International
Journal
Of Modern Engineering Research (IJMER)

Optimization of Multi Leaf Spring by using Design of Experiments & Simulated Annealing Algorithm

Narendra Yadav[1], Prof. S. A. K. Jilani[2]
[1](M E Scholar, RCET, Bhilai-India)
[2](Associate Professor, Department of Mechanical Engineering, RCET, Bhilai-India)

ABSTRACT: *This work carried out on a multi leaf spring of a tractor trolley with maximum load carrying capacity of 5 Tones. The CAD model of this MLS has been modeled in CATIA V5. After successfully preparing the CAD model, MLS is then tested in Static Structural Analysis workbench for stress and deflection computations. The finite element analysis of the leaf spring has been performed by converting the model into number of nodes and elements and then applying the relevant boundary conditions under the static loading conditions. After implementation of FEA it was observed that the red area close to shackle was undergoing maximum value of stress. This observation leads us to the workbench of Knowledge ware and this aided us in studying the response of crucial output parameters of MLS in the form of Stress and Deflection via Design of experiments. DOE paved the way for SAA where optimization was carried out in order to reach the minimal stress. The corresponding values of camber and leaf span were recorded for minimal stress.*

Keywords: *Computer Aided Design (CAD), Camber, Design of Experiments (DOE), Eye Distance, Finite Element Analysis (FEA), Multi Leaf Spring (MLS), (Simulated annealing algorithm (SAA).*

I. Introduction

A multi leaf spring is a curved shaped laminated plate with eye at both ends, generally used for the suspension in heavy vehicle. It is the oldest forms of springing techniques used. It's slender arc-shaped with uniform rectangular cross section throughout the length. The rear and front axle is mounted on the center of the arc, while the eye end is used for attaching to the chassis.

The basic problem which is encountered in MLS is the change in the dimensions of camber and leaf span due to frequent loading and continuous running of the tractor trolley. The basic observation carried out in this thesis is regarding the increase in the camber and decrease in the leaf span after a period of time. This acts as a limitation to spring action. Hence it becomes very essential to restore the spring action to the initial level. This is because the spring is always loaded and the load on it may be due to the trolley or due to its own weight. It is observed that due to the change in dimensions of camber and leaf span there is a decrease in the amount of comfort level both to the rider and the cargo loaded on it. The objective initially is to study the behavior of a MLS under static loading conditions by varying the camber and leaf span.

II. Multi Leaf Spring Dimension and Boundary Condition

The major difficulty in this work was that the rectangular cross section of the leaf spring was sweeped along the semi elliptical path. This tends to not assembled easily. So it needs to have proper attention and accuracy during the process of assembly. Hence in order to assemble in a proper manner it was very essential for us to use absolute dimensions of the each leave of MLS. The modeling and assembly of MLS has been carried out in CATIA V R20, the dimension of MLS has been maintain according to the manual measurement taken from the existing model of MLS.the dimension of MLS is as:
Leaf Span = 900 mm, Camber = 120, Thickness = 10 mm and width = 60 mm
There are two full length leaves, and seven graduated leaves used for the complete assembly of MLS.

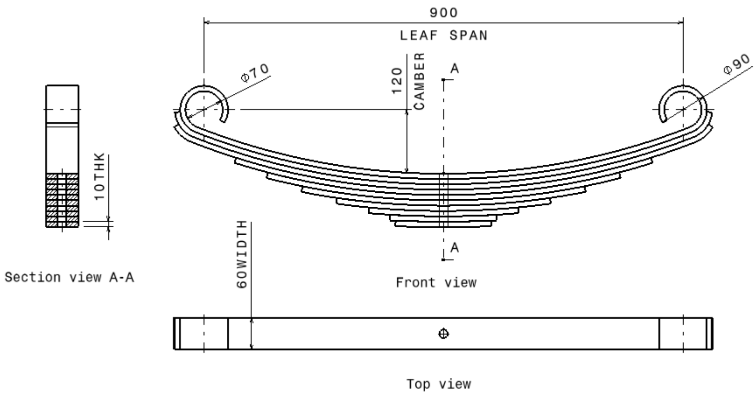

Fig. 1 Front Top & Sectional Side View of MLS

III. Existing Material

Material properties:- The properties of the material 55Si2Mn90 being used in this analysis are shown in Table 1 Mechanical Properties of EN45.

