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Computation Analysis on Ansys & Design Modification of Master Leaf Spring

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A B S T R A C T

The main intention of introducing this work is to achieve modification in the design. We use input parameters like span length (distance between eyes to eyes), camber length (Arc height at axle seat) and Ratio. The model of leaf spring prepared with the help of ANSYS design modular (ANSYS.14) software and Structural steel and stainless steel (Material) is used for the purpose of analysis and boundary condition also describe in our work. We are trying to modification in design of master leaf spring with the help increase life and efficiency of leaf spring as we have taken span length 1712mm, camber length 120mm, thickness of leaf spring 10mm, width of leaf spring 60mm and inner diameter is 20mm. Here in this paper we have been trying to focus on output result like deflection, stresses, factor of safety in stress and factor of safety in strain terms.

Over all simulations of semi-elliptical and parabolic leaf springs has done on ANSYS.14 software and under the application of constant amplitude load (50 N).Whenever we have been applied here mainly four type of approach like the length of span decrease and camber length remains constant, camber length decrease and span length constant, span length and camber length both increase with respect to other and camber length and span length decrease simultaneously

Keywords: Leaf spring, Material Compositions, Mathematics, Experiments, ANSYS

1. INTRODUCTION

According Indian standard data of bushes of leaf spring material use for manufacturing purpose is that aluminum bronze, gunmetal, phosphor bronze and steel also used for special requirement of leaf spring and outside surface finish not less than 6.3µmRa and inside surface finish not less than 1.6µmRa.In the case of assembly of leaf spring (fifth revision Indian standard) shown in Fig.3 and material preferred for manufacturing of leaf spring steel conforming to 55Si7, 60Si7, 65Si7 and 50Cr4V2 at the time of manufacturing of leaf spring number of more thing also considerable like harden ability, toughness and physical properties and tolerances on individual leaf length shall be ±3mm and hardness of spring leaves when properly heat treated shall fall in as following range shown in Table.1

Table.1.1 Heat treatment process and range

S.NO.	MATERIAL	RANGE
1	55Si7	363 to 444HB
2	60Si7	363 to 444HB
3	65Si7	363 to 444HB
4	50CrV2	415 to 485HB
5	60Cr4V2	415 to 485HB

Type of spring

Spring can be classified on the basis of applied load to them.

a. Tension springs this kind of spring having properties to stretches under the application of load.
b. Compression spring here in this kind of design to operate by compression load and spring reduce its actual size under the application of load and regain its original shape and size after remove load on it.
c. Torsion spring in this kind of case load applied an angle on it.
d. Constant spring such this spring work under constant load for same deflection cycle
e. Variable spring it is allow to resistance of coil to variation in amplitude of load such as compression.

2 Literature Review

Temesgen Batu et.al [1] one of the current focuses in product design is optimization with the aim of minimizing weight. Weight reduction has a great influence on vehicle efficiency and fuel economy, companies in the automotive sector. These improvements may have an obvious impact on the vehicle's working expenses. Weight reduction is performed by improving technical specifications and exchanging very sustainable materials for conventional ones. In this paper, design model of an existing master leaf spring was created and utilized using Solid Works parametric optimization with the aim of decreasing the weight of the leaf spring, increasing the natural frequency of the leaf spring, and expand the life span of the structure by relieving stress. With the leaf spring's thickness and width as input values, the constraint applied was limiting stress and natural frequency. The leaf spring's settings were optimized to their best possible levels.

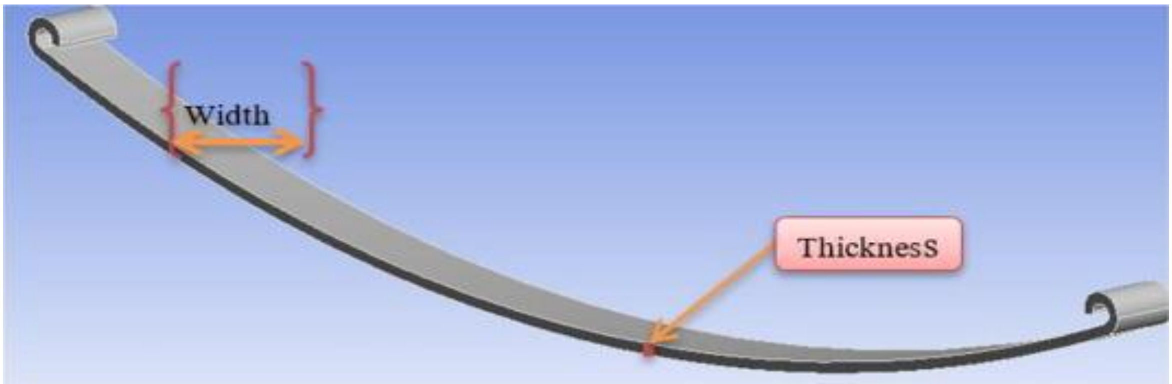


Fig. 2 master leaf spring [1]

K.M.Vinay et.al [2] this section will look at the possibilities of using a low-cost base and light-weight materials for auto leaf spring suspension. In respect of disfigurement, flexibility, determination, strain energy putting away limit, cost viability, and mass reduction, we compare conventional steel 65Si7 leaf springs with half and half composite leaf springs, such as Epoxy/E- Glass/Viscose staple fibre (40 percent:45 percent:15 present). The characteristics of half and half composite materials for leaf spring suspension models in the automotive industry have been investigated using static analysis, and the results indicate that Epoxy/E-Glass/Viscose staple fibre is the astounding the excess creation. When compared to existing steel 65Si7 suspension systems, the use of Epoxy/E-Glass/Viscose staple fibre (40 present: 45 present: 15 present) results in a 76.37 present reducing weight in leaf spring.

