DEVELOPMENT OF LEAF SPRING WITH COMPOSITE MATERIAL AND TO INVESTIGATE ITS MECHANICAL PROPERITES

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IN

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By

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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled "**DEVELOPMENT OF LEAF SPRING WITH COMPOSITE MATERIAL AND TO INVESTIGATE ITS MECHANICAL PROPERITES**" in partial fulfilment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of **Mr. Prashant Bagde**, **Assistant Professor,** Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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Signature of Examiner

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ABSTRACT

In present scenario automobile industry is focusing on composite and lightweight materials and replace conventional steel material with composite materials because of their high strength, lesser weight, our main objective is to replace multi leaf spring with mono composite leaf spring. This is done for a vehicle to give better comfort, improved damping characteristics, structural stability, leaf spring basically supports vertical load acted upon it, and most important is for fuel economy or efficiency, because day by day our natural resources are depleting, so we need to think for every sector possible. We need to examine properties of composite materials while we need to maximize load carrying capacity or to increase load bearing capacity and decreasing the deflection produced during actual condition.

Composite material has various advantages like high strength to weight ratio, easily available, easy and hassle free fabrication methods, and improvised thermal and electrical properties. Mechanical properties of a leaf spring depend on type of material use, fabrication methods, and fibre orientation. Some specific composite materials have higher stiffness and higher strain rate as compared to metals, strength of composite also depend on shape and geometry. Laminated composites consists of various layers of fibre with resin which acts as matrix material. Fibre glass and carbon fibre used for mono leaf spring fabrication. Experimental testing of leaf spring for load carrying capacity by checking load vs. deflection.

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CHAPTER 1

INTRODUCTION

1.1 Introduction to Springs

A spring is considered an elastic body, to absorb and release energy when load is applied or acted upon it. Suspension system in an automotive vehicle connects the axle and wheels to the frame or chassis of the vehicle. Primarily the function of suspension system is to support the overall weight of the vehicle and to carry the load acted upon and to absorb the shock or impact force. This also isolates the body of the vehicle and the passengers from the vibration and shocks produced during vehicle use. Load carrying capacity and performance of suspension system depends on the type of steel material (or grade), geometry and mechanical properties. Springs in suspension system are generally divided into leaf spring, which is used in heavy automotive vehicles like trucks, buses etc., other category falls into helical springs which are used in light automotive vehicles like small cars, motorcycles, bicycles and railway suspension systems etc.

1.2 Leaf Spring

A leaf spring is a simple form of spring, semi-elliptical leaf spring , a flat bar or a strip of metal, act as a structural component or member as well as device that absorbs energy, commonly used for the suspension system in automotive vehicles. Leaf springs are considered as the oldest automotive suspension components but side by side modern air suspension system are also used in many heavy trucks now a days. They are used in heavy vehicles like Trucks, Jeeps, Buses and light automotive passenger vehicles. In the figure shown below, load (P) is applied from above, which acts in the centre of the leaf spring, graduated leaf provides more support for loading carrying capacity. Additional leaves provides more load carrying capacity, strength and stiffness to automotive vehicle.

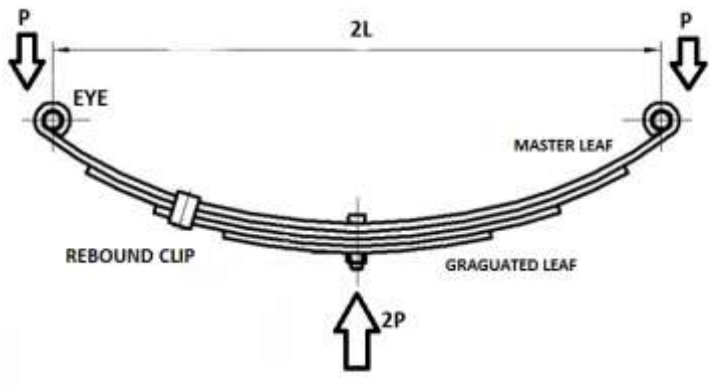


Fig 1.1 Leaf Spring

Adding more support leaves increases load bearing capacity as well as overall weight of the vehicle, mono-leaf springs are used in light motor vehicles, multi-leaf springs are for heavy loading purposes. Master leaf bears the main load and it is supported by support leafs.

1.3 Introduction to Composite Materials

A composite material is defined as the combination of two or multiple materials, generally on macroscopic scale to form another type of material that can give better performance when compared to individual components like metals and non-metals. Composite material retain its own mechanical, physical and chemical properties. Composite materials are chosen for their advantages over metals due to its light weight, strength, lifetime and better mechanical properties.

Composite materials consists of two materials, they are called matrix and reinforcement. Generally reinforcement is generally stronger, harder and relatively stiffer than the matrix, matrix carry load and distribute to the reinforcement and to the whole part.

1.3.1 Classification of Composite Materials

Composite materials are generally classified into:

(1) Particulate Composite Materials.

(2) Laminated Composite Materials.

(3) Fibrous Composite Materials.

(4) Combination of all of the above materials.

According to Matrix Constituent, it is generally divided into:

(1) Polymer Matrix Composite.

(2) Metals Matrix Composite.

(3) Ceramic Matrix Composite.

Secondary classification of composite are divided into:

(1)Whiskers

(2) Continuous Fibre

(3) Particulate

(4) Woven Composites.

Reinforcement and matrix material can be chosen according to requirement and applications. Performance of matrix as well as reinforcement rely on manufacturing as well as fabrication processes. We will be using continuous and random fibrous fabric for reinforcement, and epoxies as matrix material. We will discuss about fibrous fabric reinforcement and nature of epoxy and bonding capabilities. We will prepare different specimens using different reinforcement material and keeping same epoxy material and identify mechanical properties for specimen and composite leaf spring.

CHAPTER 2

SCOPE OF THE STUDY

Our primary focus is to fabricate a composite leaf spring also to identify mechanical properties of composite material as well as to identify its advantages over conventional leaf spring.

It was observed that a majority of the mass or overall weight gets reduced by 60 %to 75% when a leaf spring is fabricated using composite material, material was chosen as fibre glass epoxy and carbon fibre epoxy. Stresses in composite was found to be same or less, in different researches performed earlier.

