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LEAF SPRING EYE THICKNESS OPTIMIZATION USING SOLID WORKS AND ANSYS PERFORMANCE ANALYSIS

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ABSTRACT

“Comparison Analysis of Leaf Spring with Eye Thickness of 18mm and 17mm Using Solid works, and Performance Analysis Using ANSYS ” was the subject of a study. The specific load and Unladen load were used to compare the eye thicknesses of 17 mm and 18 mm. The leaf springs in the vehicles make the passengers more comfortable by reducing vertical vibration caused by the unevenness of the road geometry. When a spring loses its shape over time, the life of the spring decreases, which can cause the weight distribution on four wheels to change and make it difficult to handle. The cause of leaf spring failure is truck driving conditions such as braking, cornering, and path hole striking, which will exert tensional forces on the spring. Designing a suitable eye with increased thickness for a leaf spring can increase the life, and Static Structural analysis is performed to understand the life of the Steel leaf spring

Keywords—– LeafSpring,Static Structural,Thickness

1.Introduction

Simple springs like leaf springs are frequently used in the suspension of wheeled cars. Leaf spring is made up of spring steel which resists bending and it supports heavy-duty vehicles carrying heavy loads and also furnishes comfort to the passengers by diminishing the vertical vibration caused by the irregularity of road geometry. This leaf spring is made up of overlaid strips means one-on-one-like leaves and it reduces the vehicle's weight. It is also called a semi-elliptical spring or cart spring, it is in the shape of a slender arc and at the centre of the arc there is the location for the axle it consists of tie holes at both sides and is used to attach the leaf spring to the vehicle body. These tie holes, which are referred to as the front and rear eyes, are very important for reducing the spring's deflection and the distance between the eyes when the vehicle encounters a jump or projection. These eyes are attached to the lengthiest strip which is called the master leaf and the remaining leaves are named graduated leaves. The design of leaf spring is identified by lesser leaves commonly shorter leaves whose thickness differs from centre to end and it follows the parabolic curve [1].

The leaf spring can maintain the comfortable operation of a suspension system by absorbing and storing the energy. The theory that leaf spring working is based on a beam of uniform strength [2]. The leaf springs can be systematized in two different ways depending on the type of vehicle. The first type is simply a supported spring with two ends attached to the chassis and the second type is a cantilever leaf spring with budge free at one end and on the other end fastened to the vehicle chassis. The main function of a multi-leaf spring is to carry a sideways load, disintegrating the torque and shock absorbing. Rebound clips are usedto keep leaves in their correct position and to prevent them from shifting laterally [3].

1.1Types of Leaf spring eyes

1.1.1.Up-Turned eye

Up-turned eyes are the most ordinarily utilized sort of spring eye, given their Simple design and high toughness. They are profoundly solid since they oppose pressure because of vertical Forces on a suspension framework. In contrast to other spring eye designs, an upturned eye applies vertical forces on the direct leaf segment that was not bent to shape the eye [12].

Figure 1. Leaf Spring Configuration

1.1.2. Berlin eye

Berlin's eyes are used when high torsional loads are applied, because the loading profiles of the leaf spring expand toward the centre of the eye. Berlin Eye is a reliable and widely used design that is well-suited for lighter-duty applications and applications with lower loads and less demanding operating conditions

1.1.3. Reinforced Eye

A Reinforced Eye is achieved by adding additional material or reinforcement to the eye, such as thicker metal plates, gussets, or brackets. This reinforcement helps to distribute the loads more evenly, reduce stress concentrations, and prevent deformation, bending, or breaking of the eye under heavy loads. Reinforced Eye is typically used in heavy-duty applications, such as construction equipment, mining vehicles, or military vehicles, where high loads and demanding operating conditions are expected.

1.1.4. Military Wrapper Eye

The military wrapper is a spring eye design that has an optional leaf those folds over the principal leaf. It adds an extra layer of security and safety. If a principal leaf breaks, the primary association of the differential to the frame of the vehicle is broken and the pivot is ready to move in manners it shouldn't, which will permit different things to get harmed. With a military wrap, assuming that the primary leaf breaks, there's an extra layer that will keep the suspension associated and keep the differential where it should be.

1.1.5. Plain End Mounting Eye

It is a simple and cost-effective eye design that is typically used in lighter-duty applications, such as trailers, light trucks, or smaller vehicles. In the Plain End Mounting Eye design, the end of the leaf spring is simply cut square, without any additional reinforcement or machining. This end is then drilled or punched to create a hole for mounting to the vehicle or other components. However, the Plain End Mounting Eye may not be suitable for heavy-duty applications or applications with high loads and harsh operating conditions, as the lack of reinforcement can result in deformation, bending, or breaking of the eye under heavy loads.