Shrivastava, A. K., Pandey et.al [3] A leaf spring is a simple form of spring that is commonly used in Vehicle suspension. Furthermore, it is most likely the oldest kind of spring, E-Glass for Spring - At 4000 N, the spring-blade of the expert leaf has a mean direction of 14.85 mm. 548.97 Hz is the highest frequency. As a result, the cause of vibration at the recurrence level differs greatly from the fibre properties. With a repetition reduction of 538.32 Hz, the avoidance of the avoidance is 13.48 mm, which is quite low. Which is also very low, and this item can support a lot like standard spring materials, but the thing is beneficial in terms of weight since Carbon composite is lightweight. it is also low and such type of material support the load capacity as standard spring metal and polymer composite material but the load strength is good thing in terms of weight because Carbon Fibre does not have a reduced weight with 35% weight loss material with E-Glass materials.

Table 1.2 Deformation & Maximum stress at 4000 N [3]

S. No.	Materials	Deflection (mm)	Maximum Stress (Mpa)	Frequency (Hz)	Weight (Kg)
1	E- Glass composite material	14.85	35.54	548.97	11.14
2	S- Glass fiber composite material	15.12	35.54	621.62	10.7
3	Carbon Fiber composite material	13.48	41.73	538.32	7.1
4	EN 45 springs steel 55 Si2Mn90 Leaf springs	8.58	35.15	533.4	33.16

AkashChauhanet.al [4] automotive industry is concentrating on replacing traditional leaf springs with hybrid composite leaf springs. As a response, the current study's goal is to create polymer (epoxy)-based hybrid composites for light commercial vehicles and test their flexural strength and wear behaviour. Using the hand lay-up approach, two hybrid composites made of carbon, kevlar, and jute fibres with varying thicknesses (3 mm and 4 mm) were created. Additionally, the produced hybrid composite samples were put through a three-point bending test in accordance with ASTM D7264 and compared to traditional leaf spring material (Steel). After then, the wear behaviour of both samples was assessed. According to the findings, hybrid composites presented 44 percent and 173 percent higher flexural strength for 3 mm and 4 mm thick hybrid composites, respectively, in comparison to conventional material, as well as a weight reduction of 44 percent and 173 percent for 3 mm and 4 mm thick hybrid composites, respectively.

Khatkar, V., & Behera, B. K al [5] the 3D orthogonal reinforced composite leaf spring exhibited improved cyclic flexural and creep performance and 3S1B stuffer- binder combination was found with the highest initial flexural strength, lowest drop in cyclic flexural strength and improved creep resistance. UD based composite leaf spring exhibited comparable properties to 3S1B based composite leaf spring. Composite leaf springs were further analyzed for their surface damage due to cyclic flexural loading. Structural variation of 3D structure reinforced leaf spring has significant influence on their failure morphology 3D woven composite with minimum binder tow percentage (3S1B) could be a potential material for automotive leaf spring from cyclic flexural strength, creep resistance, stiffness retention and failure morphology point of view.

Shishay Amare Gebremeskel et.al [6] material plays very important role in every manufacturing process. The paper also describes and solves the major issues of vehicles weight through use of composite material E-Glass/Epoxy composite Their work focuses on constant cross section design, weight reduction, and design. The result shows that shear stress in much less than the shear strength (τ= 3mpa) and the design is safe even for flexural failure. They focus on their work for design of leaf spring used in three wheelers.

Y.S. Kong et.al [6] introduces an idea about fatigue life prediction of parabolic leaf spring under the application of load. Leaf spring designs for (VAL) variable amplitude of load and (FE) finite Element method use to prediction of fatigue life of leaf spring. The paper also considered number of method for analysis purpose like Morrow, (SWT) Smith Watson topper and Mean stress correction method. After the simulation and analysis we have observed fatigue life of leaf spring decreased as sequence of smooth highway, curve road, rough road.

Manas patnaik et.al [7] investigated and study of mono parabolic leaf spring by (FEM) finite element method. Modeling has done with the help of CATIA V5 R20 (software). They use input parameters like span length and camber length while output parameters are max vos mises stress and max displacement. Their results shows that when a span and camber length increased max vos mises stress increase in both conditions. But max displacement increase with increase of span length and max displacement decrease with increase of camber length.

V.R.Baviskar et.al [8] focused on the new concept works under static load condition. Model prepares on CATIA V5 R19 and analysis point of view Ansys 14 (software) is used. The intention of analysis is reduced the stress concentration on the eyes section with the help of changing the cross section of leaf spring. So result indicated that max vos mises stress and max deformation accurse at eyes section.

Subhash chandrabose et.al [9] as leaf spring used at heavy amount so its modification and design also improve for effectively working environment. The paper comprises here over all study about design and fabrication of leaf spring by using (FE) finite element model to achieve optimization of result. Result shows that semi-elliptical takes more deformation than the parabolic leaf spring like 120.4mm and 78.06mm respectively. But the value of stress of parabolic leaf spring much higher than the semi-elliptical leaf spring as 527.056mpa and 483.3mpa respectively.

