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Design, analysis, and experimental investigation of Composite leaf spring for e-Vehicle

V. Sathiyamoorthy[1], Pandit Tharun[2] and R. Ravi kanth[3]

[1,3] Faculty of mechanical engineering, KSRM college of engineering, Andra Pradesh Kadapa.

[2] student of mechanical engineering, KSRM college of engineering, Andra Pradesh Kadapa.

Abstract:

The paper briefly examines the suitability of composite leaf springs for vehicles and their advantages. Attempts have been made to reduce the costs of synthetic leaf springs to the costs of steel leaf springs. Achieving weight reduction and sufficient improvement in mechanical properties made composite material a substitute for conventional steel. Materials and manufacturing processes are selected based on cost and strength factors. The choice of design method is based on mass production. Modeling and analysis were performed using CATIA and Ansys software. The analysis is performed on existing and composite materials. The output is compared using an offset.

Keywords: design, composite, Leaf, CATIA, Ansys software.

1.0 Introduction:

In order to conserve natural resources and conserve energy, the main focus of car manufacturers in this scenario has been weight reduction. Weight reduction can be achieved mainly by using better materials, optimizing design, and improving production processes. The suspension leaf spring is one of the possible weight reduction targets for cars, as it accounts for 10-20% of the un sprung mass [1]. This improves the fuel efficiency of the vehicle and improves driving characteristics. A leaf spring should absorb vertical vibrations and shocks caused by road roughness through changes in spring deflection so that potential energy is stored as spring stress energy and then slowly released [2,3]. Thus, increasing the energy storage capacity of the leaf spring ensures a more compliant suspension system. According to research, the most suitable material for a leaf spring is one with maximum strength and minimum elasticity coefficient in the longitudinal direction.

The fatigue behavior of glass fiber-reinforced plastic (GFRP) epoxy composite materials has been previously investigated [ ]. Using the fatigue modulus and its rate of decline, a theoretical equation to predict fatigue life is created. This relationship is simplified by the deformation discontinuity criterion for practical applications[5,6]. A method to predict the fatigue strength of composite structures with some combination of frequency, stress ratio, and temperature is presented [7]. These studies are limited to single-leaf springs only. In this work, the seven-leaf steel spring used in passenger cars is replaced by a multi-leaf glass/epoxy composite spring [8]. Steel leaf springs and composite leaf springs are considered to have the same dimensions and number of leaves.

2.0 Composite Materials

Composite materials, often shortened to composites or called composition materials, are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct at the macroscopic or microscopic scale within the finished structure.

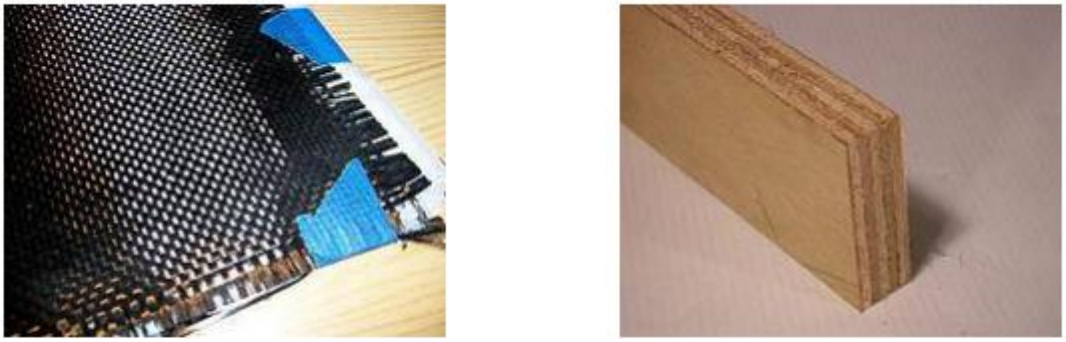

Figure1. Composite Materials

Composites it is the fastest growing "materials" market segment. Sporting goods, Aircraft, automobiles, shipbuilding, Boeing 777, disc brake pads, which consist of hard ceramic particles embedded in a soft metal matrix, shower stalls and bathtubs which are made of fiber glass are a few examples. Imitation granite and cultured marble sinks and countertops are also widely used. The most advanced examples perform routinely on spacecraft in demanding environments.