A composite material can be chosen over steel due to its weight. Moreover according to researches performed earlier it was observed that composite leaf spring has advantages and better stiffness when compared to leaf spring material. Stresses were lesser for composite spring, deflection was found to be lesser as compared to conventional material, but stiffness and deflection depends on thickness of the leaf spring, as the thickness increases, the deflection reduces. Analysis performed earlier showed that stresses in steel leaf spring is almost equal to composite leaf spring and weight was reduced to a high extent. Steel leaf spring is heavy as compared to leaf spring made of composite material. If composite leaf spring has better mechanical properties when compared to steel, then composite materials can be used to fabricate other automotive components, which can reduce overall weight. Weight reduction matters a lot when efficiency and fuel economy acts into picture. Reduction in weight can help to save fuel and reduction in manufacturing cost help in sustainable manufacturing process. In a long run a composite leaf spring with better mechanical properties and performance can give us a way to replace conventional steel leaf spring.

Future scope for this study is that we can fabricate composite material by reducing weight as less as possible, we can use carbon fibre epoxy as well as glass fibre epoxy to fabricate leaf spring. We can increase the fatigue life for leaf spring using composite material, fatigue life was found to be higher when compared to conventional leaf spring material, and bending strength, stiffness can be optimized according to performance and requirements. Our motive is to maximize load carrying capacity for composite leaf spring having constraint as weight minimization. Failure analysis helps us to determine the failure mode and criteria of failure for composite material. Failure analysis can also be performed using failure theories for different composite material. In future more experiments can be performed using different composite materials and we can examine more properties using experimental, analytical and Finite Element Method (FEM) techniques.

CHAPTER 3

OBJECTIVES OF THE STUDY

Our research work deals with testing of composite materials in order to fabricate a composite leaf spring having better mechanical properties in terms of bending strength, stiffness, tensile strength.

We will focus on weight reduction, without compromising its mechanical properties. Optimized performance in terms of maximum load bearing capacity, maintaining bending stiffness which is better and it can be used in automotive vehicles, which will result in fuel efficiency and economy. If we achieve desired output and results then composite leaf spring can be manufactured on large scale for wide range of applications.

Further, we can test more composite materials having different orientation to improve its properties. Previous research shows that use of glass and carbon fibre composite reduce weight up to 75%.

According to previous researches performed on leaf spring, some of the works are based on Finite Element Analysis, from FEA, von-misses stress, weight reduction, maximum stress and bending strength can be predicted, but when it comes to fabrication due to change in design parameters and considerations, results from FEA and experimental work may vary, depends on various constraints and boundary conditions.

We will test various composite materials (fibre glass and carbon fibre) having different orientations, and to identify mechanical properties, after getting results and properties, we will fabricate a full sized composite leaf spring and load can be applied to the fabricated leaf spring, from which load vs. deflecting curve can be achieved. Strength and stiffness can be improved by testing different various composite specimens, it can be prepared using fibre glass and carbon fibre. Mechanical properties can be identified by some tests like tensile test, flexural test, from which we can get stress vs. strain graph, bending stiffness, flexural; strength Moreover, we will compare our values and results with previous performed experiments and research related to composite leaf spring, from which we can find results for better performance and results.

CHAPTER 4

REVIEW OF LITERATURE

[Ajay B.K.] [1] Work was carried out, multi leaf spring having eight leaves used. In order to reduce manufacturing cost and cost of raw material, weight of leaf spring, The Automobile industries is trying to replace conventional steel leaf spring by modern and advanced fibre for composite spring material, the objective of research was to replace conventional steel material for leaf spring by using material glass fibre reinforced plastic. A spring with predefined and standard parameters were considered for design of composite leaves, and analysis was performed accordingly. In this study, models were designed for factor of safety around 2.5. Deflection and Stresses results were verified with analytical results from FEM. It was observed that the new derived composite spring has much less stresses as compared with the conventional steel leaf spring and weight of new modelled composite spring was drastically reduced.

[Sagar Manchanda] [2] Automotive leaf spring is the main load carrier and energy absorbing component in automotive vehicle. This also acts as a structural member for a vehicle. Keeping all these constrains in consideration, light weight along with high strength material should be used for leaf spring material selection. Composite material would help to reduce weight and improve fuel consumption without compromising the safety of the vehicle. Modification in the existing leaf spring design and material selection should be examined at every stage of the analysis depending upon the simulation results for the safe design. In the present study, leaf spring designed using design software and analysed using a finite element method, with different material (steel and composite) properties. Results of shear stress, shear strain, deformation and weight obtained from software has been taken into consideration.

[Suhas V. Gaikwad] [3] Design and analysis of composite leaf spring for light automotive vehicle was carried out using composite materials because of their mechanical properties like stiffness which is better than present traditional materials. For design parameters, a leaf spring used in TATA^{R} ACE^{TM} was collected and input was given to CATIA for creating the part geometry, it was then exported to ANSYS for Finite Element Analysis for analytical and numerical calculations. Mould were also made to fabricate composite leaf spring first by preparing mould, then the fibre cutting was performed according to measurement provided. Epoxy was prepared using Epolon5015 resin and hardener was used. Conventional leaf spring weight was 15 kg, but after fabrication of composite leaf spring using Glass Epoxy, weight was reduced to 3.13 kg, which is approx. 80% weight reduction, which is very much beneficial for fabrication of composite leaf spring.

[Subhash Khamkar] [4] There are single leaf springs and multi leaf spring used based on the application according to automotive requirement. Composites have good mechanical properties in terms of composite leaf spring material. The use of thermoset in the matrix gives the mould the ability to modify, enhance the materials physical property of the resin by blending new kind of additives, depending on the nature of its uses and applications. After experiment, overall weight of composite leaf spring (mono) got reduced by 68% for fibre glass epoxy over conventional steel leaf spring material. The percentage stiffness deterioration of conventional (steel) leaf spring was found to be higher when compared to the new fabricated composite leaf spring. This shows that the ability of steel material to resist the deformation is lower than the composite material.