Nenad Gubeljak et.al [10] determination of fatigue behavior discuses here about two importance parameter as inclusion's size and material consisted how much hardness. Two kinds of model use to determine inclusion of size as Murakami's and Chapetti's. Better result comes from S-N Curves and Experimental study. Due to change of loading ratio the life of spring will be extended in the presence of more negative values. Chapetti's model has used to determine crack of grain size under the application of maximum stress and fracture mechanics used to determine critical crack length. Due to pre stressing and shot peening stress increase on the surface of leaf spring.

Mahmut Durus et.al [11] investigated leaf spring under variable condition to optimization of better results. Similarly in this paper work carried out about fatigue life prediction of leaf spring and concluded brief study of Z type leaf spring. Leaf spring subjected to (VAL) variable amplitude of load until its take failure by trail of three (FE) finite element correlation approaches based on rate measurement, strain data and durability test to determination damage effects applied (WFT) load at hard point of model. Result shows that (FE) tip displacement and test (experimental) tip displacement 21.1mm and 20.3mm respectively and deviation take between 3.94%. Strain gage deviation occurs there 16.84% and max.demage location deviation introduce 17.92%.

Yohannes.Regassa et.al [12] as leaf spring is always under application of force or load in automobiles so the paper introduces how failure has occurred in semi-elliptical leaf spring and which kinds of reason are responsible for failure estimated by (FEM) finite element method. As for analysis purpose 10mm thick master leaf spring taken and applied numbers of modification like to change material and thickness of master leaf spring for modified design and better result. We have observer that existing design bending stress and modified design as 450 Mpa and 230 Mpa respectively in analytical methods. Max. Deflection occurs in existing and modified designs are as 7.7mm and 28mm respectively. The elastic strain has found by (FEM) that was 0.0304 for existing design and 0.0018 for modified design.

Basaran.Ozmen et.al [13] shows the working capacity and durability about leaf spring cannot be predicted as casually without taken number of trail and takes too much time for investigation. So main intention of this paper to introduce newly developed idea (novel methodology) of testing and simulation method for increase the effective product rate, development and minimize the testing time. Here two types of calculation are concluded like (FEM) finite element method for fatigue life determination and (MBS) multi body simulation for load spectra on the leaf spring.

J.J.Fuentes et al [14] generally due to presence of defects in model often failure has occurred at any stage. In this paper study about pre-mature fracture in leaf spring for identification and understanding more about pre-mature fracture few processes utilized like failure analysis, visual inspection of fractured specimen and real component. They observed here fracture located mainly at central hole due to mechanism of fatigue. Poor design, poor strength of manufacturing, materials, and manufacturing defects this parameter also could be responsible for origin of fracture. We can understand pre mature fracture by this result output like geometry of the holes, sharp corners, notches due to bolt thread and surface defects are main reason for pre mature fracture.

Vinkel.Arora et.al [15] experimental technology is most suitable way to analysis and testing durability of model before it's introduce for actual work environment. The paper concluded comparative study between (CAE) Computer Aided Engineering and experimental result. The model has prepared on CATIA and for analysis purpose ANSYS software is use. Conventional leaf spring consist 37 parts and material used to manufacturing is 65Si7 (steel). Deflections are introduced in both analysis like experimental 158mm and 156.15mm for

3.Objective:- The main objective to develop this research due to large weight of automobile, the rate of fuel consumption increase with increase the weight of vehicle. So here try to optimize the design with different material for save the material and achieved higher efficiency without compromise the load carrying capacity.

4. Design Method:- Table.4.1 design data of leaf spring semielliptical and parabolic

S.NO.	NAME	DIAMATION	UNIT
1	Span length	1712	mm
2	camber	120	mm
3	Thickness	10	mm
4	width	60	mm
5	Half length	856	mm
6	Tapper thickness	12	mm
7	Inner diameter	20	mm
8	Force	50	N

Material use to prepare model are structural steel and stainless steel and material properties are shown in table 4.2 and table 4.3 the design parameters are span length 1712mm, camber height 120mm, inner diameter of eye section 20mm, thickness of leaf spring 10mm, width of leaf spring 60mm and force applied on leaf spring 50N Meshing technique use to divide model into number of small part for better accuracy.

Table. 4.2 Stainless steel properties

S.NO	Properties	Value	Unit
1	Density	7750	kg/m^3
2	Coefficient of thermal expansion	1.7E-05	C-1
3	Reference temperature	22	
4	Young’s modulus	1.93E+11	Pa
5	Poisson ratio	0.31	
6	Bulk modulus	1.693E+11	

7	Shear modulus	7.3664E+10	Pa
8	Tensile yield strength	2.07E+08	Pa
9	Compressive yield strength	2.07E+08	Pa
10	Tensile ultimate strength	5.86E+08	Pa
11	Compressive ultimate strength	0000	

