RESEARCH ARTICLE

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Design, Analysis and Optimization of a Light weight Vehicle's Leaf Springs

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Abstract

In recent years, the automobile industry has primarily concentrated on reducing weight and improving ride quality. Because composite materials have a high strength-to-weight ratio, strong corrosion resistance, and tailorable qualities, Steel leaf springs are being phased out in favour of composite leaf springs in the automotive industry. Three strategies have been investigated to reduce vehicle weight: rationalizing the body structure, using lightweight materials for parts, and reducing vehicle size. This study describes the static and dynamic analysis of steel 55Si2Mn90 parabolic leaf springs as well as composite parabolic leaf springs consisting of E Glass fibre, Carbon fibre, and Kevlar fibre. The goal of this study is to examine the load carrying capability, stiffness, and weight reduction of composite and steel leaf springs. Dimensions of an existing steel 55Si2Mn90 parabolic leaf spring and a light commercial vehicle's composite parabolic leaf spring are taken. In terms of weight and stress developed, a comparison was made between composite and steel leaf springs. The Kevlar fiber leaf spring, after optimization, is 45.67% lower in weight than other materials and has superior riding quality than a typical steel spring with equal design criteria.

Keywords: Leaf spring, composite Material, Analysis, optimization.

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Introduction

In the current context, research and technology are focused on reducing the weight of automobiles while maintaining high material strength. Customer demand fluctuates on a daily basis. To address this issue, the automobile industry is attempting to develop new vehicles that give great efficiency at a reasonable cost. Weight reduction is primarily done by the use of superior materials, design optimization, and improved manufacturing techniques. Composite has become a very good alternative material for conventional steel due to its ability to reduce weight while improving mechanical qualities. Leaf spring is one of the components of an automobile that may be easily replaced. A leaf spring is a simple type of spring that is widely used for wheeled vehicles' suspension. Leaf springs are a type of suspension mechanism that protects passengers from road shocks. It transfers lateral loads, brake torque, driving torque, and shock absorption system via spring deflections, storing potential energy in a spring before gently releasing it. The tension bar is a well-known example of a basic spring. Because all of its elements are stressed, a tension bar is an efficient energy storage element. If composed of metal, its deformation is minimal. The only common application for it is on bicycle wheel spokes. Machines and a variety of other applications employ mechanical springs. The force exerted on a spring is proportional to its change in length as it is stretched or compressed. The spring constant of a spring is equal to the change in force put on the spring divided by the change in deflection of the spring.

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The relationship between the weights (F) given to a spring and the deflections (δ) determines its performance. If the spring is tightly coiled and the material is elastic enough, the F- δ characteristic is almost linear. The spring stiffness $k = F/\delta$, which is defined by the spring geometry and modulus of rigidity, is the slope of the characteristic.

Flat plates are used to make leaf springs (also known as laminated or carriage springs). It is one of the oldest spring types utilized in commercial and heavy-duty vehicles. Leaf springs have an advantage more than helical springs in that they deflect as the spring deflects., the spring's end are steered towards a specified path to serve as a single structural

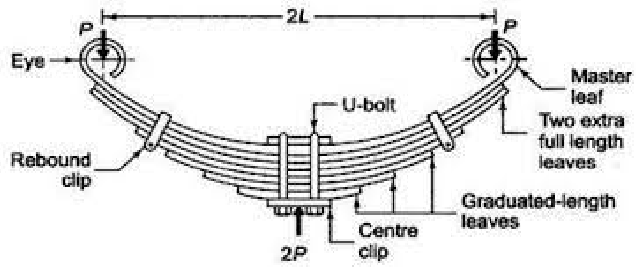


Figure 1: Geometry of leaf spring.

Table 1: Properties of E-Glass Fiber, Carbon Fiber and Kevlar Fiber

S. No.	*Properties*	*E-Glass epoxy*	*Carbon Fiber*	*Kevlar Fiber*
1	Young's modulus E), MPa	25000	70000	30000
2	Material's Ultimate tensile strengthl, MPa	440	600	480
3	The material's ultimate compressive strength, MPa	425	570	190
4	Density of the material (r), g/cm^3	1.90	1.60	1.40
5	Poisson's ratio (m)	0.20	0.10	0.20

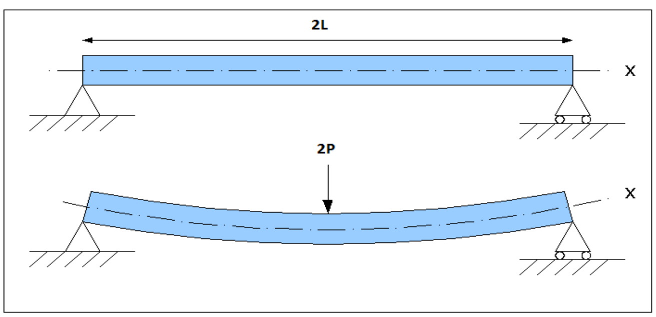


Figure 2: Simply supported beam, having a central load of 2P.