[E. Janarthan] [5] Objective was to estimate the deflection, stress and mode frequency induced in a leaf spring. This project was carried out on the experimental and computer aided analysis using finite element concept. CAD model was completed using Pro-E and the Finite Element Analysis was performed in ANSYS. Standard properties of materials were chosen for Fibre Glass-Epoxy, Three different parameters were chosen in terms of ratio of epoxy (matrix) to fibre (reinforcement). Hand layup process was chosen to fabricate three material models. A spring having predefined thickness and default parameters, which was very easy, simple and economical. Testing were performed and specimen dimensions were kept according to ASTM D standard. The flexural and tensile test was performed using the UTM (Universal Testing Machine) for different specimens. Hardness test was tested by Rockwell L-Scale. Load vs. Displacement graph and Tensile Stress vs. Displacement were achieved, Results were better for E glass 60% and 40% epoxy.

[Atul J. Pawar] [6] Design of mono leaf spring was modelled on CATIA and analysis was performed in ANSYS. Hand layup technique was used to fabricate Glass Epoxy leaf spring. Actual weight of leaf spring found to be 3500gm, E-glass/ Epoxy was found to be 2500gm, and carbon epoxy was found to be 1600gm, wait was drastically reduced. Deformation was found to be maximum in steel and less for carbon fibre. Results from static analysis was observed that the maximum displacement was found to be 288 mm for steel leaf spring, displacements observed in Fibre glass Epoxy, and for carbon fibre-Epoxy, it was 111 mm and 50 mm respectively. From the static analysis, it was observed that the von-mises stress for the steel material were 2684MPa, von-mises stress for Fibre Glass-Epoxy is 1545Mpa, for Carbon/epoxy's 813MPa. It was observed that no leaf spring has higher stress values when compared to the conventional steel leaf spring.

[Y. N. V. Santhosh Kumar] [7] Composite material for conventional metallic structures has many advantages due to their high specific stiffness and strength. This performed work involves with replacing of conventional steel leaf spring by a new composite material by using carbon fibre or glass fibre. The design parameters and values selected and analysed with the objective of weight minimization of the new designed composite leaf spring as compared to the conventional steel leaf spring material. The leaf spring (basic design) was modelled in CATIA (CAD) software and the calculations, analysis was performed using ANSYS. It was observed that the stiffness of the composite material was almost similar to that of steel, weight of new fabricated composite leaf spring was found to be 40% (approx.) when compared to conventional material.

[Prof. N.D. Patil] [8] Under this paper, weight reduction was achieved using composite material, Carbon Epoxy composite material was selected for manufacturing a mono composite leaf spring. CAD model was done using 3D commands in CATIA. Properties and parameters for composite leaf spring was also tested for validation in Finite Element Analysis ANSYS software. Boundary conditions were applied to the designed model, this research was done in order to perform different loading parameters like stress analysis, von-mises stress calculations and weight reduction. Composite material was selected because it has high strength to weight ratio. Result showed that weight of composite material was 80% lesser than conventional leaf spring material. Difference of stress level was 9% in both springs of steel and Carbon fibre.

[Ghodake A.P] [9] Material for this research was chosen as glass fibre reinforced plastic (GFRP) and the polyester resin named NETPOL1011 was used for composite leaf spring. A spring with was fabricated by hand lay-up technique without varying its dimensions by simple, easy and economical procedures. Numerical and mathematical calculation and analysis was carried using finite element analysis method using ANSYS. Results in terms of deflection, stresses, and strain energy for both steel as well as composite leaf spring material were calculated. Result reflected that, composite leaf spring has the maximum strain energy as compared to conventional steel leaf spring, weight of composite leaf spring was reduced up to 85% when compared with steel material.

[Y.Phaneendra] [10] Research consists of design and analysis was performed on leaf spring for heavy duty purpose. CAD model was completed using Pro-E and the Finite Element Analysis was performed in ANSYS, for comparison conventional leaf spring material was compared with E-glass Epoxy. Different constraints and parameters were applied for analysis. After analysis it was found that total deformation and stress was comparably less as compared to 60Si7 steel used in conventional leaf springs. After using E-glass/ Epoxy, overall weight was reduced by 68%.So the parameters and results can be used by them in automotive division to manufacture composite leaf springs due to their properties and advantages mentioned in the report. So, it was observed that the properties were better when compared to existing conventional material.

[Prof. M. C. Swami] [11] Innovation, research and increasing competition in automobile sector led to modify existing components, products by using new, smart, advanced and improved materials. Conservation of resources and environmental effect is an important issue for cost reduction. Leaf springs are globally accepted suspension systems that are still used in all kind of automobiles. Weight reduction considered as the main objective and of greater importance for vehicle manufacturers. It was observed that Composite materials significantly helps to reduce weight of the fabricated leaf spring without compromising its mechanical properties like decrease in load carrying capacity, while maintaining its stiffness. This paper consisted of standard design parameters considered for leaf spring design, material properties, analytical calculations were made by considering a specific design problem, Finite Element Method (FEM) or FEA was carried out having input parameters as same for analytical conditions with design constraint, fixed support and cylindrical support were applied and boundary conditions were applied, deformation and stiffness was analysed for composite leaf spring having various thickness, analytical and FEA results were compared for finding stress to deflection ratios.

[M. Venkatesan] [12] Design parameter, data's, and reference parameter from TATA^{R} SUMO^{TM} leaf spring was considered. Finite Element Analysis was performed to find different parameters like stress, deformation, mode frequencies for different materials. The composite material specimen was fabricated in three different modes by mixing resins at different ratios with composites and specimen was tested for tensile, flexural and bending test. Results showed that 40% of epoxy and 60% of glass fibre was optimum for composite leaf spring manufacturing and application. Load vs. deflection and load vs. stress was analysed for both materials. Analytical and FEA results were compared accordingly for experiments performed

[Syambabu Nutalapati] [13] Reducing weight of the vehicle or leaf spring while maintaining strength of components or products is the main important parameter in research issue in this current era. Researchers are aiming to develop efficient products and components using composite materials. Their objective was to compare overall weight reduction, stresses, deformation for composite leaf spring instead of conventional leaf spring (steel). The design constraint was provided as input in terms of stiffness, the material selected was glass fibre epoxy reinforced polymer was selected against conventional material. It was found that the Composite leaf spring (mono) reduced the overall weight by 84% nearly for glass fibres. The design parameters, dimensions were selected according to requirement and analysed with the objective of weight minimization, when compared to composite leaf spring to the conventional steel leaf spring. From the analysis, the results obtained that the von- mises stress for steel was 353 MPa and for E-glass/Epoxy was 178 MPa respectively. Use of composite material for leaf spring reduces the overall weight of leaf spring by 84% for glass fibre epoxy.

