Fatigue Life Evaluation of Composite Material Leaf Spring- Numerical and Experimental Approach

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Abstract - *Increasing competition and innovations in automobile sector tends to modify the existing products or replacing old products by new and advanced material products. More efforts are taken in order to increase the comfort of user. Appropriate balance of comfort riding qualities and economy in manufacturing of leaf spring becomes an obvious necessity. Use of composite materials for leaf springs is some of these latest modifications in suspension systems. The implementation of composite materials by replacing steel in conventional leaf springs of a suspension system. Automobile-sector is showing an increased interest in the area of composite material-leaf springs due to their high strength to weight ratio.*

All these will result in fuel saving which will make countries energy independent because fuel saved is fuel produced. The present work concentrates on comparison of fatigue life evaluation of composite leaf spring using numerical and experimental analysis method. In order to carryout numerical analysis Ansys Workbench is used.

Key Words: Automobile, Fatigue, Suspension system, Ansys Workbench, Leaf spring, Ansys Workbench.

1. INTRODUCTION

Multi-leaf springs are widely used for automobile and rail road suspensions. It consists of a series of flat plates, usually of semi- elliptical shape. [1]

Leaf spring is a kind of spring which is a vehicle's component setting on the suspension in purpose of carriages to support vehicle weight, absorb bumps then locate to axle. A leaf spring can serve locating to the vehicle body for some extent damping as well as spring function effect the driver feel comfort and not be vibrated by rough road [2].

The leaf serves several functions that other suspension systems might need additional hardware to serve. The leaf does the following:

- Supports some or all of the chassis weight.
- Controls chassis roll more efficiently by utilizing a higher rear moment center and a wide spring base.
- Controls reared wrap-up when not mounted with birdcage-type mounts.
- Controls axle dampening.
- Controls lateral forces much the same way a Pan hard bar does, but with very little lateral movement.
- Controls braking forces when not mounted with birdcage-style mounts.
- Better at maintaining wheelbase lengths (reduced rears steer) under acceleration and braking.

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. [3]

In materials science, fatigue is the weakening of a material caused by repeatedly applied loads. It is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The nominal maximum stress values that cause such damage may be much less than the strength of the material typically quoted as the ultimate tensile stress limit, or the yield stress limit.

Fatigue occurs when a material is subjected to repeat loading and unloading. If the loads are above a certain threshold, microscopic cracks will begin to form at the stress concentrators such as the surface, persistent slip bands (PSBs), and grain interfaces. [4] Eventually a crack will reach a critical size, the crack will propagate suddenly, and the structure will fracture. The shape of the structure will significantly affect the fatigue life; square holes or sharp corners will lead to elevated local stresses where fatigue cracks can initiate. Round holes and smooth transitions or fillets will therefore increase the fatigue strength of the structure.

As time is reduced for development of new product, the trend in industry towards the virtual release of the product. Finite element method is used to evaluate the Fatigue life evaluation of composite leaf spring, as theoretical calculation would be more complex.

2. CHARACTERISTIC OF FATIGUE

In metal alloys, and for the simplifying case when there are no macroscopic or microscopic discontinuities, the process starts with dislocation movements at the microscopic level, which eventually form persistent slip bands that become the nucleus of short cracks. Macroscopic and microscopic discontinuities (at the crystalline grain scale) as well as component design features which cause stress concentrations (holes, keyways, sharp changes of load direction etc.) are common locations at which the fatigue process begins.

Fatigue is a process that has a degree of randomness (stochastic), often showing considerable scatter even in seemingly identical sample in well controlled environments. Fatigue is usually associated with tensile stresses but fatigue cracks have been reported due to compressive loads.

