

Experimental Investigation of Mono Leaf Spring to Be Used as a Replacement for Light Weight Automobile Spring

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Abstract

This research investigates composite mono leaf springs manufactured using Carbon/Epoxy, E-Glass/Epoxy and Kevlar/Epoxy materials as alternatives to conventional EN45A steel leaf springs. Finite Element Analysis (FEA) and experimental fatigue testing were used to evaluate deformation, stress distribution, stiffness, weight reduction and fatigue life. Results show that Carbon/Epoxy offers substantial weight reduction and improved fatigue performance.

Keywords

Composite Leaf Spring, Carbon Epoxy, FEA, Fatigue Life, Automotive Suspension, ANSYS.

1. Introduction

A leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles. Originally called a laminated or carriage spring, and sometimes referred to as a semi-elliptical spring or cart spring, it is one of the oldest forms of springing, appearing on carriages in England after 1750 and from there migrating to France and Germany.

A leaf spring takes the form of a slender arc-shaped length of spring steel of rectangular cross-section. In the most common configuration, the center of the arc provides location for the axle, while loops formed at either end provide for attaching to the vehicle chassis. For very heavy vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions. While the interleaf friction provides a damping action, it is not well controlled and results in station in the motion of the suspension. For this reason, some manufacturers have used mono-leaf springs.

A leaf spring can either be attached directly to the frame at both ends or attached directly at one end, usually the front, with the other end attached through a shackle, a short swinging arm. The shackle takes up the tendency of the leaf spring to elongate when compressed and thus makes for softer springiness. Some springs terminated in a concave end, called a spoon end (seldom used now), to carry a swiveling member.

2. Literature Review

Mr. Akshay Kumar et al. Composite materials have pulled in all researchers in view of maximum caliber. The present application amassing ventures for cars eco-accommodating. Springs will reduce 77% burden. Quantifiable checks and FEA examination are represented in this paper. Advance polymer composite in express.

Shishay Amare et al. Lessening high growing or maximum natural things finding opportunity significantly huge research issue in this front line world. CM attracting examiners, enhance game plans. Endeavor decreases load of car amazing proportion of wt. of car & ought adequate, singular in a manner of speaking. The relentless cross territory plan of leaf springs is used to take great conditions of effortlessness of structure examination and its collecting technique. Besides, ensuing arrangement and propagation stresses are much underneath the quality properties of the material, satisfying the most outrageous weight disillusionment rule. The organized composite leaf springs have

moreover achieved its sufficient fatigue life. This particular structure is made expressly for light weight three-wheeler vehicles. Its model is also conveyed using hand lay-up procedure.

3. Materials and Methodology

3.1 Dynamic testing

The UTM (Instron 1342) is a servo hydraulic fluid-controlled machine, consists of a two column dynamically rated load frame with the capacity of load up to 100kN (dynamic), hydraulic power pack (flow rate 45 liter/minute) and 8800 Fast Track 8800 Controller test control systems is stand alone, fully digital, single axis controller with an inbuilt operating panel and display. The controller is fully portable and specifically designed for materials testing requirement. This controller has position, load and strain control capability. The software available with the machine is: (a) Merlin Testing Software for Tensile Test (b) da/dN Fatigue Crack Propagation Test. (c) Kic Fracture Toughness Test. (d) Jic Fracture Toughness Test.