[Sagar Manchanda] [14] Automotive leaf spring is the main load carrier and energy absorbing component in automotive vehicle. This also acts as a structural member for a vehicle. Keeping all these constrains in consideration, light weight along with high strength material should be used for leaf spring material selection. Composite material would help to reduce weight and improve fuel consumption without compromising the safety of the vehicle. Modification in the existing leaf spring design and material selection should be examined at every stage of the analysis depending upon the simulation results for the safe design. In the present study, leaf spring designed using design software and analysed using a finite element method, with different material (steel and composite) properties. Results of shear stress, shear strain, deformation and weight obtained from software has been taken into consideration.

[S. Rajesh] [15] Experimental analysis performed using composite materials and hand lay-up technique is used to prepare composite leaf spring, reinforcement for each cases and epoxy (resin & hardener) kept same. After curing of the specimen it is subjected to various loading cycles. Deflection is observed at different loading cycles, weight optimization was achieved and maximum load carrying was set for cyclic loading, load vs. deflection curve obtained after experiment, it was observed that 62.5 % of load carried using composite materials while weight was reduced by 71%, it was also calculated for load bearing strength, it was observed that composite leaf spring can bear more weight as compared to conventional materials.

[Ganesh.K] [16] Weight reduction was the focus of automobile industries & manufactures now a days. This work is performed on multi-leaf spring used in commercial vehicles. Mathematical calculations are carried out for design the multi-leaf spring. The materials of the leaf springs were chosen (SAE 9260) and fibre glass epoxy to be taken for analysis and comparison. A Finite element method was chosen for analysis with provided boundary conditions, for a multi leaf springs analysis in ANSYS Workbench software (Static Structural). The leaf spring model is designed by CAD (Pro/E) and geometry was imported in FEA software (ANSYS) with constraint and parameters, as a result a mass reduction was obtained around 22 kilograms, which showed that glass fibre epoxy can be used for fibre glass fabrication.

CHAPTER 5

EQUIPMENT, MATERIALS, AND EXPERIMENTAL SETUP

5.1 Equipment Required:

This work involves various kinds of equipment's and machines required for fabrication, for testing purpose we have used Universal Testing Machine (UTM), for Tensile and Flexural test.

Fig. 5.1. Universal Testing Machine for composite

5.2 Materials Required:

To develop and fabricate composite leaf spring, various kinds of materials required. Raw materials are divided into various categories.

Reinforcement Material: Carbon fibre fabric, glass fibre fabric and Random glass fibre fabric, shown below.

Fig. 5.2 Carbon Fibre Fabric (Unidirectional)

Fig. 5.3 Fibre Glass Fabric (Bidirectional)

Matrix Material: Epoxy Resin was used as matrix material, we have used epoxy by ARALDITE^{R} Epoxy (AW-106) and Hardener (HV953-IN). This is also known as two component epoxy adhesive.

Key properties of this epoxy material are as follows:

- High sheer and high peel strength.
- Epoxy is Tough and Resiliant.
- It has good resistance in terms of dynamic loading.
- It can bond with wide variety of materials available to common use.

Epoxy compound has two parts, resin is transparent in colour and hardener is pale yellow in colour. Both the compounds are mixed in a specific ratio so as to get maximum strength having optimal curing time.

Fig. 5.4 Epoxy (Resin & Hardener)

Other materials that were used are roller brushes, a pair of scissors, loves, goggles, acetone or white spirit, ice-cream sticks, trace or oil paper, adhesive tapes, etc.

Fig. 5.5 Other Materials (A pair of gloves, scissors)