Table. 4.3 Structural steel properties

S.NO	Properties	Value	Unit
1	Density	7850	Kg/m3
2	Coefficient of thermal expansion	1.2E-05	C-1
3	Reference temperature	22	c
4	Young's modulus	2E+11	
5	Poison ratio	0.3	
6	Bulk modulus	1.6667E+11	Pa
7	Shear modulus	7.6923E+10	Pa
8	Tensile ultimate strength	4.6E+08	Pa
9	Compressive yield strength	2.5E+08	Pa
10	Tensile yield strength	2.5E+08	Pa
11	Compressive ultimate strength	0	
12	Cyclic strain hardening exponent	0.2	
13	Cyclic strength coefficient	1E+09	Pa
14	Strength coefficient	9.2E+08	Pa
15	Strength exponent	-0.106	
16	Ductility coefficient	0.213	
17	Ductility exponent	-0.47	

4.1 PARABOLIC LEAF SPRING

Parabolic leaf spring is a modification form of leaf spring for increase working durability and life the important fact in parabolic leaf spring centre tapper area of leaf spring having some extra thickness than overall leaf spring it can be seen

4.2 SEMIELLIPTICAL LEAF SPRING

Semielliptical leaf spring is a simple form of leaf spring and the cross section of semielliptical spring not varies like parabolic leaf spring it can be seen

4.3 SIMULATION AND ANALYSIS

Analytical design parameters for semi-elliptical and parabolic leaf spring

The section shows the mathematics used for the parametric calculation of leaf spring discussed below.

Maximum bending moment equation is:-

$$\mathbf{M = W \cdot L} \qquad (1)$$

Bending stress is:-

$$\boldsymbol{\sigma_b} = \frac{\mathbf{M}}{\mathbf{Z}} = \frac{\mathbf{W \cdot L}}{(\mathbf{b \cdot t^3})/6} \qquad (2)$$

$$\boldsymbol{\sigma_b} = \frac{\mathbf{6 \cdot W \cdot L^3}}{\boldsymbol{\eta} \cdot \mathbf{E \cdot b \cdot t^3}} \qquad (3)$$

Maximum deflection at the centre of leaf spring is:-

$$\boldsymbol{\delta} = \frac{\mathbf{W \cdot L^3}}{\mathbf{3 \cdot E \cdot I}} \qquad (4)$$

Half-length of leaf spring:-

$$\mathbf{I} = \frac{\mathbf{L}}{\mathbf{2}} \qquad (5)$$

Thickness of tapered area in parabolic leaf spring:-

$$\mathbf{h_x = h_0}\left(\frac{\mathbf{x}}{\mathbf{L_1}}\right)^{\mathbf{0.4}} \qquad (6)$$

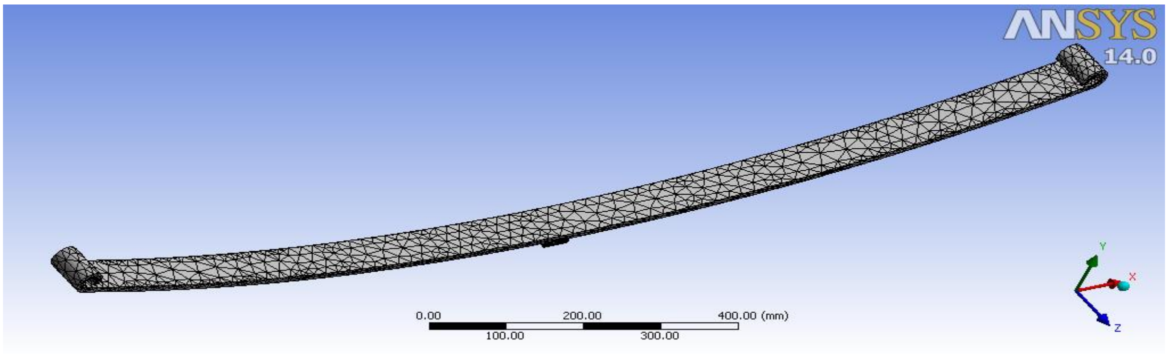
Length of master leaf spring:-

$$\mathbf{2L_1 + 2\pi\,(d + t)} \qquad (7)$$

The main advantage of preferring computational method is, it does not take too much time and also having low cost as compare to other method like experimental. Now the overall work was done on computational method rather than the experimental study and analytical method due to computing better results with sharp accuracy. We have concluded number of parameter in computational method like Material, Design parameter of modal, meshing qualities, and boundary condition.

