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Effect of Layersarrangement of Fiberglass in Leaf Spring Made from Composite Materials

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Abstract
This work includes design, manufacturing, analysis and testing of leaf spring made of composite materials instead of steel. The aim of this paper is study the effect of arrangement and number of layers for two types of glass fibers (EWR600&EMC450) with Epoxy on the leaf spring to find alternative components for the steel so as to reduce the weight of the mechanical parts and reduce the cost of manufacture, this principle plays a role in the consumption of fuel in trains ,automobile industry ,in addition to conserve natural resources, reduce the human effort of maintenance at the workplace, and increase their life therefore was selected the Leaf springs made from Composite materials instead of steel to study that aim, because of the easily manufactured and get to the mechanical specifications are acceptable or approach the original specifications of the material replaced. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. There are several materials we can use their in this field as Glass fiber, Carbon fiber, Graphite fiber. Behavior Study of Leaf Spring made of E-glass and Epoxy depending on the experiment and analysis by using ANSYS 14.5. In depending on ASTM D638 in Tensile Test, Flexure Testing according to ASTM D790 and Fatigue Test on The test of specimens were the results refer to the best arrangement of layers specimen number(5) which used layer ofEMC450, EWR600 &EWR450 respectively, when doubled the volume fraction for fiber from 24% to 48% the tensile strength and tensile modulus increased.

Keywords
Leaf spring, E-glass, composite material, layers arrangement.

Introduction

In modern industries began resort to find alternatives to fossil energy sources, due to Environmental pollution, the humanity are firstaffected them as well as other organisms.
Renewable energies were one of the most important alternatives that have been developed for work to replace fossil fuels is the most important (solar energy, wind energy), which are utilized in electric power generation and many industries such as the automotive industry.
After the emergence of a new generation of solar-powered cars, electric cars, and hybrid cars which work electricity and normal fuel (gasoline, diesel), but their uses remain limited, Because of the rapidity consumption of stored energy compared to using fossil fuels or electricity power, to other alternatives that appeared to reduce the consumption of those energy by reducing the weight of mechanicals parts in the bodies for plans and automotive, it is possible replace steel by composite materials, which have low weight compared to the weight of steel, while improving or maintaining of mechanical and chemical properties and this purpose Considered is the main aim of research.
From this basis, the idea began to the paper in the replacement of some car parts and manufacture from composite materials with some change in design, was chosen as leafspring in car passenger transport , The car that have been selected type KIA Besta .

Literature Survey

The Literature Survey mainly focuses on replacement of steel leaf spring with the composite leaf spring made of glass fiber reinforced polymer (GFRP) and mainly of the published work applies to them.
Mahmood & Davood.[1] Presented work on design, analysis and optimization of leaf spring .The aim of this work was steel leaf spring replaced with an optimized composite one, and obtain a spring with minimum weight that is capable of carrying given static external forces without failure. Here the work is carried out of a four-leaf steel spring which used in the rear suspension system of light vehicles &heavy duty vehicles. Result shows that Stresses in the composite leaf spring are much lower than that of the steel leaf spring. Compared to the steel leaf spring the optimized composite leaf spring without eye units weight nearly 80% less than the steel spring. The natural frequency of composite leaf spring is higher than that of the steel leaf spring and is far enough from the road frequency to avoid the resonance.
Malaga. Anil [2] Presented work on design optimization of leaf spring. The automobile industry has shown increased interest in the replacement of steel spring with composite leaf spring. Main purpose of this work is to replace the multi-leaf steel spring by mono composite leaf spring for the same load carrying capacity and stiffness Y. N. V. Santhosh& M. Vimal [3] Presented work on design and analysis of composite leaf spring. They are also discussed the advantages of composite material like higher specific stiffness and strength, higher strength to weight ratio. This work refer to the replacement of conventional steel leaf spring with a Mono Composite leaf Spring using E-Glass/Epoxy Main objective of this work is minimizing weight of the composite leaf spring as compared to the steel leaf spring. From result they proved that weight reduction obtained by using composite leaf spring as compared to steel was 60.48 %, and it was also proved that all the stresses in the leaf spring were well within the allowable limits and with good factor of safety. It was found that the longitudinalOrientations of fibers in the laminate offered good strength to the leaf spring.

Important remarks

The most important remarks concluded from the mentioned studies are:
1-Most studies presented focused on weight reduction for leaf springs with the possibility of maintaining some of the characteristics of composite materials compared to the materials that have been replaced.

