NON-LINEAR DYNAMIC ANALYSIS OF COMPOSITE LEAF SPRING FOR COMMERCIAL VEHICLES

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Abstract

Reinforced polymer is used for life data analysis. The dimensions of an existing conventional steel leaf spring of a heavy vehicle are taken and are verified by design calculations. Nonlinear dynamic analysis of 3-D model of conventional leaf spring is also performed using. Same dimensions of conventional leaf spring are used to fabricate a composite multi leaf spring using carbon unidirectional laminates. The load carrying capacity, stiffness and weight of composite leaf spring are compared with that of steel leaf spring analytically. The design constraints are stresses and deflections. Finite element analysis with full bump load on 3-D model of composite multi leaf spring is done using abaqus .Fatigue life of steel leaf spring and composite leaf is also predicted. This paper describes static and fatigue analysis of steel leaf spring and composite multi leaf spring made up of carbon fiber.

Key words: Leaf springs- fatigue analysis- abaqus -carbon fiber.

Introduction

NURBS surfaces 3D reconstruction is a process by which objects are reproduced in the Computer memory, keeping its physical characteristics (dimensions, volume and shape). 3D reconstruction is a difficult task that covers, in general terms, five stages: data acquisition, registration, integration, segmentation, and surface fitting. The approach presented in this paper deals with the surface fitting stage, in which the computational model of the object is obtained. NURBS is one of the most employed surface fitting models, provided that it is a standard representation of curves and surfaces and is widely supported by modern standards like OpenGL and IGES, which are used for graphics and geometric data exchange. In addition, the NURBS surface model has stability, flexibility, local modification properties and is robust to noise. Yet, the NURBS surface model has a disadvantage: the input data Points should be mapped on a regular grid structure. . The construction of the network requires constructing polygon meshes and complicated procedures of refinement, reparameterization and maintainability of the continuity between the patches, which is computationally expensive in terms of memory and processing. In this paper a new method for constructing NURBS surfaces from scattered and unorganized points is presented. In contrast with others, our method does not need to construct a network of NURBS patches. Furthermore, previous construction of polygon meshes, mesh refinement and data reparameterization are not required. Our method first detects the global bias of the point cloud fitting a regression plane to it by using weighted principal components analysis .Then, all the points are projected onto the plane and a two-dimensional regularity analysis of the point cloud is made. The analysis consists of detectingregions with low point density and regions with high point density .By inserting and removing points, based on the two-dimensional analysis, the point cloud is regularized.

A large variety of fibers are available as reinforcement for composites. The desirable characteristics of most fibers are high strength, high stiffness, and relatively low density. Glass fibers are the most commonly used ones in low to medium performance composites because of their high tensile strength and low cost. In woven fiber, fibers are woven in both principal directions at right angles to each other. Woven glass fibers is used to achieve higher reinforcement loading and consequently, higher strength. Woven glass fiber as a weight percent of laminate may be range to 65%. Woven roving are plainly woven from roving, with higher dimensional properties and regular distribution of glass fiber with excellent bonding strength among laminates possesses higher fiber content, tensile strength, impact resistance.

1.1 DEFINITIONS

A composite material is defined as a material system which consists of a mixture or a combination of two or more distinctly different materials which are insoluble in each other and differ in form or chemical composition. Thus, a composite material is labeled as any material consisting of two or more phases. Many combinations of materials termed as composite materials, such as concrete, mortar, fiber reinforced plastics, and fiber reinforced metals and similar fiber impregnated materials.Two- phase composite materials are classified into two broad categories: particulate composites and fiber reinforced composites. Particulate composites are those in which particles having various shapes and sizes are dispersed within a matrix in a random fashion. Examples as mica flakes reinforced with glass, lead particles in copper alloys and silicon carbon particles in aluminum.

Particulate composites are used for electrical applications, welding, machine parts and other purposes.

Fiber reinforced composite materials consists of fibers of significant strength and stiffness embedded in a matrix with distinct boundaries between them. Both fibers and matrix maintain their physical and chemical identities, yet their combination performs a function which cannot be done by each constituent acting singly. Fibers of fiber reinforced plastics (FRP) may be short or continuous. It appears obvious that FRP having continuous fibers is indeed more efficient.Classification of FRP composite materials into four broad categories has been done accordingly to the matrix used. They are polymer matrix composites, metal matrix composites, ceramic matrix composites and carbon/carbon composites. Polymer matrix composites are made of thermoplastic or thermoset resins reinforced with fibers such as glass, carbon or boron. A metal matrix composite consists of a matrix of metals or alloys reinforced with metal fibers such as boron or carbon. Ceramic matrix composites consist of ceramic matrices reinforced with ceramic fibers such as silicon carbide, alumina or silicon nitride. They are mainly effective for high temperature applications.

