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STRUCTURAL ANALYSIS OF LEAF SPRING BY USING DIFFERENT MATERIAL FOR AUTOMOTIVE VEHICLE

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ABSTRACT

This project works aims to study and examine the stress distribution of leaf spring. The function of a suspension system is to absorb the bumps in the road and accordingly maximizing the general overall performance of a vehicle. A type of suspension system, the leaf spring suspension system is frequently used, especially in commercial vehicles. It is important to do a proper fail proof analysis of these components prior to manufacturing and use. In our project work modeling of leaf spring is done by using CAD software i.e. Catia V5. Later this CAD modal is imported to ANSYS WORKBENCH 2016. ANSYS WORKBENCH 2016 is the latest software used for simulating the different forces acting on the component and also calculating and viewing the results. By using ANSYS WORKBENCH 2016 software reduces the time compared with the method of mathematical calculations by a human. ANSYS WORKBENCH 2016 transient structural analysis work is carried out by considered three different non-linear materials namely structural steel, Titanium Alloy & Grey cast iron and their relative performances have been observed respectively is suggested as best material for leaf spring.

Keywords: Leaf Spring, Design, Catia V5, Ansys Etc.

I. INTRODUCTION

In automobiles, the leaf spring is crucial components to provide comfortable ride and stability to the vehicle. The requirement to replace leaf spring with more robust and durable leaf spring is the major concern in transport and automotive industry. With this datum it was expected that the vehicle would be more reliable, comfortable and faster. In recent years multiple researches, on metallic and different materials were carried out to study the application of leaf springs and revealed that the use of different materials in vehicle suspension can have accountable significance.

Figure 1: A traditional leaf spring arrangement

A leaf spring can either be connected directly to the frame at both ends or attached directly at one end, normally the front, with the opposite end attached through a shackle, a quick swinging arm. The shackle takes up the tendency of the leaf spring to lengthen while compressed and accordingly makes for softer springiness. Some springs terminated in a concave end, referred to as a spoon end (seldom used now), to hold a swivelling member. There have been a whole lot of leaf springs, commonly using the word "elliptical". "Elliptical" or "complete elliptical" leaf springs noted round arcs related at their tips. This turned into joined to the body at the top center of the upper arc; the bottom center was joined to the "live" suspension components, such as a solid front axle. Additional suspension components, which include trailing arms, might be wished for this design, however now no longer for "semi-elliptical" leaf springs as used withinside the Hotchkiss drive.That employed the lower arc, subsequently its name. "Quarter-elliptic" springs frequently had the thickest a part of the stack of leaves caught into the rear stop of the aspect pieces of a brief ladder frame, with the unfastened stop connected to the differential, as withinside the Austin Seven of the 1920s. As an example of non-elliptic leaf springs, the Ford Model T had more than one leaf springs over its differential that became curved withinside the form of a yoke. As an alternative choice to dampers (surprise absorbers), a few producers laid non-steel sheets in among the metallic leaves, including wood.

Following are the main parts of leaf spring:

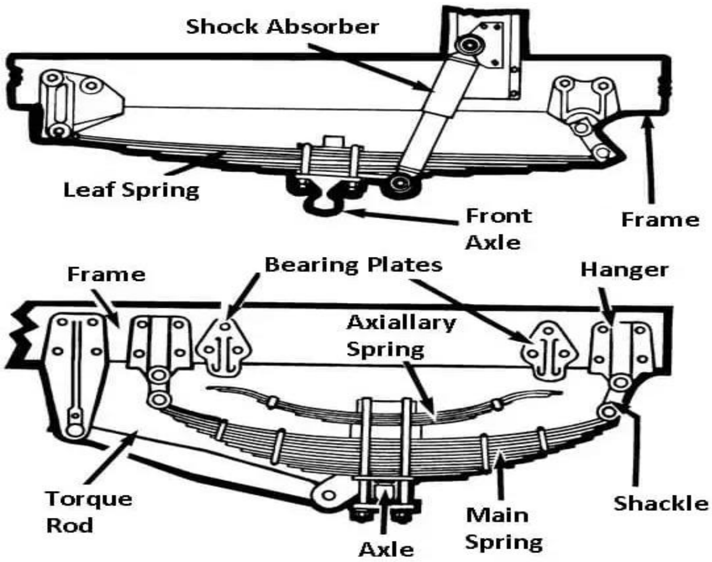

Figure 2: Leaf Spring Suspension System

1. Metal Plates or Leaves

A leaf spring includes numerous metallic plates, additionally called leaflets, layered on every different in lowering order in their size. The leaves are given a curvature called camber, which gives the leaf spring a semi-elliptic look.