5.6 Mould and Epoxy for Specimen Preparation

5.3 Experimental Setup: Fabricated leaf spring will be tested in UTM for finding mechanical properties

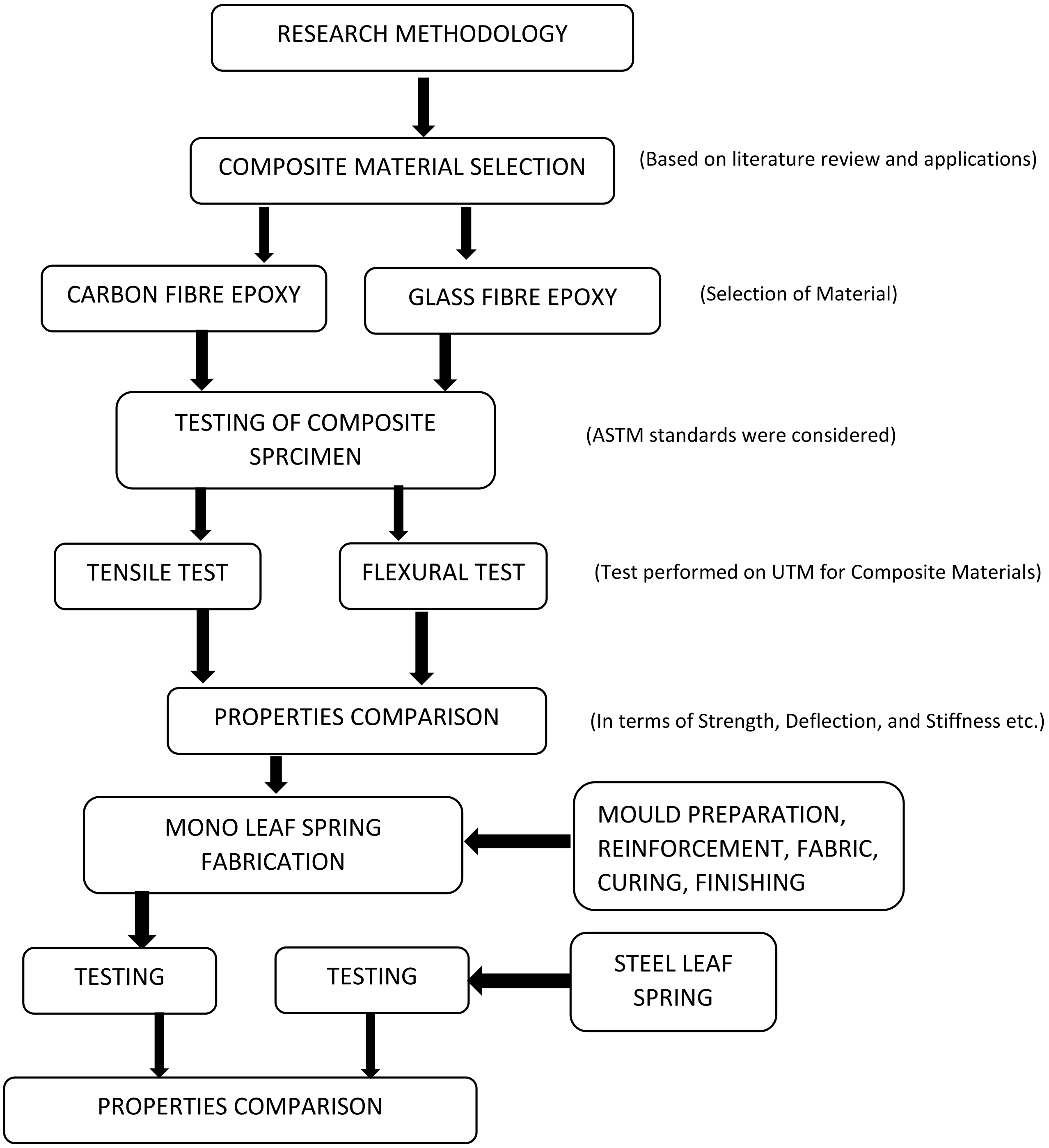
Fig. 5.7 UTM for Testing

CHAPTER 6

RESEARCH METHODOLOGY

Our objective is to develop a composite leaf spring but we need to perform tests and identify its mechanical properties.

Flowchart 6.1 Research Methodology

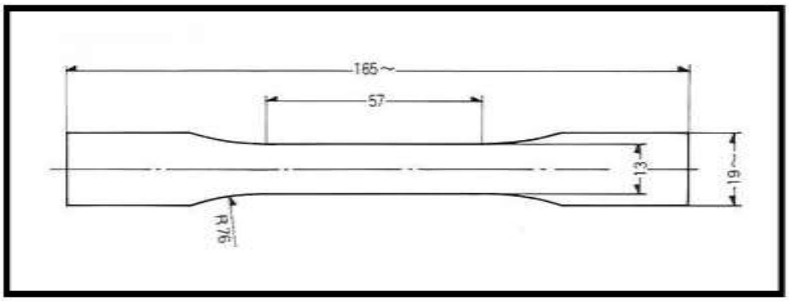


Testing of composite material include various standards that are being used worldwide and standard dimensions and procedures. Tests are performed are as follows:

6.1 Tensile Test for composite Material:

Tensile test performed using Universal testing Machine (UTM) for composite materials. Specimen is prepared using ASTM D638 Type-1 Tensile Bar.

Standard Specimen Dimensions: Type-I Tensile bar (Dumbbell Shape or I-shaped) having overall length is 165 mm, gauge length is 57mm and the thickness of the specimen is 3 mm, figure given below.



ASTM D638 TYPE-I TENSILE BAR

Fig. 6.2. ASTM D638 Type-I Tensile Bar

A die is prepared for preparing testing test specimen using mild steel plate shown below.

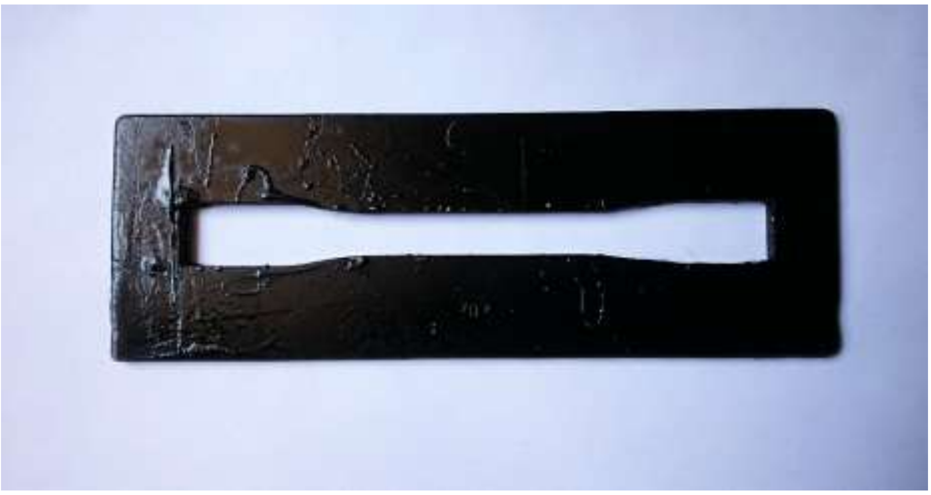


Fig. 6.3. Mild steel die for specimen preparation

Epoxy Material: We have used Araldite Epoxy AW106 & Hardener HV953-IN as matrix material, epoxy provides the strength and binds the reinforcement while with epoxy some amount of hardener is used to harden and cure the matrix material.

Fig. 6.4. Epoxy (Resin and Hardener)

Specimen Preparation:

FIBRE GLASS-EPOXY: Specimen was prepared using die and matrix material was chosen as Epoxy, reinforcement was chosen as random glass fibre, unidirectional glass fibre, bidirectional glass fibre, unidirectional carbon fibre. After preparation, ASTM-D 638, Type-I tensile bar specimen, Overall length of 165 mm, having thickness 3 mm, gauge length of 57 mm. First epoxy was uniformly distributed in the die, then layer wise fibre glass reinforcement was placed with the matrix (epoxy) material, in the figure shown below.