DYNAMIC EXPERIMENTATION

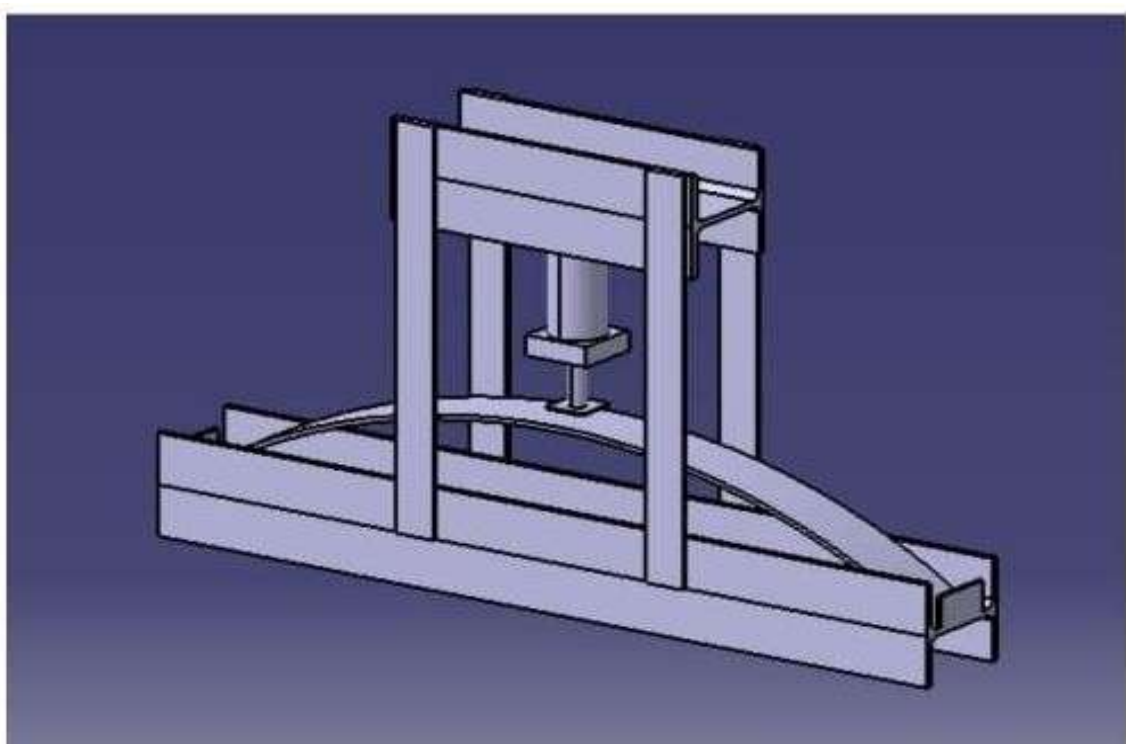


Fig 3.1 setup for dynamic testing

First we were taking I channel for supporting structure of Leaf spring. Material used for that I channel was Mild steel and dimension of base I channel was 3 foot and upper base it was 1 foot.

After that we provided we support in I channel (2 * 5) (inch * mm) for place different material leaf spring which we manufactured. One pneumatic cylinder was placed above the I channel for find out the life cycle of leaf spring. Dimension of pneumatic cylinder was 50×100 mm was placed with the help of 40×5mm plates and operated with the help of solenoid valve and reciprocating compressor. For experimentation of each leaf spring we calculate pressure and applied that pressure to respective leaf spring and observation was carried out till spring was not break.

Fatigue Strength Fatigue test is important to find the maximum load that a sample can endure for a specified number of cycles. The main reasons of fatigue failure are number of cycle, range of stress and local stress. To find out the fatigue strength, Fatigue test performed on steel spring and composite leaf spring separately. A long time is required to find the fatigue strength of leaf spring. C. Fatigue Test of Steel Leaf Spring load test machine is used to know fatigue strength which include stroke of 0-150mm. Fatigue strength of leaf spring must be stand above the 100000 cycle. The leaf spring is placed on to pneumatic load machine.

4. Finite Element Analysis

4.1. Analysis:

Static Analysis

The **finite element method (FEM)**, is a numerical method for solving problems of engineering and mathematical physics. Typical problem areas of interest include structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. The analytical solution of these problems generally require the solution to boundary value problems for partial differential equations. The finite element method formulation of the problem results in a system of algebraic equations. The method yields approximate values of the unknowns at discrete number of points over the domain. To solve the problem, it subdivides a large problem into smaller, simpler parts that are called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then uses variation methods from the calculus of variations to approximate a solution by minimizing an associated error function.

Studying or analyzing a phenomenon with FEM is often referred to as **finite element analysis (FEA)**.