4.4 MESHING

We have observed Nodes 16356 & Element 7786

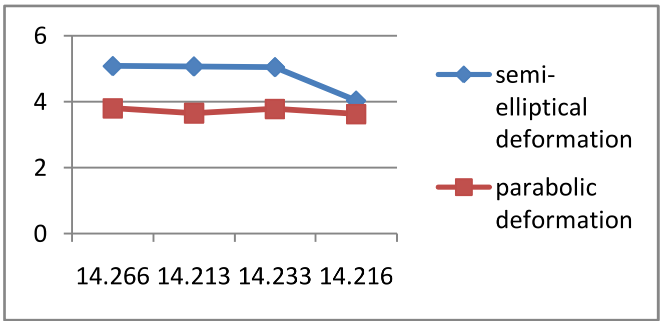


4.5 BOUNDARY CONDITION

Boundary condition basically input parameter where all data has been fixed under suitable manner as coordinate system specified location of particular portion and model belongs to which axis.
Remote displacement in case of computation method meshing technique applied on both kinds of leaf spring which is shown in Fig.4.6 (semielliptical leaf spring) and Fig 4.7 for (parabolic leaf spring) boundary condition applied such in this manner first eye of leaf spring can be rotate about Z-axis and fixed for remaining to axis like X-axis and Y-axis while second eye of leaf spring able to rotted about Z-axis and translation in X-direction and direction of force in Y-axis (longitudinal) coordinate system arrangement like for first eye (X=constant, Y=constant and Z=free) and for second eye (X=free, Y=constant and Z=free) for refine of meshing we have use trigonal mesh refinery in both case(semielliptical and parabolic leaf spring) coordinate system can b seen into Fig.4.3 and we have observed Nodes 16356 & Element 7786.so we have also observe in case of parabolic leaf spring much refine must be used due to variation in cross section area and in presence of curvature of master leaf spring.

5. RESULTS

Results and discussion are based on input parameter like span length, camber length and ratio.



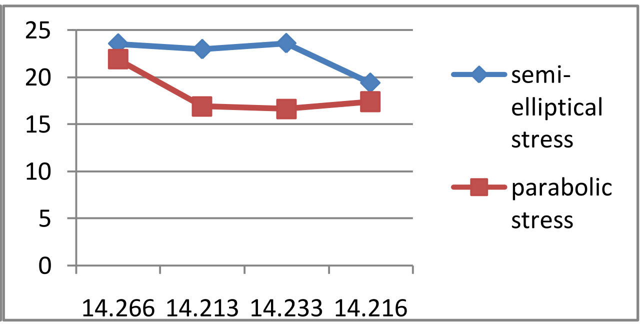
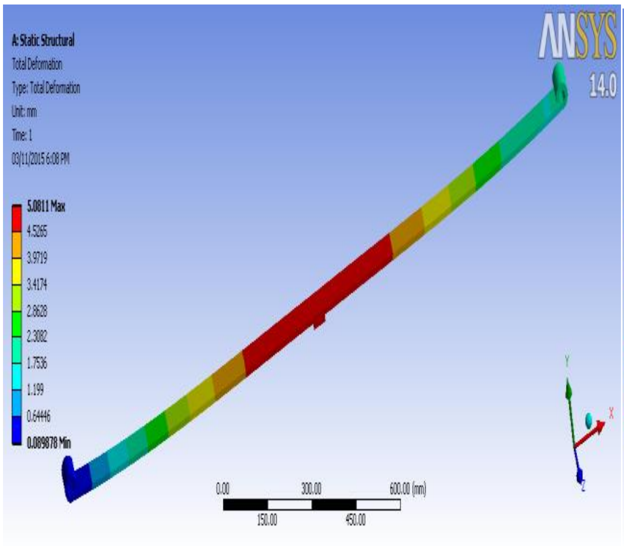


Fig.Span length change and camber length remains at constantFig. Span length change and camber length remains at constant

The above graph Fig. conclude the results based on span length and camber length, the maximum deformation found in semi-elliptical leaf spring is 5.08mm and the maximum deformation observe in parabolic leaf spring 3.7mm at same ratio of leaf spring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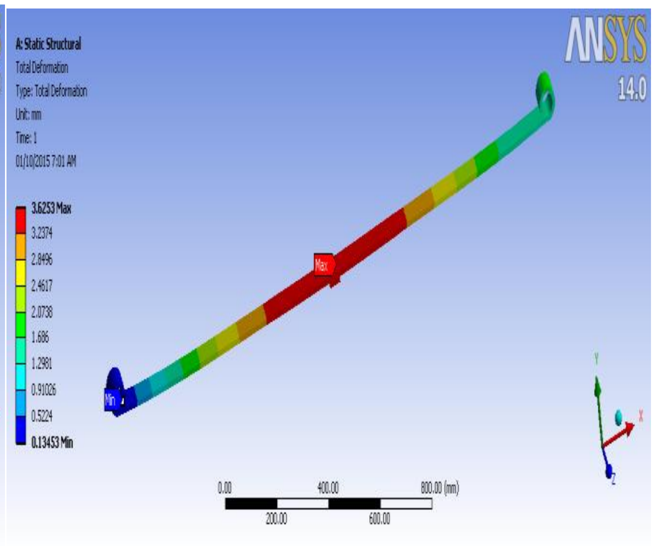
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1
5.0811 Max
0.089878 Min
ANSYS
14.0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Total Deformation
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Unit: mm
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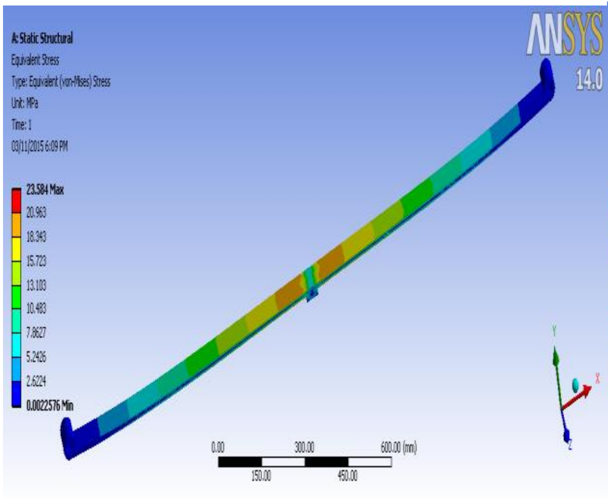
0.13453 Min
Max
Min
ANSYS
14.0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Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
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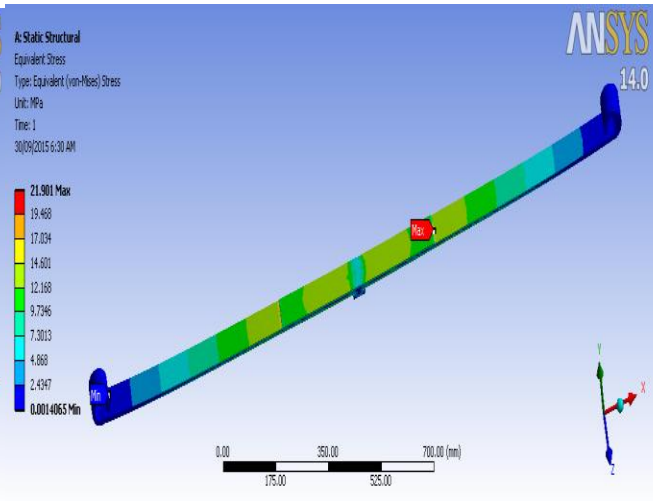
0.0022576 Min
ANSYS
14.0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Unit: MPa
Time: 1
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0.0014065 Min
Max
Min
ANSYS
14.0

