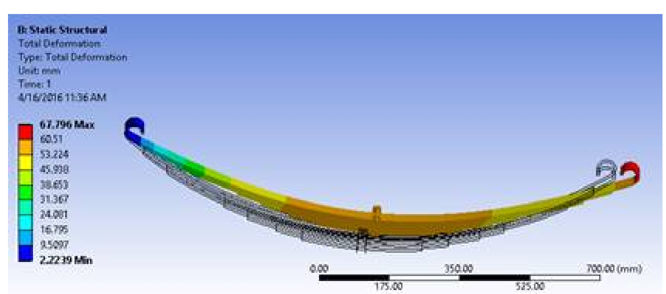


Fig.7.Deflection in Titanium alloy

©IJRASET: All Rights are Reserved

Volume 4 Issue VII, July 2016
ISSN: 2321-9653

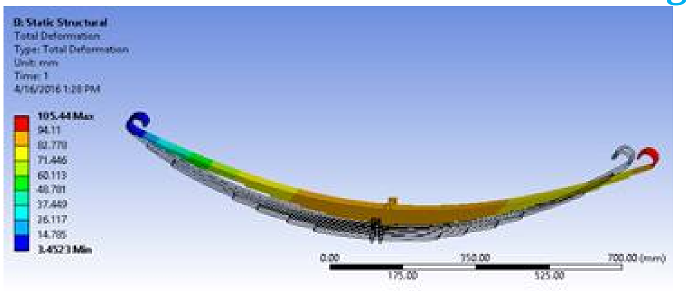


Fig.8.Deflection in E-Glass fiber composite

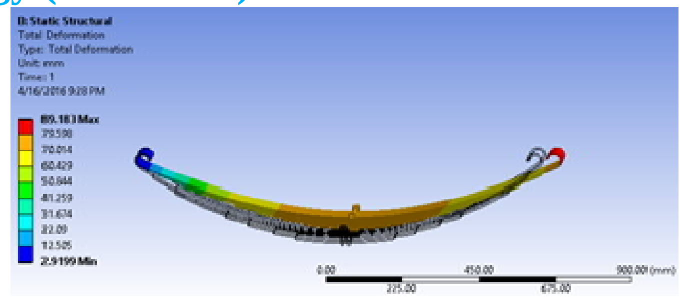


Fig.9.Deflection in S-Glass fiber composite

The above four figures shows the deflection in four different materials for model-1.The deflection attributes of model-2 are similar to that of model-1; hence the figures are not shown. As seen from the above figures, to show the deflection attributes "model with undeformed wireframe model" option is selected. The wireframe model shows the undeformed shape and colorful model shows the deformed shape.

The following results shows stress distribution of four different materials for model-1 and rated load conditions of the leaf spring.