2. Master Leaf

The longest leaf at the top of the spring is known as the master leaf. It is curved at each ends to form a spring eye. Two bolts are inserted through these eyes to set the leaf spring to the automobile body.

3. Centre Bolt

The center bolt of the leaf spring is basically structural integrity. The middle bolt is the essential component placed withinside the middle of every leaf in a hole. Its task is to is to maintain all of the leaves together. It incluids a U-bolt and a central bolt, so the leaves do not fall apart.

4. U-bolt

Mainly, the U-bolt provides the force required to firmly fasten the leaf spring and associated components together. In addition to the leaf spring, these components include the top plate, axle seat, and bottom plate.

5. Rebound Clip

Rebound clips are used to keep the leaves aligned and prevent lateral shifting of leaves during vehicle movement. In the center, the leaf spring is supported on the axle. These are steel bands held in a fixed position on either side of the central bolt.

6. Spring Eye

Most people are unaware of this part. The spring eyes are the loops on the ends of a leaf spring. They fasten to the chassis or axle using shackles or bolts in bushings pressed into them.

7. Shackle

A leaf spring can be attached directly to the frame at both ends or one end, usually the front, with the other attached via a shackle. When the shackle is compressed, the leaf increases its tendency to spring and thus creates a soft springiness.

8. Rubber Bush

Leaf spring bushings are used on the front eyes of springs and may be wrapped in steel or maybe all rubber. They provide a cushion for the leaf springs, with the front encased in steel while the rear ones are all rubber.

1.1 Objectives

- To analyse the simulation on three leaf spring model of different material for finding the failure and summaries those thing for improvement.
- To analyse the stress distribution as well as the total deformation during loading for different materials.
- To select the best suitable material with the obtained results.
- To focus on the implementation of safer leaf spring for the suspension system to reduce product weight, improving the safety, comfort and durability.

II. METHODOLOGY

Suitable methodology and solution development for any problem is the most critical part of a design and analysis-based project. In this Chapter the description of the research process is presented. This Chapter discusses the research design, types and methods used to conduct this research.

- As far as this research is concerned, the leaf spring suspension of light weight vehicle was taken for the analysis.
- The leaf spring suspension system had the parabolic design and material properties of steel are considered as the primary variables which could be altered to enhance stiffness to weight ratio. The weight reduction, exibility and enhance stiffness properties of leaf spring design would be the major concerns of this research.
- In this research the leaf spring design of TATA ACE was taken into consideration. The conventional material used for the manufacturing of this leaf spring was structural steel. However, the alternate material was chosen for leaf spring to conduct this research were three different materials i.e Structural Steel, Titanium Alloy & Grey cast iron. These three materials were selected based on their enhanced mechanical properties as compared to conventional material.
- This research aims to conduct analytical analysis on conventional and different material leaf spring.
- The analytical analysis was used to find out the maximum stress in a leaf spring subjected to static and dynamic loads.

III. SELECTION OF MATERIAL

The material used for leaf springs is usually a plain carbon steel having 0.90 to 1.0% carbon. The leaves are heat treated at highely temperature after the forming process. The heat treatment of spring metallic products has more strength and consequently greater load capacity, greater range of deflection and better fatigue properties.

In our project work we have taken three different materials i.e.Structural steel, Titanium alloy & Grey cast iron.

1. Structural Steel

Normally the material used for leaf springs is usually plain carbon steel having 0.90 to 1.0% carbon. The leaves are heat-treated after the forming process. The heat treatment of spring steel products greater strength and therefore greater load capacity, a greater range of deflection, and better fatigue properties also the features of structural steel influence the design and construction of steel structures, and the value of different steel characteristics are highlighted below.

Table 1. Properties of structural Steel

Properties	Value	Units
Density	7850	Kg/m^3
Young Modulus	$2 * 10^5$	MPa
Poission Ratio	0.3	

Shear Modulus	7.9615+E10	Pa
Bulk Modulus	1.725E+11	Pa
Tensile yeild strength	2.5E+08	Pa
Tensile Ultimate Strength	2.5E+08	Pa

2. Titanium Alloy

Titanium's characteristics allow engineers to apply a bigger wire diameter however fewer coils to offer a spring rate that is simillar to the rate of the steel spring being swapped-out. Titanium is lighter and extra controlled, and it reduces area requirements. Add to this titanium's excessive corrosion resistance, and you have material worthy of consideration for a huge variety of applications where weight and space are essiential parameters, especially for applications in harsh environments.