The greater the applied stress range, the shorter the life. Fatigue life scatter tends to increase for longer fatigue lives. Damage is cumulative. Materials do not recover when rested. Fatigue life is influenced by a variety of factors, such as temperature, surface finish, metallurgical microstructure, presence of oxidizing or inert chemicals, residual stresses, scuffing contact (fretting), etc. Some materials (e.g., some steel and titanium alloys) exhibit a theoretical fatigue limit below which continued loading does not lead to fatigue failure. High cycle fatigue strength (about 104 to 108 cycles) can be described by stress-based parameters. A load-controlled servo-hydraulic test rig is commonly used in these tests, with frequencies of around 20–50 Hz. Other sorts of machines—like resonant magnetic machines—can also be used, to achieve frequencies up to 250 Hz. Low cycle fatigue (loading that typically causes failure in less than 104 cycles) is associated with localized plastic behavior in metals; thus, a strain-based parameter should be used for fatigue life prediction in metals. Testing is conducted with constant strain amplitudes typically at 0.01–5 Hz.

Main parameters influencing fatigue life

The fatigue life of a member or of a structural detail subjected to repeated cyclic loadings is defined as the number of stress cycles it can stand before failure. Depending upon the member or structural detail geometry, its fabrication or the material used, four main parameters can influence the fatigue strength (or resistance, both used in EN 1993-1-9):

- The stress difference, or as most often called stress range,
- The structural detail geometry,
- The material characteristics,
- The environment

3. NUMRERICAL FATIGUE LIFE EVALUATION USING FEA

3.1 Finite Element Analysis of Leaf Spring

The commercial ANSYS package is used for the FE meshing, modeling and analysis module. The general structure of a Finite Element Analysis involves the following three steps

The description of the geometry, the physical characteristics and the mesh (pre-processing)

The application of finite element analysis. (solution)

The visualization and interpretation of the results of the solution. (Post processing) [5].

- Pre-Processing

The pre-processing module is used for entering all the information necessary to define the problem. This data relates to the discretization of the structure and the representation of its physical behavior.

The pre-processing module must accomplish the following three functions

Description of the geometry of the object in terms of the chosen element types.

2. Mesh generation.

3. Definition of loading and boundary condition

Fig. 3.1 shows meshed model of Leaf spring Assembly.

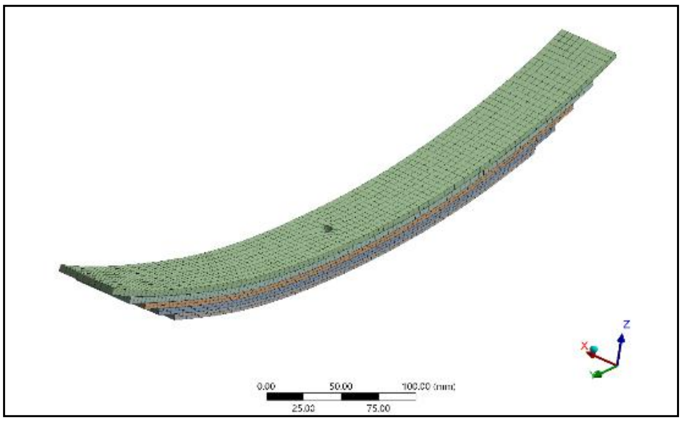

Fig. 3.1 Meshed Model

Figure below indicates the fiber orientation in composite leaf spring.

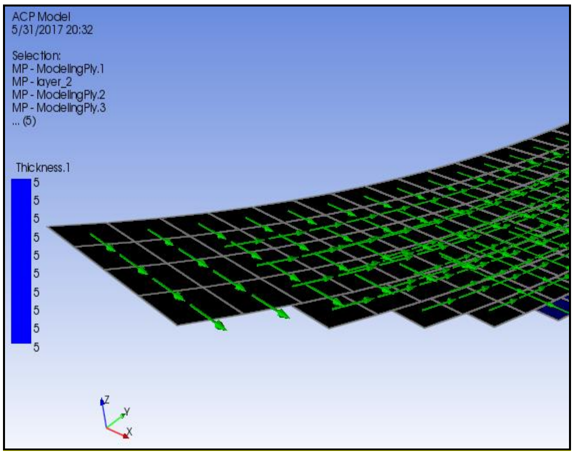

Fig. 3.2 Fiber Orientation for carbon fiber

- Solution
- Post-Processing

3.2 Fatigue Life Evaluation using FEA.

Fatigue, by definition, is caused by changing the load on a component over time. Thus, unlike static stress safety tools, which perform calculations for a single stress state, fatigue damage occurs when the stress at a point changes over time. There are essentially 4 classes of fatigue loading with the ANSYS fatigue tool:

