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Study of a Parabolic Leaf Spring by Finite Element Method & Design of Experiments

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Abstract : This work is carried out on a mono parabolic leaf spring of a mini loader truck, which has a loading capacity of 1 Tonnes. The modelling of the leaf spring has been done in CATIA V5 R20. And for finite element analysis the model was imported in the static structural analysis workbench of CATIA V5 R20. The finite element analysis of the leaf spring has been carried out by initially discretising the model and then applying the relevant boundary conditions. Max Von Mises stress and Max Displacement are the output parameters of this analysis. In order to study the behaviour of parabolic leaf spring, Design of experiments has been implemented. In DOE, input parameters such as Eye Distance & Depth of camber have been varied and their affect on output parameters have been plotted.

Keywords: Computer Aided Design (CAD), Camber, Design of Experiments (DOE), Eye Distance, Finite Element Analysis (FEA), Parabolic Leaf Spring (PLS).

I. INTRODUCTION

Parabolic Leaf sprigs are essential suspension elements used on mini loader trucks necessary to minimize the vertical vibrations, impacts and bumps due to road irregularities and to ensure safety of the loaded cargo. Parabolic Leaf springs are widely used for automobiles. The Parabolic leaf spring absorbs the vertical vibrations and impacts due to road irregularities by means of variations in the spring deflection so that the potential energy is stored in spring as strain energy and then gradually released to maintain comfort. The finite element analysis (FEA) is a computing technique that is used to obtain approximate solutions to the boundary value problems in engineering. It uses a numerical technique called the finite element method (FEM). It is now accepted by major industries across the world and a company that is able to verify a proposed design will be able to perform to the clients specifications prior to manufacturing or construction. In the present work, leaf spring has been analyzed for static strength and deflection using 3D finite element analysis. CATIA V5 R20 has been utilized in the creation of the three dimensional model and its static structural workbench for analysis when subjected to vertical loads. The variation of bending stress and displacement values are computed. To add on the different combinations of input parameters (camber & eye distance) have been taken into account & its influence on bending stress and max deflection has been studied.

II. Parabolic Leaf Spring & Dimensions

A more modern implementation of old leaf springs is the parabolic leaf spring for automobiles. The new innovative design is characterized by the use of less leaves whose thickness varies from the center to the outer side following a parabolic pattern. The mathematical equation between the thickness & the length of the spring is that of a parabola & hence it has been named as parabolic leaf spring. This results in less inter leaf friction, because of which the only contact point between the springs in vehicle is at the end and the center where the axle is connected. Spacers used in the new design prevent the other parts collisions. Besides being less in weight the main benefit of parabolic springs is their greater flexibility, which is translated as a high ride quality of the vehicle. It gives us the high ride quality which refers to the high degree of safety to the riders from the uneven road and gives high level of comfort.

Modified version of leaf springs is the parabolic leaf springs for automobiles and has better load bearing capacity with less weight. Other benefits include improved fuel economy, load carrying capacity & enhanced suspension.

In the present work parabolic leaf spring of a mini loader truck is considered for analysis. The modeling of the PLS has been carried out in CATIA V5 R20 and has the following dimensions:

1. Camber – 90.81mm
2. Distance between eyes(Eye Distance) : 1025mm
3. Thickness at the central part : 10.81mm

Note: The above dimensions have been taken with the help of an inextensible measuring tape and a vernier caliper and then the procedure of modeling the spring was initiated. The basic views of the considered parabolic leaf spring are shown in fig. 1.

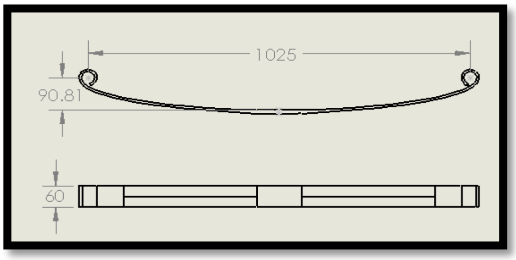

Fig.1 Front & Top view

Note : All dimensions are in mm

III. EXISTING MATERIAL

The material used for experimentation is EN45 and its mechanical properties has been mentioned in Table-1

Table--1

Material		Youngs Modulus (E) Gpa	Poisson's Ratio(M)	Density (Kg/ M^3)	Yield Strength(Mpa)
EN	IS(Old)				
EN45	55Si2 Mn90	200	0.3	7850	1500