Table 2. Properties of Titanium Alloy

Properties	Value	Units
Density	$4.43 * 10^3$	Kg/m^3
Yeild strength	880	MPa
Poission Ratio	0.342	
Shear Modulus	44	GPa
Youngs Modulus	113.8	GPa
Tensile yeild strength	140	MPa
Tensile Ultimate Strength	220	MPa

3. Grey Cast Iron

Gray Cast Iron, additionally called as gray iron, is a famous sort of iron utilized in castings. The composition of gray solid iron is 2.5%–4% carbon, 1%–3% silicon, and some additions of manganese ranging from 0.1% to 1.2%. Gray iron contains graphitic microstructures, giving the iron its gray color. This process of casting this iron is easy but it cannot be forged or worked mechanically, either hot or cold.

Table 3. Properties Grey Cast Iron

Properties	Value	Units
Density	7250	Kg/m^3
Yeild strength	827	MPa
Poission Ratio	0.28	
Shear Modulus	31	GPa
Youngs Modulus	138	GPa
Tensile yeild strength	276	MPa
Tensile Ultimate Strength	295	MPa

IV. DESIGN AND CALCULATIONS

4.1 LEAF SPRING PARAMETERS

Length of span or overall length of the spring, $2L_1$= 860

Width of band or distance between centers of U bolts or it is the ineffective length of the spring

1= 80mm

Number of full length leaves, N_F = 2

Number of full Graduated leaves N_G = 5

n = Total Number of leaves, n = $N_F + N_G$ = 2 + 5 = 7

Effective length of the Leaf Spring, $2L = 2L_1 - 1 = 860 - 80 = 780$mm

Thickness of each spring, t = 10 mm

Width of Leaf spring w = 80 mm

Camber of Leaf spring, y = 50 mm

$$\text{Length of smallest leaf spring} = \frac{\textbf{Effective Length}}{\mathbf{n-1}} + \text{Ineffective length}$$

Length of next leaf spring or n^{th} leaf spring = $\frac{\textbf{Effective Length}}{\mathbf{n-1}} \times n$ + Ineffective length

Relation between radius of curvature (R) and the camber (y), $R = \frac{(L_1)^2}{2y}$

The exact relation, y (2R+y) = 2(L1)

Length of smallest leaf spring = $\frac{\mathbf{780}}{\mathbf{7-1}} + 80 = 210$ mm

Length of next leaf spring or 2^{nd} leaf spring = $\frac{\mathbf{780}}{\mathbf{7-1}} \times 2 + 80 = 340$ mm

Length of next leaf spring or 3^{rd} leaf spring = $\frac{\mathbf{780}}{\mathbf{7-1}} \times 3 + 80 = 470$ mm

Length of next leaf spring or 4^{th} leaf spring = $\frac{\mathbf{780}}{\mathbf{7-1}} \times 4 + 80 = 600$ mm

Length of next leaf spring or 5^{th} leaf spring = $\frac{\mathbf{780}}{\mathbf{7-1}} \times 5 + 80 = 730$ mm

Length of next leaf spring or 6^{th} leaf spring = $\frac{\mathbf{780}}{\mathbf{6-1}} \times 6 + 80 = 860$ mm

Length of the 6^{th} leaf & master leaf is same = 860 mm

Radius of the curvature is found by,

$$y\,(2R+y) = (L_1)^2$$

$$50\,(2 * R + 50) = (430)^2$$

$$\therefore 2R + 50 = (430)^2 / 50$$

$$R = 1824 \text{ mm}$$

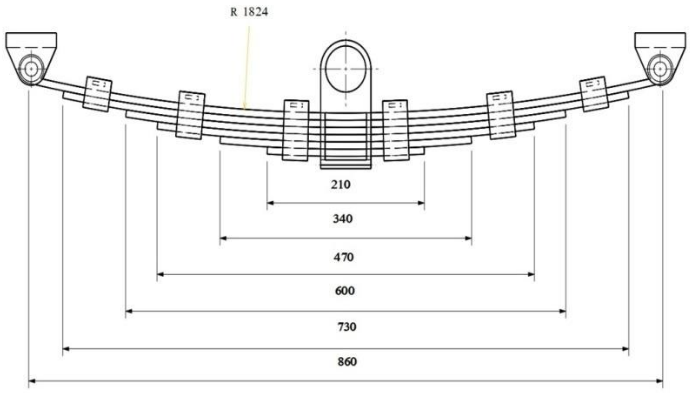

Figure 3: Dimension of the leaf spring used in Tata ACE

4.2 Weight Calculation

Here Weight and initial measurements of four wheeler "TATA ACE" Light commercial vehicle is taken.

