Journal of Mechanical Engineering Research and Developments
ISSN: 1024-1752
CODEN: JERDFO
Vol. 44, No. 2, pp. 132-140
Published Year 2021

Fabrication of hybrid composite materials leaf spring

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ABSTRACT

One of the oldest forms of spring used to have good suspension in wheeled vehicles is leaf spring. It reduces the overall fuel consumption and cost by reducing weight of the suspension systems. Replacing steel springs with composite leaf springs is one of the most effective methods. Introducing composite leaf springs to improve safety, comfort, and durability. Composite materials have a good corrosion resistance, a high strength to weight ratio, and high elastic strain energy storage capacity. The aim of this research is to investigate the structural properties of a hybrid leaf spring made of 95% Epoxy,5% carbon, 5%glass fiber, and 5% of hybrid composite of carbon and glass fiber. Hand layup was used in the fabrication due to its advantages over the other methods. The effectiveness of the proposed composite leaf spring was evaluated by implementing the mechanical tests. Tensile, Impact, Hardness and Flexural tests were done. The experimental results showed an increase in Hardness, Impact, Tensile, and Flexural strength when the reinforcing fibers are applied. The best results of the mechanical test obtained when hybrid reinforcement was applied.

KEYWORDS: carbon, glass fiber, composite material, hybrid leaf spring.

INTRODUCTION

Obadiah Elliot used leaf springs for suspending the horse drawn cart in 1804. Then it was used in the early design of motor vehicles. The spring is an elastic element, that have deflection responding to the application of external loads, and regains its original shape depending upon the magnitude of applied loads. Springs major application are usage as a shock and vibration absorber and storing potential energy by their deflection during the application of load. Almost the trucks and light vehicles used leaf spring to absorb shock and vibration. Leaf spring can enhance the suspension quality to support heavy loads. A good suspension system make the ride comfortable while leaf springs failure is catastrophic. Leaf spring advantages compared to helical spring are that the ends of the spring are guided along a definite path and it is acting as a structural member [1].

Leaf springs can be arranged in two different ways based on vehicles. Simply supported leaf spring with two ends fixed to chassis of the vehicle is the first type. While a cantilever leaf spring with one end displaced freely and the other end fixed to vehicle chassis is the second type. Steel is the commonly used material to made leaf springs that have a slender arc-shaped with rectangular cross section. Location of the axle is provides by the center of the arc. Chassis attached by loop formed at either end .Leaf spring holds axle by acting as linkage making it an important component. Carrying lateral load, breaking torque, driving torque in addition to shock absorbing are the main functions of the multi leaf springs.

A series of flat plates or leaves (having semi-elliptic shape) being held using center clip and bolts of U shape. In a multi-leaf spring two types of leaves are existed. These leaves are a graduated-length with length decreased gradually from top to bottom. A master leaf which is bent at both ends to form spring eyes is the longest leaf being in the top. A full-length leaves are the second type which supporting the transverse shear force (inserted between the master leaf and the graduated leaves). Rebound clips are used to maintain proper alignment and to restrict the lateral shifting of leaves. Although springs front end is connected with the frame by means of a simple pin joint, springs rest on the automobile axle. The frame through a flexible link (known as shackle) is connecting the rear end [2].Fig.(1) show semi elliptical leaf spring [3].