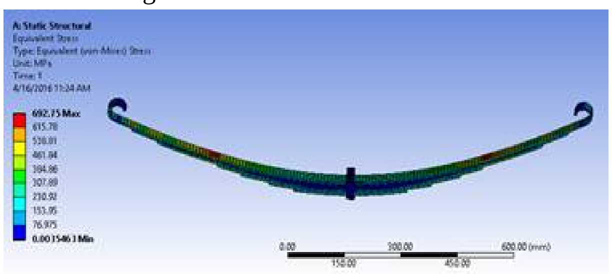


Fig.10. Stress in structural steel

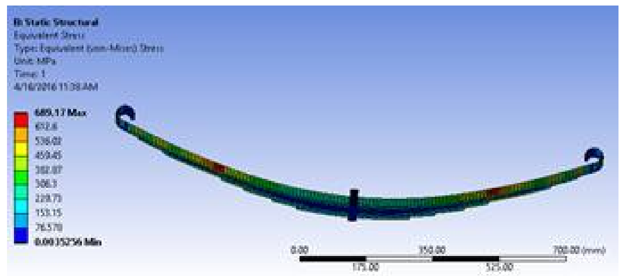


Fig.11. Stress in Titanium Alloy

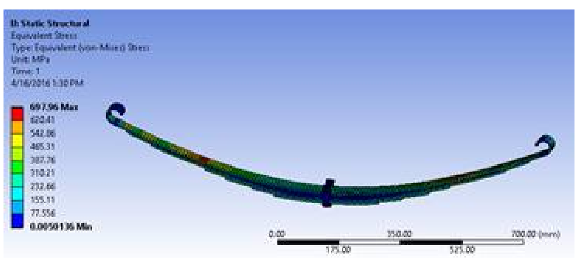


Fig.12. Stress in E-Glass Fiber composite

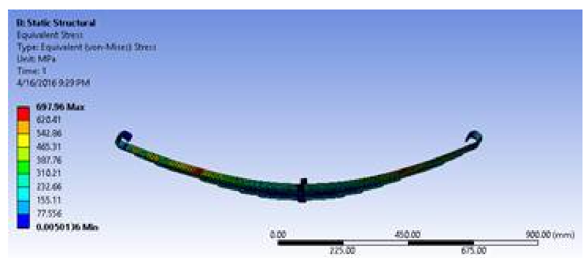


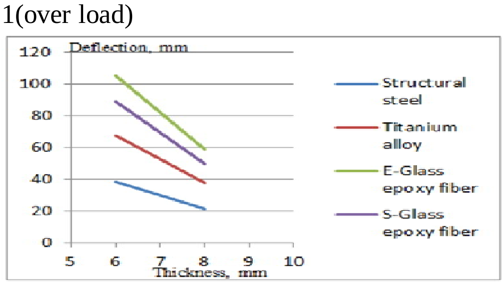
Fig.13. Stress in S-Glass Fiber composite

The above four figures show stress distribution using four different materials for model-1considering rated load condition. The stress generally concentrates in the red color area highlighted on the master leaf.

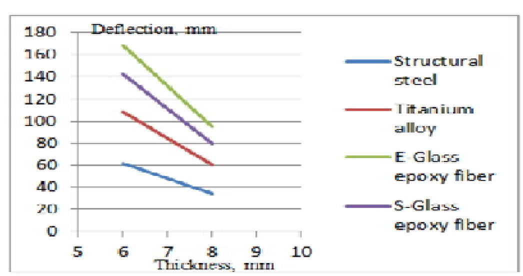
VIII. RESULTS AND DISCUSSION

Using ANSYS Workbench 16.0, leaf spring is analyzed for static load for model-1 and model-2 with four different materials viz. structural steel, Titanium alloy, E-glass fiber composite, S-glass fiber composite. The results obtained are plotted in graphical and tabular format.

Graph.1. Deflection attributes for model-1(rated load)



Graph.2.Deflection attributes for model-1(over load)



©IJRASET: All Rights are Reserved

The graph 1 and graph 2 shows the linear variation of deflection with thickness of the leaves for model-1 with rated and overloads conditions. The line of deflection for E-Glass Fiber composite shows higher deflections and steeper than the lines of deflection for other materials.

TABLE.III.DEFLECTION IN LEAF SPRING

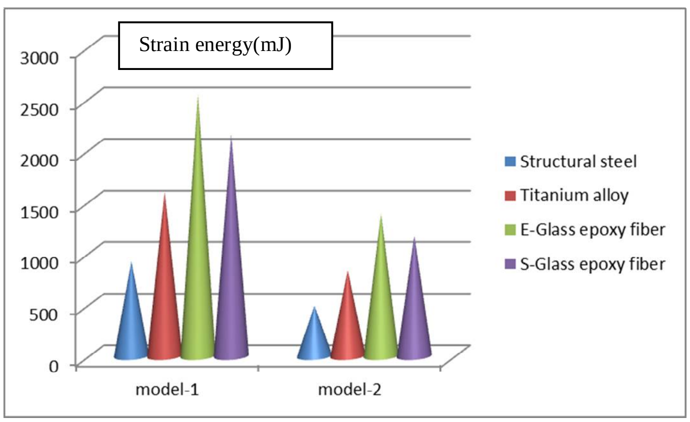
Sr. No.	Model name	Deflection in Structural steel		Deflection in Titanium alloy		Deflection E-Glass fiber composite		Deflection S-Glass fiber composite	
		Rated Load	Over Load	Rated Load	Over Load	Rated Load	Over Load	Rated Load	Over Load
1	Model-1	38.64	61.83	67.79	108.47	105.44	168.71	89.18	142.69
2	Model-2	21.64	34.62	37.96	60.75	59.03	95.05	49.93	79.89

Table 3 shows the values of deflection for model-1 and model-2 using both rated load and over load conditions. The deflection in titanium alloy (overload condition) is comparable to deflection in E-Glass fiber (rated load condition).