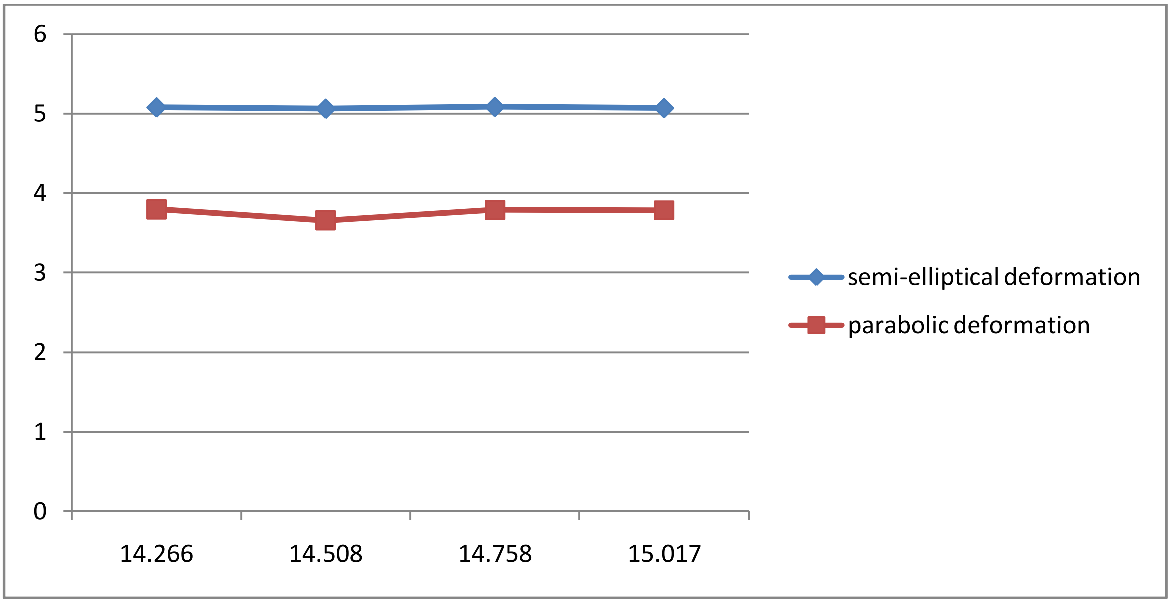

Fig. Camber length change and Span length remains at constant

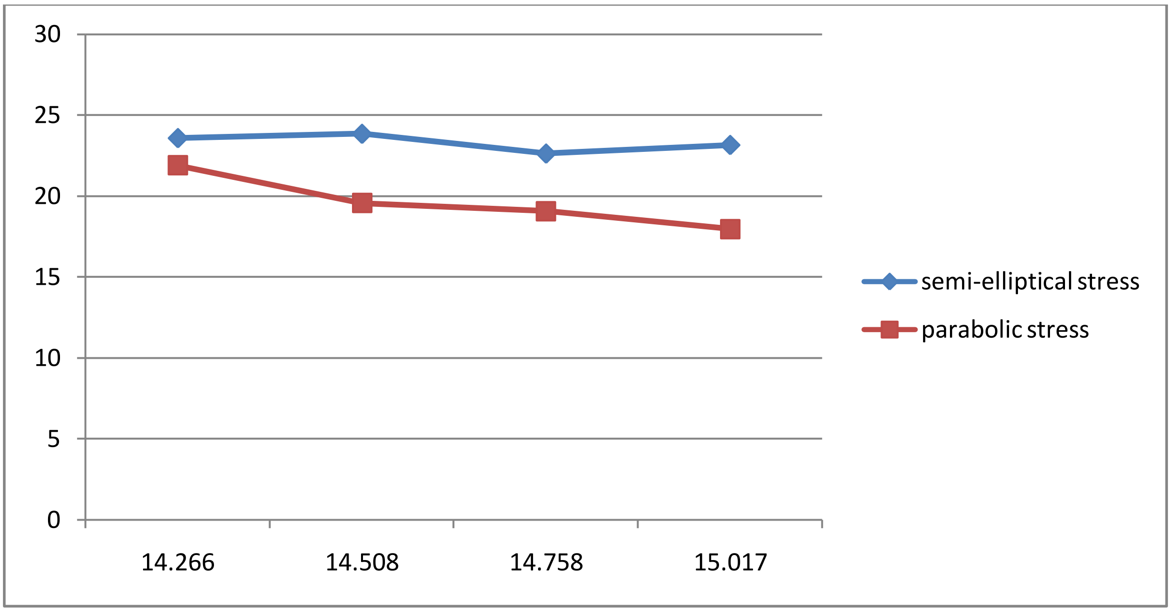

Fig. Camber length change and Span length remains at constant

Graphical result Fig. shows that maximum stress occurred 23.158Mpa in semielliptical leaf spring and maximum deformation value 5.09mm at the ratio of 14.26

