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Design of Leaf Spring for Light Commercial Vehicle for Enhanced Mechanical Properties and Reduce Weight to Improve the Performance Over a. Life

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Abstract
Light weight material and design have always being important topic's in products design across several Automobile industries An parabolic leaf spring contributes considerable amount of weight to the vehicle and need to be strong enough. This work aim's to focus on reducing weight and increasing or maintaining strength and fatigue life we conducted Analysis of mono leaf spring in Hyper-mesh and Femfat software and tried to find alternative to existing design to reduce weight of spring.

Keywords: leaf spring, thickness of leaf, Hyper-mesh/Abacus, femfat, fatigue

Introduction
Reducing weight while increasing or maintaining strength of products is getting to be highly important research issue in this modern world. This concept has been most important in automobile suspensions system such as leaf spring because the weight of leaf spring is un-sprung weight of automobile. The elements whose weight is not transmitted to the suspension spring are called the unstrung 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. The reduction of unstrung weight helps in achieving improved ride characteristics and increased fuel efficiency. The cost of materials constitutes nearly 60-70% 0f the vehicle's cost and contributes to the better quality and performance of the vehicle.

The aim of research work going to undertake is increase load carrying capacity and life cycle by modifying the existing leaf spring of light commercial vehicle. 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 purpose of this paper is to predict the fatigue life of semi-elliptical steel leaf spring along with analytical stress and deflection calculations. The suspension leaf spring is one of the potential items for weight reduction in automobile as it accounts for ten to twenty percent of the unstrung weight. This helps in achieving the vehicle with improved riding qualities. It is well known that springs, are designed to absorb and store energy and then release it. Hence, the strain energy of the material becomes a major factor in designing the springs. 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

The vehicles need a good suspension system that can deliver a good ride and handling. At the same time, the component must have an excellent fatigue life.[7]

Fatigue failure
Fatigue is one of the major issues in automotive components. It must withstand numerous numbers of cycles before it can fail, or never fail at all during the service period. Fatigue is dangerous form of failure which occurs in material when they are subjected to cyclic or otherwise fluctuating load. Failure records show that bulk of mechanism fails because of fatigue and corrosion. The first Recorded observation related to the axles of railway wagon in 19th century [20]

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Material of leaf spring

The material used for leaf springs usually a plain carbon steel having 0.90 to 1.0% carbon. The leaf is heat treated after the forming process. The heat treatment of spring steel produces greater strength and therefore greater load capacity, greater range of deflection and better fatigue properties [18]

Standard size of Automobile Suspension System

Following are standard sizes for the automobile suspension spring:

1. Standard nominal width b are: 32, 40*, 45, 50*, 55, 60*, 65, 70*, 75, 80, 90, 100 and 125mm.(Dimensions marked *are the preferred widths)
2. Standard nominal thickness (t) is: 3.2, 4.5, 5, 6, 6.5, 7, 7.5, 8, 9, 10, 11, 12, 14, 16 mm.
3. At the eye the following bore diameters are recommended: 19, 20, 22, 23, 25, 27, 28, 30, 32, 35, 38, 50, 55 mm.[18]

Literature review

Shaikh Mubassar Ali, Susan C. Mantell, and Ellen K. Longmire [1]: Author have discussed on Experimental Technique for Fatigue Testing of MEMS in Liquids in which he discussed the behavior of material related to fatigue life in corrosive environment. And also the experimental techniques which are used for microelectromechanical systems (MEMS) in corrosive liquid environment Author have performed the fatigue life testing in air and saline solution. Fatigue life of specimen tested in this paper in air was within the range of the fatigue lives. But the effect of corrosive environment on fatigue life was inconclusive.

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.

Fig 1: Untrimmed E-glass/ Epoxy composite leaf spring prototype [7]

C.K. Clarke and G.E. Borowski[19]: The Author had analyzed the leaf spring failure in vehicle from metallurgical or micro structural failure analysis in sport utility vehicle with the help of scanning electron microscope factograph of spring structure microscope factograph of spring structure. Fracture of the spring occurred at the formed forward eye, as shown in Fig. 2. Comparison of the eye with unbroken springs revealed that it had somewhat unwrapped prior to the failure.