For steel leaf spring

Parameter	Value
Material selected – Steel	EN45A
Young's Modulus, E	$2.1 \times 10^5 \text{ N/mm}^2$
Poisson's Ratio	0.266
BHN	400-425
Tensile strength ultimate	1272 MPa
Tensile strength Yield	1158 MPa
Density	$0.00000785 \text{ kg/mm}^3$

TABLE 4.1: Properties of steel leaf spring

Result for Conventional leaf spring

Sr. No	Load (N)	Deformation in spring steel Material (MM)	Equivalent Stress
1	1000	29.65	193.14
2	2000	39.82	221.64
3	3000	51.39	275.50
4	4000	76.14	315.09
5	5000	93.20	387.87
6	5400	119.12	417.83

TABLE 4.2: Results of steel leaf spring

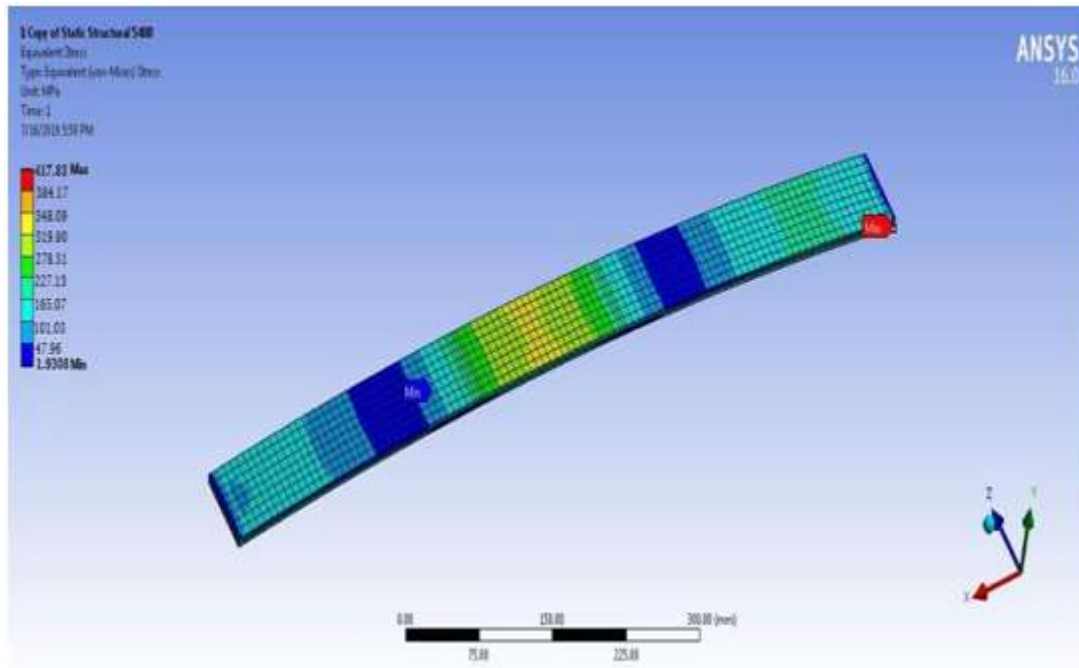


Fig .4.2 Equivalent Stress for steel leaf spring.

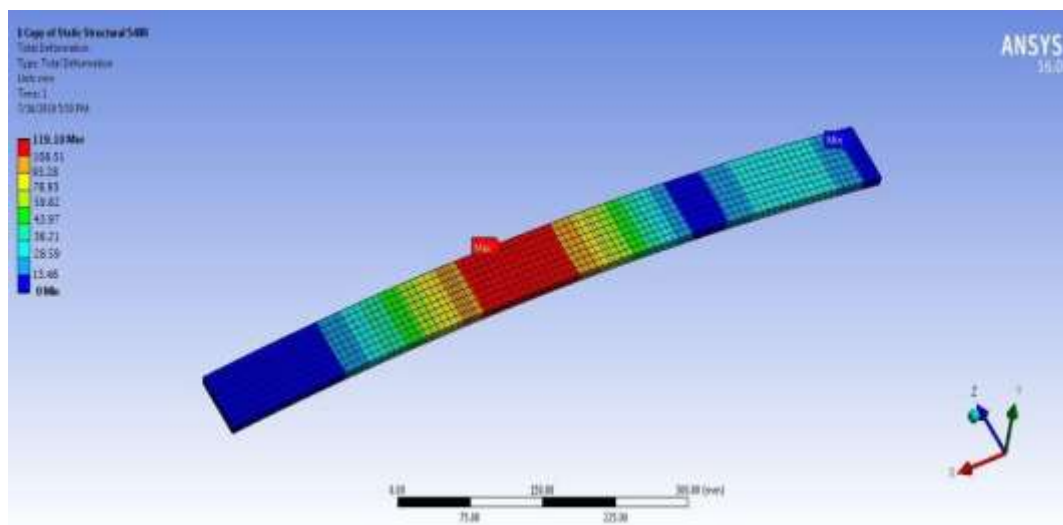


Fig .4.3 total deformation for steel leaf spring.