IV. Result And Analysis Using Method Of Finite Elements

1.1 Meshing

Meshing is basically the process of breaking the CAD model into very small elements. It is also known as piecewise approximation. Meshing are of different types, it may be comprising of 1D, 2D or 3D elements. In present case selected is shown in Table-2

Table--2

Mesh			Element type	
S. N.	Entity	Size		
1	Nodes	12084	Connectivity	Statistics
2	Elements	5905	TE10(Tetrahedron element)	5905 (100.00 %)

1.2 Boundary Conditions

As shown in Fig. 2, one eye of the leaf spring will be fixed and the other eye will have certain degree of rotation to allow the leaf spring to deflect by some amount. It has been mathematically calculated that the maximum load which the spring will be subjected to 3800 N. This particular calculation has been done on the basis of GVW (Gross Vehicle Weight), which may be defined as the total weight of the loaded vehicle. This includes the vehicle itself and the cargo that is loaded within that vehicle.

In order to perform static structural analysis it is very essential to restraint the CAD model in the same manner as it is done physically. As far as parabolic leaf springs are concerned it has two eye ends, one of which is fixed with the upper body of the mini loader truck, while the other end is attached to a shackle which allows the spring to expand along its leaf span thereby causing some degree of rotation in the shackle.

Similarly we have applied constraints to our CAD model of parabolic leaf spring shown in Fig. 3 & 4.

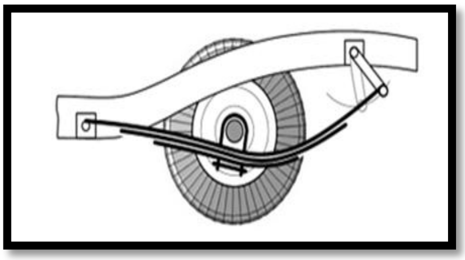

Fig.2 Suspension and Constraints

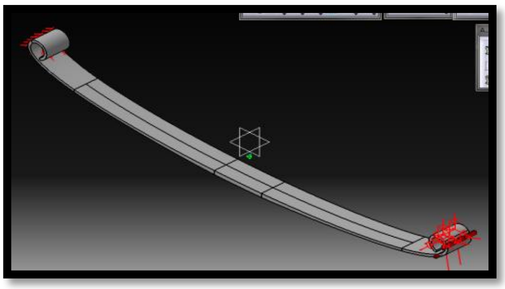

Fig.3 Applying Constraints.

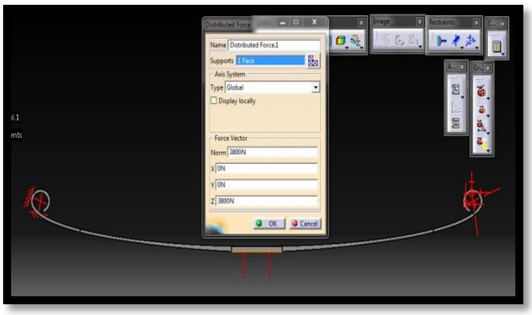

Fig.4 Applying Load

As shown in Fig. 4, the leaf spring is being treated as a simply supported beam which has a central load of 3800 N directed upwards.

4.3 Static Structural Analysis in CATIA V5 R20

After applying the boundary conditions the maximum von mises stress and maximum displacement is shown in Fig. 5 & 6.

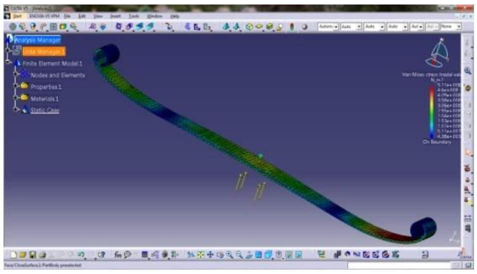

Fig.5 Von Mises Stress

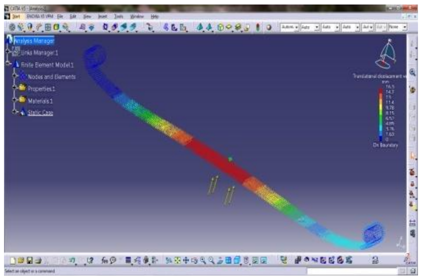

Fig.6 Displacement

Outputs on the basis of existing dimensions has been mentioned in Table-3 :

Table--3

S.N.	Output Parameter	Value
1	Maximum Displacement	16.3079mm
2	Maximum Von mises stress	5.11017e+008 N_m2
3	Energy	30.008 J
4	Mass	4.549kg

V. DESIGN OF EXPIREMENTS

The Design of experiments (DOE) is a tool for determining the significance of different factors affecting process quality and for calculating optimal settings for controllable factors. For example we may believe that operating temperature and wave height affects the number of defects from a wave solder machine. DOE provides a fast & efficient means for determining the values of these parameters that would produce the fewer number of defects.