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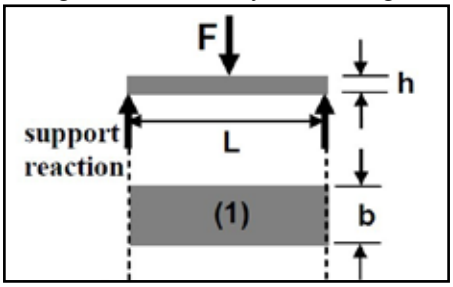
2-Some of these studies investigated the effect of fibers orientation in the matrix (resin) in tensile and flexural test.
In this present work, the effect of arrangement layers of E-glass fibers type EWR600&EMC450 in one direction 0-90 in an epoxy resin, and effect of that arrangement of layers on the tensile and bending test also the fatigue behavior of composite laminate under high cycling load (R=-1) fully reversible bending.

Design of a leaf spring:

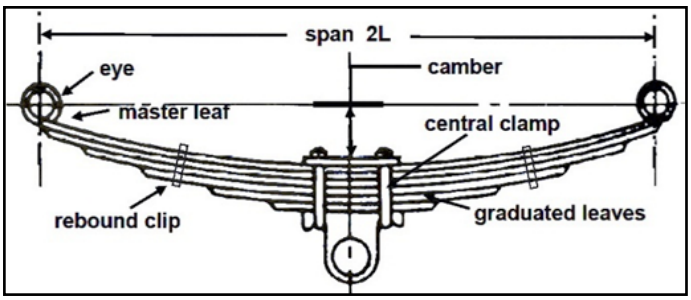
In the beginning we must have an idea of working principle of a leaf spring, let us think of the diving board in a swimming pool. The diving board is a cantilever with a load, the diver, at its free end. The diver initiates a back and forth swing of the board at the free end and uses the spring action of the board for jumping. The diving board is basically considering a leaf spring.



$$\sigma_{max} = \frac{3FL}{bh^2}$$

$$\delta_{max} = \frac{2FL^3}{Ebh^3}$$

Fig. 1 : Simply supported beam



Where:

σ_{max}= the maximum stress

δ_{max}= the maximum deflection

F = load on the leaf

L = long of leaf

b = leaf width

h = leaf thickness**figure -2- steel leaf spring**

The Finite Element Analysis

The finite element analysis FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition. The stresses generated in composite leaf spring at full load.

