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Virtual Validation of Parabolic Leaf Spring under the Static Load Condition by using FEA

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Abstract – The parabolic suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for ten to twenty percent of the unsprung weight. This helps in achieving better riding improvement. Springs are designed to absorb and store energy and then release it. Hence, the weight, cost and strain energy of material becomes a major factor in designing the springs. It can be easily observed, lower modulus and density will have a greater specific strain energy capacity. The introduction of parabolic leaf spring can reduce the weight of the suspension system without any reduction in load carrying capacity and stiffness. Since parabolic leaf spring has more elastic strain energy, storage capacity, and high strength-to-weight ratio as compared to conventional semi elliptic leaf spring.

Springs are placed between the road wheels and the vehicle body. When the wheel goes bump condition, it rises and deflects the spring upward, there by storing energy there in. On releasing, due to the elasticity of the spring material, it rebounds there by expending the stored energy. In this way the spring starts vibrating. Of course, amplitude of leaf spring decreases gradually on account of internal friction of the spring material.

Key words-: Suspension, parabolic leaf spring, FEM, Stress analysis, strength to weight ratio

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INTRODUCTION

Leaf springs are one of the oldest suspension components that are still frequently used, especially in commercial vehicles. The past literature survey shows that leaf springs are designed as generalized force elements where the position, velocity and orientation of the axle mounting gives the reaction forces in the chassis attachment positions. Another part has to be focused, is the automobile industry has shown increased interest in the replacement of conventional semi elliptic leaf spring with parabolic leaf spring due to ride, high strength& weight ratio.

Therefore analysis of the parabolic leaf spring is studied. The objective of this project is to present modelling and analysis of parabolic leaf spring and compares its results. Modelling is done using Pro-E (Wild Fire) 5.0 and Analysis is carried out by using ABAQUS software for better understanding. It is seen that the existing parabolic leaf spring has more stress as compared to new modified parabolic leaf spring for same stiffness (same load carrying capacity).

All the analysis for the parabolic leaf spring is done by using ABAQUS. For parabolic leaf spring, the same parameters are used that of for modified leaf spring. So a virtual model of leaf spring was created in Pro-E. Model is imported in ABAQUS and then material is assigned to the model. These results can be used for comparison with the existing parabolic leaf spring.

MODELLING

Computer model of parabolic leaf spring forms the basis of our work. It is very essential that the developed computer model is exactly a replica of the physical specimen. The parabolic leaf spring has been modelled in PRO-E WF-5 In Part Design and assembly workbench.

CAD Modeling of any project is one of the most time consuming process. One cannot shoot directly from the form sketches to Finite Element Model. CAD modeling is the base of any project.CAE software will consider shapes, whatever is made in CAD model. Although most of the CAD Modeling software have capabilities of analysis to some extent and most of CAE software have capabilities of generating a CAD model directly for the purpose of analysis, but their off domain capabilities are not sufficient for large and complicated models which include many typical shapes of the product. The model of the parabolic leaf spring structures also includes complicated profile, which are difficult to make by any of other CAD modeling as well as CAE software. CAD modeling of the complete parabolic Leaf Spring structure is performed by using PRO-E CREO-5 software. CAD model of leaf spring consists of total 3 different parts which are assembled together in assembly design to make a complete multi leaf spring model, out of all 17 parts; some parts are similar in shape & size.

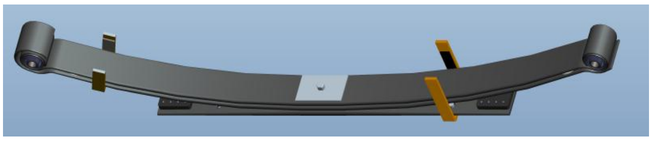

Fig.1: Modelling of parabolic leaf spring

LEAF SPRING DESIGN PARAMETERS

To design parabolic springs, the terms like span, no load assembly camber, loaded camber, stack height, opening, and seat length are used, and these parameters are termed as design parameters. Then layout drawing of the leaf spring assembly has to be prepared. The line which passes through the centre of the eyes is termed as datum line for the springs with eyes. Span is termed the distance between the centres of the eyes. The distance from the datum line to the point where the centre bolt or the cup centre intersects the top surface of the main leaf when the spring is not loaded is called free camber or free height. This may be either positive or negative. The distance from the datum line to the point where the centre bolt or the cup centre intersects the top surface of the main leaf when the spring is loaded is called loaded camber. Ride clearance may be termed as the spring travel on the vehicle from the design load to the metal to metal contact position or the deflection from the design load to the metal to metal contact position. Stiffness factor takes into consideration the leaf length and type of end used. The various design parameters of the leaf spring assembly of light commercial-

Spring Type: Parabolic Leaf Spring with Void Cavity bushes

Free Camber: 135 mm

Distance between eyes: 1260mm

Thickness at the central part: 15 mm

Stack Thickness: 48 mm

Gross Vehicle Weight: 2950 kg.