1.1.6. Reverse eye

The changing of a spring's eyes is one of the most common changes. Spring eyes are the circles at the end of a leaf spring. They join to either the undercarriage or hub via shackles or dashes in bushings squeezed into them [12].

1.2. Factors that are affecting Leaf-Spring to failure

Spring leaves are subjected to five deformations during truck operations: tension, compression, bending, shear, and torsion. The truck maintenance practices show that after some time, spring leaves undergo degradation in which their physical and mechanical properties change because of the embrittlement of the material, which causes fatigue cracks during heavy loads. Using composite materials can reduce this embrittlement and increase the life of the leaf spring [4].

Some loads are ignored when designing the leaf spring, such as windup during vehicle braking and suspension roll, which will exert additional loads on the leaf spring. It will cause the spring eye to fail which caused a catastrophic accident involving a sport utility vehicle. So the improper design of the leaf spring eye will cause catastrophic accidents [6].

1.3. Comparison of Leaf Spring Eye Design

The leaf spring eye plays a critical role because most of the stress is induced in the leaf spring eye. This stress can be reduced by changing the design of the eye. There are two kinds of designs: standard designs and cast designs. After analyzing both the designs in ANSYS, it is observed that in the case of a casted eye, the bending stress is increased by 19.08%, and factor safety is reduced by 13% as compared to the standard eye. Casted eye is therefore not recommended for design [13].

For designing of vehicle leaf spring, there are two types of eye designs they are Military wrapper eye and Reinforced eye. When analysis is carried out on these eyes it has gone through four types of loads Specific load, laden load, Unladen load, and 2G load: by comparing the results of von Misses stress and deflection, they are almost the same, but the military wrapper eye is stiffer than the reinforced eye because the wrapper on the second leaf should be utilized as an eye when there is a failure in the first leaf eye [14].In this paper we are designed the Up-Turned eye.

1.4. Design considerations for leaf spring eye

Some important design considerations when designing and analysing a leaf spring in Solid Works and ANSYS include:

1.4.1. Load specifications: The leaf spring should be designed to withstand the expected load and stress under various operating conditions.

1.4.2. Material selection: It is critical to ensuring that the leaf spring can withstand the load and stress requirements. Yield strength, ultimate strength, and modulus of elasticity are all important material properties to consider.

1.4.3. Geometric constraints: The leaf spring design should take into account the suspension system's available space as well as the allowable deflection.

1.4.4. Manufacturing feasibility: The design should be able to be manufactured and produced. The designer should consider the manufacturing process's limitations as well as the design's cost implications of the design.

1.4.5. Method of analysis: Analytical and numerical methods should be used to analyse the leaf spring design. Solid Works and ANSYS are two popular software tools for leaf spring analysis, and the designer must ensure that the analysis models and parameters used are accurate and appropriate for the design.

1.4.6. Optimization: To improve the design, the designer can use optimization techniques to identify the best combination of parameters such as leaf thickness, number of leaves, and material properties. This can help you lose weight and perform better [16].

1.5. ANSYS analysis procedure

ANSYS analysis procedures typically include the following steps:

1.5.1. Preprocessing: In this step, you use ANSYS Design Modeller to create the geometry of the model you want to analyse, or you import it from Solid Works software. You must also specify the boundary conditions, material properties, and any other relevant input data for the analysis.

1.5.2. Mesh generation: After creating the geometry, you must generate a mesh in order to discretize the model into smaller elements. To create the mesh, you can use ANSYS Meshing or meshing software. The quality of the mesh can have a significant impact on the accuracy and convergence of the analysis, so paying attention to the meshing process is critical.

1.5.3. Solving: In this step, you run the analysis by solving the equations governing the model's behaviour with ANSYS Mechanical or another solver. Analyses supported by ANSYS include structural, thermal, fluid, and electromagnetic analyses.

1.5.4. Postprocessing: Once the analysis is complete, you can use ANSYS Mechanical or postprocessing software to review and analyse the results. You can use various plots, such as stress and displacement plots, to visualise the results and extract specific data points of interest.

1.5.5. Iteration: If the results do not meet the desired criteria or objectives, the model or input parameters may need to be adjusted and the analysis repeated. The iterative process is repeated until you obtain satisfactory results.

1.5.6. Reporting: Finally, you must prepare an analysis report that includes a summary of the problem, methodology, results, and conclusions. Any assumptions made, limitations of the analysis, and recommendations for future work should all be included in the report [16].