- Constant amplitude, proportional loading
- Non-constant amplitude, proportional loading
- Constant Amplitude, non-proportional loading
- Non-constant amplitude, non-proportional loading

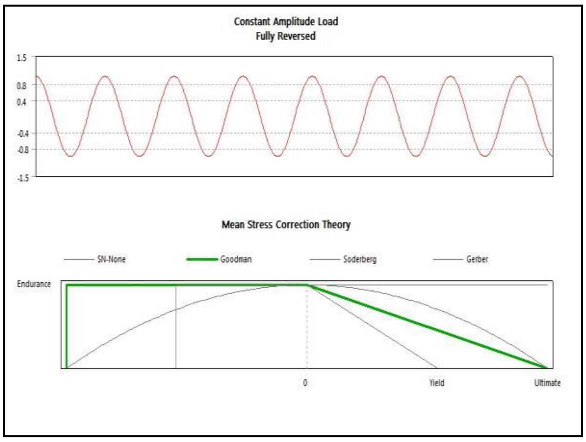

Fig. 3.3 Theories of fatigue life

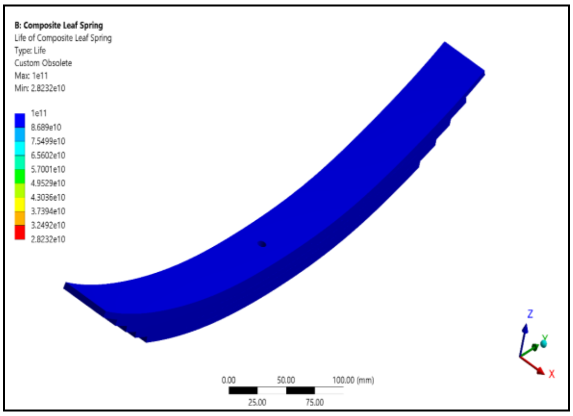

Fig. 3.4 Fatigue life for composite leaf spring

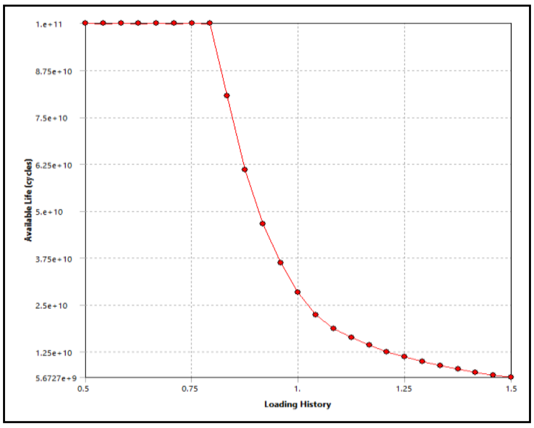

Fig. 3.5 Life cycle Vs Loading History for composite leaf spring

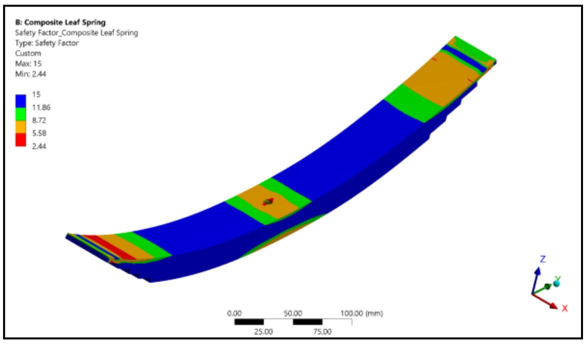

Fig. 3.6 Safety factor for composite leaf spring

Table 3.1 Numerical results for Fatigue life Composite material leaf spring.