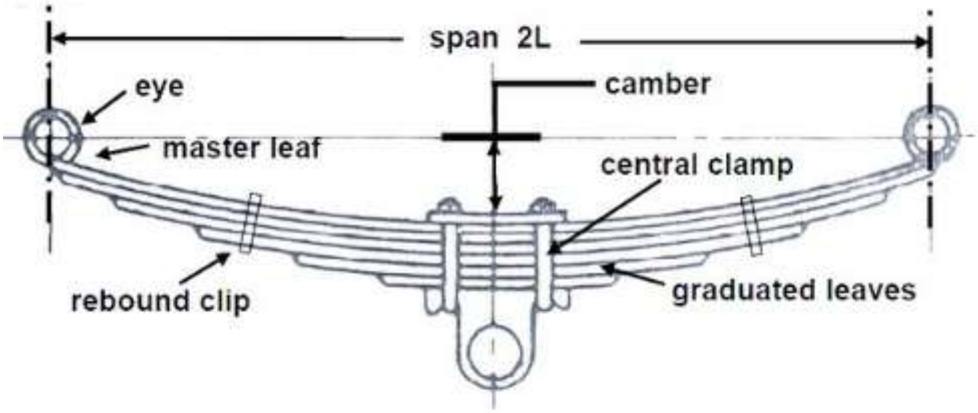


Figure 1. Semi elliptical leaf spring [3**]**

The most appropriate material to made leaf springs must have maximum strength and minimum modulus of elasticity in the longitudinal direction. Failure of conventional leaf springs arise accident, that may be reduced by introducing a gradually failed composite leaf springs [4].The introducing of better material design optimization, and better manufacturing processes weight reduction can be achieved primarily. For weight reduction in automobile, suspension leaf spring is one of the potential items having ten to twenty percent than that of un-sprung. That causing an improvement in riding quality [5]. Absorbing and storing energy and then releasing it is the main function of spring design. The major factor in designing the springs is the strain energy of the material. The specific strain energy can be expressed as [6].

$$u = \frac{\sigma^2}{2\rho E} \quad (1)$$

The equation above shows that materials having lower density and Young modulus have higher specific strain energy. Reducing the weight of the leaf spring without any reduction on load carrying capacity and stiffness can be achieved by introducing composite materials. Compared to that of steel, composite materials have more elastic strain energy storage capacity and high strength-to-weight ratio. The bending and Von Misses, stresses, and deflections are the design constraints. Absorbing vertical vibrations and impacts due to road irregularities performed by the leaf spring. Vibrations in the spring deflection cause the potential energy stored in the spring as strain energy and then released slowly [7].

Fiber-reinforced polymers instead of steel advantages are:-

(a) Their high damping factor have the possibility of reducing Noise, vibration, and ride harshness.
(b) Lower maintenance costs because of the absence of corrosion problems.
(c) Favorable impact on the manufacturing costs due to lower tooling costs. [8].

Ideally suited for suspension (leaf spring) applications are advanced composite materials. Increasing the strength and reducing the stresses induced during application by adjusting their elasticity [9]. To show the comparative results with the steel springs, the analysis of composite material leaf springs has become essential. Many studies have been made. Anjish M George (2017) made a leaf spring from E-glass/Epoxy, E-glass/banana/Epoxy, and flax, E-glass/Epoxy. The applied fibers were chosen to reduce weight and cost. A weight reduction of 88.49% was obtained when steel replaced by E-glass/flax/Epoxy hybrid composite leaf spring [10]. S.Seralathan used three different materials in manufacturing leaf springs. ANSYS finite element was performed to analyze the congenital steel, glass/ Epoxy and hybrid composite (combination of both steel and glass Epoxy) leaf springs. Using the new composite materials causes a 34% mass reduction and a 60% reduction in maximum principle stresses [11].

K.Umanath (2020), the fabrication of a leaf spring made up of three different composite materials was considered. Open molding method was considered to fabricate the springs. The first layer of the composite was carbon fiber and the second layer was Epoxy while the third layer was made from pineapple fiber. Because the composite material has smart corrosion resistance, high strength to weight ratio, the result showed high strength, hardness, and light weight [12]. T.G. Loganathan (2019), change from conventional steel leaf springs to carbon reinforced polymer composite was explored. To have considerable strength, with associated weight reduction increases the performance of the vehicle and minimized fuel consumption. Better results of fatigue life and flexural behavior of composite leaf spring were investigated using finite element analysis. It was seen that the weight of carbon fiber reinforced polymer is lesser than steel and the deformation is lesser than steel so the stiffness is higher and more fatigue life of composite material [13].