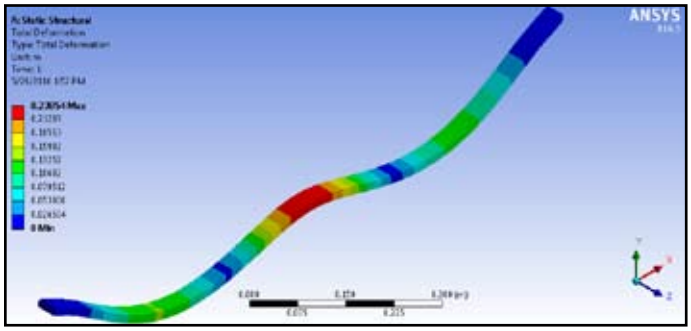


Fig. 3 : Solid Model of CompositeLeaf Spring

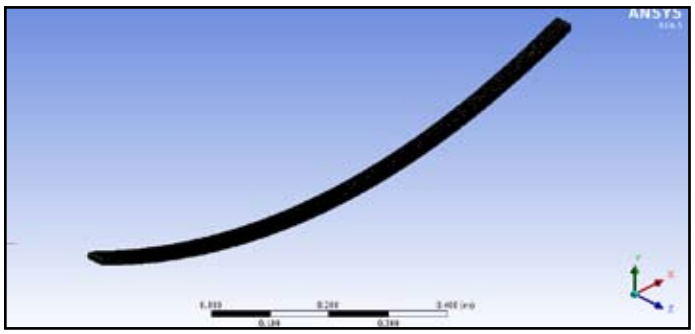


Fig. 4 : Deformation in Composite Leaf Spring

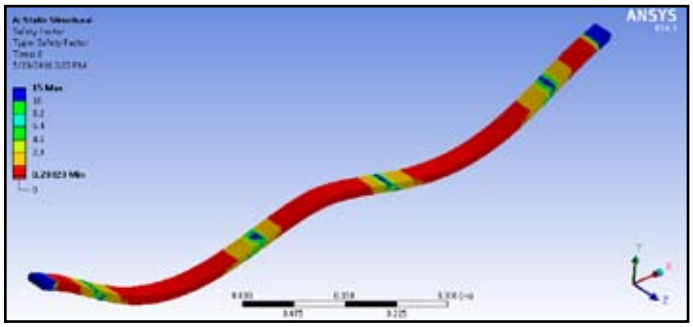


Fig. 5 : Safety factor in Composite Leaf Spring

Equipment and Techniques of Experiment

In experimental work a new composite material produced by hand layup and vacuum bag technique, The materials used in manufacture of leaf spring are :-
The Pieces were casting into a wooden mold each piece has Dimensions 40 cm length and 30 cm width and thickness 6mm. We got six samples from the mold according to arrangement of layers:
S1: It has been used five layers of EMC450, one layer of EWR600 and one Layer of EMC450
respectively.
S2: It has been used four layers of EMC450, one layer of EWR600 and two Layers of EMC450
respectively.
S3: It has been used three layers ofEMC450, one layer of EWR600 andthree Layers of EMC450
respectively.
S4: It has been used two layers of EMC450, one layer of EWR600 two Layer ofEMC450, one
layer of EWR600 andone layer of EMC450 respectively.
S5: It has been used one layer of EMC450,one layer of EWR600 until the Seventh layer

respectively.
S6: It has been used seven layers ofEWR600.

Tensile Test

The dimension of the tensile specimen produced according to ASTM D 638M type (I) andtensile testing machine , type Testometric micro 500 AX 25 universal machine with a speed range(0.5mm/min- 5mm/min) and load (4N-2500N) , (40N-25000N).
From the tensile test the results of tensile strength were:

Table (1) : Tensile Strength (Mpa)

No.	Tensile strength(Mpa)			
	Test 1	Test 2	Test 3	Average
S_1	121.962	134.667	135.5	130.71
S_2	138.5	139.2	127.7	135.13
S_3	131.24	140.1	138.5	136.62
S_4	170.23	137.705	141.205	149.72
S_5	172	174.372	168.962	171.778
S_6	169.12	158.11	154.654	160.628

And the results of young modulus were:

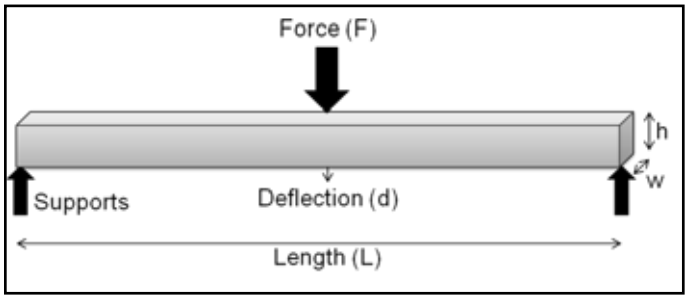
Table (2) : Tensile Modulus (Mpa)

No.	Tensile Modulus(Gpa)			
	Test 1	Test 2	Test 3	Average
S_1	1.27	1.78	1.75	1.6
S_2	2.67	1.714	1.54	1.97
S_3	1.57	1.38	1.404	1.45
S_4	1.304	1.75	1.67	1.57
S_5	3	1.29	1.7	2
S_6	1.56	1.25	1.2	1.34

Fig. (6) : The specimens after tensile test

Bending Test:

The flexural properties of the plain glass composites were obtained by (3- Point) Bending static tests. Typical stress-displacement curves for both materials.



Figure(7) simply supported beam

$$\sigma = \frac{3FL}{2wh^2}$$

σ = Ultimate stress

F = The load (force) at the fracture point (N)

L = The length of the support span=111mm

w= the width of specimen = 20mm

h= thickness of specimen =6mm

Table (3) : Bending Strength

No.	Bending Strength(MPa)			
	Test 1	Test 2	Test 3	Average
S1	226.74	244.2	274.3	248.413
S2	222.2	235	296.3	251.15
S3	300	264	272.5	279
S4	264.5	236	199.5	233.33
S5	378.14	284.16	280.1	314.13
S6	253	315.55	360.5	309.7

Table (4) : Bending Modulus

No.	Bending Modulus(GPa)			
	Test 1	Test 2	Test 3	Average
S1	13.19	13.2	15.22	13.87
S2	12.366	10.414	13.191	11.99
S3	19.79	19.78	17.99	19.2
S4	13.19	12.366	14.133	13.23
S5	28.266	15.22	16.45	19.98
S6	15.22	17.988	15.22	16.14

Results

From the results of the analysis of leaf spring made from composite materials by the ANSIS 10 and experimental we got:

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Table (5) : Compere the stress results between FEA & Experimental

