WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

CFD Investigation for Structural Analysis of a Leaf Spring

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DOI: https://doi.org/10.55248/gengpi.2022.3.10.21

A B S T R A C T

Numerical and computer modelling have been playing a significant role in the Computer Aided Engineering (CAE) process of many products over the most recent 60 years. Simulation offers extraordinary benefits in the turn of events and examination period of items and offers a quicker, better and more practical way than utilizing actual models alone. A leaf spring is the simplest type of suspension framework, widely used in heavy commercial vehicles. commercial simulation software and experimental analysis was carried out for the model of electric auto rickshaw leaf spring. Considering electric auto rickshaw's own weight and seven passenger's weight with factor of safety, the material selection for leaf spring was 50Cr1V23 which have good mechanical and chemical properties for using as leaf spring. Leaf spring was fabricated by using this alloy 50Cr1V23 for designed dimensions. Deflection and stress has been calculated theoretically for same load as commercial simulation software analysis. The computational analysis was carried out on commercial simulation software 18.2. In this research work leaf spring has been analysed using commercial simulation software static analysis considering inter-leaf contact, the stress distribution, strain and deflection obtained. The results highlight theoretical deflection, stress and strain compare with commercial simulation software results. The comparison results showed that results varied 8.9 % deflection and 7.33% stress in commercial simulation software results from theoretical results. Deflection vs. force, stress vs. strain graph plotted from commercial simulation software analysis results and graph showed that they were proportional to each other's.

Keywords:*Leaf-Spring, Commercial simulation software analysis, Stress, Strain, Deflection,*

1. 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. Arc-shape slender piece of steel is used to make leaf spring that is combined with the same material in smaller sizes and bolted together creating a reinforced bow-like item. Then it is attached to the rear axle and the chassis providing support to any additional weight that is added to a vehicle, preventing the axle from buckling in and snapping from the pressure of an extreme amount of weight [1].

The main purpose of suspension system designed for automobile is to provide sufficient comfort for passengers as well as should improve the handling ability of car. Leaf spring provide a smoother ride by absorbing any bumps in the road. Another purpose of leaf spring is to locate the axle and control the height at which the vehicle rides and helps keep the tires aligned on the road.Today leaf springs are still used in heavy commercial vehicles such as vans and trucks, sport utility vehicle (SUVs), and railway carriages. For heavy vehicles, they have the advantage of spreading the load more widely over the vehicle's chassis, whereas coil springs transfer it to a single point [2].

Leaf springs are generally monitored on the basis of its deflection attributes and ability to store and absorb the strain energy. The energy absorbing capacity of spring is determined by the stiffness of springs. A semi elliptical leaf spring as shown in fig. 1. Handling of car refers to the stability of vehicle during cornering, off road drives etc. The stiffness of springs should be more to improve stability of vehicle. For automobile both comfort as well as stability is essential [3].

The elastic property of steel leaf spring allows for a pliancy within the suspension for comfort and control of a car while moving. Fuel efficiency and emission gas regulation of automobiles are two important issues. Therefore, nowadays automobile industries are trying to make that vehicle which can provide high efficiency with low cost, for that increase the fuel efficiency and reduce the weight of the automobile are the main consideration [4].

2. Methodology

The spring is an elastic body, it is distorted when load applied on it and it will come back to its original shape when load is removed. When leaf spring is loaded then it deflects, the upper side of each leaf tips slides or rasp against the lower side of the leaf above it. Therefore, it produces some damping which reduces spring vibrations, but since this available damping may change with time. Leaf spring (also known as flat springs) is made out of flat plate [5].

In this research work Electric Auto Rickshaw was considered for this leaf spring application. Simple supported beam type leaf spring used in Electric Auto Rickshaw.

3. Design and construction of a typical leaf spring

3.1 Design of a typical Leaf Spring

Leaf spring conventional design methods based on the application of empirical and semi-empirical rules along with the use of available information in the existing literature. The leaf spring design depends on load carrying capacity and deflection [6].

Selection of Material:

Hence, Electric Auto Rickshaw is considered for design of the leaf spring. Medium carbon steel bar was selected to construct. Table 1 shows Chemical properties and Table 2 shows Mechanical properties of Medium Carbon Steel.