Fig. 6.5. (Unidirectional) Fibre Glass Epoxy Specimen (ASTM D638 TYPE-I Tensile Bar)

CARBON FIBRE-EPOXY: Specimen is prepared using carbon fibre fabric and epoxy, having length of 165 mm, thickness of 3mm, ASTM D638 type-I tensile bar, dumbbell shaped.

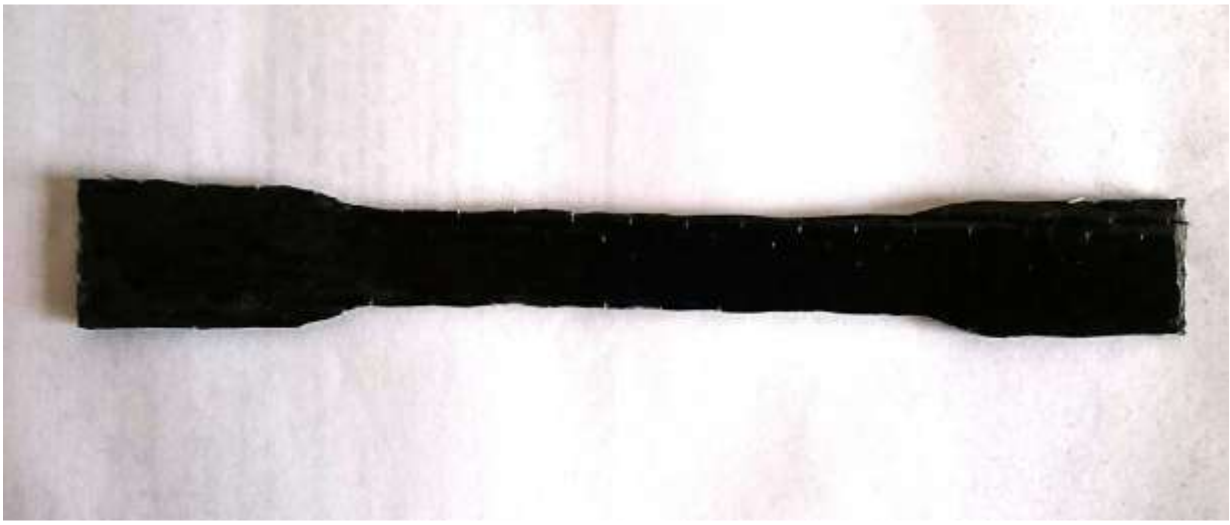


Fig.6.6 (Unidirectional) Carbon fibre-Epoxy Specimen (ASTM D638 TYPE-I Tensile Bar)

CARBON-GLASS FIBRE EPOXY SPECIMEN: ASTM-D 638 Type-I, both carbon fibre as well as fibre glass used to prepare the specimen along with epoxy as matrix material, figure shown below. A layer of carbon fibre along with a layer of fibre glass is used for layering, then epoxy is applied to the die cavity along with reinforcement. It is allowed to cure, then it is pulled out from die and edges and sharp corners were eliminated using sand paper.

Fig. 6.7 Unidirectional carbon-glass fibre epoxy specimen (ASTM D638 TYPE-I Tensile Bar)

RANDOM FIBRE GLASS SPECIMEN: Tensile bar of Type-I ASTM-D 638 for random glass fibre (fibre mat) is used to prepare specimen, fibre sheet is cut according to standard dimensions

Fig. 6.8. (RANDOM) Fibre glass epoxy specimen (ASTM D638 TYPE-I Tensile Bar)

From Tensile test, various parameters and properties can be achieved.

Tensile Strength (**σ**) = Load Applied (**P**) / Cross-sectional area of the material (**A**).

Young's Modulus (E) = Stress (**σ**) / Strain (ϵ), where ϵ *denotes strain,*

Where ϵ *= Change in Length (l) / Original Length (δl).*

Stress vs. Strain Relationship: It can be obtained from graph, generated after performing tensile test in the Universal Testing Machine (UTM).

Load vs. Deflection Curve: This curve shows us the relationship between applied load and deformation/deflection. Other parameters like Percentage Elongation, Overall elongation, true stress, engineering stress, and strain at different loading conditions can be obtained from tensile test. Universal Testing Machine (UTM) is used for testing composite specimens. Specimen is mounted into clamping jaws, first loading parameters are set according to ASTM standards.

Fig. 6.9. Universal Testing Machine (UTM) for composite materials.

6.2 Flexural Test for Composite Material:

Flexural test also called bending test, we have followed 3-point flexural test having support at 2 ends and load (P) is applied from top to the mid-section of the test specimen. Generally specimen is loaded at Universal testing Machine (UTM) for composite materials. For testing specimen is loaded into the support span and load is applied according to the specified procedure. Specimen is prepared using ASTM D7264 standard for testing flexural properties having rectangular cross section.

Specimen Dimensions: Specimen is prepared using ASTM D7264 standard, having overall width of 13 mm, specimen thickness of 4 mm, and length of the specimen should be 20% (or more) than the support span. Images of the prepared specimens shown below.

Fig. 6.10. Fibre Glass Epoxy (Unidirectional) Flexural Test Specimen ASTM D-7264

Fig. 6.11. Carbon Fibre Epoxy (Unidirectional) Flexural Test Specimen ASTM D-7264

From Flexural test, following results and properties can be obtained:

Flexural Strength (σ_f): It can be calculated by $\sigma_f = (3xPxL) / (2xbxh^2)$

Where, P= Load Applied, L = Length of the span, b = width of the span, h = thickness of the span.

Bending Stiffness: It is defined as the load applied per unit deflection, it is denoted by (K) = P/ w, Where P = Load applied and w = deflection.

Other parameters and values can be obtained like Maximum Flexural Stress, Stress at Strain.

Universal Testing Machine (UTM) for FLEXURAL TEST:

We have used 3-point flexural test in which specimen is mounted into support span and load is applied from upper loading head.

Fig. 6.12. UTM for composite material

Fig. 6.13. 3-Point flexural test support span

6.3 Development of Composite Leaf Spring:

We will fabricate a mono composite leaf spring using carbon fibre epoxy compound, having unidirectional fibre orientation, we have tested composite materials and it was found that unidirectional fabric have higher tensile and flexural strength.

We have considered a standard leaf spring used in light automotive vehicle, dimensions provided below.