Fig 2: The broken halves of the spring have been placed together in a manner exaggerating the opening of the eye before rupture. [19]

He concluded that

• The presence of sulfur segregation at the mid plane weakened the spring.

• The spring was cracked for some time in advance of the accident.

• The prior cracking in the spring was extensive enough to reduce the strength of the spring to the point where normal dirt road forces were adequate to produce rupture.

• Marks in the wheelwells and on the road surfaces were consistent with and support rupture of the spring at the start of the accident sequence.

• The rock strike possibility was ruled out because forces adequate to rupture the spring were present

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well in advance of the rock strike, and well marks were not consistent with short-duration forces expected from a rock strike

Mouleeswaran Senthil Kumar, Sabapathy Vijayarangan [3] : Author have described static and fatigue analysis of steel leaf spring and composite multi leaf spring made up of glass fibre reinforced polymer using life data analysis. It is proved that the analytical formula predicts the fatigue life of component with E-glass/epoxy composite material.

Hwang and Han relation: $N = \{B(1 - r)\}^{1/C}$
Where, N is the number of cycles to failure B = 10.33 C = 0.14012; $r = \sigma_{max}/\sigma_u$; σ_{max} .
Finally he concluded that composite leaf 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. The conventional multi leaf spring weighs about 13.5 kg whereas the E-glass/Epoxy multi leaf spring weighs only 4.3 kg. Thus the weight reduction of 68.15 % is achieved. Besides the reduction of weight, the fatigue life of composite leaf spring is predicted to be higher than that of steel leaf spring. Life data analysis is found to be a tool to predict the fatigue life of composite multi leaf spring. It is found that the life of composite leaf spring is much higher than that of steel leaf spring.

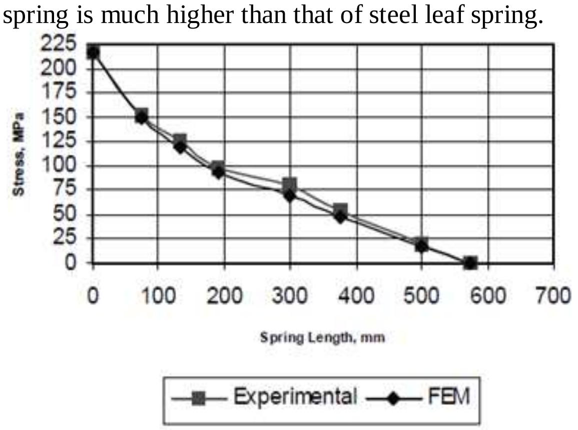

Fig 3: Variation of longitudinal stress of composite leaf spring

Hand book on "Suspension Specialist" [13] :where author have suggested various failure causes of leaf spring like, Overloading, Shock Absorbers, Brake Adjustments, Protective Coatings, Surface Condition, Decarburization and Steel Quality. And also he focused on various types of fatigue failure i.e. Early Life Failures, Midlife Failures, Late Life Failures and suggested remedies for when we have to repair leaf spring and when to replace the leaf spring.

Finite Element Modeling:

Nowadays, CAD and CAE tools are used extensively in the industry for the design of leaf spring. First we modeled the mono leaf ***Flow chart showing complete FEA method [4]***

spring in UG and then we preprocessed the iges model in Altair Hyper-mesh V10 and we used Abacus as solver. And further fatigue analysis is done in FEM FAT software. We have used CAE to compact development cycle by implying CAE as much as possible to reduce the actual experimentation test.