Table 1: Mechanical Properties of EN45

PARAMETER	VALUE
Young's Modulus (E)	200GPa
Poisson's Ratio	0.3
Tensile Strength Ultimate	1962 MPa
Tensile Strength Yield	1800 MPa
Density	7850 kg/m^3
Thermal Expansion	11x10-6 / ^{o}C

IV. Load and Boundary Conditions

One eye of the leaf spring is kept fixed (cylindrical support) and the other eye is given certain degree of rotation to allow the leaf spring to deflect by some amount along its length to meet the actual conditions which is shown in figure 4.14. After this load is applied of magnitude 12500 N in the upward direction at the centre of the MLS. This particular calculation of load to be applied has been done on the basis of GVW (Gross Vehicle Weight). This has been clearly shown the figure 2

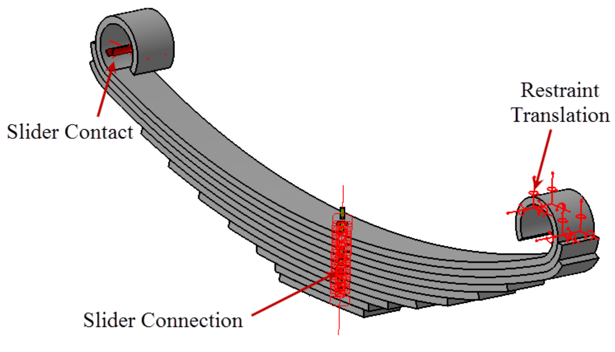

Fig. 2 Boundary condition of MLS

V. Static Structural Analysis in CATIA V5 R20

After applying the boundary conditions the maximum von mises stress and maximum displacement is shown in Fig. 3 & 4

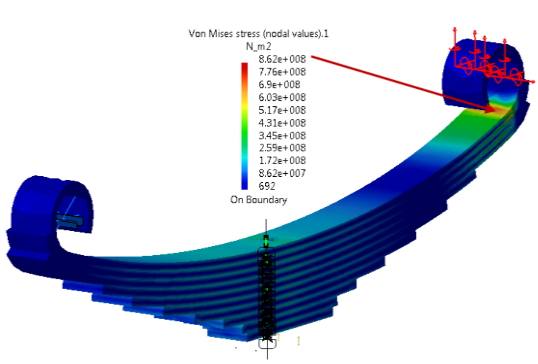

Fig. 3 Max. Stress at near eye end

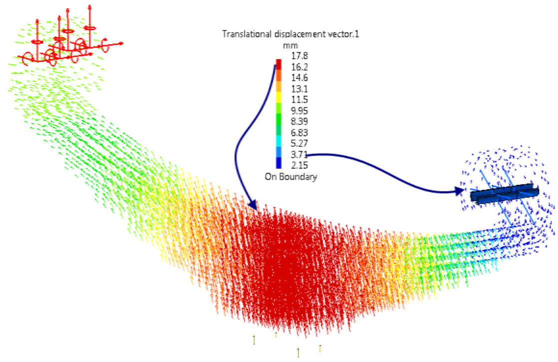

Fig. 4 Max. Deflection

The values of stress and deflection obtained by FEA are shown in Table 4.3 below.

Table 2 Output parameters by FEA

S.N.	PARAMETER	VALUE
1	Max Von Mises Stress	8.621x108 N/m2
2	Max Deflection	17.756 mm
3	Energy	100.085 J
4	Mass	30.877 kg

VI. Design of Experiments

After applying FEA, Design of experiments is performed for the same model where camber and leaf span were varied in a specific range that is camber between 110 mm to 130 mm & leaf span between 870 mm to 930 mm. It took approximately 300 minutes to compute the results based on 400 combinations of camber and leaf span. The optimum value for the stress is 587100000 N/m^2 and the camber is 123.68.