Total weight acting downwards = Gross Vehicle Weight × gravity

= 2950 x 9.81 = 28939.5 N.

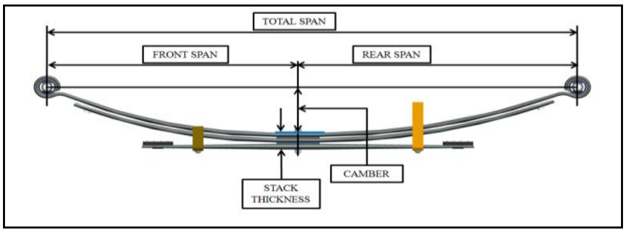

Fig.2 Leaf Spring parameters

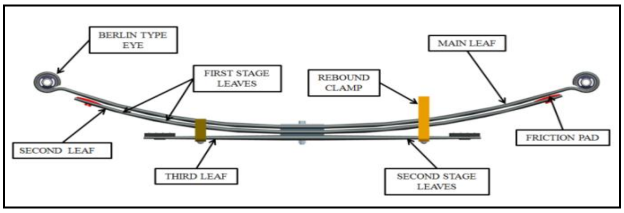

Fig.3 Leaf Spring nomenclature

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 thick leaf sections are used. The material used for the experimental work is 65Si7/SUP9 .The chemical composition of the material is shown below -

Table 1: Mechanical Properties

Quantity	Value	Unit
Young's modulus	200000	MPa
Tensile strength	650 - 880	MPa
Elongation	8-25	%
Fatigue	275 - 275	MPa
Yield strength	350 - 550	MPa
BHN	380-432	--

Table 2: Physical Properties

Quantity	Value	Unit
Thermal	10	e-6/K
Thermal conductivity	25 - 25	W/m.K
Specific heat	460 - 460	J/kg.K
Melting	1450 - 1510	°C
Density	7700 - 7700	kg/m^3
Resistivity	0.55 - 0.55	$Ohm.mm^2/m$

FE MODELING

Meshing involves division of the entire model into small pieces called elements. This is done by meshing. It is convenient to select the free mesh because the leaf spring has sharp curves, so that shape of the object will not alter. To mesh the leaf spring, the element type must be decided first. Here, the element type is solid 72. The element edge length is taken as 22 and is refined the area of centre bolt.

Any continuous object has infinite degree of freedom which makes the analysis impossible to be carried out and hence meshing is carried out. Meshing is a process of reducing the infinite degree of freedom to a finite degree of freedom problem thereby leading to solution of the analysis. 49382 elements, a 49337 10-node element having quadratic displacement behaviour with three degree of freedom at each node is considered.

BOUNDARY CONDITIONS

The leaf spring is mounted on the roller. The frame of the vehicle is connected to the ends of the leaf spring which are formed in the shape of an eye. The front eye of the leaf spring is coupled directly with a pin to the frame so that the eye can rotate freely about the pin but no translation is occurred. The rear eye of the spring is connected to the shackle which is a flexible link; the other end of the shackle is connected to the frame of the vehicle. The rear eyes of the leaf spring have the flexibility to slide along the X-direction when load is applied on the spring and also it can rotate about the pin. The link oscillates during load applied and removed. Therefore the nodes of rear eye of the leaf spring are constrained in all translational degrees of freedom, and constrained the two rotational degrees of freedom. It has been mathematically calculated that the maximum load which the spring will be subjected to is 1150 Kg. 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.