2.1 Materials Selection

Materials account for almost 65-70% of the vehicle's costs and affect the quality and performance of the vehicle. Even a small reduction in vehicle weight can have a wider financial impact. Composite materials have proven to be suitable substitutes for steel in terms of vehicle weight reduction. Therefore, a component material was chosen for the design of the leaf spring.

2.3 Fiber Selection

The most used fibers are carbon, glass, kevlar, etc. From these, glass fibers are selected based on the cost factor and strength. The types of fiberglass are C-glass, S-glass and E-glass. C glass fibers are designed to improve surface treatment. S-glass fibers are designed to give a very high modularity, which is used especially in the aerospace industry. E-glass fiber is a high-quality glass that is used as a standard reinforcing fiber in all current systems and has good mechanical properties. Thus, E-glass fiber was found suitable for this application.

2.4 Resins Selection

In the case of an FRP leaf spring, the shear strength between laminae is controlled by the matrix system used. Because they are thickness-wise reinforcing fibers, the fibers do not affect the shear strength between the layers. Therefore, the laminar shear strength properties of the matrix system should be well-matched to the selected reinforcing fiber. Thermosetting resins such as polyester, vinyl ester, and epoxy resin are used to make fiber-reinforced plastics (FRP). Of these resin systems, epoxies have better interlayer shear strength and good mechanical properties. There fore epoxy was found to be the best resin for this application. different grades of epoxy resin and combinations of hardeners are classified based on their mechanical properties.

From these grades, the epoxy resin grade Dobeckot 520 F was chosen and the hardener used for this application is 758. Dobeckot 520 F is a solvent-free epoxy resin. Which, together with hardener 758, cures to hard resin.

Hardener 758 is a low viscosity polyamine. Dobeckot 520 F, hardener 758 combinations are characterized by

- Good mechanical and electrical properties.
- Faster curing at room temperature.
- Good chemical resistance properties.

2.5 Properties of E-Glass / Epoxy Composite:

By considering the property variation in the tapered system improper bonding and improper curing, etc. some constant of property value are reduced from calculated values using equations.