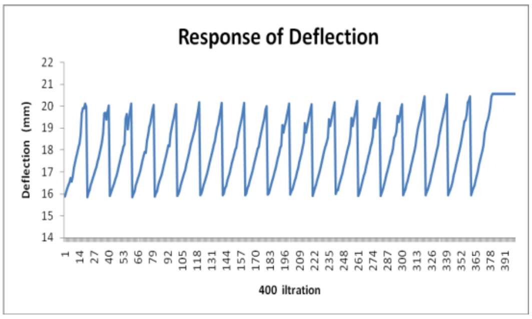

Fig. 5 Variation in deflection in MLS

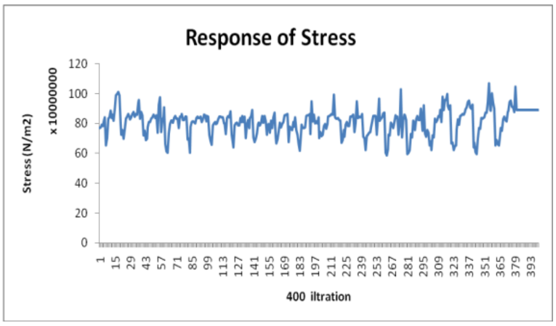

Fig. 6 variation in Stresses in MLS

VII. Optimization by SAA

In any optimization whether linear or non-linear there has to be an objective function which is supposed to be either maximized or minimized. In our case we will select Max Von Mises Stress as our objective function. We have to make sure that stress is reduced. As we know that stress directly depends on the dimensions of the existing MLS, hence in order to perform the optimization and compute various values of stress, the input parameters such as camber and leaf span will be varied. This is stochastic search process which will bounce itself from one local minimum to the other and ultimately it will reach a global minimum. In order to perform the optimization we need to open the optimization workbench in CATIA V5 and the initialize the parameters or factors affecting the outcome.

Table 3 Output parameter of SAA and DOE

S No.	Parameters	Stress via DOE (N/m^2)	Stress via SAA (N/m^2)
1	Existing stress	862100000	862100000
2	Optimized Stress	587100000	672923200
3	Percentage Reduction	32	22

SAA is basically a search algorithm and it starts the first iteration with maximum temperature and then gradually cools down to reach the most optimum configuration. As per the results obtained it was observed that in the 82nd iteration the stress value computed was minimum and has clearly shown in Figure 6.

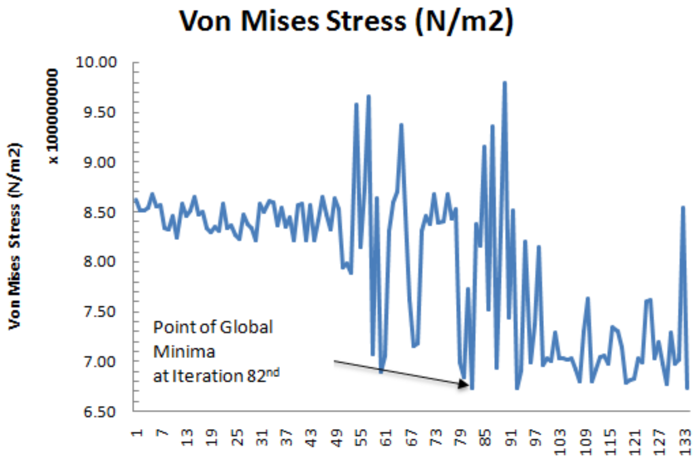

Fig. 7 Variation of Stress as per the iterations via SAA

VIII. Results

- **Stress & Deflection computations from the existing dimensions by FEA**

Stress and deflection are being calculated for the existing model. It is found that Max Von Mises stress is 862100000 N/m2 and corresponding deflection is 17.756 mm.

- **Stress & Deflection computations by DOE**

With reference to the Table 3, it is clear that the optimum value for the stress is 587100000 N/m^2 and the camber is 123.68.which is 262th iteration in DOE table and the parameters corresponding to this stress are as follows: Camber = 123.68 mm & Leaf Span = 873.1 mm.