The iges files are imported to hyper mesh where we can do preprocessing i.e. finite element modeling. The purpose of FEM is to make a model that behaves mathematically as being and create appropriate input files for different finite element solvers.we meshed the model in hyprtmesh which is well showed in fig 5

Fig 5: Meshing of mono leaf spring in hyper mesh

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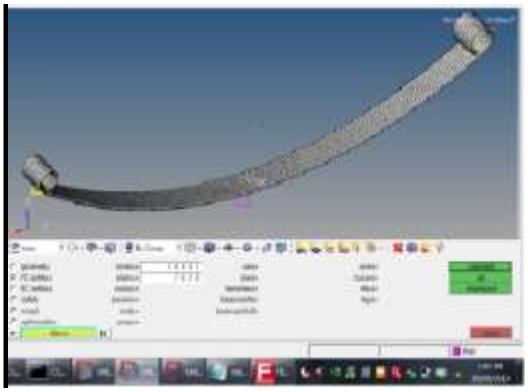

Fig 6: model showing number of nodes and elements

Here number of nodes are 10441 and elements are 7020 as showed in fig 6 and for further analysis we created a Rigid body element to apply boundary conditions. Which is showed in fig 7.

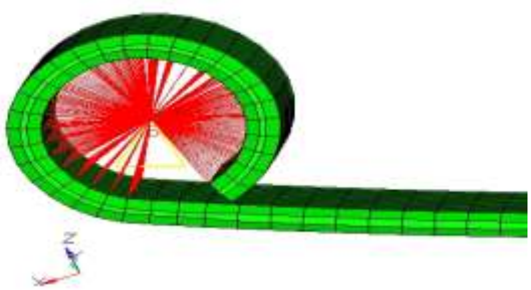

Fig 7: Rigid body element at mono leaf spring eye.

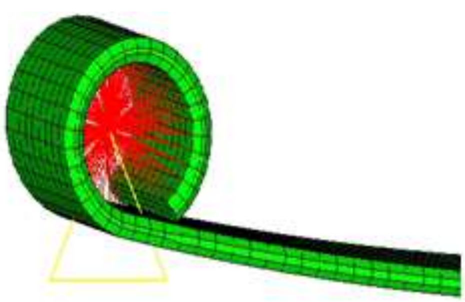

***Fig 8: Boundary Conditions at mono leaf spring eyes*.**

Rigid body element node was connected to remaining nodes of eye with rigid body element 2 i.e. all follow the path or action as per master node as showed in fig 7 and for front eye only Y direction rotation is free and remaining degree are constrained and for rear eye only x direction rotation is allowed

A center node is being created for reference at the point where spring center point is get flatterned. As maximum displacement of spring so we create a center node at distance of champers height i.e. 142 mm and we gaved the displacement to spring at a distance touching the center node i.e. degree of freedom 3 [degree of freedom along translation direction] equal to 142 mm and then by using solver Abacus we determine stress, stiffness, maximum deflection and maximum stress area.

And then this we move to FEM FAT which is used for fatigue analysis same result are called in FEMFAT and we view this result in hyper view. Fatigue life analysis we gave the input form 2 lakes to 5 lakes and view result. Red colour shows fatigue life less than 2 lakes and green color shows fatigue life satisfied. We found stiffness of spring is 4.5385 N/mm for a load of 635.4 N and deflection 142 mm.

And then this we move to FEM FAT which is used for fatigue analysis same result are called in FEMFAT and we view this result in hyper view. Fatigue life analysis we gave the input form 2 lakes to 5 lakes and view result. Red colour shows fatigue life less than 2 lakes and green color shows fatigue life satisfied.