3.0 SOFTWARE OVERVIEW

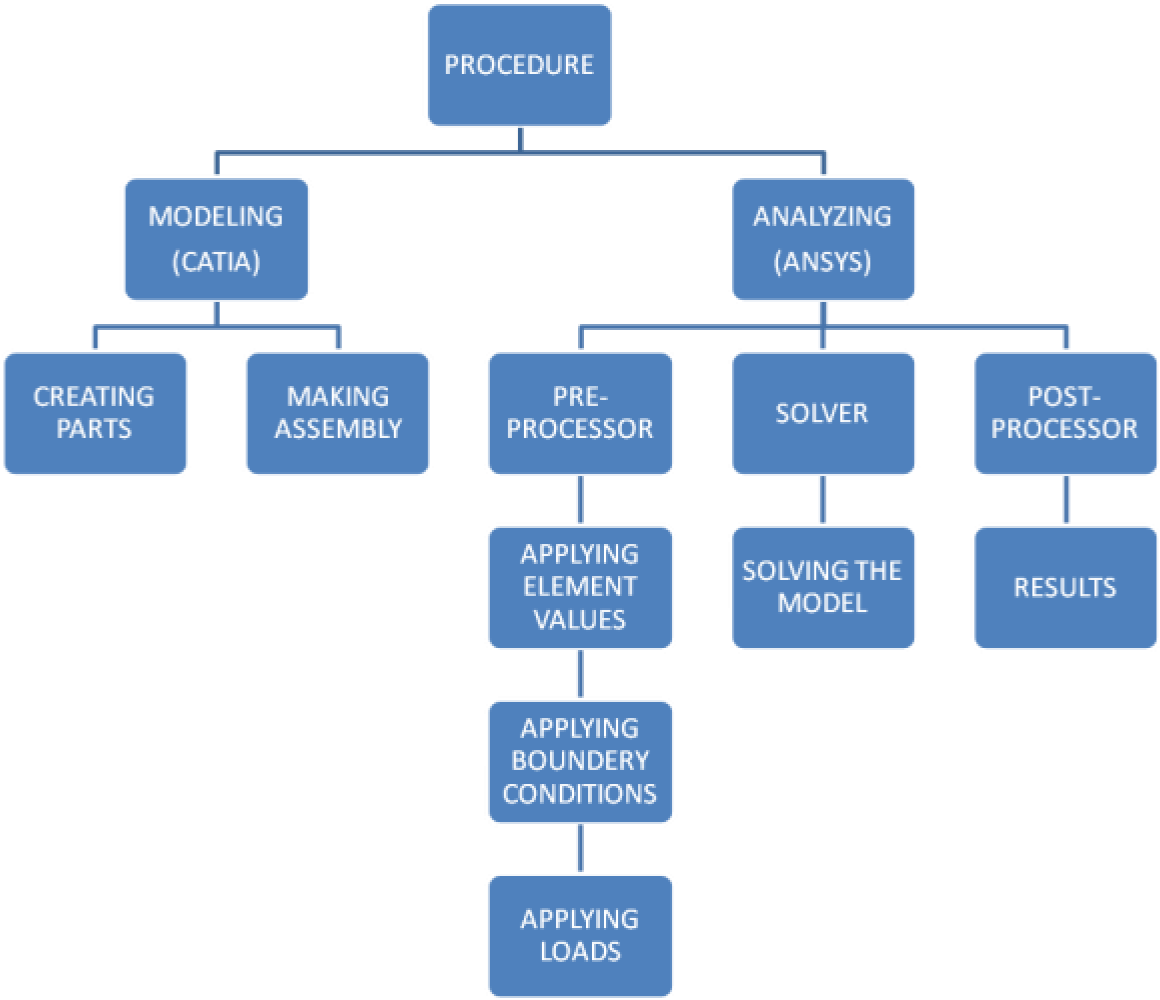

Figure 2: SOFTWARE OVERVIEW

3.1 ANSYS:

ANSYS is a complete FEA simulation software package developed by ANSYS Inc – USA. It is used by engineers worldwide in virtually all fields of engineering. Structural, Thermal, Fluid (CFD, Acoustics, and other fluid analyses), Low-and High-Frequency Electromagnetic.

3.2 STRUCTURAL ANALYSIS

Structural analysis is probably the most common application of the finite element method. The term structure (or structure) refers not only to civil engineering structures such as bridges and buildings, but also to naval, aeronautical and mechanical structures such as ship hulls, airframes and engine casings, as well as mechanical components such as pistons, engines. parts and tools.

3.3 TYPES OF STRUCTURAL ANALYSIS

The seven types of structural analyses available in the ANSYS family of products are explained below. The primary unknowns (nodal degrees of freedom) calculated in the structural analysis are displacements. Other quantities, such as strains, stresses, and reaction forces, are then derived from the nodal displacements. Structural analyses are available in the ANSYS Multiphysics, ANSYS Mechanical, ANSYS Structural, and ANSYS Professional programs only.

3.4 EXPLICIT DYNAMIC ANALYSIS

This type of structural analysis is only available in the ANSYS LS-DYNA program. ANSYS LS-DYNA provides an interface to the LS-DYNA explicit finite element program. Explicit dynamic analysis is used to calculate fast solutions for large deformation dynamics and complex contact problems. In addition to the above analysis types, several special-purpose features are available: Fracture mechanics, Composites, Fatigue, p-Method, and Beam Analyses.

4.0 Modeling Composites

Composites are somewhat more difficult to model than an isotropic materials such as iron or steel. We need to take special care in defining the properties and orientations of the various layers since each layer may have different orthotropic material properties. In this section, we will concentrate on the following aspects of building a composite model: Choosing the proper element type, Defining the layered configuration, Specifying failure criteria, and Following modeling and post-processing guidelines.

4.1 Choosing the Proper Element Type

The following element types are available to model layered composite materials: SHELL99, SHELL91, SHELL181, SOLID46, and SOLID191. Which element we choose depends on the application, the type of results that need to be calculated, and so on. Check the individual element descriptions to determine if a specific element can be used in our ANSYS product. All layered elements allow failure criterion calculations.