Weight of vehicle= 980 kg

Maximum load carrying capacity= 1700 kg

Driver weight =70 kg

Total weight= 1000 + 1700+70 = 2750 kg

Acceleration due to gravity (g) = 9.81 m/s^2

Load acting onleaf spring = 2750 x 9.81 = 26977.50N

Rear suspension = 60% of Total weight = 0.60 x = N

Therefore Total weight = **16186.50 N**

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Since rear suspension consists of 2 springs therefore the load on 1 spring = 16186.50/2

= 8093.25N

So, Maximum load given on each spring 8093.25 N

V. MODELING AND ANALYSIS

CATIA offers a complete set of tools for modeling, assembly, simulation, and manufacturing drawings and may be used in the entire product development process. It helps more than one product development from conceptualization, design, and engineering to manufacturing. Leaf spring of TATA ACE vehicles is taken for modeling and analysis. The 3D modeling of leaf spring is carried out using Catia V5. Figures 4 given below show one of the models of leaf spring used in analysis.

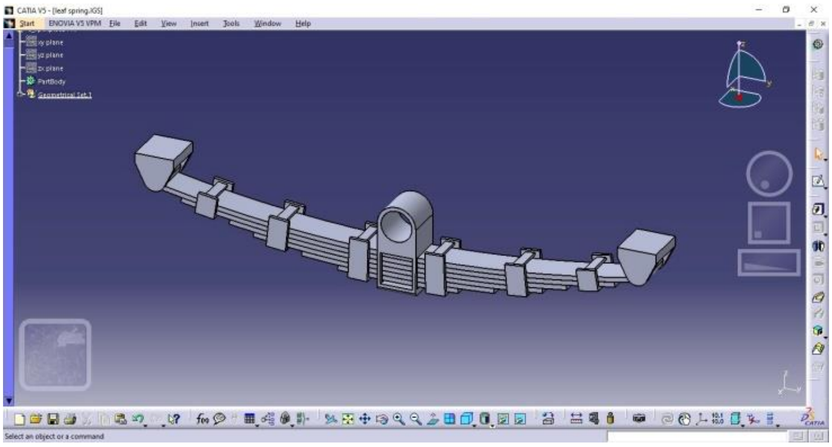

Figure 4: Catia Model

5.1 ANSYS result discussion for structural analysis

1. Ansys Geometry

After assigning the element type of the leaf spring structure, the catia model is converted into the IGES format and imported into ANSYS Workbench.

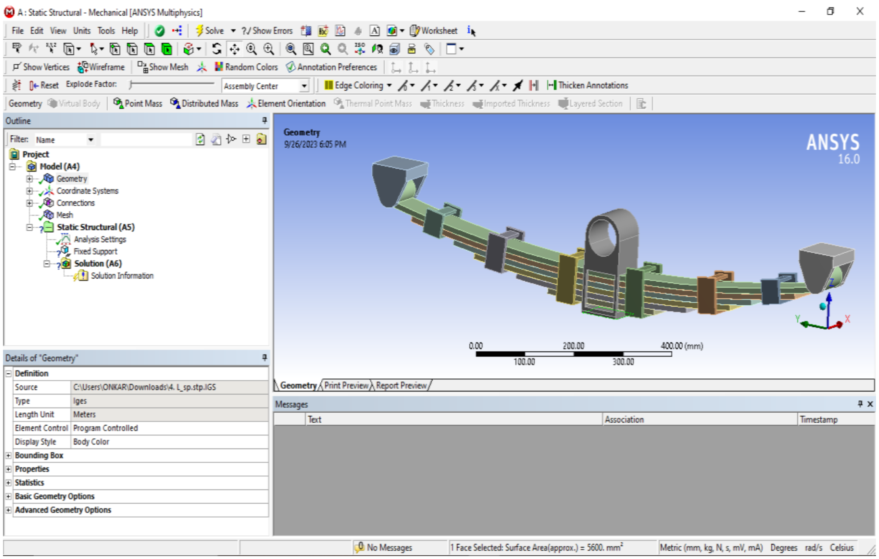

Figure 5: Ansys Geometry

2. Meshing

Figure 5 shows the meshed model of leaf spring. Meshing is an important process of an analysis and it should be performed on the leaf spring structure. Meshing is the procedure of dividing the created model in wide variety of elements or factors which includes nodes.

