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Experimental and Numerical Analysis in Carbon Fiber Composite Leaf Spring

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ABSTRACT

Now-a-days automobile manufacturers around the world is concentrating on weight reduction in the vehicles. Around 10-20% of the mass of the automobile was reduced by reducing the mass of the spring leaf. The carbon fiber leaf spring is fabricated and analyzed for reducing the weight. It was found that the new carbon fiber spring has good load carrying capacity. In addition, it has excellent stiffness. Moreover, it stores high strain energy. It has great strength to mass ratio. The solid model of carbon fiber leaf spring was made through CREO and analysis was executed through Ansys software.

Keywords: Creo, FEA, Carbon fiber leaf spring;

1. INTRODUCTION

Leaf spring found its application as the suspension in the automobiles. The major benefit of using leaf spring compare to the helical compression spring is that its ends can be guided over the specific path and also it acts as a structural member [1]. For heavy vehicles many number of individual leaf spring are stacked together in the progressive manner towards the shorter leaf. The main axle is placed at the midpoint position of shorter leaf spring. This is attached to the chassis by using tie holes at the main leaf ends. In the conventional steel leaf spring damping action is provided by the interleaf friction but this causes the traction in motion of the leaf spring [2]. Therefore, through better design and optimization process mono composite leaf spring is designed to overcome these difficulties. Since leaf spring is responsible for absorption of vertical and impact load caused through deflection, the potential energy created due to loading is been stored as strain energy in the spring and release the same when load is being removed. Hence for this cause the material selected should have less modulus of elasticity and high strength in longitudinal track [3-5]. In this study, the carbon fiber leaf spring was designed and fabricated and compared the obtained results with the standard results obtained from the steel leaf spring.

2. METHODOLOGY

2.1. Fiber Selection

Leaf spring constitute a considerable amount in manufacturing of the vehicle so smaller reduction in heaviness of the vehicle produces larger pecuniary effect in vehicle manufacturing. For obtaining better operational result at reduced weight composite fiber materials namely, kevlar, carbon, glass fibers were utilized [6-8]. Composite fiber materials are selected for this purpose because of its following properties such as high fatigue strength, great specific strength and modulus, durable, corrosion resistance and low coefficient of thermal expansion etc. from this various types of composite fiber materials available carbon fiber is been selected due availability at wider range of tensile strength and elastic modulus allowing designer to use proper version to meet application needs [9].

Table 1: Properties of carbon fiber

Material selected	Carbon fiber
Young`s modulus (Gpa)	70
Ultimate tensile strength(Mpa)	310
Poisson ratio	0.33
Shear Modulus(Gpa)	5
Mass Density(g/cc)	2.7
Yield Strength(Mpa)	276
Thermal Expansion Coefficient(strain/K)	2.1

2.2. Resin Selection

In fiber reinforced plastics, inter laminar strength between two fibers sheets are been controlled by the matrix system used as an adhesive [6]. Many thermosetting polymers such as vinyl ester, poly ester and epoxy resins can be used in reinforcement of fibers. Among these thermosetting polymers epoxy resin is used due to following properties, little shrinkage, great strength, less toxicity, outstanding bond to numerous substrates, chemical resistant. Another major advantage of using epoxy resin is that it can be formulated to generate specific physical and mechanical properties.

The epoxy resin used in this process is liquid DEB ardalite and hardener used is aradur (TTA). They are mixed in a 10:8 ratio. This combination is selected since it cures at room temperature and dimensionally stable.

2.3. Design

Different vehicles have different loading capacity and according to that leaf spring is been designed. A vital constraint in designing leaf spring is flexural strength and it should rise towards end of the leaf. [5]. Design constraints are the various parameters that involve in the design of the component which satisfy the physical limitations.

$$\sigma_b = \frac{M_y}{I} \tag{1}$$

$$\sigma_b = \frac{12PL}{bt^3(3n_e+2n_g)} \tag{2}$$

$$chamber\ radius = \frac{2pl^3}{nEbt^3} \tag{3}$$

(Note: These formulas are taken from design data book)