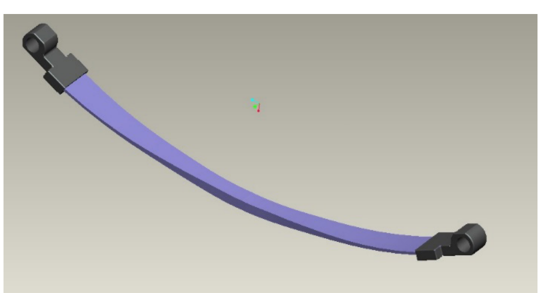


Figure 3: Three Dimensional Model of Leaf Spring

part. In addition to shocks, the leaf springs can handle braking torque, lateral stresses, and driving torque. Figure 1 illustrates

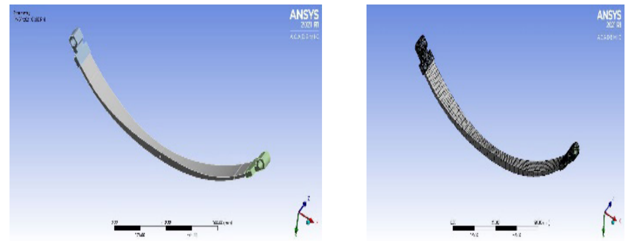


Figure 4: Modeling and meshing of the leaf spring

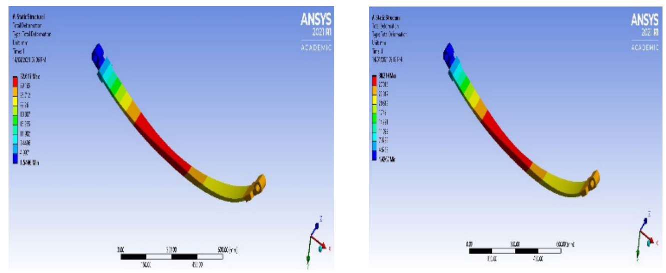


Figure 5: Deflection of Kevlar Fiber and E-Glass Fiber for maximum static load.

the geometry of a leaf spring.

Materials and Design Selection

Selection of Materials

The cost of a car is 60-70% determined by the materials used., hence the performance of the vehicle is improved. Even a great economic impact is caused due to small weight reduction in automobile. Composite material is only materials that can replace steel and help in weight reduction at the same time. So it's best that the leaf spring is made from composite material

Choosing a Design

This spring is analogous to a simply supported beam, and flexural analysis on springs is performed with this in mind. Bending and transverse shear stresses are applied to the simply supported beam.. Significant parameter of the leaf spring design is flexural rigidity.

Design calculations of conventional spring in the leaves cantilever Beam is what the Leaf Spring is. As a result, the load operating on each leaf spring assembly is also acting on the two ends of the leaf spring. Because the Cantilever Beam is taken into account, the load acting on the Leaf Spring is divided in two.

3D Modeling and Finite Element Analysis

Solid Modeling

A solid model is a digital depiction of the geometry of a real-world or created object. The majority of the time, the design process is iterative. Points, curves, and surfaces can

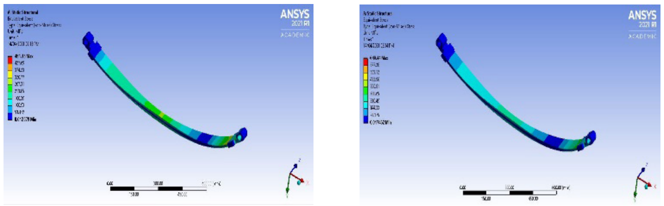


Figure 6: Stress develop Kevlar Fiber and E-Glass Fiber for maximum static load

Table 2: Deflection at different loads (static)

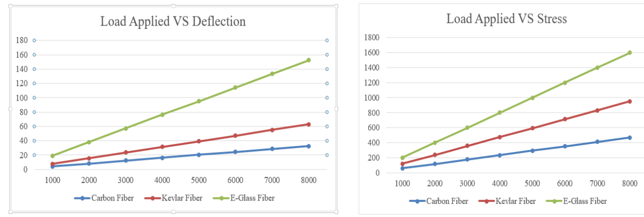
Load Applied (N)	*Deflection (mm)*		
	E-Glass Fiber	*Carbon Fiber*	*Kevlar Fiber*
1000	11.201	4.077	3.776
2000	22.403	8.154	7.553
3000	33.604	12.231	11.330
4000	44.805	16.309	15.107
5000	56.005	20.386	18.884
6000	67.208	24.463	22.660
7000	78.409	28.540	26.437
8000	89.610	32.617	30.214

Table 3: stress at different loads (static)

Load Applied (N)	*Stress (N/Mm^2)*		
	Carbon Fiber	*Kevlar Fiber*	*Glass Fiber*
1000	58.62	60.14	81.18
2000	117.24	120.29	162.36
3000	175.87	180.43	243.54
4000	234.49	240.57	324.72
5000	293.11	300.72	405.90
6000	351.73	360.86	487.08
7000	410.35	421.01	568.26
8000	468.97	481.15	649.44