Material Model / Type:

Length of the Leaf Spring (2L): 1000 mm, where L = 500mm

Width of the Leaf Spring (W): 50 mm

Thickness of spring (t): 7mm mm

We have prepared a composite leaf spring, having identical dimensions, we have prepared a mould, having identical radius of curvature. We have chosen a wooden plywood box for fabrication. Dimensions were taken from standard conventional leaf spring.

Fig. 6.14. Prepared mould for composite leaf spring.

Fig. 6.15. Curing of Composite Mono Leaf Spring

Fig. 6.16 Carbon Fibre Epoxy Mono-Leaf Spring

Fig. 6.17 Glass Fibre Epoxy Mono-Leaf Spring

6.4 Testing of Mono-Composite Leaf Spring

Leaf spring was tested in UTM and compression load was applied, and it was tested for deflection. Testing were performed for both carbon fibre as well as glass fibre epoxy mono leaf spring. We will mount the leaf spring in a channel beam for support and load will be applied in the mid span.

Load vs. Deflection was obtained from testing of leaf spring made of different leaf springs.

Images shown below are the test performed under UTM for finding various properties

Fig. 6.18 UTM for leaf spring testing

Fig. 6.19 Carbon Fibre Epoxy Mono leaf spring under UTM for testing

CHAPTER 7

PROPOSED WORK PLAN WITH TIMELINES

This work includes distribution of time in a sequential manner, we have studied about various kind of composite materials and fabrication of composite materials.

Month 1: January 2017	We have studied about composite materials and their properties regarding to strength, loading and performance. We have reviewed other research papers related to leaf spring, composite materials, and fabrication of composite leaf spring. We have studied about various other materials required for preparing composite specimen, various kind of epoxy materials for our work purpose.
Month 2: February 2017	We have acquired various raw materials for preparing specimen for Tensile as well as for Flexural Test. We have prepared specimens according to ASTM standards. We have prepared moulds for preparing specimens. We have used Glass fibre and Carbon fibre for specimen preparation. Each specimen took around 2 days for curing, it also depends on epoxy to hardener ratio.
Month 3: March 2017:	We have started to test different specimens that had been prepared previous month, some specimen failed due to clamping and fabrication defects, so some were eliminated and best specimen were chosen and tested under Universal Testing Machine. We have also prepared composite leaf spring according to standard dimensions form a leaf spring present in market for automotive vehicles.
Month 4: April 2017:	We have tested fabricated leaf spring for defects and fabrication errors, other modifications were done and literature review was done for knowledge and informational purposes. We have tested under UTM for load vs. deflection for composite leaf spring and to compare with conventional leaf spring. After obtaining readings and results we have competed our result with other published papers for comparison and validation. We have prepared graphs and tables for report and dissertation work purpose, we have review for missing parameters and errors, then it was rectified accordingly.

CHAPTER 8

EXPERIMENTAL WORK

Experimental work has been divided into various phases according to applied research methodology. We have prepared our test specimens for tensile and flexural test. Below the images of the die and specimen are shown accordingly.

8.1 Assumptions Considered:

The specimen prepared has uniform composition of fabric (carbon fibre/ glass fibre) as well as the matrix material (epoxy resin).

The matrix materials was distributed in the specimen.

The dimensions for the specimen were considered accurate and according to the ASTM Standards.

Curing process was constant for all specimen.

During testing, the experimental errors were maintained at minimum levels.

For all specimens, the fabric to epoxy ratio were kept constant.

During fabrication of composite leaf spring, the fabric direction as well as epoxy layering were considered to be uniform.

Some errors like air pockets and voids were neglected, as hand lay-up was chosen.

During testing of composite leaf spring, the loading provided at mid-span and at end reaction support was provided.

Composite Leaf Spring was considered to have minimum dimensional errors.

8.2 Die Preparation:

Fig. 8.1 Die for Tensile Testing (ASTM D 638 type I Tensile Bar)

PREPARED SPECIMEN: SET 1 (Tensile Test)

Fig. 8.2 ASTM D 638 type I Tensile Bar Specimen for Fibre Glass

PREPARED SPECIMEN: SET 2 (Tensile Test)

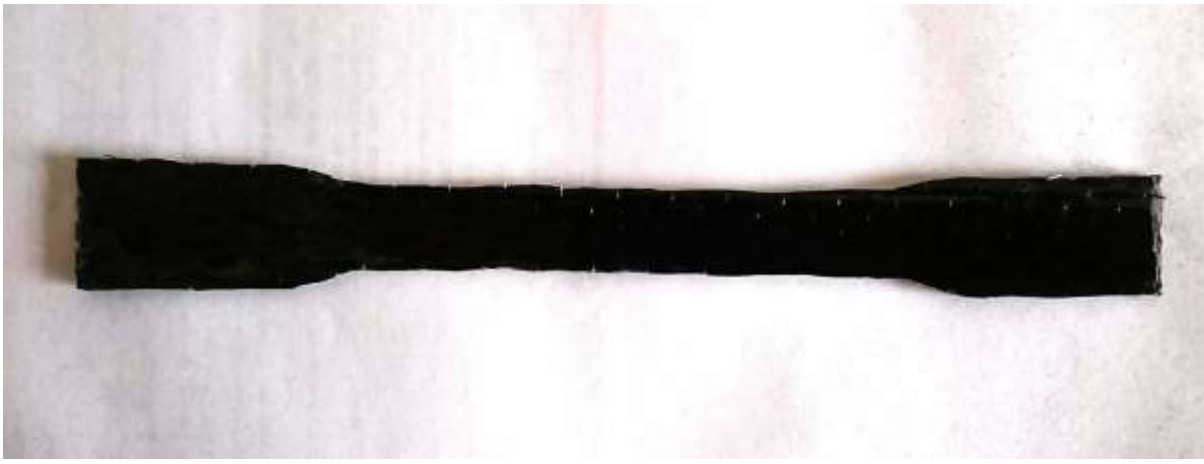


Fig. 8.3 ASTM D 638 type I Tensile Bar Specimen for carbon fibre epoxy

Fig. 8.4 ASTM D 638 type I Tensile Bar Specimen for carbon-glass fibre epoxy

PREPARED SPECIMEN: SET 3 (Flexural Test)

Fig. 8.5. Flexural Test Specimen

8.3 Testing of Composite Materials: Testing of materials performed by Universal Testing Machine for composite materials. Both Tensile and Flexural Test were performed on specimens, shown in the images shown below.