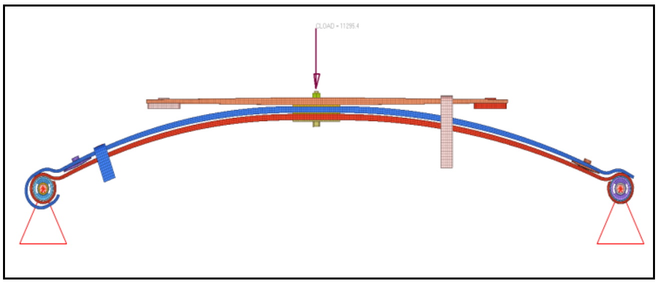

Fig.4: Boundary Condition

STATIC LOADING

The load is distributed equally by all the nodes associated with the center bolt. The load is applied along FY direction. To apply load, it is necessary to select the circumference of the bolt hole and consequently the nodes associated with it. It is necessary to observe the number of nodes associated with the circumference of the bolt hole, because the applied load needs to divide with the number of nodes associated with the circumference of the center bolt.

The first step of the FEA was to calculate the spring under the static loading. This loading case indicated that the stress is distributed equally in the static loading. The static load was determined from the axle mass of the vehicle. The distribution of the axle mass for the single spring in the rear axle was 1150 kg. The displacement of the spring roller is equally important. In theoretical loading situation the spring is almost straight.

As the finite element analysis of multi leaf spring is performed using Abaqus workbench. The multi leaf spring for conventional steel shows deflection and bending stress under load. It is obvious that maximum stress is developed at inner side of the eye sections i.e. the red colour indicates maximum stress, because the constraints applied at the interior of the eyes. Since eyes are subjected to maximum stress, care must be taken in eye design and fabrication and material selection. The material must have good ductility, resilience and toughness to avoid sudden fracture. Thus factor of safety must be increased near the eye. The same procedure is carried out for composite leaf springs, hybrid leaf springs, by changing the material properties of the corresponding materials.

ANALYSIS OF THE RESULTS

Stress

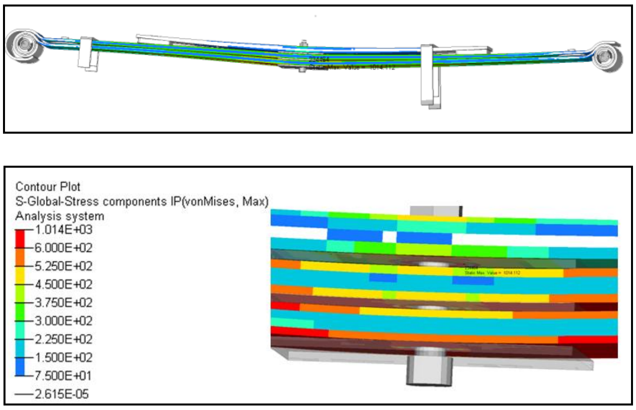

Fig.5: Contour Plot for leaf spring

Displacement

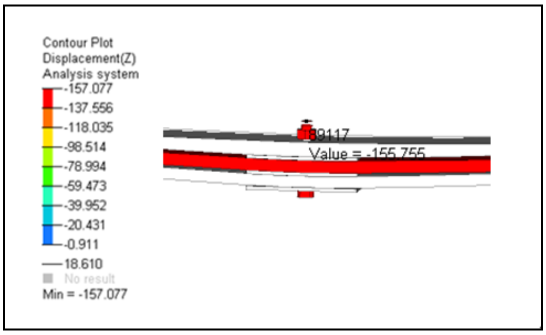

Fig.6: Displacement plot

The main object was to determine the effect of improvement in springs Structure. The force in the direction of the z-axis did not produce any displacement to the spring in the FEA. Magnitude of the force was quite small in the dynamic simulation.

FEA did not shown any difference between the unclamped and clamped spring because the stress was created from forces in y and x axis. Magnitude of the torque moment over the x-axis was also quite small in the dynamic simulation. Results for the examination were defined from the static loading, normal driving and from curve driving.

CONCLUSION

The objective was CAD Modelling and analysis of leaf of light commercial vehicle. For existing leaf spring stress exceeds beyond the given limit which is validated experimentally. Design and validated new parabolic leaf spring to overcome the existing leaf spring stress limit as per SAE spring design manual.

The results obtained from this analysis are showing that the designed components are safe and well within limiting values.

Analysis of designed components has also been carried out for their durability and sustainability. Though while designing parabolic leaf spring; additional factor of safety is assured and in each section no compromise is made with type of material used and amount of material used as there was no constraint to limit the weight of components to a certain value. Modal analysis and static structural analysis are carried out for parabolic leaf spring.

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