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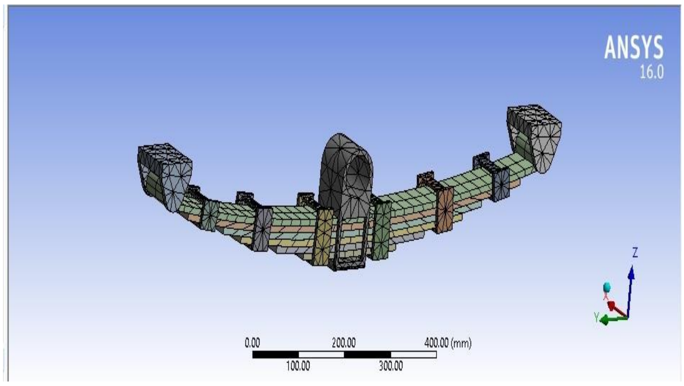

Figure 6: Meshed Model

3. Boundary Conditions

Figure7 shows the boundary conditions which are applied for structural analysis. The boundary conditions are as follows:-

A. Fixed Support: - The notation in the figure7 shows the points where leaf spring fixed i.e. all degrees of freedom are locked.

B. Moment: - This means the calculated load for required deceleration is applied on both eye surface of the leaf spring.

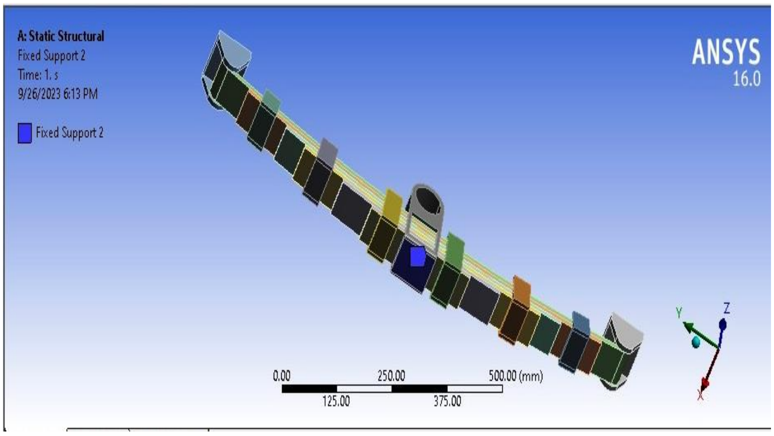

Figure 7: Fixed Support

5.2 Structural analysis

Structural analysis of leaf spring is carried out for three different materials. For each leaf spring equivalent von mises stress, Total deformation & elastic strain are calculated in ANSYS and the results of each leaf spring are discussed.

