ANALYSIS OF LEAF SPRING CONDITIONS FOR HEAVY DUTY VEHICLE

VANDANA JAIN & TRAPTI SHARMA

Assistant Professor, Automobile Engineering Department, RJIT, Tekanpur, India

ABSTRACT

This paper aims to analyse leaf spring and compare nipping and non-nipping of leaf spring condition. For this purpose, multi leaf springs, made up of structural steel have been selected. As leaf spring contributes to considerable amount of weight of the vehicle, and hence needs to be strong enough. Leaf spring is a simple form of suspension spring and is subjected to varying stress cycles leading to fatigue failure. The focus is on to reduce the weight of suspension system, while maintaining the strength. The behavior of a vehicle is directly affected by its suspension system, i.e. vibration characteristics, riding performance and comfort that are directly related to its suspension system.

As per the previous studies, two types of leaf springs are generally used in automobile i.e. with nipping and without nipping. Here, a comparison is presented to understand the behavior of stress, deformation and failure criterion. As leaf spring plays a vital role not only in automobile industry, but also many other areas, where impact load is the criteria for failure.

Hence, its analysis is essential to predict its behavior under loading condition. The leaf spring of steel is designed for a heavy duty vehicle, and is modeled in SOLID WORK 13. The designed leaf spring is then analyzed by ANSYS 14 to study various stresses, induced due to the loading over it. Analysis was done with all boundary conditions, which includes loading and constraints. A comparison of leaf spring with nipping and without nipping was carried out.

KEYWORDS: Leaf Spring, Nipping, Ansys 14, Mesh, Fatigue & Factor of Safety

INTRODUCTION

A spring is defined as an elastic body, whose function is to distort when loaded, on removal of load to recover its original shape and retain the original position. Leaf springs (also known as flat springs) absorb the vehicle's vibrations, shocks and bump loads by means of spring deflections, so that the potential energy is stored in the leaf spring and then relieved slowly. It is an important part of the suspension system, which allows vertical tire and wheel movement in vehicles and carries the weight of the vehicle. When additional load is placed on a spring, because of more passenger or object or because of tire meets a bump, the spring absorbs this load, by deforming it temporarily and after the removal of load, it regains its shape. These are normally of semi elliptical shape, having a main leaf with an eye at each end. Multi leafs are assembled to form a group of leaves of different lengths and made stronger by making the leaves thicker. The flexibility of leaf spring can be increased by increasing the length of leaves.

The entire vehicle load rests on leaf spring, which is mounted on the axle of the vehicle. One of its ends connected to frame i.e. front end by a simple in joint, while other end i.e. rear end is connected by a shackle. Shackle is in the form of flexible link, which is connected between rear eye of leaf spring and frame. As the projections come on the road's surface, vehicle starts moving up and down, this leads deflection in leaf spring, as the spring goes under deflection the length between both the eyes change. If both the ends of spring will be fixed, then spring will not be able to accommodate this deflection in the form of change in length. The shackle is provided at one of its end to provide flexible connection to accommodate this change in length. The front end of the leaf spring is fixed i.e. motion in all the directions are constrained,

while rear eye is free in X-direction and connected to shackle. As the load applies on the axle, it transfers to leaf spring and deflect it in the direction perpendicular to the load applied.

LITERATURE REVIEW

- M.VENKATESAN presented the design and experimental study of leaf spring made up of composite glass fiber reinforced polymer for light weight vehicles. Load carrying capacity, stiffness and weight savings are compared with that of steel leaf spring. Analysis with ANSYS 10 and experimental study has shown that the composite spring has 67.35% less stress, 64.95% higher stiffness and 126.98% higher natural frequency as compare to the existing steel leaf spring. By optimizing the composite leaf spring, a weight reduction of 76.4% is achieved.
- Subhash Chandrabose presented a brief study on analysis, design and fabrication of parabolic leaf spring. Along with the study a finite element model has been deployed to optimize and improve the design.

In the same direction [3], B. Vijay Lakshmi has shown the static and dynamic analysis of composite spring for heavy duty vehicle. The analysis has been done to compare the weight saving, load carrying capacity and stiffness for leaf spring of different material E-GLASS/EPOXY, C- GLASS/EPOXY, S- GLASS/EPOXY and steel leaf spring. As per the result, composite material posses better performance than that of the steel leaf spring.

An extension in above work was done by [4] jadhav Mahesh. He presented an analysis of mono leaf spring used for Maruti 800 vehicle and concluded, as the development of mono leaf spring of composite material with constant cross section area in which, stress level at any point in the leaf is considered constant, because of parabolic type of thickness that was proved to be very effective.

