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Minimization of Stress of a Parabolic Leaf Spring by Simulated Annealing Algorithm

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ABSTRACT
A leaf spring is simple form of spring, generally used for the suspension in automotives. Earlier it was like a slender arc-shaped having length of a spring steel of rectangular cross-section. In this paper analysis is done for leaf spring whose thickness varies from the center to the outer side following a parabolic pattern. The development of a parabolic tapered leaf spring enabled the springs to become lighter, but also provided a much improved ride to the vehicle through a reduction on interleaf friction. To move further, authors take an opportunity to perform a Finite element analysis (FEA) on the spring model so that stress and damage distribution can be observed. In this paper, we describe its basic structure, stress characteristics, engineering finite element modeling for analyzing & high stress zones. The equivalent von-misses stresses are plotted.

Keywords – **Camber, Computer aided engineering (CAE), Eye distance, Finite element analysis (FEA), Parabolic leaf spring, Static loading, Simulated annealing algorithm.**

1. INTRODUCTION
Development of a leaf spring is a long process which requires number of tests to validate the design and manufacturing variables. We have used CAE to shorten this development thereby reducing the tests. A systematic procedure is obtained where CAE and tests are used together. CAE tools are widely used in the automotive industries. In fact, their use has enabled the automakers to reduce product development cost and time while improving the safety, comfort, and durability of the vehicles they produce. In this paper work is carried out on the front end leaf spring of a mini-loader truck. The objective of this work is to carry out computer aided design and analysis of a conventional leaf spring. The material of the leaf spring is 55Si2Mn90. The CAD modeling and finite element analysis of the leaf spring is done in CATIA V5R20.

2. MATERIAL
The basic requirements of a leaf spring steel is that the selected grade of steel must have sufficient harden ability for the size involved to ensure a full martenstic structure throughout the entire leaf section. In general terms higher alloy content is mandatory to ensure adequate harden ability when the thick leaf sections are used. The material used for the experimental work is 55Si2Mn90. The other designation of this material is shown in Table-1 and its chemical compositions are shown below in Table -2.

Table – 1

International Standard	Equivalent Grades			
	IS	**DIN**	**BS**	**AISI**
EN45	55Si2Mn90	55Si7	250A53	9255

Table – 2

Grade	C %	Si%	Mn%	Cr%	Mo%	P%	S%
55Si2Mn90	0.55	1.74	0.87	0.1	0.02	0.05	0.05

Many industries manufacture steel leaf springs by 55Si2Mn90 material. These materials are widely used for production of parabolic leaf springs and conventional multi leaf spring. Leaf spring absorbs the vertical vibrations, shocks and bumps loads (induced due to road irregularities) by means of spring deflection, so that the potential energy stored in the leaf spring and then relieved slowly. Ability to store and absorb more amount of strain energy insures the comfortable suspension system.

3. DESIGN PARAMETER
Parameters of the steel leaf spring used in this work are shown in Table - 3.

Table – 3

PARAMETER	VALUE
Material selected - steel	55Si2Mn90
Young's Modulus (E)	200GPa
Poission's Ratio	0.3
Tensile Strength Ultimate	1962 MPa
Tensile Strength Yield	1500 MPa
Leaf Span	1025 mm
Camber	90.81 mm
Density	7850 kg/m^3
Thermal Expansion	11×10^{-6} / °C

4. CAD MODELING

CAD Modeling is the base of any project. Finite Element software will consider shapes, whatever is made in CAD model. The model of the mono parabolic leaf spring is prepared by using CATIA V5 R20 software. The 2D and 3D model of the mono parabolic leaf spring is shown in fig. 1 and fig. 2 respectively.