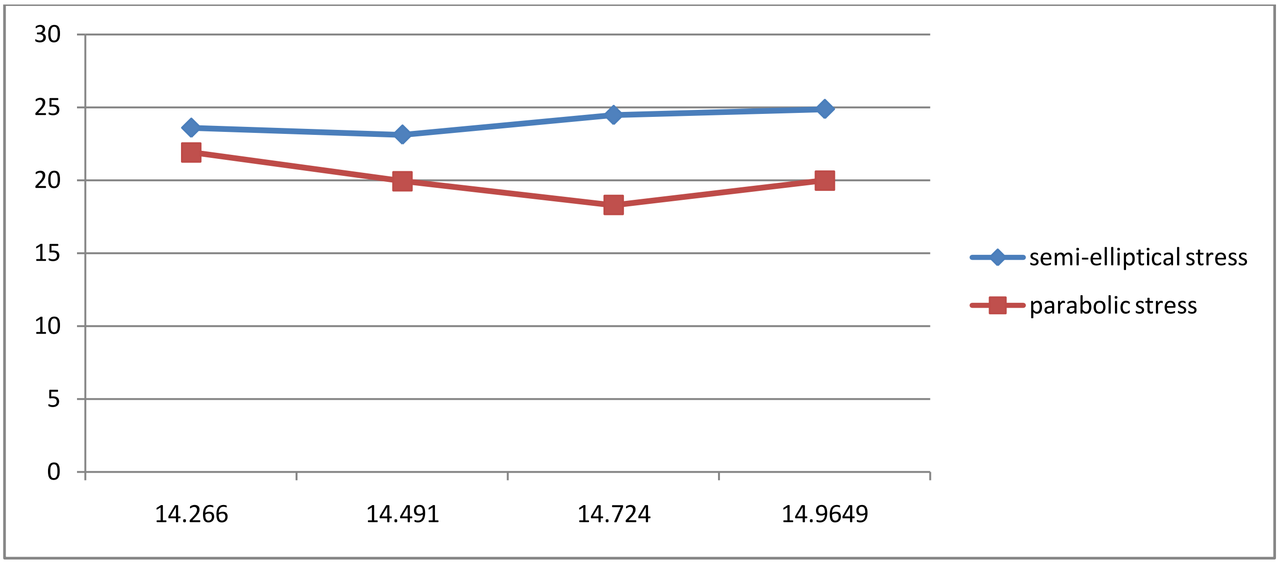

Fig. Camber length and Span length change simultaneously in decreasing Order

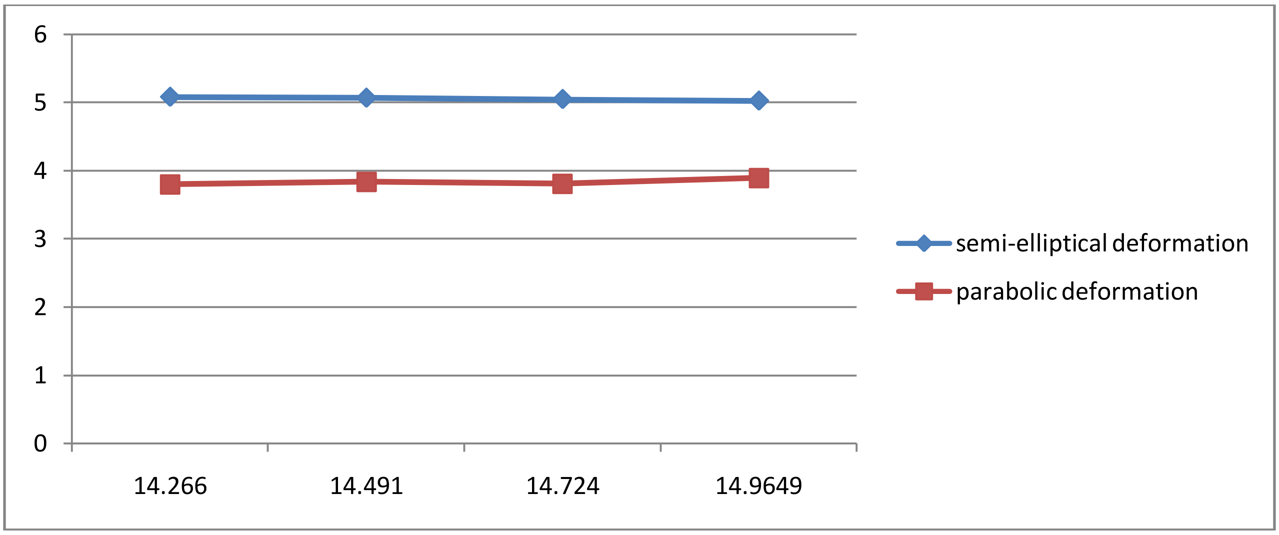

Fig.Camber length and Span length change simultaneously in decreasing Order

We see in Fig. Minimum stress and deformation value observed in leaf spring 23.58 Mpa and 5.02mm respectively which is shown in Fig. and Fig. respectively at different-different ratio of leaf spring the maximum deformation of semielliptical leaf spring is 5.08mm and the maximum value of stress is 24.87Mpa found at different-different ratio of leaf spring and value.

6. CONCLUSION

a. Semi-elliptical type of leaf spring shows poor results as compare to parabolic leaf spring at same boundary condition and same application of loads.

b. As we decrease the value of span length in both the conditions we observed that the deflection and stress of semi-elliptical 5.081 and 23.584 respectively is higher as compare to parabolic leaf spring where deflection and stress is 3.7989 and 21.901 respectively.

c. We see in our study that if the ratio of span and camber length increase in case of semi-elliptical leaf spring then with the increase of this ratio the value of deformation goes down and stress increases. In case of parabolic leaf spring with the increase in this ratio the opposite condition occurs means the value of stress decreases and deformation increases.

d. We also noted that when we decrease the camber length in both the conditions the deflection and stress of semi-elliptical leaf spring shows higher values.

e. We have observed that ratio of leaf spring decrease with decrease the span length then average amount of factor of safety of semielliptical and parabolic leaf spring increase at same ratio.

References

1. Temesgen Batu Multi objective parametric optimization and composite material performance study for master leaf spring Volume 45, Part 6, 2021, Pages 5347-5353

2. K.M.Vinay Mechanical characterization and static analysis of fibre based hybrid composite multi leaf spring

3. Shrivastava, A. K., Pandey, R., Ramani, H. B., & Chourasia, S. N. (2021). Modal analysis of polymer composite based leaf spring by Additive layer manufacturing using FEA method. Materials Today: Proceedings. doi:10.1016/j.matpr.2021.06.183
4. AkashChauhanet. Fabrication of polymer hybrid composites for automobile leaf spring application Materials Today: Proceedings 22 September 2021