R M Patil (2014) Metallic leaf spring add significant static weight to the vehicles and reduce their fuel efficiency. Composite materials are found to be potential materials for replacing these conventional metallic leaf springs due to their properties like corrosion resistance and high strength to weight ratio. Composite leaf spring is fabricated then the experimental tests. The material used are glass/Epoxy and found the weight reduction 57.23% compared to the metallic leaf spring the stiffness lower 18% than steel leaf spring [14]. Manjunath H.N, a different composite material (E-Glass/Epoxy, Graphite/Epoxy, Boron/Aluminum, Carbon/Epoxy, Kevlar/Epoxy) and steel were used to make a comparative study in respect of stiffness, deflection and stress. Compared to conventional steel springs with similar design specifications. It is found that the composite leaf spring has good performance characteristics compared to conventional steel springs with similar design specifications. The minimum deflection and stress, high stiffness compared to other composites Boron/Aluminum has [15]. D.Lydia Mahanthi, light weight vehicle design and analysis of composite leaf spring was studied. Using Kevlar with spring materials contributes a considerable amount of spring weight reduction of the vehicle and needs to be strong enough. Kevlar is least in weight and withstands high loads with less deformation when compared to other materials. Static analysis of both steel and composite leaf springs like EN47, KEVLAR, S-Glass Epoxy, & E-Glass relieved that KEVLAR is the best [16].

AIMS OF THE STUDY

1- Reducing the overall fuel consumption and cost by reducing weight of the suspension systems.

2- Replacing steel springs with composite leaf springs since introducing composite leaf springs to improve safety, comfort, and durability.

3- Improving leaf springs life's since composite materials leaf springs have a good corrosion resistance, a high strength to weight ratio, and high elastic strain energy storage capacity.

4-Investigating the structural properties of a hybrid leaf spring made of 95% Epoxy,5% carbon, 5% glass fiber, and 5% of hybrid composite of carbon and glass fiber .

5- Showing that hand layup is an advantageous method when applying in the fabrication due to its benefits over the other methods.

6- Evaluating the effectiveness of the proposed composite leaf spring by implementing the mechanical tests (Tensile, Impact, Hardness and Flexural tests).

MATERIALS AND METHODS

The matrix of the composite material is Epoxy (Cleaver) re-inforced with carbon, glass, and hybrid fibers [17] with the properties listed in Table 1, Table 2, and Table 3 respectively. The reinforcement material are 5% for carbonglass fiber and 2.5% for carbon and glass fiber from the total weight. Hand lay-up molding was used to prepare the composite. To ensure an appropriate bonding sequence and having the required thickness of the final composite sheet. The reinforcing fibers are placed layer by –layer according to required sequence. Epoxy resin mixed with the hardener in 3:1 ratio (1hardener and 3 Epoxy). The brush was used to cover the fiber layers with Epoxy. The first layer was Epoxy and then a layer of glass or carbon, or a hybrid of both fibers placed according to the desired weight percent ,Table.4 show the reinforcement percentages .The composite sheets were left at room temperature for 24 hours to ensure complete curing of Epoxy. Then the sheet was inserted into the drying oven at (60 C°) for 1 hr. to remove the stresses and air bubbles that formed during the layering process. Samples were cut from the sheet according to ASTM shown in Table. 5 for the desired mechanical tests. Fig.(1) shows Epoxy, Carbon ,glass fiber used.

Table 1. The properties of Epoxy [17]

Type	**Epoxy resin**	**hardener**
Mixing proportion	3	1
Specific gravity	1.14 ± 0.1	1.02 ± 0.1
color	colorless	brown
Viscosity (mPa.s)	550 ± 50	
Pot life (min)	30 ±10 at 23º C	
Hardening time (h)	24 – 36 at 23º C	
Tensile strength	68-80 MPa	
Deformation	5-7%	
Modulus of elasticity	2.9-3.2 MPa	
Impact energy (charpy)	30- 50 kJ / m2	

Table 2. The properties of carbon fibers [17]

parameter	**value**
Mass density	1.5 gr /cm3
Longitudinal Modulus E1	142 GPa
Longitudinal Modulus E2	10.3 GPa
Poissons Ratio	0.27
Longitudinal Tensile strength	1830 Mpa
Traverse strength	57 MPa
In Planar shear Strength	71 MPa
Longitudinal Compressive Strength	1096 MPa
Traverse Compressive	228 MPa

Table 3. The properties of E-glass fibers [18]

parameter	Value
Density	2.56 gr /cm3
Tensile strength	3445 MPa
Modulus of elasticity	76 GPa
Tensile elongation	2.75 %
Fiber diameter	13 µm
Chemical composition	52.4 sio2,14.4 Al2O3 ,10.6B2O3, 4.6 Mgo ,17.2 Cao and 0.8 other