WORKING PRINCIPAL OF SPRING

The suspension leaf spring is one of the potential items for the weight absorption in automobile, as it accounts ten to twenty percent of the un-sprung weight. In the design of springs, strain energy becomes the major factor. The relationship of the specific strain energy can be expressed as

$$U = \sigma^2 / \rho E$$

Where σ is the strength, ρ is the density and E is the Young's Modulus of the spring material. It can be clearly observed from the above relation that the material having lower modulus of elasticity and density will have a greater specific strain energy capacity.

DESIGN OF LEAF SPRING

Leaf springs are made from flat plates, and have many advantages over helical spring which is widely used in automobile industry. The ends of the leaf spring can be guided along a definite path, as it deflects and acts as structural member along with absorbing energy. It can carry different types of load, such as lateral loads, brake torque, driving torque and shock as well.

Let

Thickness of plate = t

Width of plate = b , and

Length of plate = L

Effective length of spring = $2L_1 - 2l/3$

Length of smallest leaf = $(\text{Effective length}/n-1) + \text{ineffective length}$

Length of next leaf = $(\text{Effective length}/n-1) \times 2 + \text{ineffective length}$

Length of $(n-1)^{\text{th}}$ leaf = $(\text{Effective length}/n-1)(n-1) + \text{Ineffective length}$

Length of Master leaf = $2L_1 + \Pi(d+t) \times 2$

Maximum bending moment, $M = WL$

Section modulus, $Z = bt^2/6$

Bending stress, $\sigma = M/Z = 6WL/nbt$

SPECIFICATIONS OF SPRING

Table 1: Specifications of Leaf Springs

S. No	Parameter	value
1.	Total length of spring eye to eye	1130 mm
2.	No of full length leaf	01
3.	Total number of leaf	04
4.	Thickness of leaf	10 mm
5.	Width of leaf	80 mm
6.	Radius of curvature	3125 mm
7.	Maximum load given on spring	2000 N
8.	Material	Structural steel

NIPPING OF LEAF SPRING

Leaf spring is normally an assembly of two or more leaves. Largest one is known as master leaf. In case of nipped leaf spring, the master leaf has slightly larger curvature as compare to leaf which is just below the master leaf. This difference creates a gap between the two leaves as indicated in the figure 1. During the assembly of spring, by tightening the central bolt, an initial bent is created. Because of tightening, a little compressive stress is introduced at the inside curvature of the master leaf, while at the outside of the curvature, tensile stress is produced. These stresses are known as initial stresses in the master leaf. Apart from these stresses an additional leaf is also placed beneath. The master leaf has tendency to flatten out, because of this, the additional leaf resulted stress pattern will be reverse of that master leaf. Tensile stress is produced at the inner surface of curvature, and compressive stress is produced at the outer surface of curvature. Hence, in the loading condition of spring, both master leaf as well as additional leaf is subjected to tensile stress at the inner surface of curvature and compressive stress at the outer surface of curvature. Because of the opposite nature of initial stress and loading stress, the master leaf experiences less stress on both the surfaces. In additional leaf, due to the same nature of initial as well as loading stress, it experience more stress as compared to master leaf. But, it is to be noted that the higher stress of the additional leaf is shared between all other leaves than the master leaf. This process of relieving stress in the master leaf is known as “Nipping of leaf spring”. All the leaves of a multi leaf spring have certain amount of nipping, because of this; there will be a gap between the leaves. This gap is resulted in uniform distribution of stress and accumulated dusts can also be cleaned.

Figure 1: Representation of Nipping Between Two Leaves

EXPRESSION FOR INITIAL GAP OR NIP

$$C = 2WL^3/2nEbt^3$$

$$\text{Load on clip bolt, } W_b = 2Nf.Ng.W/n(2Ng+3Nf)$$

$$\text{Final Stress, } \sigma = M/Z = 6WL/nbt^2$$

MATERIAL

The basic requirements of a leaf spring steel is that the selected grade of steel must have sufficient hardening ability for the size involved, to ensure a full martensitic structure throughout the entire leaf section. To ensure the adequate hardness in case of thick leaf sections, higher alloy content is necessary. The material used for the experimental work is ALLOY STEEL.

The structure of material and its characteristics are related to performance of spring and determined first.