TABLE.IV. STRESS IN LEAF SPRING

Sr. No.	Model name	Stress in Structural steel		Stress in Titanium alloy		Stress E-Glass fiber		Stress in S-Glass fiber	
		Rated Load	Over Load	Rated Load	Over Load	Rated Load	Over Load	Rated Load	Over Load
1	Model-1	692.75	1108.4	689.17	1102.7	697.96	1116.7	697.96	1116.7
2	Model-2	646.86	1035	640.9	1025.4	656.61	1050.6	656.61	1050.6

Table 4 shows the values of stress for each model using rated load and over load conditions. It is observed that the stress developed is slightly higher in model-1 as compared to model-2 due to lower thickness of leaves in case of model-1.



Graph.3. strain energy plot

Above plot compares strain energies for models. For model-1 strain energy is higher as its energy storing capacity is higher on the virtue of its deflection.

TABLE.V. MASS COMPARISON OF LEAF SPRING

Materials	Mass of Model-1(kg)	Mass of Model-2(kg)
Structural Steel	12.51	17.17
Titanium Alloy	7.06	9.69
E-Glass fiber	4.09	5.62
S-Glass fiber	3.95	5.42

From the above table it can easily be observed that conventional steel leaf spring is having higher mass as compared to any other material in the analysis. Mass of the leaf spring generally correlates with its ride and fatigue properties. For model-1 S-Glass epoxy

©IJRASET: All Rights Reserved

fiber exhibits lowest value of mass and thus superior ride properties and higher fatigue life.

IX. CONCLUSION

A. Leaf spring model with S-Glass fiber and E-Glass fiber material have lower mass compared to structural steel and titanium alloy. Total mass of S-Glass Fiber composite , E-Glass fiber composite, Titanium alloy, structural steel considering model-1 as reference is 12.51 kg, 7.06 kg, 4.09 kg, 3.95 kg respectively.

B. Under same static load,stress in composite leaf spring is slightly more than structural steel leaf spring.

C. Under same static load, deflection in E-Glass fiber and S-Glass fiber is comparably more than conventional structural steel leaf spring.

D. Composite leaf spring exhibits greater deflections giving better ride properties and comfort due to its lower mass and higher deflection rate.

E. It is Observed that strain energy in E-Glass Fiber composite is higher as compared to other materials due to its energy storing capacity on virtue of its deflection.

REFERENCES

[1] A Srinivas Kurna, Arpit Mathur, and Sandeep Sharma, “Investigation of Stresses and Deflection in Multi Stage Leaf Spring of Heavy Duty Vehicle by FEM and Its Experimental Verification”, SAE Technical paper, year 2015

[2] Murathan Soner, Metin Tanoglu, Nilay Guven, Mustafa Karaagac, Rasim akyali, Ozay Aksoy, Tolga Erdogus and Ahmet Kanbolat, “Design and Fatigue Life Comparison of Steel and Composite Leaf Spring”, SAE Technical paper, year 2012

[3] Pengbo Wang, Chongliang Zhang and Yongquan Liu, “Simulation and Design of Leaf Spring Characteristics”, SAE Technical paper, year 2009

[4] Subhash Chandrabose, C. Thamotharan, P. Naveenchandran and R. Anbazhagan, “Design Optimization and Analysis of a Parabolic Leaf Spring”, Middle-East Journal of Scientific Research, year 2014