1.6. Effect of changing the thickness in the eye of leaf spring

There are two distinct eye types: the upturned eye and the Berlin's eye. The Berlin's eye is most frequently used to withstand torsional loads because the loading is applied at the eye's centre. Compared to Berlin's eye, the military eye is a more complicated and advanced design that offers improved results as well as dependability. Leaf spring eye design has a significant role in heavy trucks. Failure of leaf springs can cause fatal accidents, so the design should prevent failure under braking, cornering, and pothole-striking loading conditions. These can be reduced based on the material yield strength and with an eye thickness of 17mm can suppress these loading conditions [6].

1.7. Design Properties of leaf spring

Table.1.Design properties

Properties	Value
Young’s modulus	2e5Mpa
Possion’s Ratio	0.29
Brinell Hardness number	415-461
Tensile ultimate Strength	1495Mpa
Tensile yield Strength	1196Mpa
Density	7.7e-6 kg/mm^2

2. Literature review

It is determined that the maximum safe load for the specified specifications of the leaf spring is 7700N after modelling the leaf spring and doing static analysis using ANSYS software. The inner side of the eye segments is where the majority of stress is observed to develop; hence consideration must be taken in the production, design, and material selection of eyes. The selected material must have good ductility, resilience, and toughness to avoid sudden fracture providing safety and comfort to the occupants [8]. When the leaf spring is fully /half loaded, The Experimental & CAE values differ in deflection by 1.17%, which demonstrates the validity of our CAD model and analysis. When compared to experimental observations, the bending stress for completely loaded is raised by 12.30% in CAE analysis, while it is increased for half loaded. For fully and partially loaded leaf springs, the maximum equivalent stress is 172.5 MPa and 86.29 MPa, respectively, which is less than the yield stress of 250 MPa. Thus, the design is secure [9].

By increasing the number of layers in the leaf spring the tensile strength and bending loads are increasing as well as the hardness of the material is not changing [5]. The results show that the designs with a thickness below 16 mm failed under those extreme load cases, whereas the design with a thickness of 16 mm only slightly passed the requirement. Therefore, in consideration of the safety factors, the spring eye design with a thickness of 17 mm yields the best solution to these dynamic load cases. Finding the most appropriate spring eye design under those extreme load cases is crucial in preventing insufficient and overdesign conditions. This analysis also aims to prevent vehicle accidents caused by spring eye failure due to improper designs [6].

The width of the steel leaf spring is held constant, and the variation of natural frequency with leaf thickness, span, camber, and the number of leaves is investigated. The current study shows that the natural frequency increases with camber and remains nearly constant with the number of leaves, but it decreases with the span. For various road irregularities, the natural frequencies of various parametric combinations are compared to the excitation frequency. The values of natural and excitation frequencies are the same for both springs because the geometric parameters of the springs are nearly identical except for the number of leaves [7].

The leaf spring was created with the solid tetrahedron 10 - node -187 elements. Using dynamic analysis, it is determined that the applied pressure of 1.77 M pa is safe for the given specifications and design of the leaf spring. The stresses in the eyes of a composite leaf spring are significantly lower than those in steel spring eyes. The strength-to-weight ratio of composite leaf spring eyes is higher than that of conventional steel leaf spring eyes of similar design [10].

The current study focused on the design of leaf springs while taking into account vehicle arrangement dimensions and fatigue life requirements from the vehicle manufacturer for specific operating loads. Using the FE method, a serial parabolic 2-leaf spring for heavy-duty vehicle front axles was designed. Vertical loads from straight-ahead driving and biaxial loads from full vehicle braking are taken into account as design criteria. The stress limits were exceeded, and an approximately uniform distribution of stress was achieved along the length of the two leaves [11].When four loads (Specific load, Unladen load, Laden load, and 2G load) are applied to both the Military Wrapper eye and Reinforced eye, it is found that Von-Misses stress and total deformation are the same for both eyes, but that deformation is slightly lower in Military eye because of too high stiffness. Military eyes are therefore selected for heavy-duty applications where great safety is required [14].The leaf spring is described as a beam of uniform strength made up of leaves of identical thickness, where the fibre stress is constant along the length of the beam, according to [15]. For the majority of springs, this approximation is acceptable as long as it meets the layout work's accuracy requirements and takes into account a few correction factors for the estimated length, overhang, camber, breadth, thickness, and the number of leaves. The design parameters that the parameters fall under are listed in Table 2.