The leaf springs are specially designed to absorb vibrations, shocks and bump loads induce due to irregularities of the road in the form of spring deflection. Because of the deflection, potential energy is stored in spring and released slowly. This ability of spring to store and absorb more strain energy ensures efficient suspension system.

MODELING OF LEAF SPRING

In the present work, the 3D geometric model of the leaf spring of a heavy weight commercial vehicle is developed using the above design data, which was without nipping. Same data has been used to design a leaf spring with applying nipping, as per equation 1 for comparison of both the models. The models are prepared by using SOLIDWORK modeling software. Figures 2 (a) & (b) are showing solid models of leaf springs, with and without consideration of nipping.

As the modeling of the leaf spring completed, the analysis was carried out on ANSYS-14. Following assumptions were made during the analysis:

- The leaf spring is considered as homogenous and isotropic.
- The problem domain is considered as axis- symmetric.
- Inertia & body force effects are negligible during the analysis.

Figure 2: (A) Model of Leaf Spring without Nipping (B) Model of Spring with Nipping

MESHING

Meshing is the process of dividing the model into small number of pieces. Meshing can be done through the different types of elements. Depending upon the convenience and suitability to the problem, any one of them can be selected. Because leaf spring has sharp curves, so it is convenient to select free mesh. Here, solid 45 elements are used to mesh the model with the element edge length being taken as 5 mm. Here, the total number of elements is 2225 and total number of nodes is 8099. Figure 3 (a) & (b) are showing meshed models of both the cases.

Figure 3: (A) Meshed Model of spring without Nipping (B) Meshed Model of Spring with Nipping

BOUNDARY CONDITIONS

Figure 4: (A) Boundary Conditions Applied on spring without Nipping (B) Boundary Conditions Applied on spring with Nipping

FINITE ELEMENT ANALYSIS

Finite element analysis (FEA) is a computer based technique, which is used to analyze the strength and to predict the behavior of engineering structure. It can also be used to calculate the deflection, stresses, strain energy, vibration, buckling behavior and many other phenomena. Low cost of modern computers has made finite element analysis, adaptive

to many discipline and many companies. In finite element analysis model is broken down in small number of pieces. The behavior of the model can be described by the individual behavior of an element with a simple set of equations. As the elements are joined together to form a complete structure, similarly equations describing the behavior of individual elements is joined together in large set of equation to predict the behavior of engineering structure. This large set of equations can be easily solved by use of computer. By the result of these equations, computer extracts the behavior of a single element, and then whole problem domain. From this, it can get the stresses, deflection, strain energy, fatigue behavior and failure, etc. of the individual part or all structure.

The leaf spring is mounted on the axle of the vehicles; the eye shape ends of the leaf spring are connected to the frame of the vehicle. One of the eyes i.e. front eye is connected to the frame with the help of pin, so that the eye can rotate freely about the pin, but translation of front eye does not allow. Other eye i.e. rear eye is connected to the frame by a shackle, means this link is fixed.

COMPARISON

Equivalent (Von-Mises) Stress

Figure 5: Von- Mises Stress Result (A) Without Nipping (B) With Nipping

Total Deformation

Figure 6: Total Deformation Result (A) without Nipping (B) with Nipping

Safety Factor

Figure 7: Safety Factor (A) without Nipping (B) with Nipping

Table 2: Analysis Result for Both the Cases of Leaf Spring

Results without Nipping	Minimum Value	Maximum Value
1. Equivalent stress (Von- mises)	2.633e07Pa	2.2079e08Pa
2. Total Deformation	8.467e-05 meter	0.0007603meter
3. Safety Factor	1.1329	15
Results with Nipping	Minimumvalue	Maximum Value
1. Equivalent stress	1.326e07 Pa	1.1933e08 Pa
2. Total Deformation	4.644e-5 meter	0.000107 meter
4. Safety Factor	2.0851	15

CONCLUSIONS

The 3-D models of structural steel leaf springs were analyzed using ANSYS. A comparison was made between structural steel leaf spring with and without consideration of nipping, with respect to equivalent stress (von- mises), total deformation and factor of safety.

From the results, it is observed that the leaf spring with nipping has less stress and total deformation as compare to without nipping leaf spring with similar design specifications and material. Maximum factor of safety for both the cases are same, while minimum factor safety is less in without nipping leaf spring, as compared to the other.

So, it can be concluded that in case of nipped leaf spring, the gap between each leaf does not constraint the deformation of adjacent leaf. Hence, the deformation is more as compare to without nipped spring, as a result of which, stress is also less in nipped leaf spring.

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