DOE Procedure:

a) Select factors to be tested & a measure of process outcome.
b) Select test setting for each factor.
c) Select the appropriate orthogonal array.
d) Run the tests.
e) Analyze the results.
f) Calculate optimum setting for each factor.
g) Run confirmation test(s).

In this work camber and eye distance are selected as input parameters and max displacement, max von mises stress as output parameters. Design of experiments has been implemented by varying camber from 90 mm to 95 mm in steps of 10 and by varying eye distance from 1020 mm to 1030 mm in steps of 10. After running design of experiments the graphs between input and output parameters has been plotted which is shown in Fig.9, 10, 11 and 12.

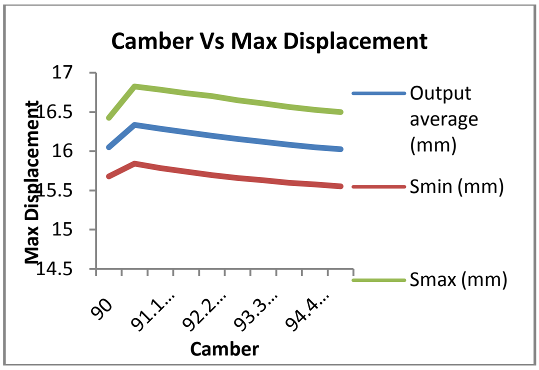

Fig.9 Effect of varying camber on Displacement

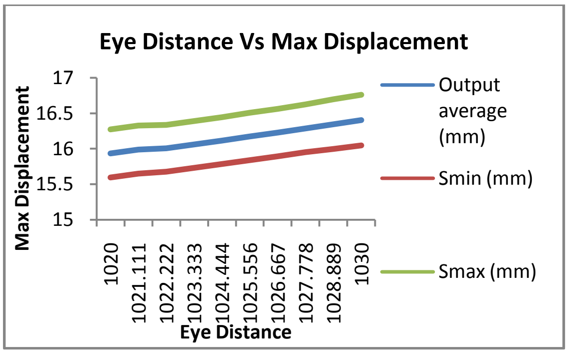

Fig.10 Effect of varying eye distance on displacement

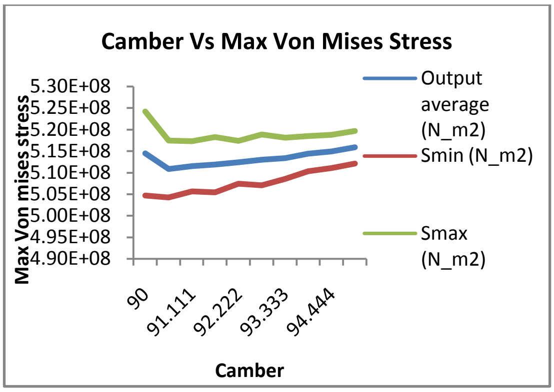

Fig.11 Effect of varying camber on von mises stress

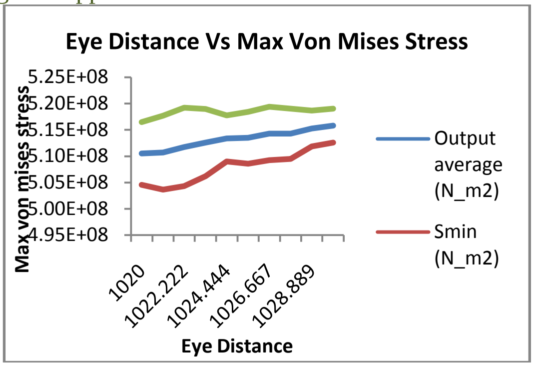

Fig.12 Effect of varying eye distance on Von mises stress

VI. CONCLUSION

After performing the design of experiments the following observations have been made:

a) With reference to fig.9, as the camber is increased there is a decrease in the average amount of displacement.
b) With reference to fig. 10, if the eye distance is increased there is an increase in the average amount of displacement.
c) With reference to fig. 11, if the camber is increased there is an increase in the average amount of von mises stress.
d) With reference to fig. 12, if the eye distance is increased there is an increase in the average amount on mises stress.

Hence it is conclude that the optimum setting of dimensions pertaining to parabolic leaf spring can be achieved by studying the various plots obtained from Design of Experiments.

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