Table.2.Design parameters of the leaf spring

Span(L)	1150±3
Load rate(k)(N/mm)	159.11±7%
Load(N)	
Rated(P/g)	12959
Maximum (P_{max})	28010
No load camber(C_a)(mm)	95±4
Seat length(mm)	100
Total number of leaves(N)	12
Number of full length leaves(X)	2
Maximum thickness of the individual leaf(t)x Width(b),(mm x mm)	8x70
Ride clearance(X_c)(mm)	94.6
Stiffening factor(SF)	1.1
Required fatigue life(N_f) at (1.3 ±07g)	70000cycles

According to [13], the same load applied to both cast and standard eye leaf springs results in an identical 2.9% stress reduction and a 5.44% increase in deflection. It is concluded that cast eyes are also safe under the specified loading circumstances because the maximum stress caused is lower than the yield stress. The area of a minimum factor of safety will fail earlier in the case of the casted eye since the minimum factor of safety is reduced by 13.1% in that scenario. As a result, casting an eye is not advised. In comparison to experimental testing, it is concluded that CAE tools offer a cost-effective and faster solution; however, the outcomes may vary within the given range.

Torsional and tensional forces along the leaf spring eye design were taken from the simulation under the braking, cornering, and pothole-impacting load scenarios, as is explored in [6]. The extracted forces were fed into a finite element simulation model as the load input to determine the primary surface stress of the spring eye designs. The stress level of the spring eye design with a thickness of 17 mm outperformed all three severe loading scenarios, according to an analysis of the material's yield strength. The findings further demonstrate that in those extreme load conditions, the designs with a thickness of less than 16 mm failed, but the design with a thickness of 16 mm barely met the requirement.

3. Theoretical design specifications of Leaf Spring.

3.1 Design specifications for leaf spring model in solidworks2017

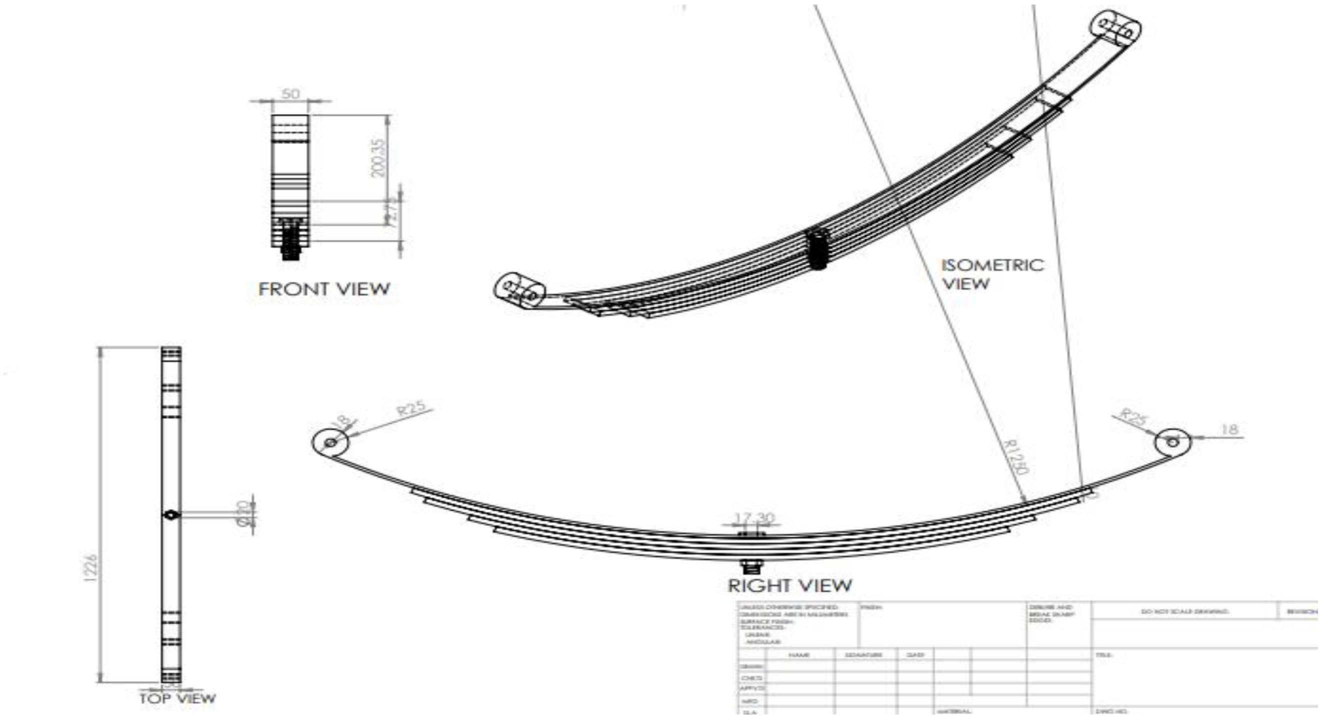


Figure 2. Two Dimensional of leaf spring geometry

Table.3.Design Specifications of Leaf spring

Parameter	Value	Unit	Notation
Total length of leaf	1226	Mm	2L
No. Of full-length leaves	1	Unit	Nf
No. of graduated leaves	4	Unit	Ng
Total number of leaves	5	Unit	N
Nut Diameter	20	Mm	D
Width of leaf	50	Mm	W
Inside diameter of eye	18	Mm	D
Radius of curvature	1250	Mm	R

4. Analysis of Leaf Spring in ANSYS 2020 R1.

The software package that is used is ANSYS 2020 R1 it is general-purpose tool and it is a cost effective for performing virtual prototyping [1].