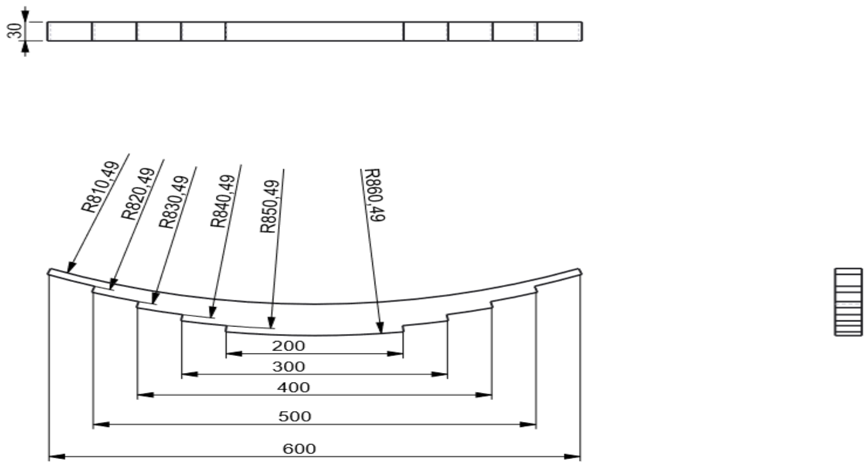

Figure 1. Diagram of composite leaf spring

Table 2: Dimensions of composite leaf spring

Parameters	Value
Chamber radius	815mm
Master leaf length	600mm
Second leaf length	500mm
Thickness	10mm
Width	30mm
Third leaf length	400mm
Fourth leaf length	300mm
Fifth leaf length	200mm
Spring weight	0.6kg

2.4. Fabrication

Various techniques are available for manufacturing of the carbon reinforcement plastic. Here we choose hand layup technique for construction of carbon fiber leaf spring. The wooden mould is been cut to the desired shape and placed firmly using supports [4]. The carbon fiber sheet of desired dimensions are been cut. Initially releasing agent is applied on the wood and carbon sheet is been pasted. Upon this layer epoxy resin is been applied uniformly and another layer of carbon fiber sheet is being pasted. Roller is been passed to remove the entrapped air bubbles between the layers [9]. This process is been repeated until the required dimensions is achieved. Generally, it takes about 60 minutes for pasting a layer of leaf spring of thickness 10mm and it is allowed to cure for about 6-7 days.