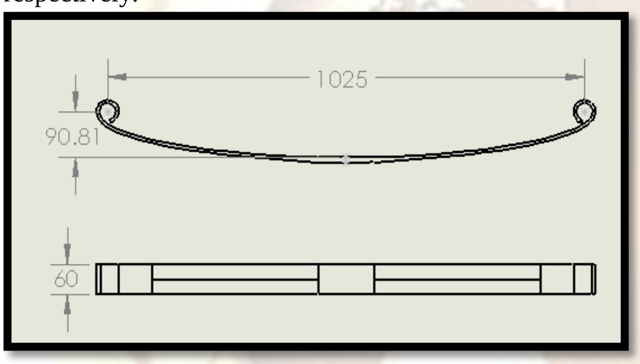

Figure - (1)

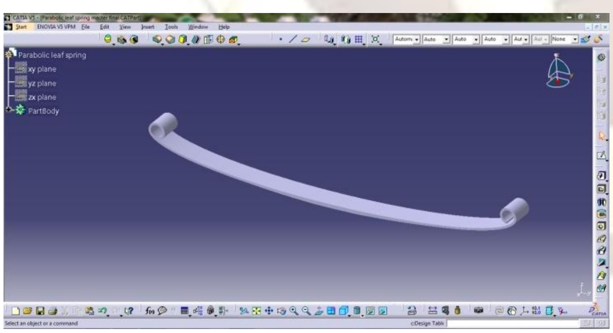

Figure - (2)

5. RESULT & ANALYSIS

The CAD model of leaf spring is analyzed in CATIA V5R20. For the analysis of stress and displacement one eye end is kept fixed and the other is maintained at sliding contact. The load is applied at the mid of the parabolic leaf spring of amount 3800 N in vertically upward direction. And mechanical properties for 55Si2Mn90 are defined in CATIA V5R20 as mentioned above. In this parabolic tetrahedron element with element size 10 mm and absolute sag of 2 mm is considered.

There are many algorithms available in CATIA. Here simulated annealing algorithm is used for minimization of the stress.

Simulated Annealing Algorithm was performed by ranging camber from 90 mm to 95 mm in auto steps and ranging eye distance from 1020 mm to 1030 mm in auto steps. Here the deflection was set as a constraint and was kept equal to 15mm. Algorithm performed 188 iterations and the optimizer suggested that the best result was obtained at iteration no. 90th signifying the minimum von misses stress of all the iterations and this is shown in fig. 3. Hence the input parameters corresponding to iteration no 90 are correct and modification of Parabolic Leaf Spring can be carried out. The values obtained in 90th iteration is shown in Table – 4.

Table – 4

No. of Iteration	Maximum Von Mises (N/m^2)	Camber (mm)	Eye Distance (mm)
90	5.09E+08	90.395007	1024.246478

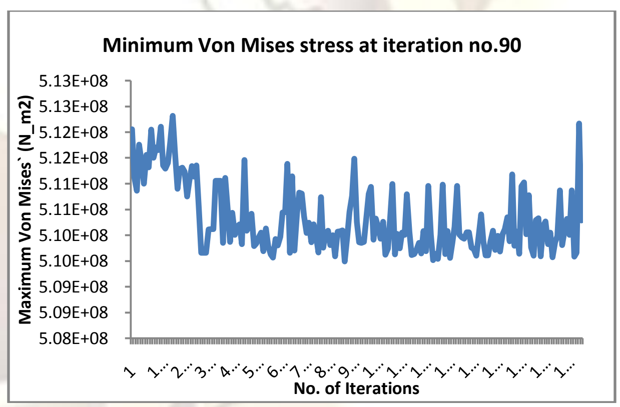

Figure - (3)

Stress distribution on the Parabolic leaf spring is shown in fig. 4 and corresponding displacement is shown in fig. 5.

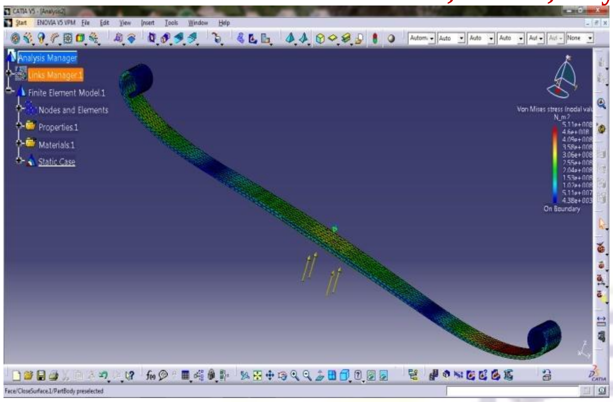

Figure - (4)