4.2 SHELL99

Linear Layered Structural Shell Element SHELL99 is an 8-node, 3-D shell element with six degrees of freedom at each node. It is designed to model thin to the moderately thick plate and shell structures with a side-to-thickness ratio of roughly 10 or greater. For structures with smaller ratios, we may consider using SOLID46. The SHELL99 element allows a total of 250 uniform-thickness layers. Alternately, the element allows 125 layers with thicknesses that may vary bilinearly over the area of the layer. If more than 250 layers are required, we can input our own material matrix. It also has the option to offset the nodes to the top or bottom surface.

4.3 Design Selection

The leaf spring behaves as a simply supported beam and the bending analysis is performed as a simply supported beam. A simply supported beam is subjected to both bending stress and transverse shear stress. Flexural stiffness is an important parameter in leaf spring design and controls whether it increases from the two ends to the center.

4.4 Comparison With Steel Leaf Spring

The purpose of this work is to evaluate the suitability of composite leaf springs for automobiles, considering cost-effectiveness and strength. A comparison of multi-leaf and single-leaf compound springs is made with the same requirements and loading conditions. The comparison is based on four main factors such as weight, ride comfort, price and strength.

5.0 Design of Leaf Spring

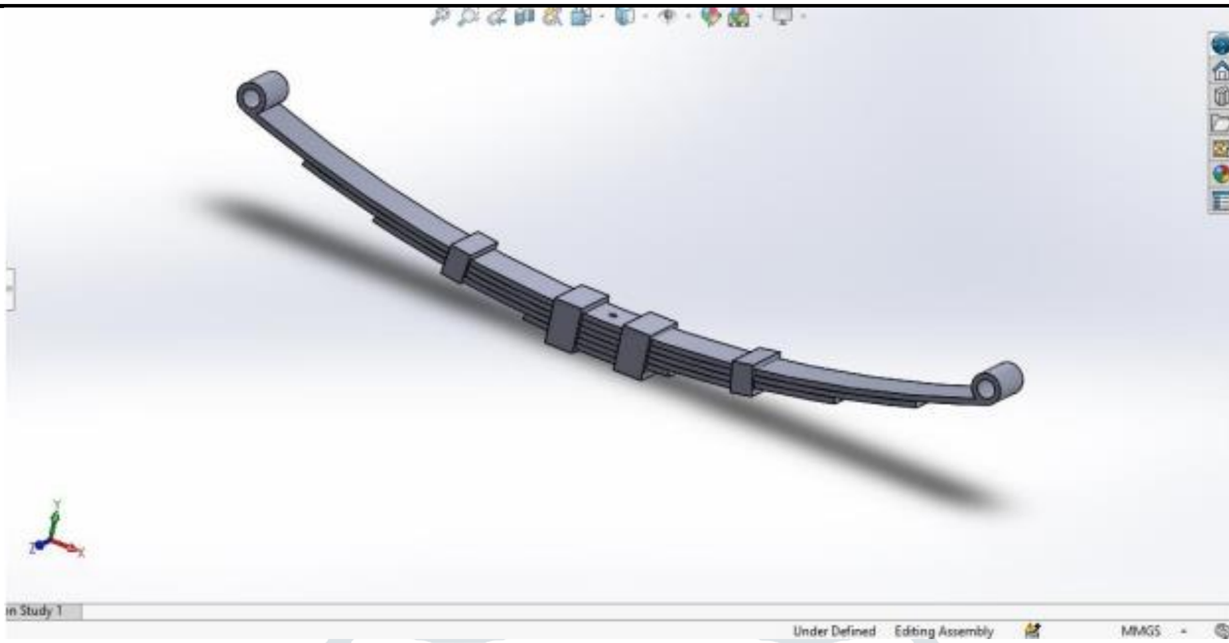

Figure 3. design of leaf spring

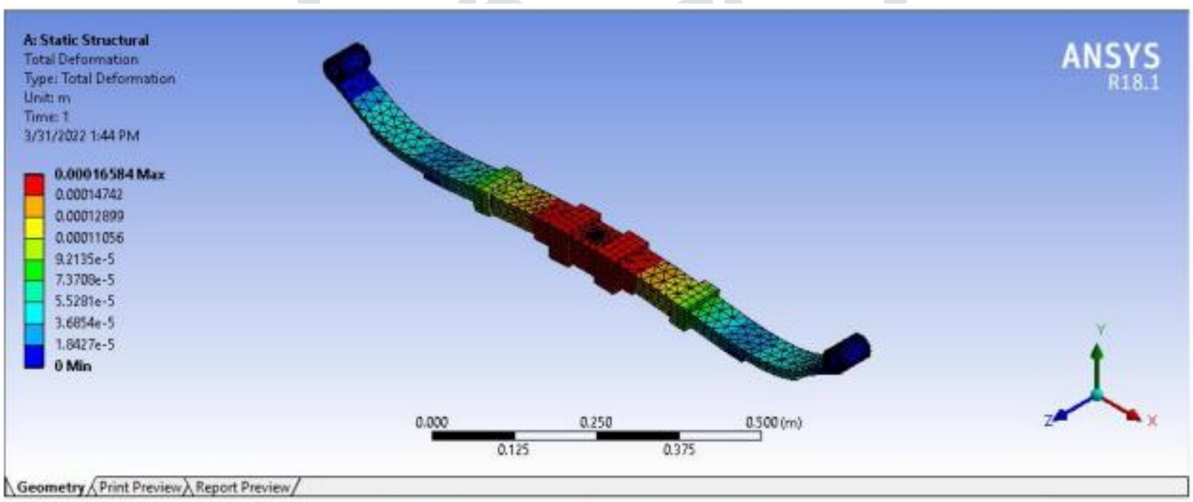

Figure 4. STRUCTURAL STEEL FORCE APPLIED 5 KN

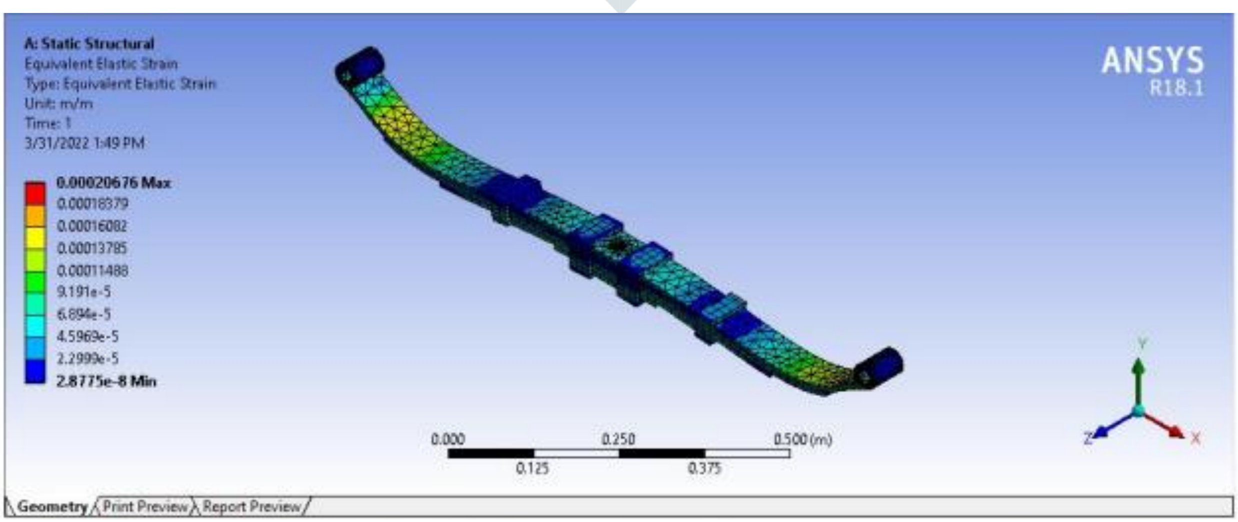

Figure 5. Equivalent Elastic Strain

6.0 CONCLUSION

Based on the resulting numerical and experimental studies, synthetic leaf springs were found to be lighter and more economical than conventional steel leaf springs with similar performance. Therefore, composite leaf springs are suitable as a replacement for convection leaf springs. Furthermore, the following conclusion is drawn.

1. The composite leaf spring is constructed using the standard cross section method.
2. A 3-D model of a composite leaf spring is analyzed by finite element analysis.
3. A static test was performed to predict the stress and displacement at different locations under different load values.
4. FEM analysis results are verified with test results.
5. A comparative study is made of composite and steel leaf springs in terms of weight, ride quality, cost and strength.

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