Table 1: Chemical properties of medium carbon steel [7]

Name	Percentage
Aluminium	0.0200 – 1.15 %
Carbon	0.1 – 1.29 %
Chromium	0.130 – 4.50 %
Copper	0.2 - 0.5 %
Iron	78.7 – 100 %
Manganese	0.10 – 3.0 %
Nickel	0.150 – 10.0 %
Silicon	0.05 – 2.20 %
Vanadium	0.03 – 1.0 %

Table 2: Mechanical properties of medium carbon steel [6]

Name	Unit
Tensile ultimate strength	450 - 2730 MPa
Tensile yield strength	245 - 1800 MPa
Modulus of elasticity	187 - 213 GPa
Bulk modulus	152 - 163 GPa
Poisson ratio	0.280 - 0.300
Density	7.75 - 7.89 g/cc
Brinell hardness number	126 - 578

Boundary Condition:

Total Length of the spring = (58 + 4) cm = 62 cm = 620 mm

No. of full length leaves (n_f) = 02

No. of graduated leaves (n_g) = 04

Thickness of each leaf (t) = 5 mm

Width of each leaf (b) = 47 mm

Total load = Electric auto rickshaw self-weight + seven passenger's and other weight

= 350 kg + 700 kg

= 1050 kg = 1050*9.81 = 10300.5 N

3.2 CAD model of a typical leaf spring

On the basis of the design a CAD model drawn in a professional software DSS Solid works 2016 is given below Fig. 1:

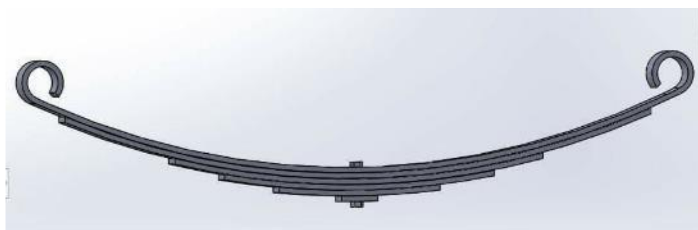

Fig.1: CAD model of the semi elliptical leaf spring

3.3Construction

The steel alloy bar was cut into designed 6 different lengths for multi leaf spring by using hand grinding machine then tampered in furnace approximately at 300 degrees Celsius and then cooled it at room temperature. It increased ductile property of steel bar. Six leaves were assembled by a centre bolt.The constructed leaf spring is shown below Fig. 2:

Fig. 2: Constructed leaf spring

4. Result and analysis

4.1 Load Test of Leaf Spring

Maximum load can carry by this leaf spring was determined by Universal Testing machine (UTM). The maximum load carrying capacity of this leaf spring was 20 kN. It was observed that the semi-elliptical leaf spring changed to straighten steel bar when load reached 20 kN.

The total load 20 kN divided into 5 times. Respective deflection for gradually increasing load as shown as table 3.

Table 3: Respective deflection for gradually increasing load

Load (kN)	Deflection (mm)
4	0.98
8	2.08
12	3.80
16	4.25
20	4.5

4.2 Commercial simulation software static analysis result

commercial simulation software results shown for adaptive meshing. Von-misses stress, total deflection and equivalent elastic strain as shown in Fig. 3, Fig. 4 and Fig. 5 respectively.

4.2.1 Static analysis of Von-misses stress contours

Von misses stress contours shown as Fig. 3. The results are shown in range of 0.42162 MPa to 496.25 MPa. There have colour variation to show how change of stress along the leaf spring. Red colour denote maximum stress and blue colour denote minimum stress. There have two probe to show maximum and minimum stress at where in the leaf spring.

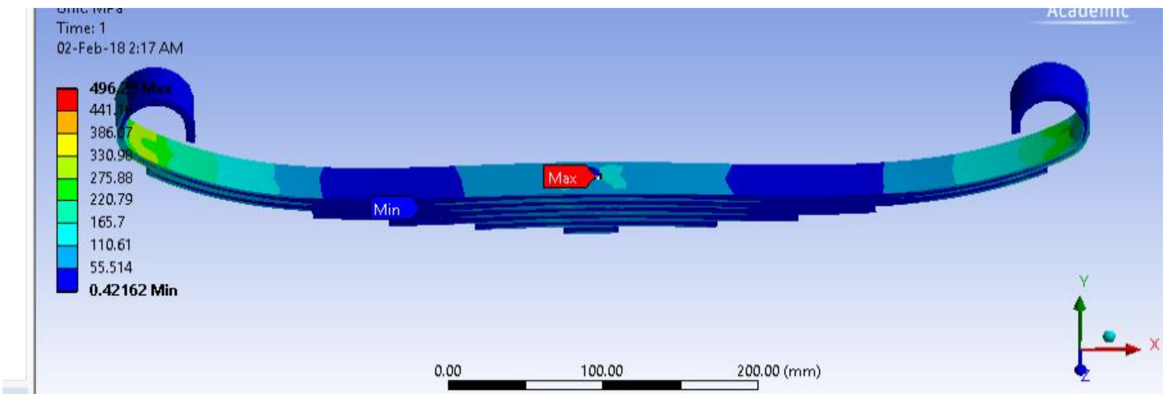

Fig. 3: Von misses stress contours

4.2.2Static analysis of maximum deflection contours

Maximum deflection contours due to load shown in Fig. 4. The results are shown in range of 0.22569 mm to 3.5858 mm.