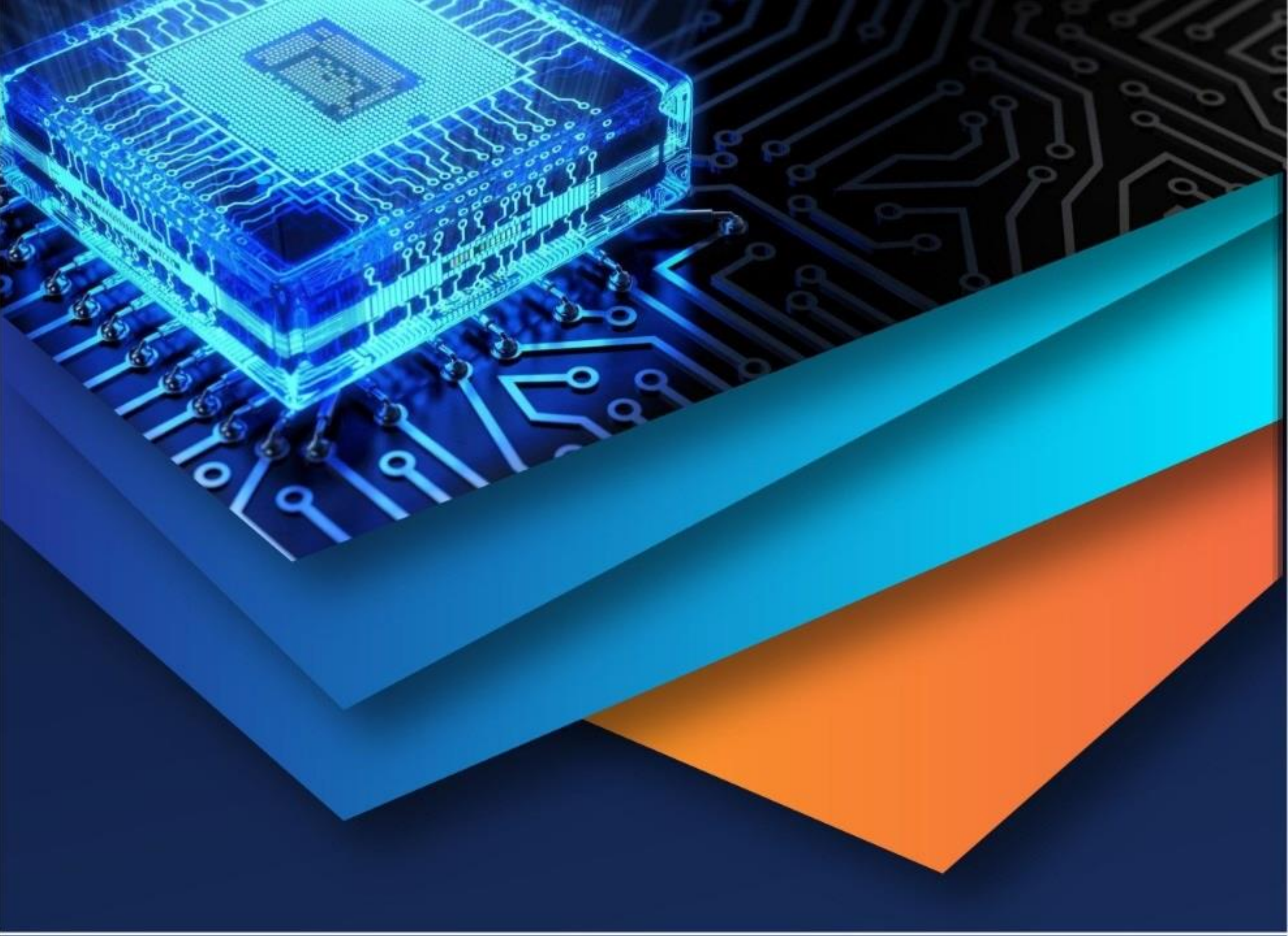
[5] Rupesh N. Kalwaghe, Prof. K. R. Sontakke, “Design and Analysis of Composite Leaf Spring by Using FEA and ANSYS”, International Journal of Scientific Engineering and Research, year 2015

[6] Shahrukh Shamim, Jamil Anwer, “Design and optimization of Automotive multi leaf spring by finite element method”, international journal of research in aeronautical and mechanical engineering,year 2014

[7] Yogesh Sharma, Dr. V.N. Bartaria, “Comparison of Performance of Multi Leaf Springs of Automobile after Changing Its Cross Section”, year 2015

[8] R.S. Khurmi J.K. Gupta, “A textbook of Machine Design”. Eurasia Publishing, Year 2005

©IJRASET: All Rights Reserved



10.22214/IJRASET

INDEX COPERNICUS
45.98

ISRA JIF
IMPACT FACTOR:
7.129

SJIFactor
TOGETHER WE REACH THE GOAL
IMPACT FACTOR:
7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)