MATRIX TYPE	FIBRES	MATRIX
Polymer	E-glass S-glass Carbon(graphite) Kevlar Boron	Epoxy Polyimide Thermoplastics Polyester Polysulfone
Metal	Boron Carbon (graphite) Silicon carbide Alumina	Aluminum Magnesium Titanium Copper
Ceramic	Silicon carbide Alumina Silicon nitride	Silicon carbide Alumina Glass ceramic Silicon nitride
Carbon	Carbon	Carbon

1.2 FIBERS

Materials in fiber form are stronger and stiffer than that used in a bulk form. There is a likely presence of flaws in bulk material which affects its strength while internal flaws are mostly absent in the case of fibers. Further, fibers have strong molecular or crystallographic alignment and are in the shape of very small crystals. Fibers have also a low density which is disadvantageous.

1.3 GLASS FIBRES

The most common fiber used in polymeric fiber reinforced composites is the glass fiber. The main advantage of the glass fiber is its low cost. Its other advantage is its high tensile strength, low chemical resistance and excellent insulating properties. Among its disadvantages are its low tensile modulus somewhat high specific gravity, high degree of hardness and reduction of tensile strength due to abrasion during handling. Moisture decreases the glass fiber strength. Glass fibers

1.4 POLYMERIC MATRIX

Matrix materials are used to transfer stress between reinforcing fibers and to protect them from mechanical and environmental damage. They provide bonding strength between the fibers.
we may divide the thermosets into five categories:-
(1) Polyester resin,
(2) Epoxy resin,
(3) Vinyl ester resin,
(4) Phenolic resin and
(5) High performance resin.

SURFACES

Surfaces have a fundamental role in applications such as computer graphics, virtual reality, computer games, and in the computer-aided design of cars, ships, aircraft, and buildings.

Definition 1

A subset of R3 of the form {x,y,z) : F(x,y,z) = 0} for some function F: R3→R is called an implicit surface. When F is a polynomial in x, y, and z, the surface is called an algebraic surface. If the partial derivatives of F exist, then the points of the surface satisfying

$$F(x,y,z) = \frac{\partial F}{\partial x}(x,y,z) = \frac{\partial F}{\partial y}(x,y,z) = \frac{\partial F}{\partial z}(x,y,z) = o$$

1.5 STRUCTURAL ELEMENTS

A statically determinate simply supported beam, bending under an evenly distributed load.
Any structure is essentially made up of only a small number of different types of elements:

1. Columns
2. Beams
3. Plates
4. Arches
5. Shells
6. Catenaries

1.6 DESIGN AND FORMING ANALYSIS OF LEAF SPRINGS

Ever increasing demands of high performance together with long life and light weight necessitate consistent development of almost every part of automobile. Increasing competition and innovations in automobile sector tends to modify the existing products or replacing old products by new and advanced material products. A suspension system of vehicle is also an area where these innovations are carried out regularly. Leaf springs are mainly used in suspension systems to absorb shock loads in automobiles like light motor vehicles, heavy duty trucks and in rail systems.

1.7 OBJECTIVE OF THE WORK

The objective of this project is as follows:
Compare the load carrying capacity, stresses, deflection and weight savings of composite leaf spring with that of steel leaf spring.The focused on the implementation of composite materials by replacing steel in conventional leaf springs of a suspension system to reduce product weight, improving the safety, comfort and durability.

1.8 DESCRIPTION OF THE PROBLEM

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 un-sprung weight.

It is observed that the leaf springs tend to break and weaken at the eye end portion which is very close to the shackle and at the centre.

The conventional steel leaf spring has higher weight, which also affect the fuel efficiency

1.8 METHODOLOGY

1. Design a leaf spring.
2. Material Selection.
3. Model in catia.
4. Assembly the model.
5. Non linear analysis using abaqus.
6. Applying boundary conditions and load in model.
7. Result and conclusions.

MATERIAL SELECTED

In the existing material Plain carbon steel was used, whereas the proposed Material would be made up of Carbon/Epoxy composite leaf spring.