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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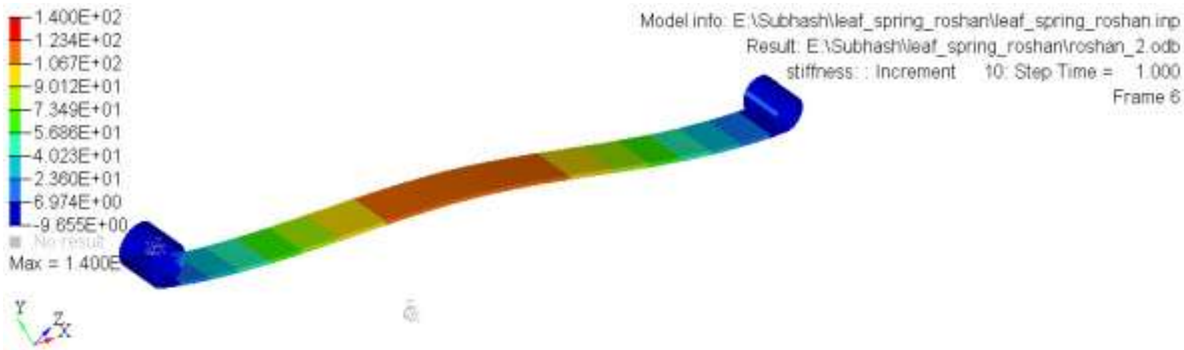

Fig 9: Deformation of mono leaf spring

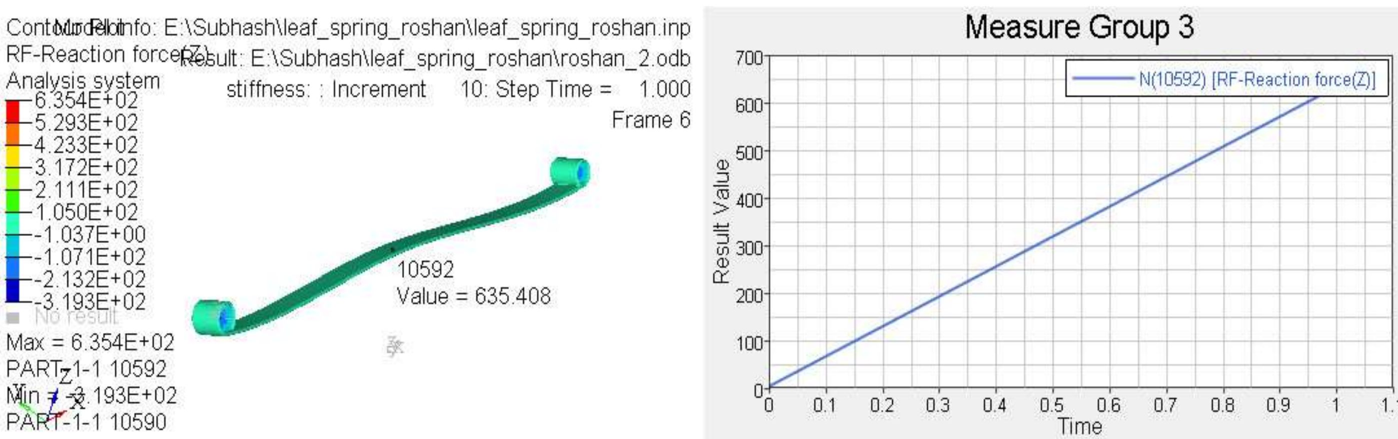

Fig 10 : Graph showing relation in time and load applied.

Fig 11: Fatigue life analysis

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.

Scope

High strength, and reduced weight and improved fatigue life and this research work will be beneficial for researchers form automobile industries to get the feasible alternative to existing leaf spring

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Fig12: Typical Fatigue Life Testing Machine

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Conclusion

As we know that the cost of material constitute nearly 60-70% of vehicle cost and contributes to better quality and performance of the vehicle by reducing thickness less than existing thickness (5mm) up to the thickness which will be satisfying the fatigue life of existing spring will be selected. We expect that with 0.5 mm reduction of thickness 10% marerial will be saved from each main leaf. Though reduction of material for each spring is less but we know that vehicles are manufactured in tonnages and for each vehicle 4 spring are needed means almost this will give definitely large reduction in material cost and we will be performing for 4.5mm or 4mm. and if both satisfies we will select optimum of both and which can be best solution for reducing weight

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