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A Review of Fatigue Analysis for Leaf Spring Using Finite Element Methodology and Experimentation for Evaluating the Variation in Material and the Geometry Affecting the Performance Over Life

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Abstract

Parabolic leaf spring plays a vital role in the suspension system. Since the failure of leaf spring is attributable to its fatigue loading. Cycle loads of a constant or varying magnitude and direction act and on the suspension system of the automotive that is sustained and borne by the leaf spring while the vehicle runs along the road. Pot-holes and bumps add the shock loads. This work aims to focus its research over assumption of the constant amplitude loading of the leaf spring for a passenger car. Finite element modeling would be employed to evaluate the existing design while offering the best alternatives for design. Feasible design alternatives would be started using F.E. Methodology. The benchmark design would be validated in advance for offering credibility to the F.E. model. Further analysis would be done for recommend of the most suited design for leaf spring..

Keywords: leaf spring, material property, fractures mechanics.

Introduction

The leaf spring is widely used in automobiles and one of the components of suspension system. It needs to have excellent fatigue life. As a general rule, the leaf spring must be regarded as a safety component as failure could lead to severe accidents. The suspension leaf spring is one of the potential elements for weight reduction in automobiles as it leads to the reduction of un-sprung weight of automobile. The elements whose weight is not transmitted to the suspension spring are called the un-sprung elements of the automobile. The elements whose weight is not transmitted to the suspension spring are called the un-sprung elements of the automobile. This includes wheel assembly, axles, and part of the weight of suspension spring and shock absorbers. The leaf spring accounts for 10-20% 0f the un-sprung weight.

Aim of The project going to undertake is to increase the load carrying capacity and life cycle by modifying the existing leaf spring of light commercial vehicle (LCV).We can find leaf springs in almost all four wheelers. A leaf spring protects a four wheeler from the unevenness of the road. Thus a leaf spring necessarily serves the following purposes:

- Increase service life of a four wheeler
- Increase user comfort.

Fatigue failure is the predominant mode of in-service failure of many automobile components. This is due to the fact that the automobile components are subjected to variety of fatigue loads like shocks caused due to road irregularities traced by the road wheels, the sudden loads due to the wheel traveling over the bumps etc. The leaf springs are more affected due to fatigue loads, as they are a part of the unstrung mass of the automobile.

Nowadays, CAD and FEA tools are used extensively in the industry for the design of leaf spring.
Aim of The project going to undertake is to increase the load carrying capacity and life cycle by modifying the existing leaf spring of light commercial vehicle (LCV).

Materials for Leaf Springs: The material used for leaf spring is usually a plain carbon steel having 0.90 to 1.0% carbon. The leaves are heat treated after the

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forming process. The heat treatment of spring steel produces greater strength and therefore greater load capacity, greater range of defection and better fatigue property [5]

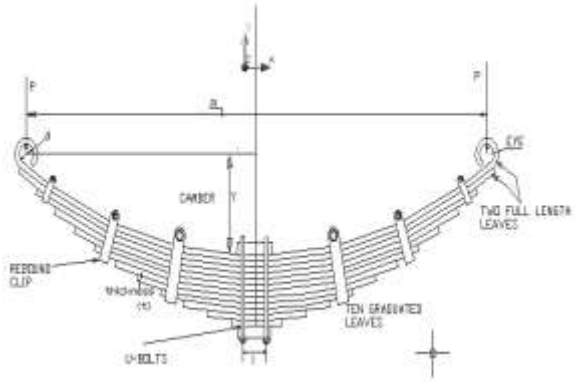

Figure 1: Leaf spring [8]

Literature review

W.F Jones III [4]have Analyzed the failure that occurred in a type 304 stainless steel leaf spring attached to the undercarriage assembly of airport shuttle train material was 304 (Austenitic wrought stainless steel) UNSS30400.The best think of this paper is that author have focused more in metallurgical aspects. He recommended improved assembly procedures to ensure proper alignment there by reducing the improved stresses.

Kumar Krishan and Aggarwal M.L.[6] in this paper research is work carried on multi leaf spring having nine leaves used by a commercial vehicle is discussed. based on the specific energy of steel spring and some composite material. The E-glass/epoxy is selected as spring material compared to steel spring the composite spring is found to have 67.35% lesser stress, 64.95% higher stiffness and 126.98% higher natural frequency than that of existing steel leaf spring and weight reduction of about 68.18% is achieved. Besides the weight reduction the Fatigue life of composite spring is predicted to be higher than that of leaf spring

Gulur Siddaramanna Shiva Shankar, Sambagam Vijayarangan [8] The Author have done his research work on design, analysis fabricate and testing of unidirectional Glass fiber/ Epoxy composite mono leaf spring without end joints and composite leaf spring boundary end joint using hand layup technique the weight reduction of 85% is obtained for E glass/Epoxy, and 91% for graphite and carbon/Epoxy over convectional leaf spring. He focused his work over reducing the weight of leaf spring by using composite.

Shishay Amare Gebremeskel[7] this paper have very nicely explained the detailed procedure to produce the prototype of single leaf spring made up of (Epoxy resin)material with the help of hand layup method. (40 layers of E-glass fiber of 0.4 mm is made) In this paper analytical method using Hwang and Han relation: $N - \{B(1-r)\}^{1/c}$; to calculate the fatigue life of composite leaf spring and then he validated his analytical result with FEA method using Abaqus/CAE 6.10.