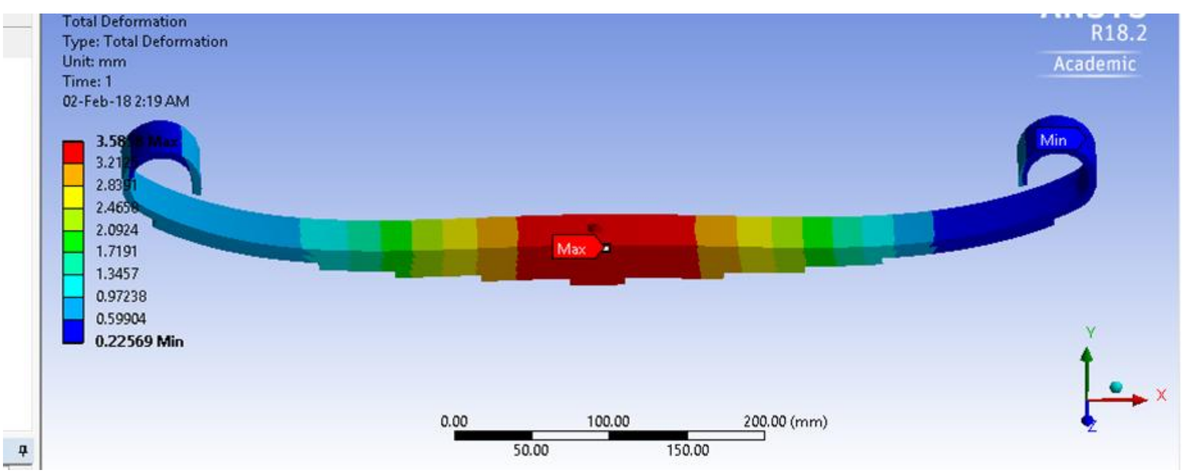

Fig. 4: Maximum deflection contours due to load

4.2.3 Static analysis of equivalent elastic strain

Equivalent elastic strain contours is shown in Fig. 5. The results are shown in range of 6.5962e-6 mm/mm to 2.4198e-3 mm/mm

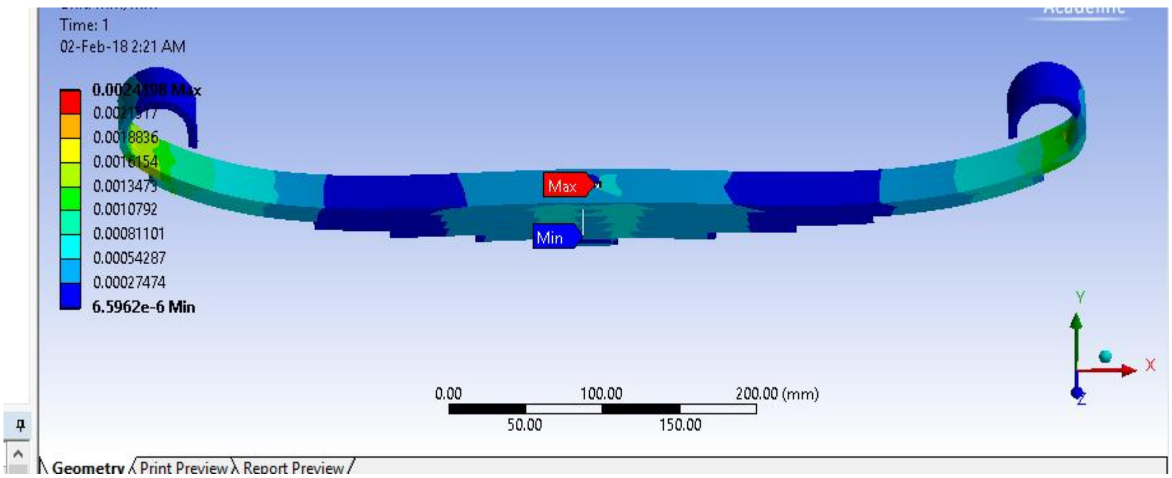

Fig. 5: Equivalent elastic strain contours

4.2.4 Comparison between analytical results and static analysis results of steel leaf spring

The results variations are shown in table 4. There the results varied 8.906% in stress and 7.33% in deflection from analytical results for 2.575 kN load. Experimental deflection result for 2.575 kN also shown. For boundary conditions, contact conditions and others systematic causes commercial simulation software results varied from analytical results. Table 4 shows theoretical and static analysis result comparison for leaf spring.

