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Design and Analysis of Elliptical Leaf Spring for Light Agricultural Machines with CFRP Material

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***Abstract*— In general, suspension system has achieved with elliptic leaf springs. In small agricultural machines, weight has important factor. Weight loss can achieved by using carbon fiber reinforced plastic(CFRP) material. In this paper, ANSYS as simulation tool, has used to study the stress of CFRP elliptic leaf springs. Simulation and experimental results of elliptical leaf spring were compared. The error observed in experimentation and simulation were 2.55%. Analysis of elliptic leaf spring for different forces were studied, 6Kg load gives minimum %error.**

***Keywords*— CFRP; ANSYS; Elliptical leaf spring**

I. INTRODUCTION

Elliptical Leaf springs has special kind of springs used in small agricultural machines. A elliptic leaf spring has an elastic body, whose function has to distort when loaded and recover it's original shape when the load were removed [8]. Static analysis defines the safe stress and corresponding load of the elliptical leaf spring. The basic design employs high tensile "U" formed leave, situated such as forming an elliptical shape when joined together in the center portion with plates. Boron/Aluminum and Graphite/Epoxy were best suitable composite material for leaf spring [3]. Semi elliptic leaf spring were optimized for the critical part like eye, bolt etc. to minimize the overall weight of the assembly without hampering its structural strength [4]. Reduction of weight and how economical than conventional leaf spring by FRP leaf spring [5]. Comparison for the load carrying capacity, stiffness and weight savings found 64% reduction in bending stress and 57% reduction in deformation for same loading condition of composite leaf spring with that of steel leaf spring [6]. The dimensions of an existing conventional steel leaf spring of a light commercial vehicle were taken for design and experimental analysis of composite leaf spring made of glass fiber reinforced polymer compared to steel spring, the composite leaf spring were found to have 67.35% lesser stress, 64.95% higher stiffness and 126.98% higher natural frequency than that of existing steel leaf spring. They reduced weight of 76.4% by using optimized composite leaf spring [7]. Without any reduction on load carrying capacity and stiffness it has possible to reduce the weight of spring by glass fiber rein forced plastic (GFRP) [9]. Comparison of Glass Fiber Reinforced Plastic Leaf Spring with Steel leaf spring for their behavior under loading [10]. Static and fatigue analysis of a steel leaf spring of a light commercial vehicle (LCV) [11]. It has thus evident that the efforts were being made to investigate the stress of heavy duty vehicles. However there is no report on the small agricultural machine study to reduce stress and deflection during operation.

II MODELING & SIMULATION

The geometry of elliptical leaf spring consists elliptical plate having 177mm major diameter, 81mm minor diameter, 85mm width and 1.5mm thickness. The mild steel plate 92mm length and 85mm width has used to join ends of elliptical plate. In this study, force applied is varied by 4Kg, 6Kg, 8Kg, 10Kg and 12Kg. Flat plate were joined to elliptical leaf spring by using M5 nut and bolts. The same dimensions of elliptical leaf spring were used in the simulation.

The unidirectional fibers used for hand layup method of manufacturing. Hot curing system were used to refine the layers and reduce porosity to increases stiffness. We have selected first of all ratios of epoxy and carbon as follows,

Table 1 Ratios of carbon and epoxy

Sr.	Epoxy(%)	Carbon(%)
1	40	60
2	50	50
3	60	40

Continuous-fiber composites were used having 0.4mm thickness fibers and four layers of fibers used for manufacturing. We have selected 300gm/m^2 fibers and arranged in oven fabric method of manufacturing. We have arranged fibers as 0^0 and 90^0 for manufacturing. We have selected epoxy as resin having 4 layers were used . We found 60% carbon and 40 % epoxy gives maximum strength. Structured meshing method is used for meshing the geometry in ANSYS software, selected extremely coarse mesh. The force applied on elliptic leaf spring has vary from 4Kg to 12Kg.