Properties of Outline Row 3: Structural Steel				
	A	B	C	D E
1	Property	Value	Unit	
2	Density	7850	kg m ⁻³	
3	Isotropic Secant Coefficient of Thermal Expansion			
6	Isotropic Elasticity			
7	Derive from	Young's Modulus and...		
8	Young's Modulus	2E+11	Pa	
9	Poisson's Ratio	0.3		
10	Bulk Modulus	1.6667E+11	Pa	
11	Shear Modulus	7.6923E+10	Pa	
12	Field Variables			
13	Temperature	Yes		
14	Shear Angle	No		
15	Degradation Factor	No		
16	Alternating Stress Mean Stress	Tabular		
20	Strain-Life Parameters			
28	Tensile Yield Strength	2.5E+08	Pa	
29	Compressive Yield Strength	2.5E+08	Pa	
30	Tensile Ultimate Strength	4.6E+08	Pa	
31	Compressive Ultimate Strength	0	Pa	

Table No. 4.4 Steel properties

4.2 FEA results:

Similarly the values of the deflection and maximum stresses for the steel leaf and composite mono leaf spring obtained from the FEA analysis are tabulated in the table given below.

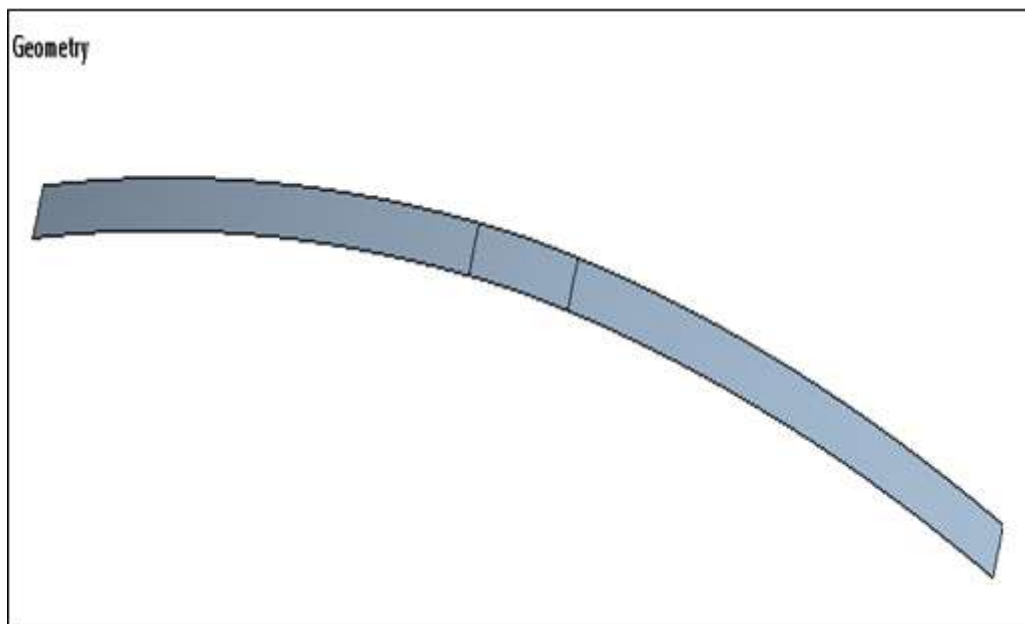


Fig 4.4. Geometry of leaf spring

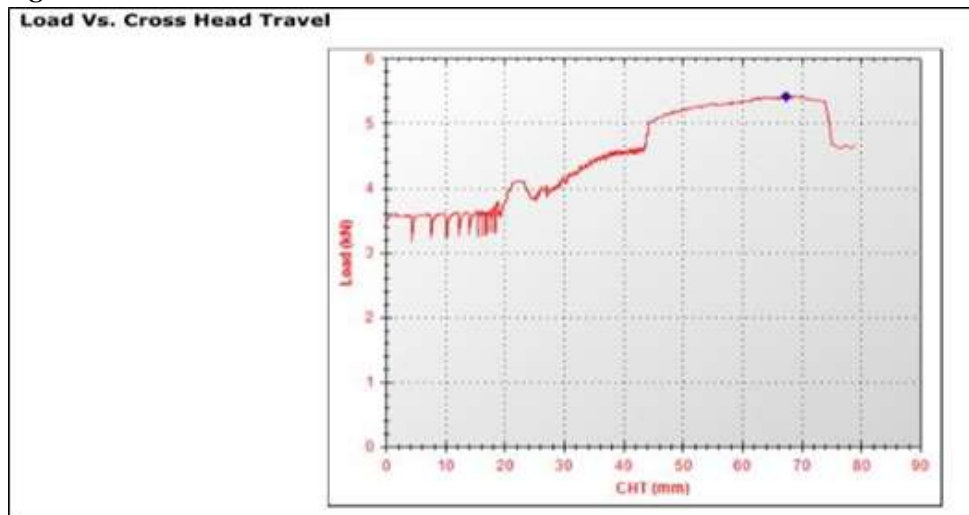
Properties of Outline Row 3: Epoxy Carbon UD (230 GPa) Prepreg			
	A	B	C
1	Property	Value	Unit
2	 Density	1.49E-09	mm ³ t
3	 Orthotropic Secant Coefficient of Thermal Expansion		
8	 Orthotropic Elasticity		
9	Young's Modulus X direction	1.21E+05	MPa
10	Young's Modulus Y direction	8600	MPa
11	Young's Modulus Z direction	8600	MPa
12	Poisson's Ratio XY	0.27	
13	Poisson's Ratio YZ	0.4	
14	Poisson's Ratio XZ	0.27	
15	Shear Modulus XY	4700	MPa
16	Shear Modulus YZ	3100	MPa
17	Shear Modulus XZ	4700	MPa