4.1 Introduction and procedure

The leaf spring which is modelled in the Solid works is imported to the ANSYS to perform Static structural Analysis with loads of Specific load(4905N) and Unladen load(12645N).The specific load is useful for understanding the stress and strain that a material or structure can withstand without experiencing failure or deformation. It is often used in the design and testing of mechanical systems to ensure they can handle the loads when they are subjected to use. The Unladen load includes the weight of vehicle itself as well as any standard equipment such as engine and transmission. It is important to understand the Unladen load to analyze the performance of leaf spring suspension system. The leaf spring must support the weight of the vehicle when it is empty and when it is carrying passengers. This Unladen load determines the minimum stiffness and strength required of leaf springs and also amount of force required to compress the springs [14].In this paper we are comparing the Maximum Principle stress of the leaf spring with eye thickness of 17mm and 18mm by applying specific load and Unladen load and It was carried out in ANSYS work bench. By comparing the maximum principle stress one can determine which design is more suitable for particular application. When there is low maximum principle stress that spring should be less likely or deform under the applied load. So maximum principle stress has crucial aspect in leaf spring design it helps in determining the strength and durability of spring under various loading conditions.

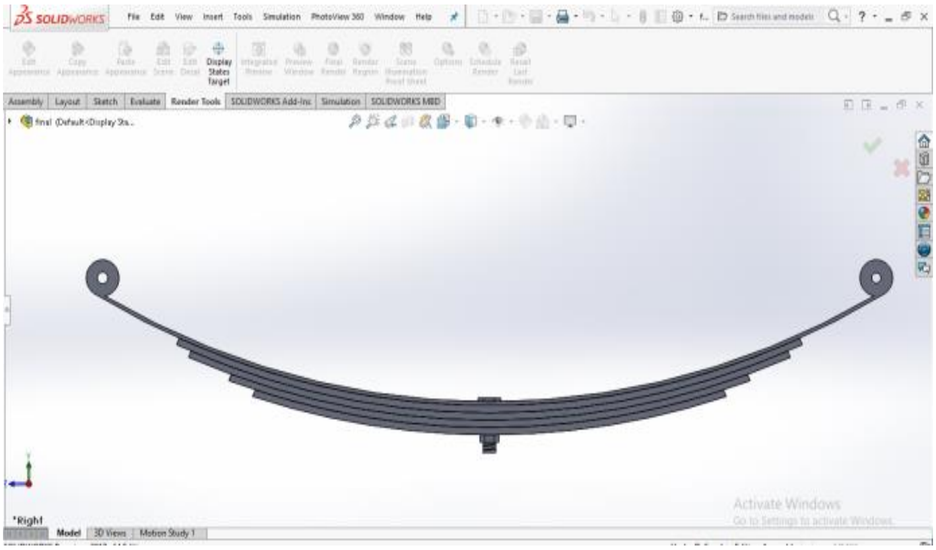
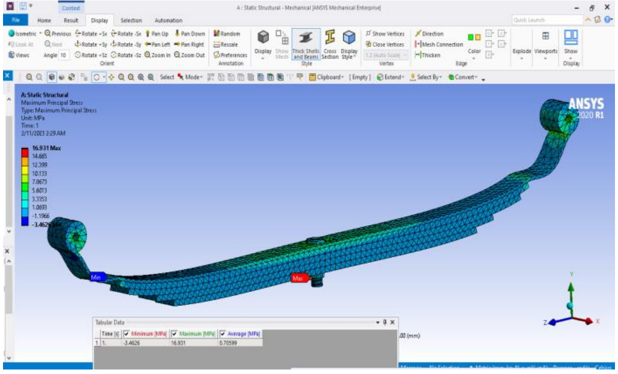


Figure 3.Three Dimensional Model of Leaf spring

4.2. Result Analysis

Comparing the maximum principle stress, deformation, and von-Misses stress on leaf springs with 17mm and 18mm thick eyes under a specific load (4905N).