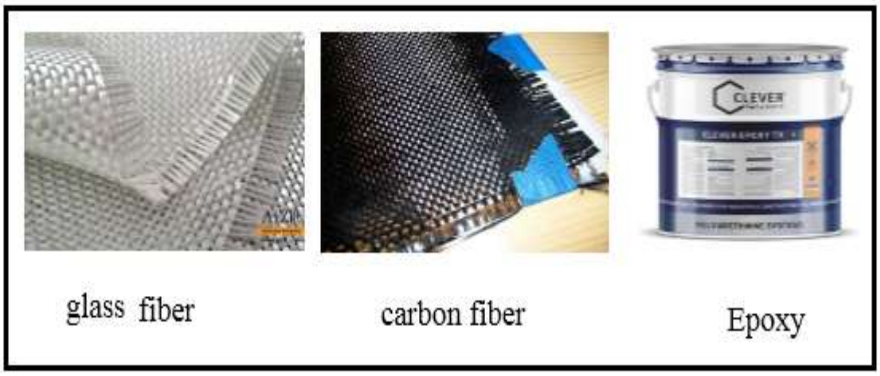


Figure 1. Epoxy, Carbon, glass fiber used.

Table 4. Type of used samples

No of samples	Content
A1	Epoxy + hardener
A2	A1 reinforced with 7 layers of carbon fibers
A3	A1 reinforced with 7 layers of glass fibers
A4	A1 reinforced with3 layers of glass and 4 layer of carbon fibers

EXPERIEMENTAL TEST

Tensile Test

Tensile strength was measured using a controlled electro-mechanical testing device. Loading the ASTM D638 samples to fracture with a constant load of 30 kN at 5 mm/min speed and 50 mm span length [19]. Tensile strength and deformation were calculated considering the stress strain curves. Three samples of each composite were tested and then the average was considered for all blend and composite sample to have the best evaluation of the tensile tests.

Hardness Test

Enabling the assessment of the properties of a material and helping to identify the appropriate materials for the required purpose hardness testing was considered as a quality control test. ASTM D 2240 was considered to perform Shore D test with the indenter properties shown in Fig.(2) . The average was considered of the three device readings taken for all blends and composites. Fig. (2) show hardness test sample dimensions[9].

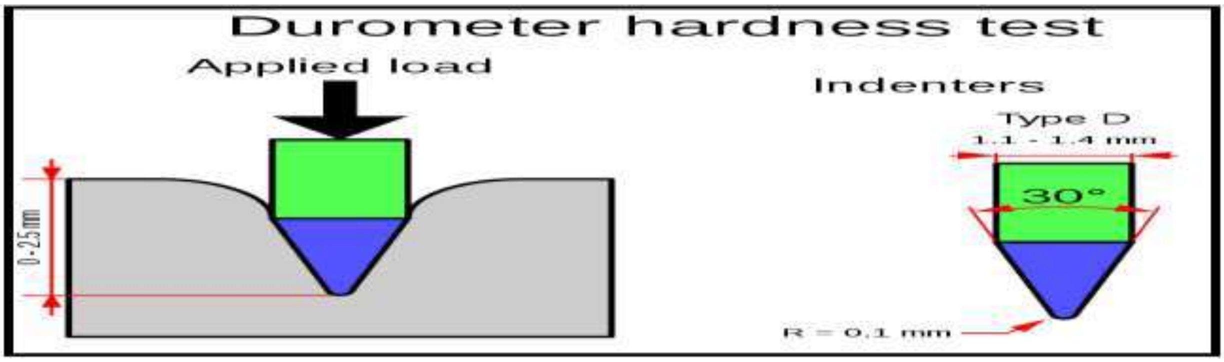


Figure 2. Hardness test sample dimensions

Flexural Test

The amount of strength an object can afford before breaking or distorting is flexural strength. Instron Universal Testing Machine (Tiniuse Olsen, U.K., model HKT 50 KN) was used to conduct the flexural test according to ASTM specifications [20]. 5 mm/minute is the cross-speed, 50 mm is the span length. The rectangular sample sizes were 4 mm thickness, 12-14 mm width, and 96 mm length cut from the composite sheet. Flexural strength was determined using three samples for all composites.