No.	Tensile Modulus(Gpa)			
	Test 1	Test 2	Test 3	Average
S_5	2.5	2.72	2.5	2.573

After doubled volume fraction from 24% to 48% and reduce thickness for the specimen S5 the results were:

Table (6) : Tensile Strength

No.	Tensile Strength(Mpa)			
	Test 1	Test 2	Test 3	Average
S_5	273.135	285.519	287.404	282.02

Table (7) : Tensile Modulus for composite materials

Stress N/mm^2	Experimental	**FEA**
S1	273.135	256.05
S2	285.519	256.32
S3	287.404	262.56

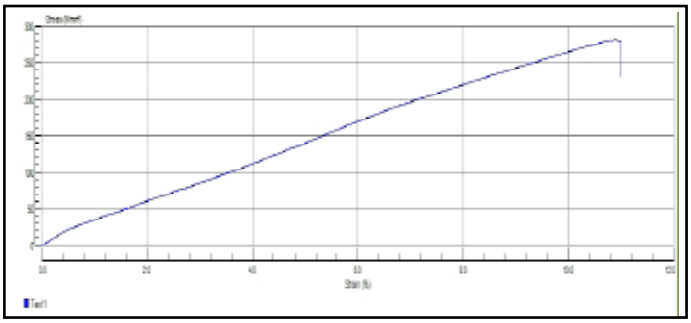

Fig. (8) : Tensile strength of fiberglass for [S5]

Table (8) : Bending Strength for composite materials

No.	Bending Strength(Mpa)			
	Test 1	Test 2	Test 3	Average
S_5	250.43	331.6	342.4	308.14

Table (9) : Bending Modulus for composite materials

No.	Bending Modulus(Gpa)			
	Test 1	Test 2	Test 3	Average
S_5	16.12	22.26	28.2	22.2

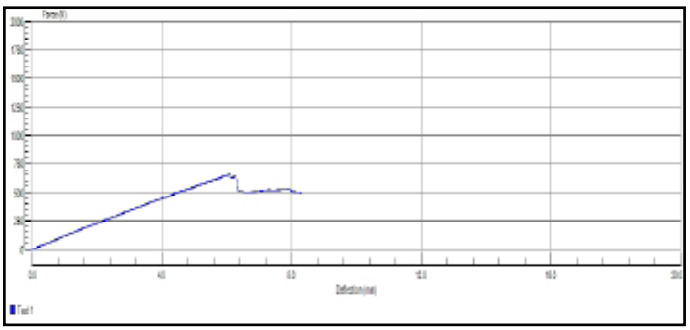

Fig. (10) : Bending Force of fiber glass for new [S51]

Fatigue Test

The fatigue results are shown as Stress-fatigue life (N) curves, the nominal stress range for the test were calculated using the applied stress under constant deflection. All the tests were performed using HI-TECH alternating bending instrument and at a stress ratio of R=-1. In this paper the experimental work was performed with constant value of deflection (4.4 mm) and fully-reversed bending for composite material follow S_5 specimen.

The ultimate stress was 282 Mpa and the yield stress was 61Mpa, as you can see a significant difference between them, so we took 60% of the value of the ultimate stress.

Table (10) : Stress-fatigue life (N)

Rate of stress	stress(Mpa)	No. of cycles(N)
100%	169.2	1700
95%	160.74	9000
90%	152.28	13000
85%	143.82	22000
80%	135.36	28000
75%	127.2	48000
70%	118.44	65000
65%	109.98	124000
60%	101.52	190000
55%	93.06	232000
50%	84.6	273000
45%	76.14	295000
40%	67.68	315000
35%	59.22	365000
30%	50.76	380000

Conclusion

The main conclusions drawn from this work the effect of arrangement and number of layers for the reinforcement material represented in two types of E-glass fiber type EWR600 & EMC450 with matrix material represented in Epoxy consist Resin type SIR Siropol 8340 &Hardener ButanoxM-50 , depending on tensile, bending and fatigue test ,the behavior are listed below:

1- In the general the mechanical properties were better in the specimen S_5 , It has been used one layer of EMC450, one layer of EWR600 until the seventh layer respectively ,the thickness was 6mm and the volume fraction is 24% .

2- After the reduced of thickness to 4 mm and double the volume fraction to be 48% we noted the tensile strength and tensile modulus are increased while the bending strength remained or little reduced because of the thickness is reduced form 6mm to 4mm and the bending modulus is increased.

3-we suggest use volume fraction for fiber not less 48% with the possibility of using other fibers instead of EMC450 such as carbon fiber or Kevlar fiber or Graphite fiber.

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