Table 4: Comparison of theoretical and static analysis result for leaf spring

Parameters	Analytical results	Static analysis results	Percentage Variation	Experimental result
Von-misses stress (MPa)	544.768	496.25	8.906%	-
Maximum deflection (mm)	3.34067	3.5858	7.33%	3.88

4.3Variation of spring deflection for respective load

The graph was plotted forcommercial simulation software static analysis data take into consideration. The total load 2575.125 N classified into 10 steps. Where X-axis denote total deflection considering maximum values and Y-axis denote force. In the graph shows that deflection and force change proportionally shown in fig. 6.

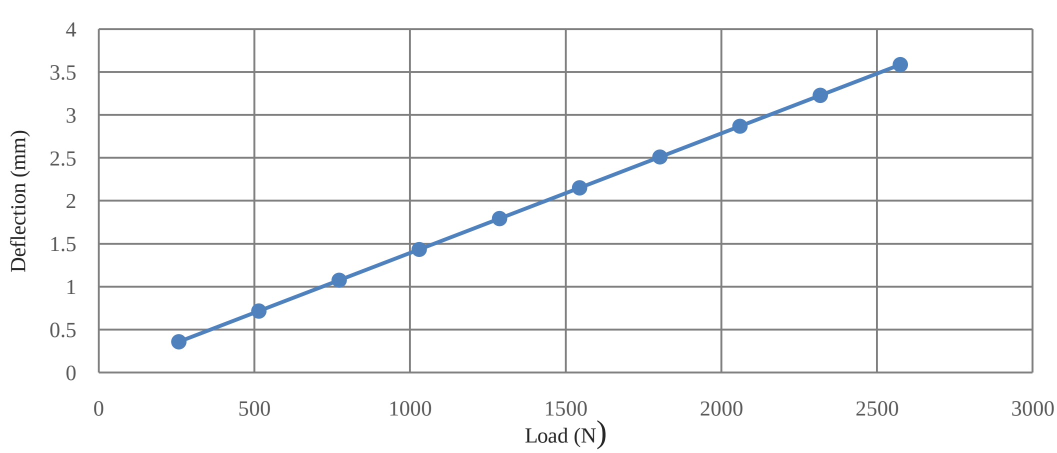

Fig. 6: Variations of spring deflection for respective load

4.4Variation of stress for respective strain

The variation of stress for respective strain graph plotted from commercial simulation softwarestatic analysis results 10 data take into consideration and it shown in Fig.7. Where X-axis denote equivalent stress considering maximum values and Y-axis denote equivalent elastic strain. In the graph shows that stress and strain change proportionally.

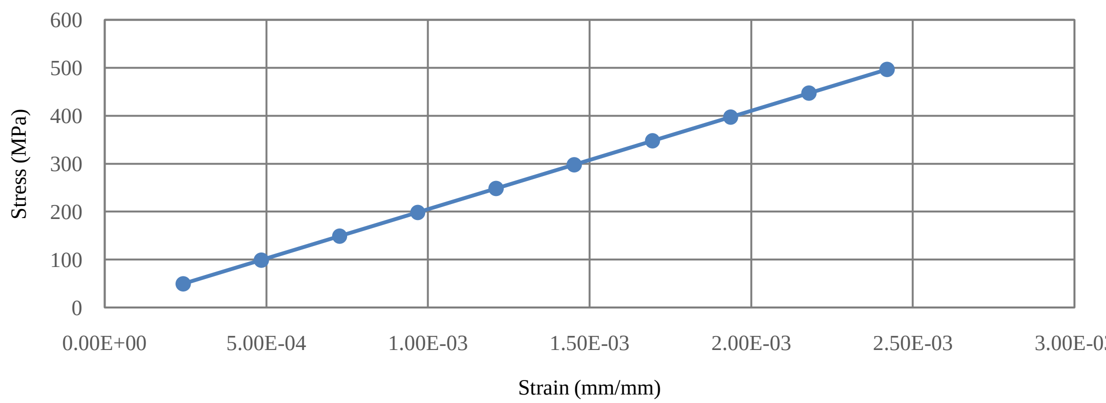

Fig. 7: Variations of Stress for respective strain

5.Conclusion

Design, construction, analytical and commercial simulation software static analysis has been investigated and maximum load carrying capacity experimentally investigated. The results are presented as follows, the construction and testing of steel leaf spring has been carried out. The maximum load carrying capacity was determined by universal testing machine and it was 20 kN.Comparison has been made between theoretical results and commercial simulation software results for same amount of load. From the commercial simulation software static analysis results it is found that there is a maximum displacement of 3.5858 mm and the analytical maximum displacement is 3.3406 mm. From the commercial simulation software static analysis results, it is also seen that the von-misses maximum stress in the steel leaf spring is 496.25 MPa and the analytical maximum stress is 544.768 MPa. There is a 8.90% result variation in stress and 7.33% result variations in deflection.

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