Simulation result of elliptical leaf spring with CFRP material at 12Kg load as follows.

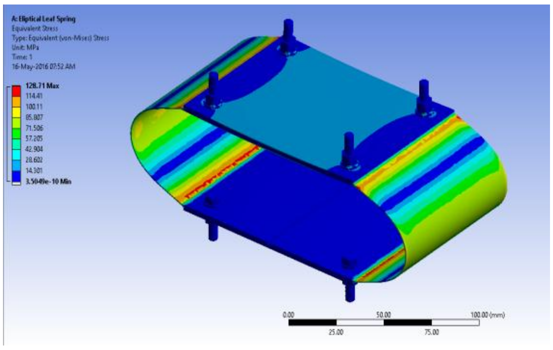

Figure 3 Equivalent(Von-Mises) stress in elliptical leaf spring with CFRP material at 12Kg load

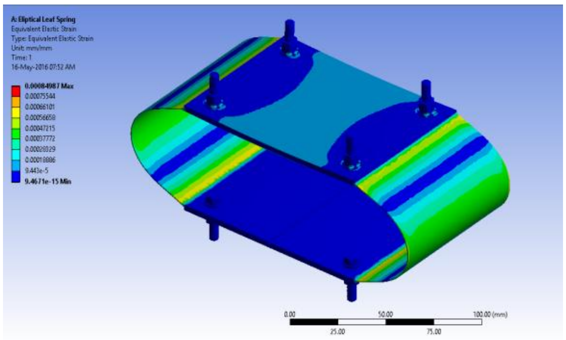

Figure 4 Equivalent elastic strain in elliptical leaf spring with CFRP material at 12Kg load

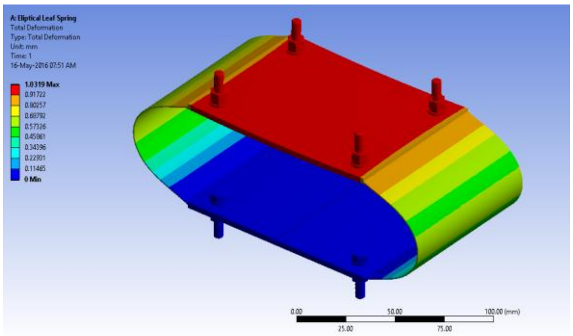

Figure 5 Total deformation of elliptical leaf spring with CFRP material at 12Kg load

Simulation of various elliptical leaf springs with CFRP material was carried out at different forces.

Table No 2 ANSYS Simulation Results for CFRP materials elliptical leaf spring for equivalent deflection, equivalent (Von-Mises) stresses developed and total deformation.

Sr. No.	Load (Kg)	VonMises stresses (MPa)	Equivalent strain (mm/mm)	Total deformation (mm)
1	4	42.904	0.00028329	0.34396
2	6	64.355	0.00042494	0.51594
3	8	85.807	0.00056658	0.68792
4	10	107.26	0.00070823	0.8599
5	12	128.71	0.00084987	1.0319

It has been observed that deflection of elliptical leaf spring changes along with force applied.

III EXPERIMENTAL SETUP

A universal testing machine (UTM) were used to test compressive strength of materials. We have selected 440mm length, 85mm width and 1.5mm thickness to fabricate elliptical leaf spring by hand lay method. A mild steel plate having 92mm length, 85mm width and 1.5mm thickness were used to join ends of elliptical leaf spring. A hole of 6mm diameter were drilled to pass bolts throughout the elliptical leaf spring. The plate were bolted to elliptical leaf spring by using M5 nut and bolt assembly. A point load were used for compression test on elliptical leaf spring. Results of the experimental investigation in elliptical leaf spring are presented as below under loading.