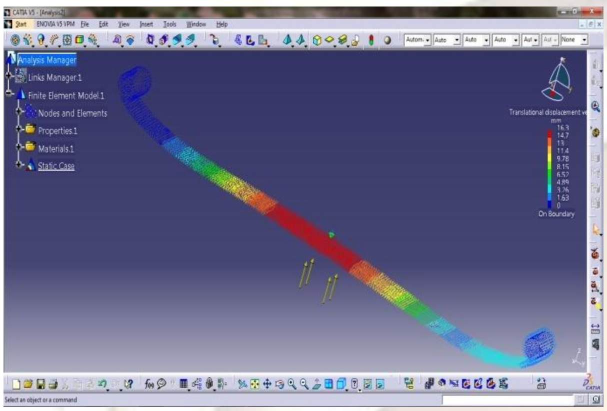

Figure - (5)

Variation of Von Mises Stress with respect to Camber And Eye distance is plotted in fig. 6 and fig. 7 on the basis of data obtained from simulated annealing algorithm.

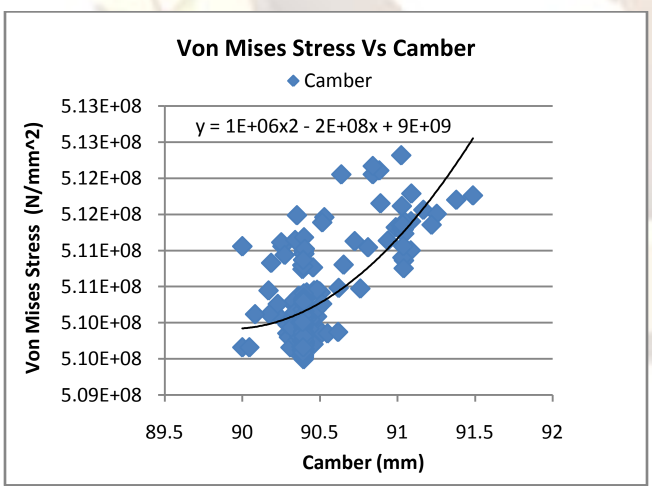

Figure - (6)

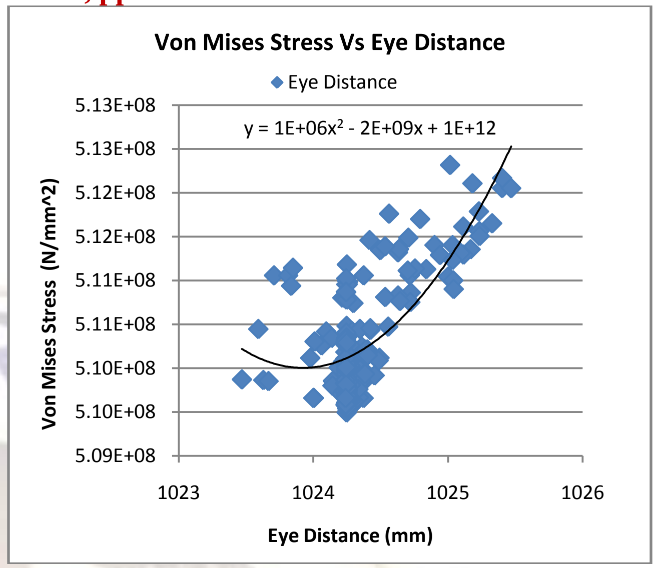

Figure - (7)

6. CONCLUSION

This work involves design and analysis of a conventional leaf spring under static loading conditions. The 3D model is prepared in CATIA and then CAE analysis is also performed in the same software. The results obtained from CATIA using Simulated Annealing Algorithm, shows that the stress is minimized in the 90^{th} iteration. So modification in parabolic leaf spring of mini loader truck can be done as camber and eye distance equivalent to 90.395007 mm and 1024.246478 mm to reduce the maximum stress.

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