Table 4.5 Material Properties of carbon

5. Results and Discussion

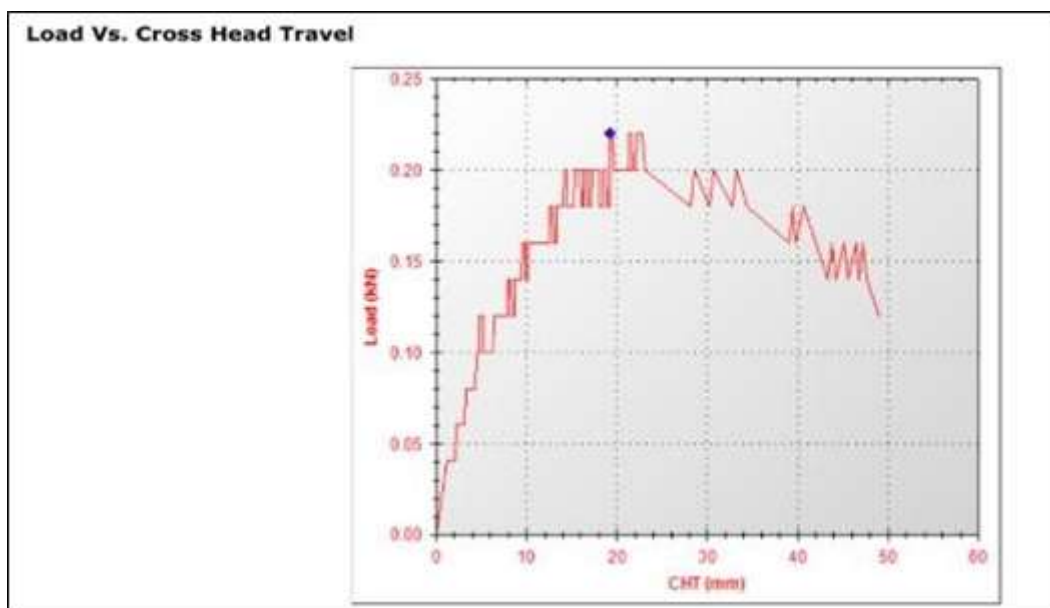
Leaf spring Performance Analysis

Carbon Leaf Spring



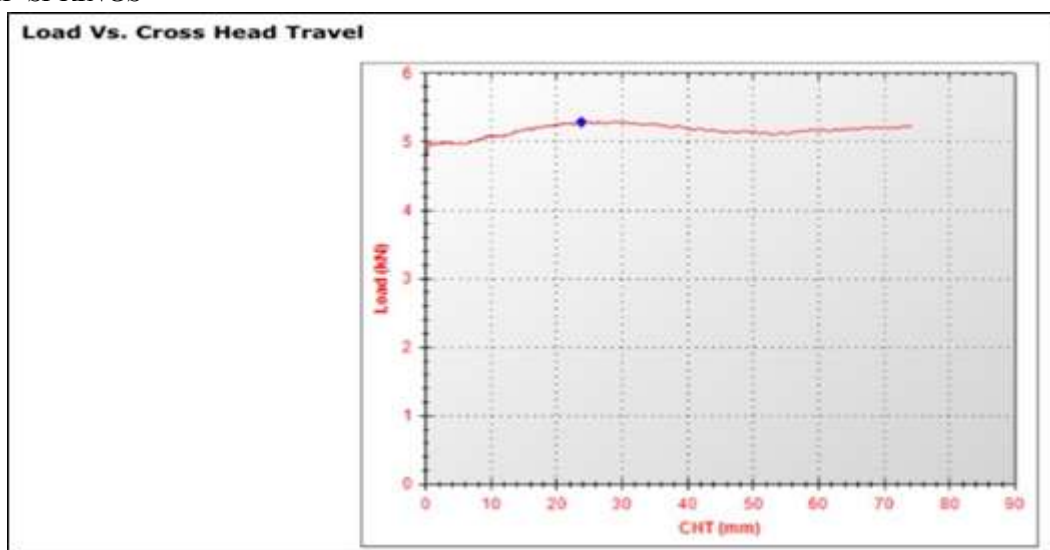
Graph 5.1 Carbon Leaf Spring Load Vs. Deformation

EPOXY GLASS LEAF SPRING



Graph 5.2 Epoxy Glass Leaf Spring load Vs. Deformation

KEVLAR LEAF SPRINGS



Graph 5.3 Kevlar Leaf Springs Load Vs. Deformation

Steel vs Carbon Epoxy Results

Load(N)	Carbon Def(mm)	Carbon Stress(MPa)	Steel Def(mm)	Steel Stress(MPa)
1000	23.8	146.25	29.25	193.14
2000	47.61	203.23	39.82	221.64
3000	71.4	240.77	51.39	275.5
4000	95.02	285.85	76.14	315.09
5000	119.04	346.37	93.2	387.87
5400	128.5	380.15	119.12	417.83

6. Conclusion

1. The present work focused on the design and analysis of a composite leaf spring as an alternative to the conventional steel leaf spring used in automotive suspension systems. The study was carried out to reduce the overall weight of the vehicle while maintaining the required strength, stiffness, and fatigue life. Composite materials such as E-Glass/Epoxy and Carbon/Epoxy were considered due to their high strength-to-weight ratio and excellent corrosion resistance.
2. A detailed literature survey revealed that composite leaf springs offer significant advantages over conventional steel springs in terms of weight reduction, energy absorption, and durability. Based on the design requirements, a composite mono leaf spring model was developed and analyzed using Finite Element Analysis (FEA). The stress distribution, deformation, and structural behavior under loading conditions were evaluated and compared with conventional steel leaf springs.
3. The analysis results demonstrated that the composite leaf spring can effectively withstand the applied loads while exhibiting lower weight and acceptable stress levels. The weight reduction achieved contributes directly to improved fuel efficiency, reduced emissions, and enhanced vehicle performance. Furthermore, the composite material showed better resistance to corrosion and fatigue, making it a suitable alternative for modern automotive applications.
4. The major contributions of this project are:
 - a. Design and modeling of a composite mono leaf spring.
 - b. Structural analysis using Finite Element Analysis (FEA).
 - c. Comparison of composite and conventional steel leaf springs.
 - d. Evaluation of stress, deformation, and weight reduction characteristics.
 - e. Demonstration of the feasibility of composite materials for automotive suspension systems.

The outcomes of this work indicate that composite leaf springs can successfully replace conventional steel springs in light and medium-duty vehicles, leading to improved efficiency, performance, and sustainability.

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