Figure 6 Schematic of experimental setup

Figure 7 Fracture of elliptical leaf spring with CFRP material during test at 4650N

Table 4 Variation of Von-mises stress with load

Sr. no.	Load (Kg)	Von-mises Stress (MPa)
1	4	42.904
2	6	64.355
3	8	85.807
4	10	107.26
5	12	128.71

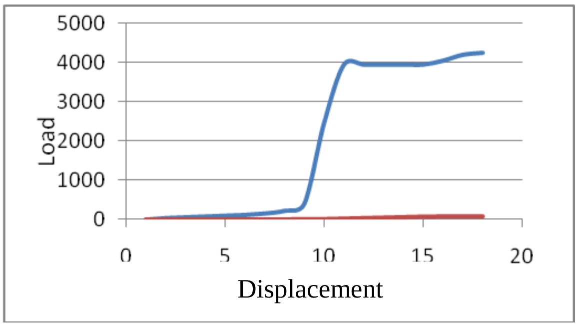

Figure 8 Load vs. displacement for elliptical leaf spring with CFRP material

IV RESULTS & ANALYSIS

It has seen that from the above graph that when load increases the bending stress increases linearly. At minimum loads both ANSYS and experimentation results were very close. It has observed that maximum stress developed at upper side of the elliptic leaf spring i.e. the red color indicates maximum stress, because the constraints applied at the bottom side of elliptic leaf spring. Since upper side were subjected to maximum stress, care must be taken in upper side design and fabrication. The CFRP material has good ductility, resilience and toughness to avoid sudden fracture. Static analysis were performed to find the Von-Mises stress by using ANSYS software and these results are compared with bending stresses calculated by experimentation at various loads and is shown in Table 5.

Table 5 Comparison between simulated and experimental results for Von-mises Stress

Sr. No.	Load (Kg)	Von-mises Stress (MPa)		Error (%)
		ANSYS	Experimental	
1	4	42.904	41.854	2.44
2	6	64.355	63.250	1.71
3	8	85.807	82.697	3.11
4	10	107.26	104.549	2.52
5	12	128.71	124.84	3

A graph is plotted as shown in Figure 8 with displacement(mm) on the X-Axis and load(Kg) on the Y-Axis.

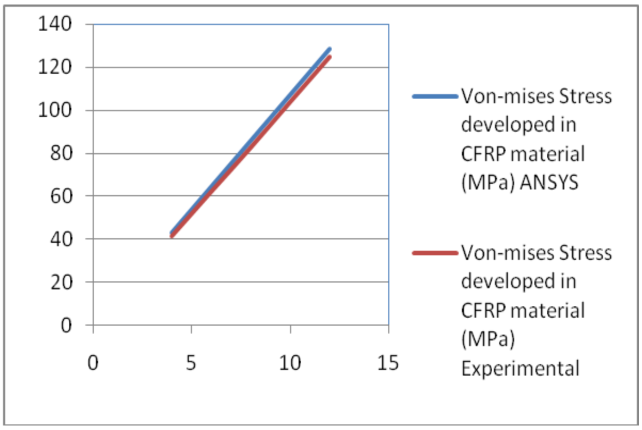

Figure 8 Comparison of ANSYS simulation results and experimental results

V CONCLUSIONS

Simulation and experimentation on the elliptical leaf spring were performed in this study. Simulation and experimental stress were approximately same for elliptical leaf spring. To improve the stress of elliptical leaf spring, use of deflection with forces i.e. 4Kg, 6Kg, 8Kg, 10Kg and 12Kg were investigated. Based on the above simulated results, the following conclusions can be made:

1. Deflection of elliptic leaf spring mainly depends on force applied.
2. The results demonstrated that material can improve stresses.
3. All the simulation results are compared with the experimental results and it has found that they are nearly equal to each other.
4. The 6Kg load gives minimum %error in bending stress.
5. A weight reduction by using CFRP composite elliptic leaf spring.
6. It is concluded that there is no objection from strength point of view for using elliptical leaf spring with CFRP material.

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