Table 4: Deflection at different loads (Transient Dynamic Loading)

Load Applied (N)	*Deflection (mm)*		
	Carbon Fiber	*Kevlar Fiber*	*Glass Fiber*
1000	3.945	3.685	8.696
2000	7.310	6.885	15.363
3000	10.281	9.716	21.625
4000	13.033	12.33	27.724
5000	15.654	14.81	33.729
6000	18.187	17.198	39.683
7000	20.657	19.522	45.604
8000	23.082	21.801	51.497



Graph 1: Load verses deflection and Stress develop (Static)

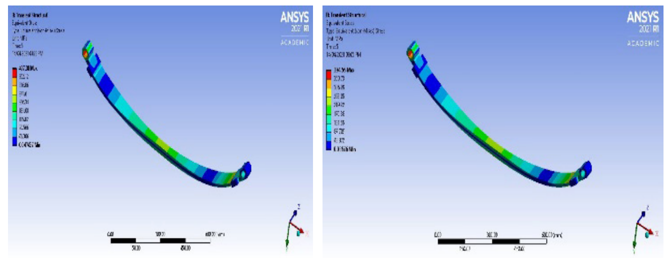


Figure 7: Dynamic Stress induced in Kevlar Fiber and Carbon Fiber

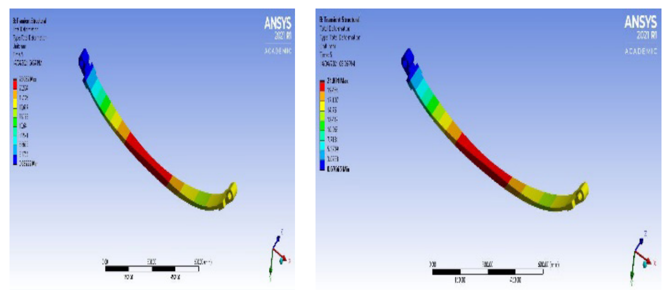


Figure 8: Deflection in Kevlar Fiber and Carbon Fiber during Dynamic Analysis

be specified and stitched together to define electronic representations of an object's border. The outcome is a digital approximation of the geometry of an object or an assembly of objects that is unambiguous, full, and detailed.

Modelling of leaf spring is done by PTC CREO. Leaf spring which is to be modelled is having a constant cross section area, varying lengthwise thickness and breadth. Hence it is not possible to generate mono composite leaf spring directly.

Analysis of a Composite Leaf Spring Using Finite Element Methodology

3D finite element analysis is used to examine the composite leaf spring's static strength , deflection. The current study makes use of the ANSYS 21.0 general-purpose programme for calculating finite elements. The composite leaf spring is modelled in PTC CREO was imported into ANSYS 21.0.

Results for Different Loads

Dynamic Analysis

The dynamic analysis also carried out on composite mono leaf spring in ANSYS software. The Load is applied with respect to

Table 5: Stress at different loads (Transient dynamic loading)

Load Applied (N)	Stress (N/mm^2)		
	Carbon Fiber	Kevlar Fiber	Glass Fiber
1000	54.842	52.697	81.249
2000	105.76	102.08	163.75
3000	153.95	148.86	236.37
4000	200.62	194.13	302.91
5000	251.51	240.06	365.29
6000	305.15	293.1	424.51
7000	357.04	344.55	481.24
8000	407.38	394.56	535.94

Table 6:

Material	Stress (Mpa)	Deformation (Mm)	Weight (Kg)	Weight Reduction (%)
55Si2Mn90	522.24	89.560	28.49	-
Carbon Fiber	468.97	32.617	17.53	37.92
Kevlar Fiber	481.15	30.214	15.34	45.67
E-Glass Epoxy	649.44	89.610	20.82	28.18

time. The reaction of a structure subjected to a time-sensetive stress, taking into account inertia and damping effects, is determined using a transient dynamic analysis.. The complete technique or the modal superposition approach can be used to perform a time-transient analysis in ANSYS Workbench. To calculate the transient response at each point, the full method employs the whole system matrix.

Stress and Deflection at different loads (Transient Dynamic Loading)

Comparison of Weight and Deformation

Conclusion

Static structural analysis was carried out on both steel and composite leaf springs.. Composite leaf springs and steel leaf springs with the same design and load carrying capacity were compared. Stress and displacements were calculated analytically and using ANSYS for steel and composite leaf springs, respectively. Also, the deflection, stress analysis and load analysis has been carried out and the result are satisfactory. Weight reduction of 37.92, 45.67, and 28.18% is obtained in material such as carbon fiber, Kevlar fiber and E-glass Epoxy respectively when compared with 55Si2Mn90. As a result, the goal of minimising unsprung mass is realised to a greater extent. Hence, best material that can be used is Kevlar Fiber instead of 55Si2Mn90 for light weight vehicle.

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