1. Material: - Structural Steel

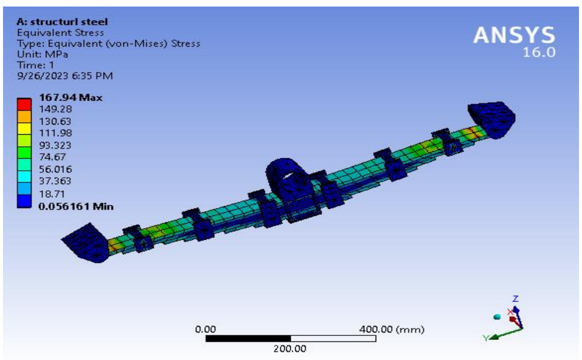

Figure 8: Equivalent Von Mises stress for steel

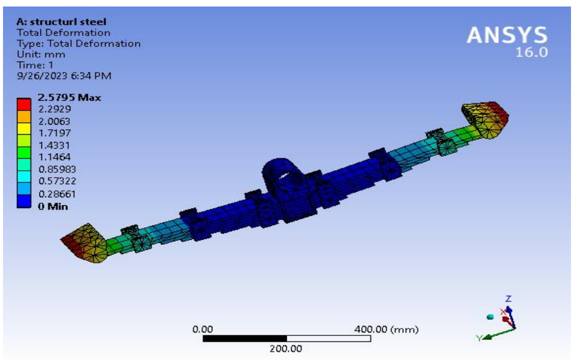

Figure 9: Total Deformation for steel

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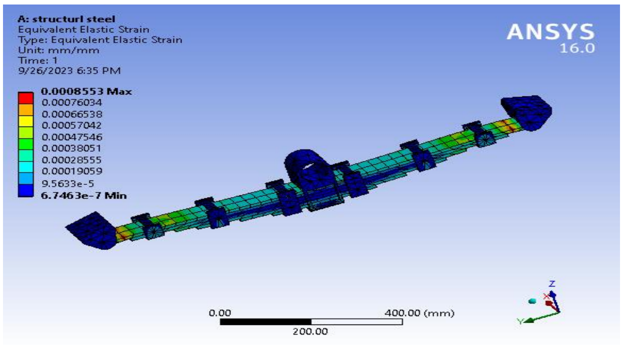