Impact test

A practical method that gives an accurate indication of the strength of the material and its resistance to breaking under stress at high speed is the impact strength test. Impact strength was calculated using equation (2) [21].

$$I.S = Uc/(A) \quad (2)$$

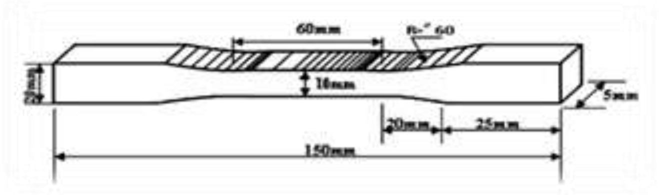
Where,

I.S: Impact strength (J/m^2).

Uc: Energy necessary to break the sample (J).
A: Cross section area of sample (m²).

The standard specification of impact testing are carried out according to (ASTM- 256) by using a Charpy impact test instrument of model IMI, which is designed to measure the impact fracture energy of polymeric materials[22].Table 5 showed ASTM for all test samples.

Table 5. Sample dimensions and standard specifications of tests [23]

Test	Samples Dimensions	Standard Specification
Tensile test		ASTM-D638M
Impact test		ASTM-256
Flexural test		ASTM-D790
Hardness test		ASTM-D2240

RESULTS AND DISSCUSION

Tensile test

The experimental results in Figure 3 showed that the addition of carbon and glass fibers into Epoxy causes an increase of the tensile values to 184, 170 and 145 Mpa for samples A4, A3, and A2. The greatest increase when hybrid reinforcement of fibers are introduced (combining the excellent properties of the two fiber). That increase because Epoxy resin is a brittle material having low tensile strength when reinforced with fibers tensile strength increases. Carbon and glass fibers have high ultimate tensile strength and ductility, imparting strength and toughness to the Epoxy matric.

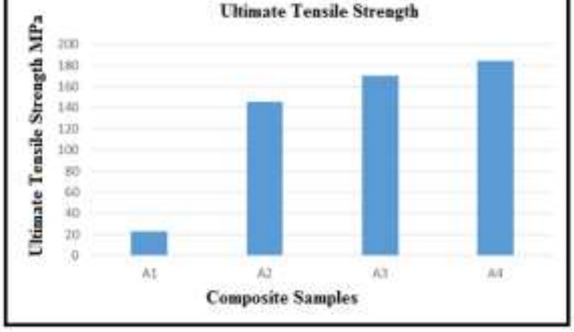


Figure 3. Tensile strength of composite samples

Hardness Test

Shore D hardness tests are in Table [6] below. It can be noticed that an increase in composite hardness was obtained. The maximum increase when glass fibers are applied. High strength and the ability to absorb the external load are the reasons causing A2 and A3 having high values of hardness compared to that of A1 [24].While the maximum value obtained when carbon and glass fibers gathered in sample A4.

Table 6. Results of the hardness test

Sample	Hardness (Shore D)
A1	76.9
A2	82.5
A3	84.4
A4	85.5

Flexural Test

Flexural test defines the ability of resisting breaking when pressure is applied .The result shown in Fig. (4) showed that the flexural value of A1 is 105 MPa. Epoxy is a brittle materials having low ability to absorb load and deform .The values of A2, A3, A4 are (278, 953, 333).Reinforcement with fibers imparts an increase in the flexural strength. Fibers distribution on a large area of resin carrying the maximum parts of loads, increase the stiffness of composite materials