- **Stress & Deflection computations by SAA**

With reference to the Table 3, the database obtained, it was observed that in the 82nd iteration von mises stress of magnitude 672923200N/m2 was minimum and the parameters corresponding to this stress are as follows: Camber = 123.8 mm & Leaf Span = 918.4 mm.

IX. Conclusion

The result obtained from FEA, SAA and DOE, it is observed that the most optimum setting of parameter was found in DOE. There was a considerable reduction in the magnitude of stress. We conclude that near about 32 percent of reduction in the stresses by DOE, while in SAA there was only 22 percentage of reduction in the stress. The new value of stress found by DOE is 587100000 N/m^2 for this magnitude, the corresponding parameter of camber is 123.6 and leaf span is 873.

References

[1] Narendra Yadav, Mr. Praveen Tandon Mr. S.A.K. Jilani , Material Optimization of Leaf Spring of Tractor Trolley by FEA, *International Journal of Modern Engineering Research, vol. 4 Issue 4* , 2014, 40-44.

[2] Gulur Siddaramanna Shiva Shankar, Sambagam Vijayarangan, "Mono Composite Leaf Spring for Light Weight Vehicle Design, End Joint Analysis and Testing", *J. of Materials Science*, Vol. 12, pp. 220-225, Issue 3, 2006.

[3] Sachin G. Wagle, Satish S. Oesai, S. B. Wadkar, "Optimized Design & Analysis of Parabolic Leaf Spring Considering Braking, Cornering & Bump loads", *National Conference of computational methods in Mechanical Engineering*, pp. 47–52 , September 2005.

[4] Ahmet Kanbolat , Murathan Soner, Mustafa Karaagaç, Tolga Erdogus, "Parabolic Leaf Spring Optimization and Fatigue Strength Evaluation on The Base of Road Load Data, Endurance Rig Tests and Non Linear Finite Element Analysis", *SAE International*, 2011

[5] Kumar Krishan and Aggarwal M.L. "A Finite Element Approach for Analysis of a Multi Leaf Spring using CAE Tools", *Research Journal of Recent Sciences*, Vol. 1, pp. 92-96, December 2012.

[6] N.P.Dhoshi, N.K.Ingole, U.D.Gulhane, "Analysis and Modification of Leaf Spring of Tractor Trailer Using Analytical and Finite Element Method", *International Journal of Modern Engineering Research*, Vol. 1, pp. 719-722, Issue 2, December 2012.

[7] Dakshraj Kothari, Rajendra Prasad Sahu and Rajesh Satankar, "Comparison of Performance of Two Leaf Spring Steels Used For Light Passenger Vehicle", *International Journal of Mechanical, Automobile & Production Engineering*, Vol. 2, pp. 9-16, Issue 1, 2012.

[8] Kumar Krishan, Aggarwal M.L, "Computer Aided FEA Comparison of Mono Steel And Mono GRP Leaf Spring", *International Journal of Advanced Engineering Research and Studies*, Vol. 1, pp. 155-158, Issue 2, January-March, 2012.

[9] C.K. Clarke and G.E. Borowski, "Evaluation of a Leaf Spring Failure", *Journal of Failure Analysis and Prevention*, Vol. 5, pp. 54-63, Issue 6, December 2005.

[10] K.K. Jadhav and R.S. Dalu, "Experimental Investigation & Numerical Analysis of Composite Leaf Spring", *International Journal of Engineering Science and Technology*, Vol. 3, pp. 4759-4764, Issue 6, June 2012.

[11] Vinkel Arora, Gian Bhushan and M.L. Aggarwal, "Eye Design Analysis of Single Leaf Spring In Automotive Vehicles Using CAE Tools", *International Journal of Applied Engineering and Technology*, Vol. 1, pp. 88-97, Issue 1, October-December, 2011.

[12] M.Joemax Agu and V.C.Sathish Gandhi, "Finite Element Analysis of Leaf Spring Considering The Nature of the Material", *International Conference on Intelligent Science & Technology*, 2011.

[13] M. M. Patunkar, D. R. Dolas, "Modelling and Analysis of Composite Leaf Spring under the Static Load Condition by using FEA", *International Journal of Mechanical & Industrial Engineering*, Vol. 1, pp. 1-4, Issue 1, 2011.