Figure 10: Elastic strain for Steel

2. Material: - Titanium Alloy

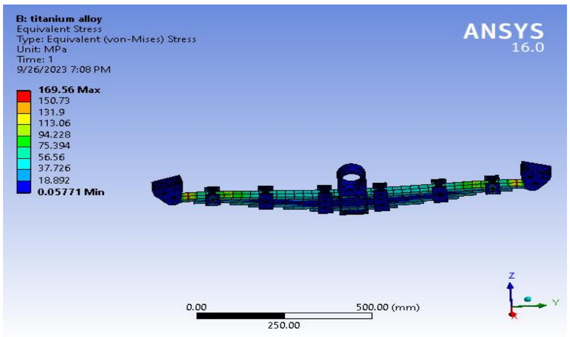

Figure 11: Equivalent Von Mises stress for steel

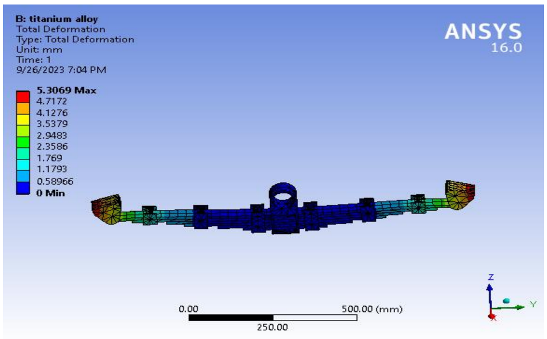

Figure 12: Total Deformation for steel

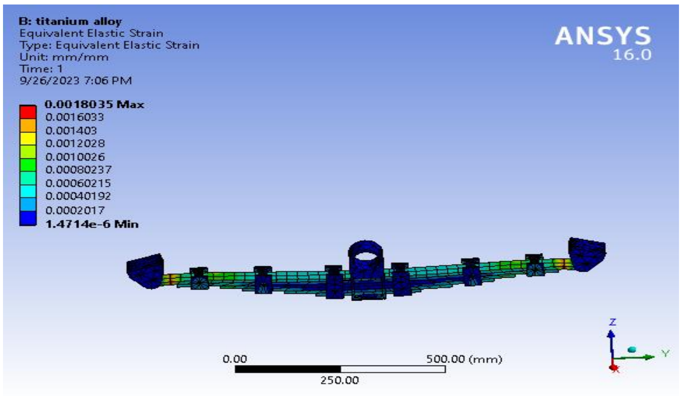

Figure 13: Elastic strain for Titanium Alloy

3. Material: - Grey Cast Iron

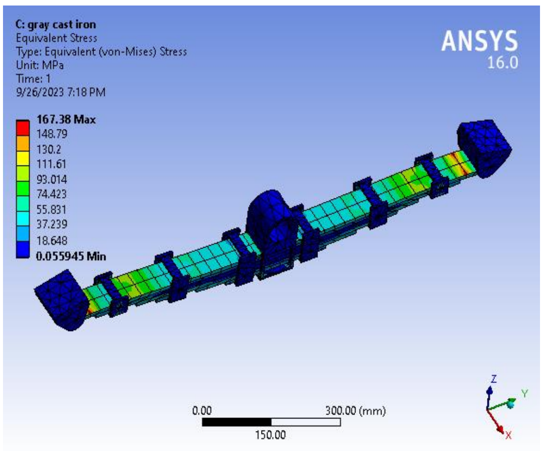

Figure 14: Equivalent Von Mises stress for steel

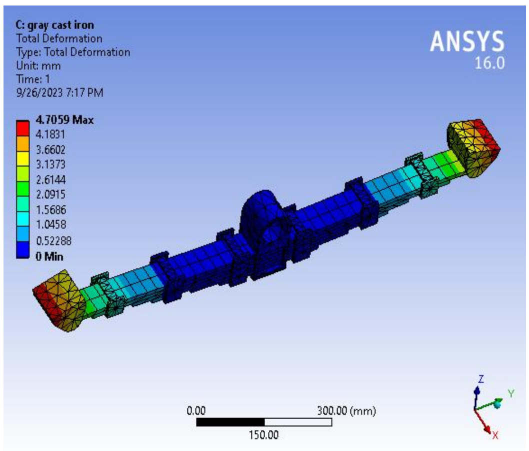

Figure 15: Total Deformation for steel

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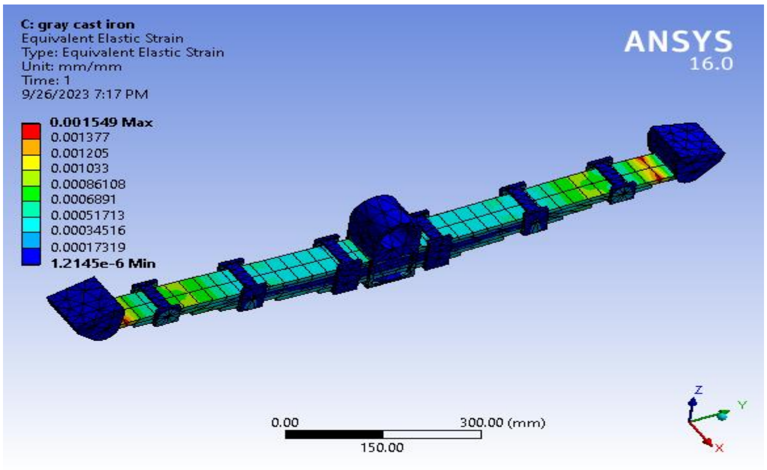

Figure 16: Elastic strain for Grey Cast Iron

VI. RESULT AND DISCUSSION

The car is believed to be stationary and the leaf spring undergoes static loading condition and analyse the Von-mises Stress, Total Deformation and Strain Energy values for each material property. The load acting on the leaf spring equals 8093.25 N which is shown in Figure 7. Results obtained for Deformation, Von-mises Stress and Strain Energy are shown below in Table 4.

Table 4. Obtained Results

Material	Structural Steel		Titanium Alloy		Grey Cast Iron	
Values	Max	Min	Max	Min	Max	Min
Equivalent Von –Mises stress (Mpa)	167.94	0.056161	169.56	0.05771	167.38	0.055945
Total Deformation(mm)	2.5795	0	5.3069	0	4.7059	0
Elastic Strain	0.00085	6.74e^7	0.001803	1.47e^6	0.001549	1.214e^6

Results for selected parameters are obtained for all design cases of leaf spring. Here we observed results on the materials namely Structural steel, Titanium Alloy & Grey cast iron.

1. From the table analysis, the leaf spring is subjected to axial load of 8093.25 and analysis is carried out using ANSYS 16.0 software.
2. The user generated mesh was found to be optimum as per requirements.
3. As per analysis results, the deformation of the body is in acceptable range as per safety norms.
4. As per analysis results, the maximum stress of the body is in vertical direction along the base leaf and the value suggests the design is safe.

But comparing the three material we found that grey cast model has lowest equivalent stress & lowest deformation found in structural steel

VII. CONCLUSION

The project was mainly aimed to minimize the stress & deformatiom developed between the leaves; therefore changing the design of leaf spring by modifying the traditional leaf spring. The modified design of leaf spring was created including traditional leaf spring,

In the present work, a structural leaf spring is chosen because of its high strength and minimum deflection for the same load.

1. A semi-elliptical multi leaf spring is designed for a four wheel automobile under same loading condition using three different materials.

2. The maximum stress and deflection in leaf spring is observed for the titanium alloy the structural steel has minimum deflection.

3. Therefore there's extensive distinction withinside the stresses and deflection in leaf springs under the same static load conditions. Stresses and deflection in structural steel leaf spring found to be less as compared to the other leaf spring.

4. From above analysis it is concluded that the structural steel leaf spring is the better that of other leaf spring.

VIII. REFERENCES

[1] Shahriar Hasan1, a Finite Element Analysis of Automobile Leaf Spring. https://www.researchgate.net/publication/351428769 Conference Paper · March 2021

[2] Shokrieh, M.M. and Rezaei, D., 2003. Analysis and optimization of a composite leaf spring. Composite structures, 60(3), pp.317-325.