The conventional steel leaf spring has some problems which are listed as follows:

Due to continuous running of the mini loader vehicle there is a decrease in the level of comfort provided by the spring.

5.5 SOLID MODELLING OF LEAF SPRING

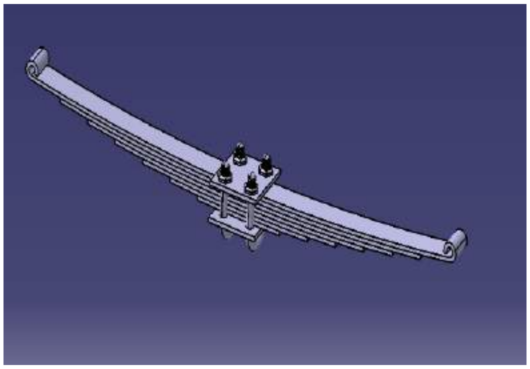


Fig: 5.1: *3D model of leaf spring*

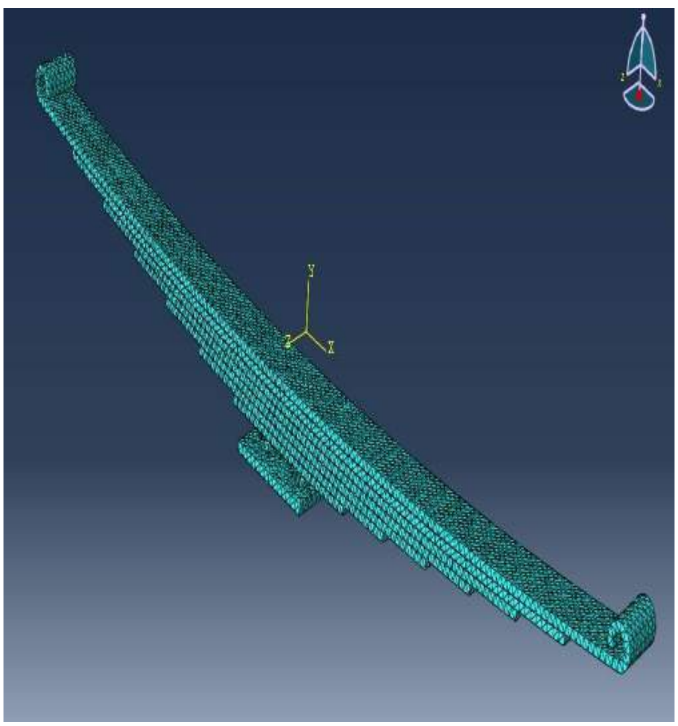
S.No	Parameters	Steel value	Composite Value
1.	Material	Plain carbon Steel	Carbon/Epoxy
2.	Tensile Strength	1962 N/mm^2	1841 N/mm^2
3.	Young's Modulus of leaf spring	210Gpa.	E_1=75 Gpa
4.	Total length of the spring(Eye to Eye)	950 mm	950 mm
5.	Poisson's ratio (μ)	0.28	μ_1=0.25 μ_2=0.24 μ_3=0.28
6.	Free camber (At no load condition)	110 mm	110 mm
7.	No of full length leave(Master Leaf)	01	01
8.	Thickness of leaf	10 mm	20 mm
9.	Width of leaf spring	50 mm	35 mm
10.	Maximum load given on spring	3400 N	3400 N
11.	Spring Weight	3.16 kg	2.46 Kg

STEPS FOLLOWED FOR ANALYSIS

- ✓ The geometry of the leaf spring to be analyzed is imported from solid modeller catia in STEP format, this is compatible with ABAQUS
- ✓ The element type and material properties such as Young's modulus and Poisson's ratio are specified.
- ✓ Meshing the three-dimensional leaf spring model .Figure shows the meshed 3D solid model of leaf spring
- ✓ The boundary condition and external loads are applied.
- ✓ The solution is generated based on the previous input parameters.
- ✓ Finally the solution is viewed in a variety of displays

MESHED MODEL OF LEAF SPRING

No of elements size	**: 8**
Element shap	**: tetrahedral**
Geometrical order	**: quadratic**
No of elements	**: 75000**
No of nodes	**: 25000**