Figure 3: Trimmed final prototype of E-glass/Epoxy composite leaf spring [7]

Ahmet Kanbolat , Murathan Soner, Mustafa Karaagaç, Tolga Erdogus[2] This paper is just like a design data book for leaf spring which gives failure reasons related to leaf spring.

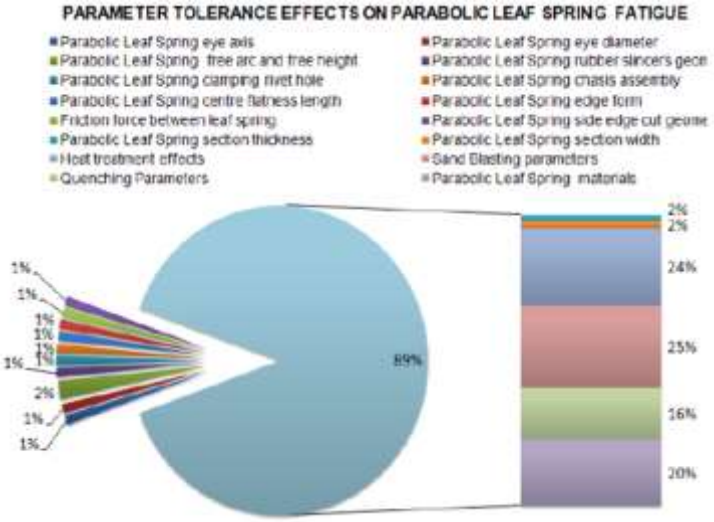

Figure 2: Parameters affecting the fatigue life of parabolic leaf spring [2]

This paper has focused the various parameters or factors related to design, manufacturing, material etc affecting the fatigue life of leaf spring.

This is determined by applying new geometric, material and production variables and by using design of experimental studies method.

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Over all review:

- Very few of researchers have focused on Metallurgical aspects of failure of steel leaf spring.
- Very little research is done on the geometrical variation effect on composite leaf spring
- Most of researchers have taken the composite as an only alternative. Instead of any other grade of steel.

Problem definition

After viewing literature on leaf spring the key reason for failure of the suspension spring being through the mode of `Fatigue' induced due to cyclic loading, this work shall pursue the problem for finding feasible Design alternatives for the problem at hand. Any catastrophic failure of the leaf spring would eventually arise into secondary failures of the other supported parts and would be particularly dangerous while the vehicle is in motion. The geometry for the existing spring needs further study and evaluation for suggesting remedy to the premature failure of the spring. The centre distances between the eyes of the leaf spring to remain unchanged as also the total height of the spring. The methodology deployed for evaluation should have ease for manipulation with reliability of results.

Figure 4: Typical Leaf Spring used for Automotive Application

Objectives

This research work aims to focus on the following objectives:

1) Engage Finite Element Modeling methodology for finding solution to the problem
2) Secure geometry for the Leaf Spring and assign the material properties to the same for the existing variant
3) Determine through structural analysis the Load vs. Deflection as well as Stress vs Strain using Linear Static Structural Analysis (ANSYS/ MSC Nastran/ RADIOSS)
4) determine the Fatigue life of the component using inputs from the Structural analysis while assigning the output to a suitable solver for Fatigue analysis (N-Code/ MSC Fatigue/ FEM FAT)
5) Offer mathematical treatment to the problem case for finding preliminary responses
6) Evaluate the options for material change or geometry change using the CAE solvers
7) Visualize the results using Post-processor
8) Conduct experimentation for the existing levels for the Design parameters and validate the model
9) Extend the analogy for extrapolating the results for validation using the new level for the given Design parameter.
10) Recommend the solution to the problem considering feasibility for implementation
11) Investigate by Scanning electron microscopy/ Fractography of fracture surface of actual steel leaf spring

Experimentation

Develop a physical setup for experimentation in the form of a fixture. Mount the fixture over the Fatigue Testing SPM. Secure the existing part model over the fixture. Apply loads per the inputs referred for Analytical study. Load the component at the required frequency or offer a `low cycle fatigue' in case the specified frequency cannot be deployed due to the limitation over the machine. An accelerated life testing can be performed upon assigning a suitable factor. Alternatively, a fixed number of cycles could be deployed for finding the permanent set occurring in the Test Piece along with other phenomena of interest. The same could be extrapolated to arrive at results of the Test.

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Figure 5: Typical Fatigue Life Testing SPM.

Validation

Since deploying a complete test may not be feasible, the test can be conducted for fixed number of cycles for extrapolation of results. The results would be compared with the Mathematical treatment offered earlier or the Analytical methodology using CAE practices. Thesis work to be validated based on the comparative evaluation of the results. Any average data point within about 20% deviation might be acceptable while making assessment for validation.

Conclusion

A comparative review study of research work in leaf spring is done and it is observed that high strength and reduced weight and improved fatigue life are most disserving factors associated with leaf spring which can be achieved by composite material or any geometrical variation in existing leaf spring.

This research work will be beneficial for researchers from automobile industries to get the feasible alternative to existing leaf spring.

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