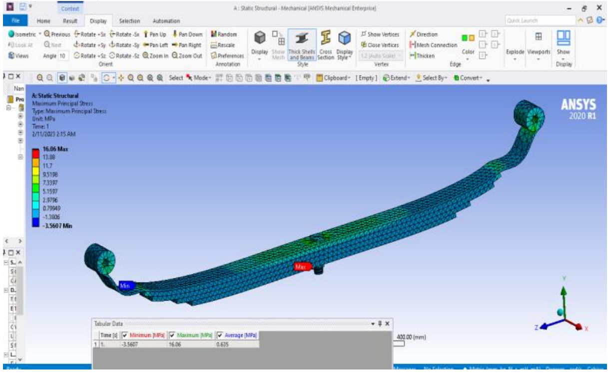


A: Static Structural
Maximum Principal Stress
Type: Maximum Principal Stress
Unit: MPa
Time: 1
2/11/2023 2:29 AM

Tabular Data

	Time [s]	☑ Minimum [MPa]	☑ Maximum [MPa]	☑ Average [MPa]
1	1.	-3.4626	16.931	0.70599

Figure 4.Maximum principle stress of leaf spring with 18mm thickness of eye at specific load



A: Static Structural
Maximum Principal Stress
Type: Maximum Principal Stress
Unit: MPa
Time: 1
2/11/2023 2:15 AM

Tabular Data

	Time [s]	☑ Minimum [MPa]	☑ Maximum [MPa]	☑ Average [MPa]
1	1.	-3.5607	16.06	0.635

Figure 5.Maximum principle stress of leaf spring with 17mm thickness of eye at specific load

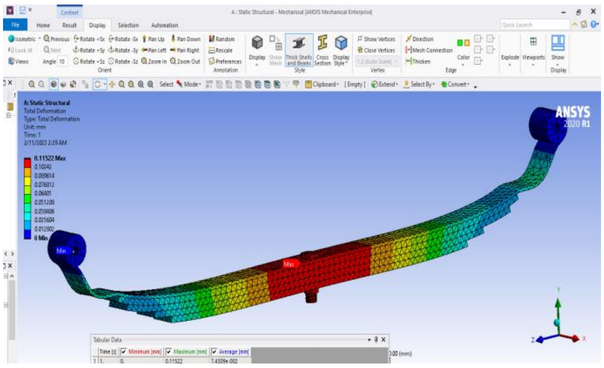


Figure 6.Deformation of leaf spring with 18mm thickness of eye at specific load.

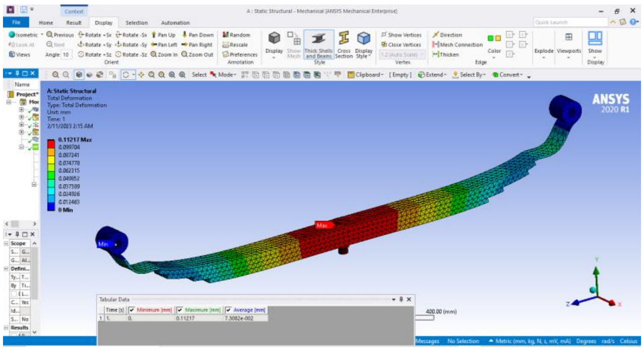


Figure 7.Deformation of leaf spring with 17mm thickness of eye at specific load.

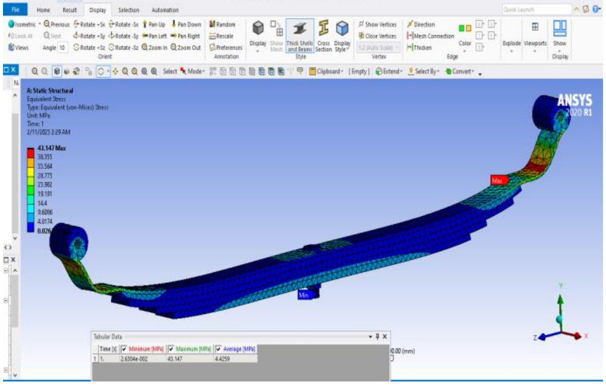


Figure 8.Von-Missess Stress of leaf spring with 18mm thickness of eye at specific load

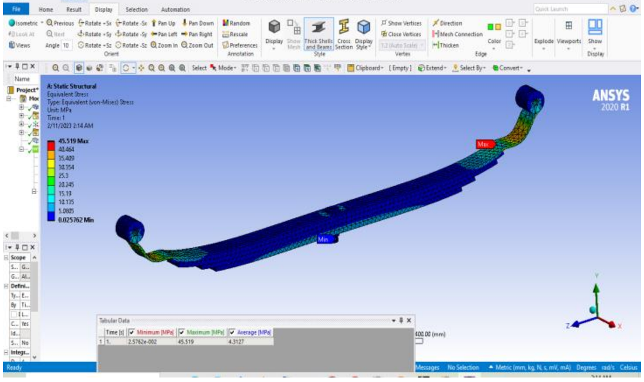


Figure 9.Von-Missess Stress of leaf spring with 17mm thickness of eye at specific load

Comparison of Maximum principle stress, Deformation and Von-Misses Stress from Static structural analysis on leaf spring with eye thickness of 17mm and 18mm with Unladen load(12465mm).