Meshed model of leaf spring

8 LOADING AND BOUNDARY CONDITION

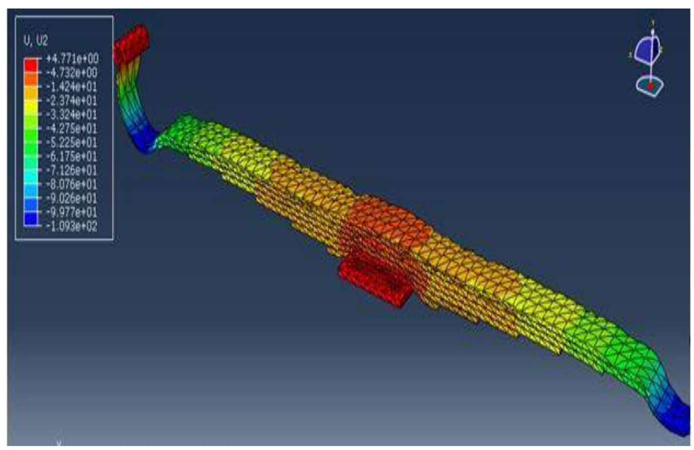
8.1 FIXED SUPPORT

Fixed support has restriction to move in X and Y direction as well as rotation about that particular point. For the leaf spring analysis one eye end of the leaf spring is fixed to the chassis of the vehicle and the fixed support at another eye end of the leaf spring model. So this eye end of the leaf spring cannot move in any of the directions i.e. all the degrees of freedom are blocked.

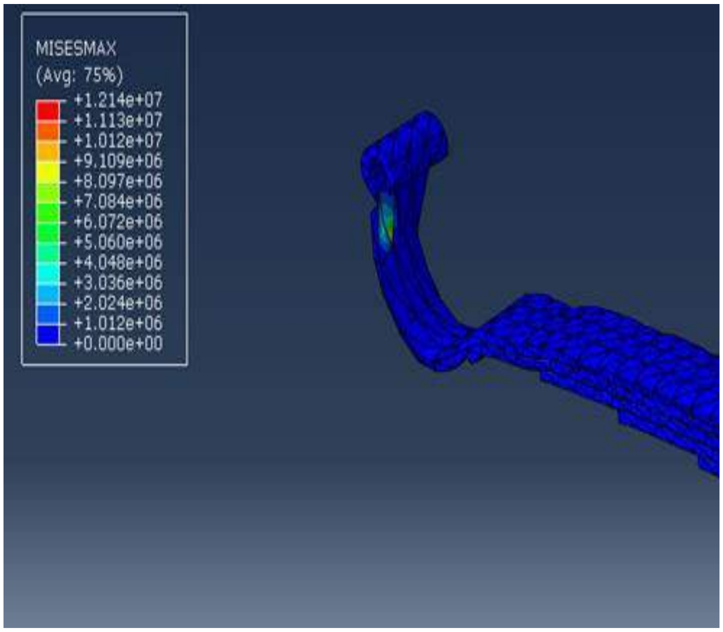
8.2 CYLINDRICAL SUPPORT

As there is shackle provided at other end of the leaf spring because of which the leaf spring only translates in one plane and other movements i.e. degree of freedom are blocked. So with the reference of this a cylindrical support is applied to the other eye end of leaf spring model. This support allows the movement of the leaf spring in X axis, rotation about Z axis and fixed along Y axis.

RESULTS FOR CONVENTIONAL LEAF SPRING



Conventional leaf spring displacement at load direction



Fatigue stress for conventional leaf spring

RESULTS:

S.No	Parameter	Steel Material	Composite Material
1	Stress	1.426e7 N/mm2	2.9e6 N/mm2
2	Absolute stress	1.313e6 N/mm2	7.393e5 N/mm2
3	Von misses stress	1.426e7 N/mm2	2.9e6 N/mm2

CONCLUSION

A comparative study has been made between composite leaf spring and steel leaf spring with respect to weight and strength. By employing a composite leaf spring for the same load carrying capacity, there is a reduction in weight of 11% than the steel spring. Based on the results, it was inferred that carbon/epoxy laminated composite mono leaf spring has superior strength and stiffness and lesser in weight compared to steel material considered in this investigation. From the results, it is observed that the composite leaf spring is lighter and more economical than the conventional steel spring. Considering by plasticity range for both materials. The composite material has low plastic strain and equivalent plastic strain. It defines the material can withstand at high tensile strength. From that result the composite materials have high potential energy absorption.

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