Figure 2. Fabrication details

2.5. Analysis

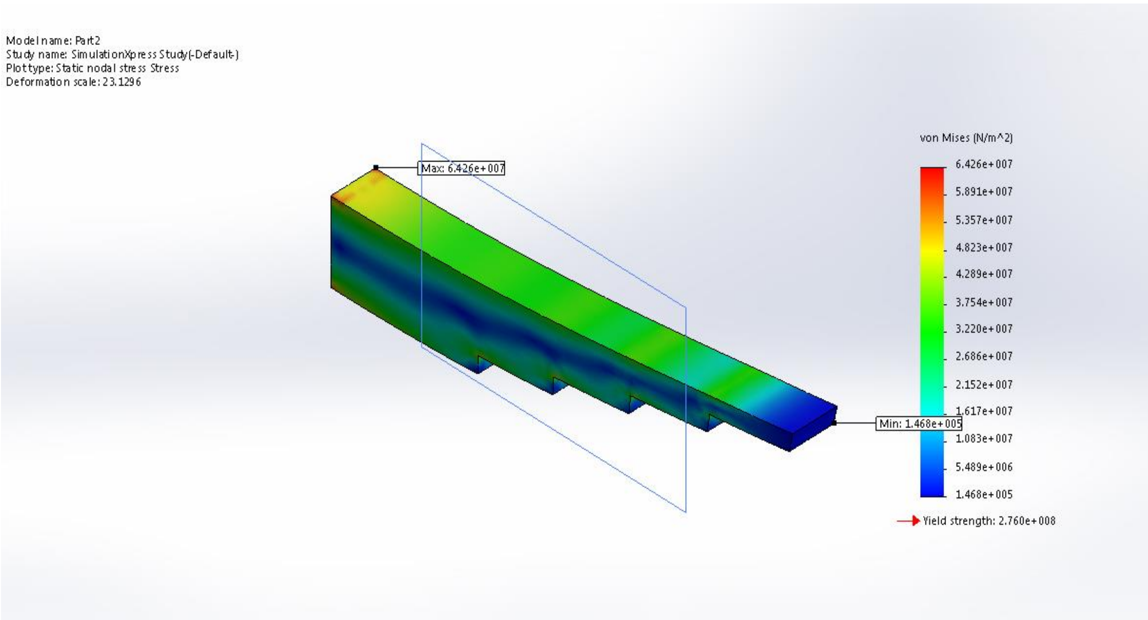

Figure 3. Von misses stress of Carbon fiber leaf spring

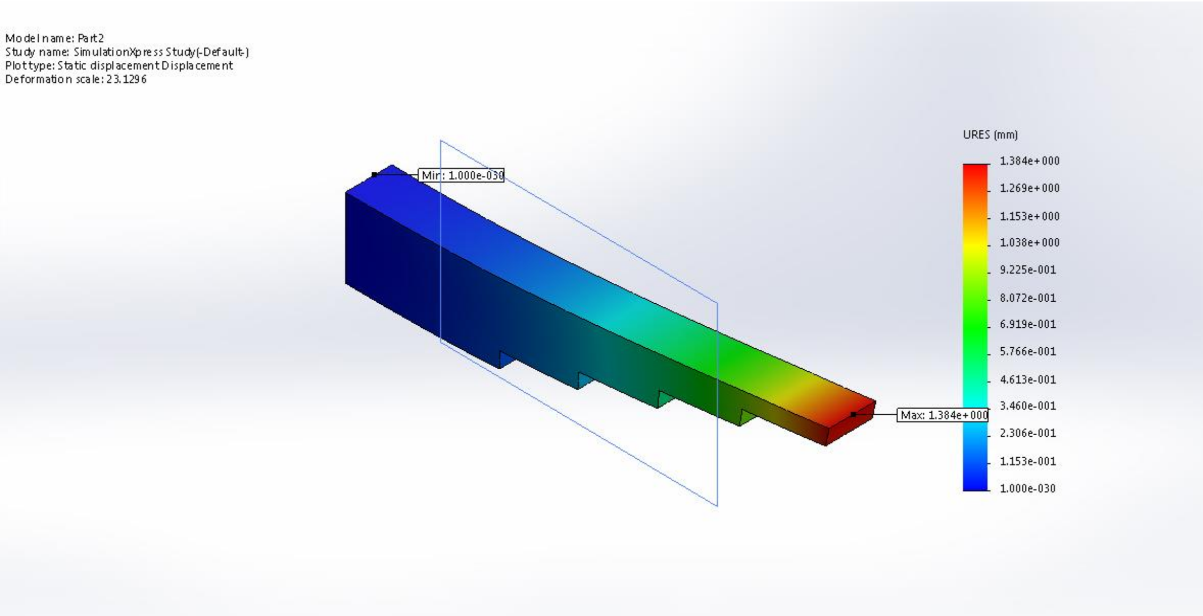

Figure 4. Deflection test for carbon fiber leaf spring

Finite element analysis for deflection and von misses stress has been performed using ANSYS. In this work existing steel spring is exchanged with carbon fiber spring. By choosing the dimensions modelling is done using CREO [3]. As leaf spring is symmetric about its axis only cantilever section is considered for analysis by applying the boundary conditions the point load of 4000N is applied at its end.

3. RESULTS AND DISCUSSION

As mentioned in the table the weight of carbon fiber leaf spring is significantly less related to the steel one while retaining the mechanical properties. Hence the reduction of unsprung weight is been achieved which increases the handling of the vehicle. It is also evidence that the stress produced is comparatively less which increases the fatigue life of the component.

Table 3. Result for deflection test

Sl. No	Load (W)		Dial gauge reading in mm		Actual deflection (δ) mm
	kg	N	Loading	Unloading	
1	20	196	0.6	0.6	0.6
2	40	392	1.2	1.21	1.205
3	60	588	1.8	1.9	1.85
4	80	784	2.4	2.5	2.45
5	100	981	3.0	3.0	3

Table 4. Comparison of results

S. No	Material	Parameters	FEA	Experimental
1.	Steel [1]	Load (N)	4100	4050
		Stress ($\frac{N}{mm^2}$)	648	665
		Deflection (mm)	89	92
		Weight (kg)	6.2	
2.	Carbon fiber	Load (N)	4000	4000
		Deflection (mm)	67	87
		Stress ($\frac{N}{mm^2}$)	432	471
		Weight (kg)	0.6	

In steel leaf spring stress concentration is maximum at holes which is provided for bolted joints. But in this carbon fiber leaf spring the stress concentration is avoided due to absence of holes [7]. In rugged road conditions causes chipping in the carbon fiber leaf spring causes degradation may occur. Hence it is advised to use in a light motor vehicle.

4. CONCLUSION

- Carbon fiber leaf spring was fabricated and tested for results. Unsprung weight has been significantly reduced by carbon/epoxy laminated leaf spring.
- 3-D modelling of spring is executed by CREO and analysis of the model is been carried out using ANSYS. Stress concentration around holes in the steel leaf spring was eliminated by this new spring.
- Stress produced on action of load is less compared to steel leaf spring hence it increases fatigue life.
- Provides high damping than conventional steel leaf spring thereby increases the comfort in ride.
- Due to chipping of spring it is suitable for smooth road conditions and can be used in high performance vehicles.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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