	Composite
Min	2.8 e^10
Max	1.11 e^11

4. EXPERIMENTAL FATIGUE LIFE EVALUATION USING FEA

Experimentation is one of the scientific research methods, perhaps the most recognizable; in a spectrum of methods that also includes description, comparison and modeling. While all of these methods share in common a scientific approach, experimentation is unique in that it involves the conscious manipulation of certain aspects of a real system and the observation of the effects of that manipulation. Experimentation gives real insight of the system. In order to find out actual results experimentation is necessary because in theoretical analysis behavior of system parameters considered is linear but in actual those system behaves nonlinear in actual practices, so in order to find out difference in theoretical and experimental analysis experimentation is necessary.

In this section description of elements of experimental setup is provided along with experimental procedure and experimental results. In order to carryout Experimental analysis of composite leaf spring of light motor vehicle car for its static and fatigue life evaluation following instrumentation is required.

4.1 Elements of Experimental Setup:

In order to carryout analysis of composite leaf spring of light motor vehicle car for its static and fatigue life evaluation following instrumentation is required. A few prominent instruments are required and most of them are from Department of Mechanical Engineering, P.G. Research Lab for static analysis. There are normally two main types of measurement equipment include Strain gauge, Strain gauge indicator. In order to carry out the experimental fatigue life evaluation Auto cluster development and research institute helped. Test certificate is also provide in appendix.

- Instron Hydro plus Actuator Dynamic and Fatigue Testing Systems:

Instron offers an extensive range of fully-integrated dynamic and fatigue testing systems from 1000 N up to 5000 KN. Incorporating servo hydraulic, servo-electric and linear motor technologies, these test instruments cover a broad range of fatigue, dynamic, and static testing applications. These applications include high-cycle fatigue, low-cycle fatigue, thermo-mechanical fatigue, fracture mechanics, crack propagation and growth studies, fracture toughness, bi-axial, axial-torsional, multi-axial, high strain rate, quasi-static, creep, stress-relaxation, and other types of dynamic and static tests.

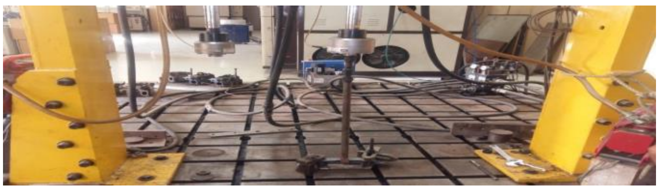

Fig. 4.1 Experimental Fatifue Life Evaluation Setup

In order to reduce the testing times following boundary condition are considered.

- Compressive Load: 30 Kg
- Frequency: 2 Hz
- No. of Cycles: 3600

Once 3600 cycles finished observed the composite leaf spring for any crack.

4.2 Result

Table below shows the results of Fatigue life evaluation from Instron Hydro plus Actuator Dynamic and Fatigue Testing System.

Table 4.1 Experimental results

Sr. No.	Sample Name	Test Description	Test Condition	Test Result
1	Composite Leaf Spring	Fatigue Test	Compressive Load: 30 Kg Frequency: 2 Hz No. of Cycles: 36000 only	No cracks obser ved up to 36000 cycles.

5. CONCLUSIONS

From Numerical and Experimental Fatigue life evaluation it is observed that composite leaf spring is having infinite life. Experimental results showed in general a good agreement with numerical results obtained for Composite multi leaf spring However, some differences indicating the necessity to improve the model input data as well as the experimental procedure.

From above calculation it is proved that FEA results are consistent and can be used as alternative time consuming experimental method.

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