[3] Jun, K., Zhenyu, W. and Zhiping, C.X.Y., 2019. A review on material selection, design method and performance investigation of composite leaf springs. Composite Structures, p.111277.

[4] Roselita Fragoudakis eta l .Optimizing the development and manufacturing of 56SiCr7 leaf springs , Science direct , Elsevier, International journal of fatigue 103(2017), 168- 175.

[5] Sancaktar, E. and Gratton, M., 1999. Design, analysis, and optimization of composite leaf springs for light vehicle applications. Composite structures, 44(2-3), pp.195-204.

[6] Raghavedra, M., Hussain, S.A., Pandurangadu, V. and PalaniKumar, K., 2012. Modeling and analysis of laminated composite leaf spring under the static load condition by using FEA. International Journal of Modern Engineering Research (IJMER), 2(4), pp.1875-1879.

[7] Zheng Yinhuan Finite element analysis of composite leaf spring 2011 6th International Conference on Computer Science & Education (ICCSE)

[8] Suprith, N., Annamalai, K., Naiju, C.D. and Mahadevan, A., 2013. Design and analysis of automotive multi-leaf springs using composite materials. In Applied Mechanics and Materials (Vol. 372, pp. 533-537). Trans Tech Publications Ltd.

[9] Sedlacek, F., Bernardin, P. and Lasova, V., 2016, January. Design of a composite leaf spring for railway vehicles. In Proceedings of the 27th DAAAM International Symposium on Intelligent Manufacturing and Automation. Vienna, Austria: DAAAM International.

[10] Rajesh, S., Bhaskar, G.B., Subash, R., Pazhanivel, K. and Sagadevan, S.S., 2017. OPTIMIZAREA PROIECTARII ARCURILOR CU FOI COMPOZITE FOLOSIND METODOLOGIA SUPRAFETEI DE RASPUNS/OPTIMIZATION OF COMPOSITE LEAF SPRING DESIGN USING RESPONSE SURFACE METHODOLOGY. Revista Romana de Materiale, 47(1), p.98.

[11] Chen, Z., Yang, S. and Song, Q., 2017. Fatigue reliability design of composite leaf springs based on ply scheme optimization. Composite Structures, 168, pp.40-46. Carello, M., Airale, A.G., Ferraris, A., Messana, A. and Sisca, L., 2017. Static design and finite element analysis of innovative CFRP transverse leaf spring. Applied Composite Materials, 24(6), pp.1493-1508.

[12] Fragoudakis, R., Savaidis, G. and Michailidis, N., 2017. Optimizing the development and manufacturing of 56SiCr7 leaf springs. International Journal of Fatigue, 103, pp.168-175.

[13] J.Y. Cherruault Testing of Fiber Composite Leaf Spring for Heavy Axle Loads Journal of Thermoplastic Composite Materials Volume 24, Issue 1 Pages: 111 – 132 July 9, 2010

[14] Carello. and Bhaskar, G.B., 2014. Response of composite leaf springs to low velocity impact loading. In Applied Mechanics and Materials (Vol. 591, pp. 47-50). Trans Tech Publications Ltd.

[15] Jenarthanan, M.P., Kumar, S.R., Venkatesh, G. and Nishanthan, S., 2018. Analysis of leaf spring using Carbon/Glass Epoxy and EN45 using ANSYS: A comparison. Materials Today: Proceedings, 5(6), pp.14512-14519

[16] G. Goudah, E. Mahdi, A.R. Abu Talib, A.S. Mokhtar, et al.Automobile Compression Composite Elliptic Spring. IJET. 2006; 3(2): pp-139-147.

e-ISSN: 2582-5208
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Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

[17] Dev dutt Dwivedi, V.K.Jain, (2016) “Design and Analysis of Automobile leaf spring”ISSN (PRINT): 2393-8374, (ONLINE): 2394-0697, VOLUME-3, ISSUE-1.

[18] G. Goudah, AUTOMOBILE COMPRESSION COMPOSITE ELLIPTIC SPRING. International Journal of Engineering and Technology, Vol. 3, No.2, 2006, pp. 139-147

[19] M. M. Patunkar, D. R. Dolas. Modelling and Analysis of Composite Leaf Spring under theStatic Load Condition by using FEA.IJMIE. 2011; 1(1): pp-1-4.

[20] Kumar Krishan, Aggarwal M.L. A Finite Element Approach for Analysis of a Multi Leaf Spring using CAE Tools. RJRS. 2012; 1(2): pp-92-96.