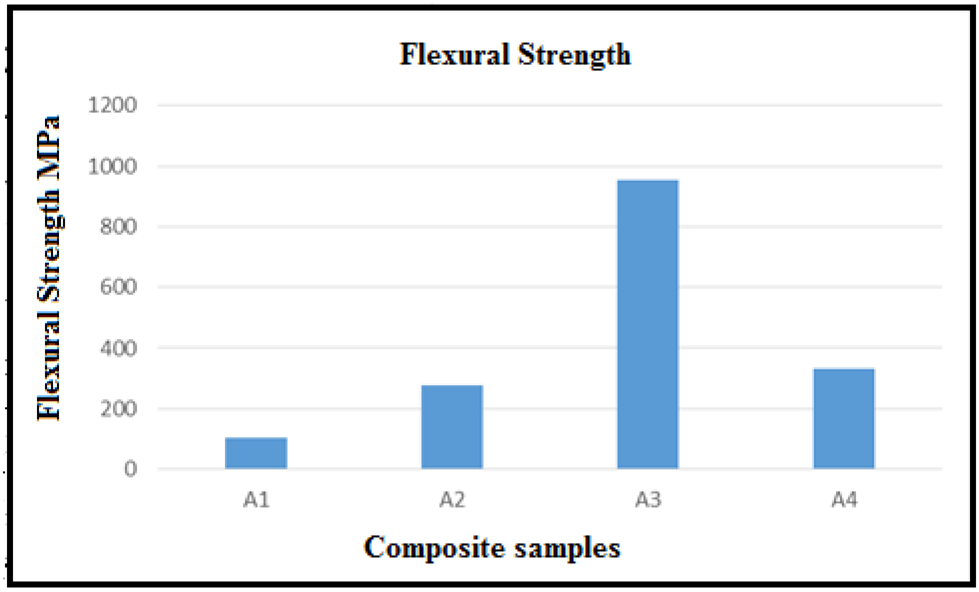


Figure 4. Flexural strength values of composite sample

Impact Test

Charpy impact test was used to measure the toughness of the composite material .A materials toughness is a factor of its ability to absorb energy during fracture .The results shown in Fig(5) indicates that the impact strength of Epoxy is 13kJ/m^2 and the impact strength values of A2,A3,A4 are 91 ,186 ,146 kJ/m^2 respectively. The impact resistance of the Epoxy is very low due to brittleness. Reinforcing it with the fibers, the impact resistance increases because fibers bear the bulk of the impact energy.

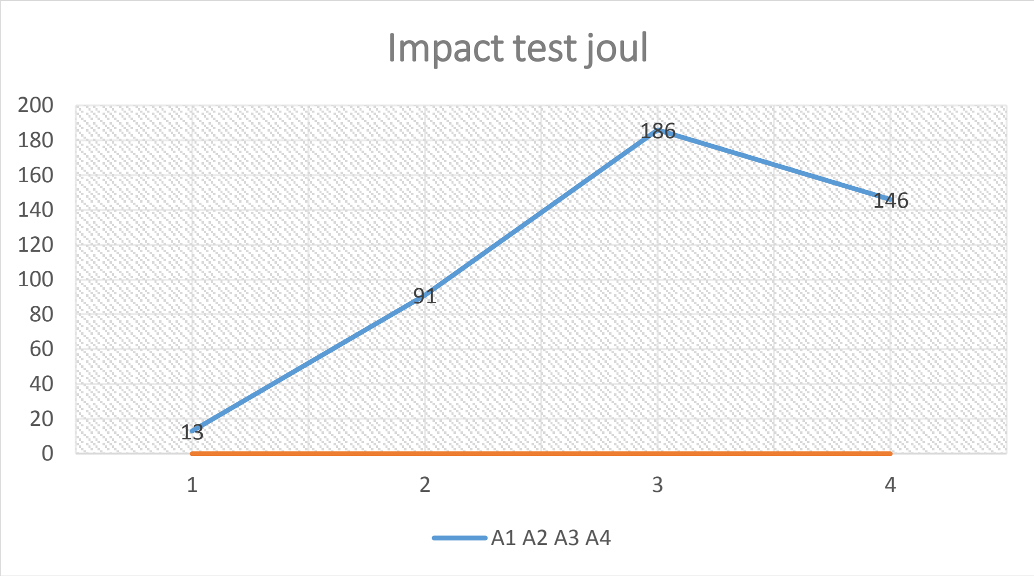


Figure 5. Impact energy values for composite samples

CONCLUSIONS

1- Experimental results showed that Epoxy has low tensile strength, impact, and flexural strength.
2- The values of tensile, impact, and flexural strength of matric were improved when reinforced with carbon and glass fibers.
3-Glass fiber gave the best mechanical properties for impact test and flexural test because of high strength and ductility the Glass fiber.
4-Glass and carbon fiber have high tensile strength making the proposed hybrid composite beneficial.
5-Using Epoxy / Glass and carbon fiber reduce the composite weight significantly because the three component of the composite having a small densities compared to that of steel.
6- studying the mechanical properties of the hybrid composite strengthen the validity of using this composite in manufacturing the leaf spring.

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