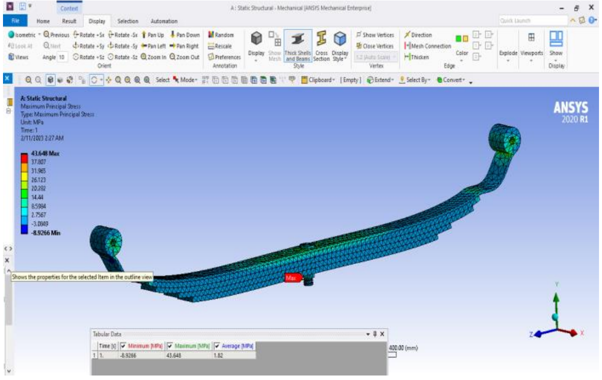


Figure 10.Maximum principle stress of leaf spring with 18mm thickness of eye at Unladen load.

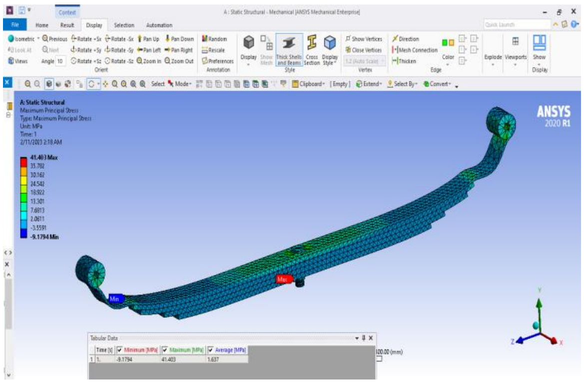
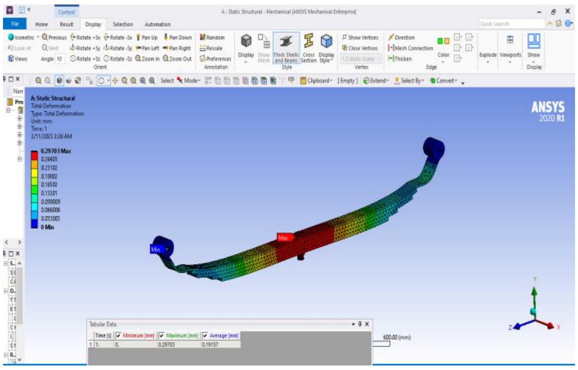


Figure 11.Maximum principle stress of leaf spring with 17mm thickness of eye at Unladen load

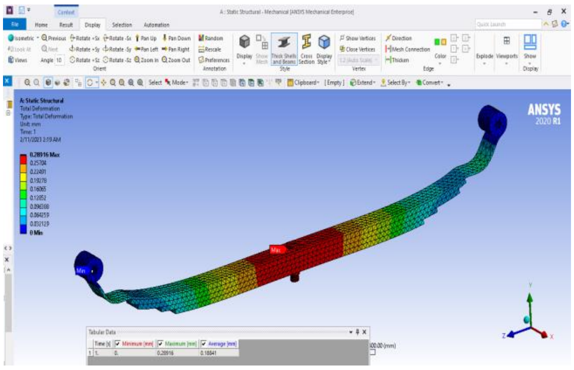


A: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1
2/11/2023 2:26 AM

Tabular Data

	Time [s]	☑ Minimum [mm]	☑ Maximum [mm]	☑ Average [mm]
1	1.	0.	0.29703	0.19157

Figure 12.Deformation of leaf spring with 18mm thickness of eye at Unladen load.

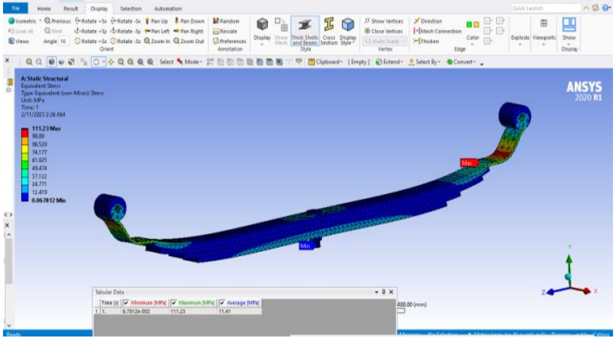


A: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1
2/11/2023 2:19 AM

Tabular Data

	Time [s]	☑ Minimum [mm]	☑ Maximum [mm]	☑ Average [mm]
1	1.	0.	0.28916	0.18841

Figure 13.Deformation of leaf spring with 17mm thickness of eye at Unladen load.