5. Khatkar, V., & Behera, B. K. (2021). Experimental investigation of textile structure reinforced composite leaf spring for their cyclic flexural and creep behaviour. Composite Structures, 258, 113439 doi: 10.1016/j. compstruct.2020.113

6. Shishay Amare Gebremeskel. Design, simulations, and prototyping of single composite Leaf Spring for Light Weight Vehicles. Global Journal of Researches in Engineering Mechanical and Mechanics Engineering Volume 12, Issue 7, Version 1.0, Year 2012.

7. Y.S Kong, M.Z Omar, L.B Chua, S. Abdullah. Fatigue life prediction of parabolic leaf spring under various road conditions. www.elsevier.com. 2014

8. Manas Patnaik, Narendra yadav, Ritesh Dewangan. Study of parabolic leaf spring by finite element method and design of experiments. www.ijmer.com. Vol. 2, ISSUE 4, 2012.

9. V.R Baviskar, P.L Sarode, I.N Wankhede, N.P Salunke. Static analysis of master leaf spring. www.IJRET.com. Vol. 03, 2014.

10. Subhash Chandrabose, C. Thamotharan, P. Naveenchandran, and R. Anbazhagan. Design optimization and analysis of a parabolic leaf spring. Middle East journal of scientific research. 2014

11. Nenad Gubeljak, Mirco D. Chapetti, JozepPredan, BojanSencic. Variation of fatigue threshold of spring steel with pre-stressing. www.sciencedirect.com. 2011.

12. R.B Charde, Dr. D.V Bhope. Investigation of stresses in master leaf of leaf spring by FEM and its experimental verification. www.IJEST.com 2012

13. Punam. P. Patil. Critical review of research paper for analysis of multi leaf spring. www.IJLTET.com. 2014

14. Mahmud Durus, LeventKirkayak, Aykut Ceyhan, KaganKozan. Fatigue life prediction of Z type leaf spring and new approach to verification method. www.sciencedirect.com 2015

15. Yohannes Regassa, R. Srinivasa Moorthy, and RatnamUppala. Failure analysis of semi-elliptical of master leaf spring of passenger car using finite element method. Global journal of researches in engineering mechanical and mechanics engineering. Vol. 13, 2013

16. Basaran Ozmen, BerkukAltiok, AlperGuzel, Ibrahim Kocyigit, SerterAtamer. A novel methodology with testing and simulation for the durability of leaf springs based on measured load collectives. www.sciencedirect.com. 2015

17. J.J Fuentes, H.J Aguilar, J.A Rodriguez, E.J Herrera. Premature fracture in automobile leaf springs. www.sciencedirect.com. 2009

18. Vinkel Arora. A comparative study of CAE and experimental results of leaf spring in automotive vehicles. www.IJEST.com 2011