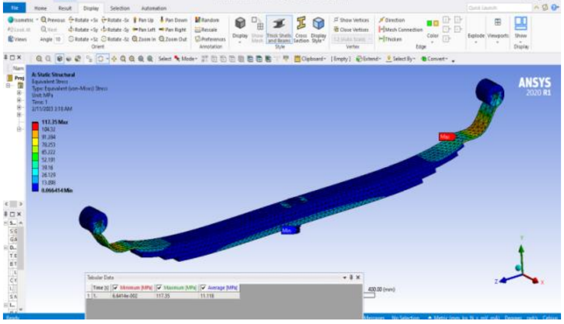


A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
2/11/2023 2:26 AM

Tabular Data

	Time [s]	☑ Minimum [MPa]	☑ Maximum [MPa]	☑ Average [MPa]
1	1.	6.7812e-002	111.23	11.41

Figure 14.Von-Missess Stress of leaf spring with 18mm thickness of eye at Unladen load



A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
2/11/2023 3:18 AM

Tabular Data

	Time [s]	☑ Minimum [MPa]	☑ Maximum [MPa]	☑ Average [MPa]
1	1.	6.6414e-002	117.35	11.118

Figure 15.Von-Missess Stress of leaf spring with 17mm thickness of eye at Unladen load

4.3. Comparison of Analysis for steel leaf spring eye with thickness of 17mm and 18mm

According to the comparison made between the leaf springs with thicknesses of 17mm and 18mm under the loading conditions of Specific load and Unladen load, the leaf spring with thicknesses of 18mm has more maximum principle stress and deformation than the leaf spring with thicknesses of 17mm. Von misses stress is greater for 17mm thick leaf springs than for 18mm thick leaf springs.

Table 4: Comparison Table for Specific load (4905N)

Comparison Of Stress	Thickness of eye	
	18mm	**17mm**
Maximum Principle Stress(Mpa)	16.931	16.06
Deformation (mm)	0.11522	0.11217
Von-Misses Stress(Mpa)	43.147	45.119

Table 5: Comparison Table for Unladen load (12465N)

Comparison Of Stress	Thickness of eye	
	18mm	**17mm**
Maximum Principle Stress(Mpa)	43.648	41.403
Deformation (mm)	0.29703	0.28916
Von-Misses Stress(Mpa)	111.23	117.35

5. Results & Discussions

This paper presented a comparison of leaf spring eyes with thicknesses of 17mm and 18mm created in solid works and analysed in ANSYS using Specific load and Unladen load. According to the findings, maximum principle stress and deformation are greater for 18mm thickness eye leaf springs than for 17mm thickness eye leaf springs, and von-Misses stress is greater for 17mm thickness eye leaf springs than for 18mm thickness eye leaf springs.

Because maximum principle stress plays a significant role, it is frequently used to predict whether a material or structure will fail under a given set of conditions. It also indicates a material's ability to withstand external loads and stresses and can be used to predict failure under specific conditions. So, in this paper, a 17mm eye thickness leaf spring eye can withstand loads and has a longer life than an 18mm eye thickness leaf spring eye.

6. References

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[3] Fabrication Of Hybrid Composite Materials Leaf Spring Ekhlas Edan Kader,Rania Adwan, Lutfi Yousuf Zedan Mechanical Engineering Department, University Of Diyala, Baqubah, Diyala, Iraq *Corresponding Author Email:Ekhlasedan_Eng@Uodiyala.Edu.Iq

[4] Experimental Study And Optimization Of Leaf Spring

[5]Design And Analysis Of Glass Fiber Reinforced Polymer (Gfrp) Leaf Spring B.B.Deshmukh 1*, Dr.S.B.Jaju 2 1 Student, Iv Semester M. Tech (Cad/Cam) E-Mail: Bhushan.Deshmukh03@Gmail.Com 2 Professor E-Mail: Sbjaju@Gmail.Com 1*,2 Mechanical Engineering Department, G. H. Raisoni College Of Engineering, Nagpur. 440016 (India)

[6] Failure Assessment Of A Leaf Spring Eye Design Under Various Load Cases Y.S. Kong A , S. Abdullah A,B, M.Z. Omar A,B,⁎, S.M. Haris A,B A Department Of Mechanical And Materials Engineering, Faculty Of Engineering And Built Environment, UniversitiKebangsaan Malaysia, 43600 UkmBangi, Selangor Darul Ehsan, Malaysia B Centre For Automotive Research, Faculty Of Engineering And Built Environment, UniversitiKebangsaan Malaysia, 43600 UkmBangi, Selangor, Malaysia

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