Fig. 8.6. Tensile Testing for composite materials.

Fig. 8.7. Flexural Testing for composite materials.

After testing results and readings were recorded and test specimens collected accordingly. Here the images of the specimens, after testing shown below.

Fig. 8.8. Tested Specimens (Tensile Testing)

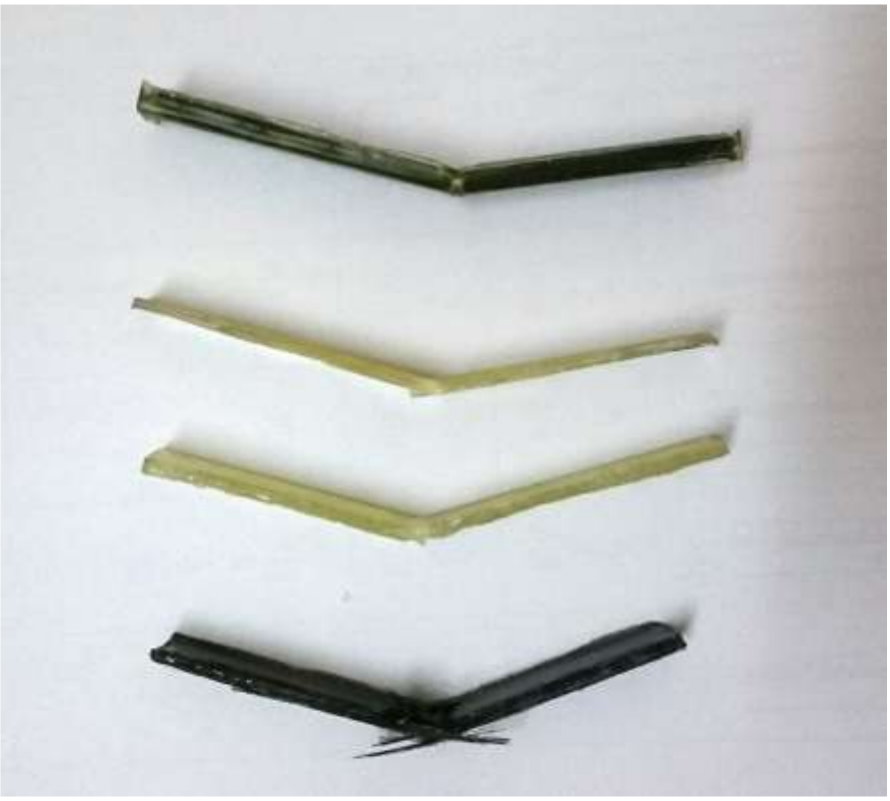


Fig. 8.9. Tested Specimens (Flexural Testing)

8.4 Mould Making: Composite Leaf spring was fabricated using a mould and hand layup was used to prepare specimen. Epoxy was used along with fabric layers, it was then allowed to cure. Mould was prepared using ply wood and dimensions used by taking reference from conventional material.

Fig. 8.10. Mould for Composite Leaf Spring.

The image shown below represents the Hand-Layup method for fabricating Leaf Spring, for uniform distribution of epoxy, roller brush was used.

Fig. 8.11. Hand Lay-up Method (composite leaf spring)

8.5 Fabricated Composite Mono-Leaf Spring:

Fig. 8.12. Glass fibre Epoxy Leaf Spring

Fig. 8.13. Carbon fibre Epoxy Leaf Spring

Fig. 8.14. Universal testing Machine

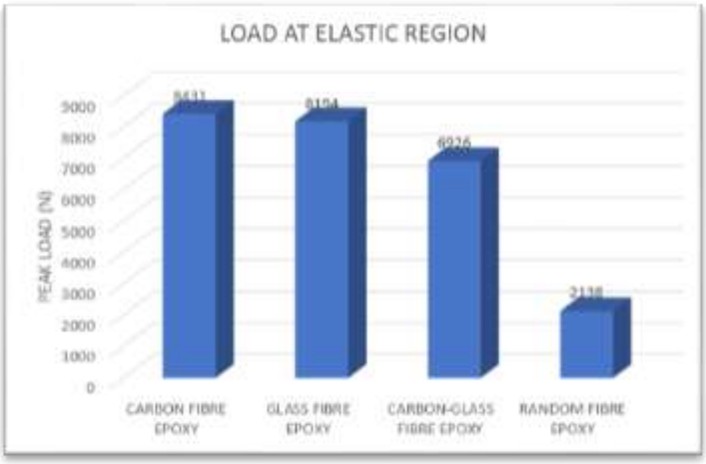
CHAPTER 9

RESULT AND DISCUSSION

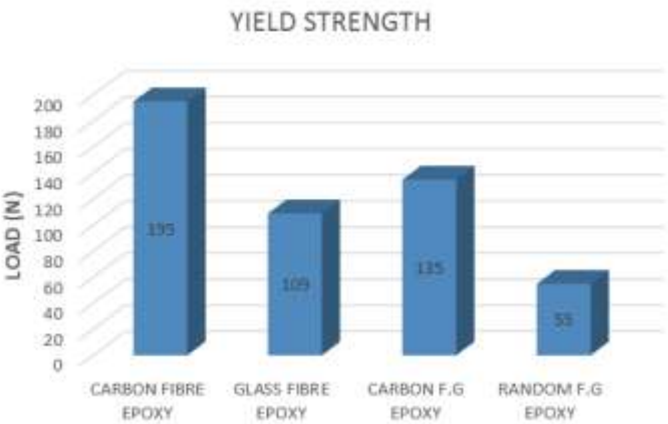
9.1 TENSILE TEST: We have performed Tensile Test, Flexural test in order to find various mechanical properties, in terms of tensile strength, bending strength, deflection. We have performed tensile test for ASTM D638 Type-I Tensile Bar.

Table 9.1. Results Obtained from Tensile Test

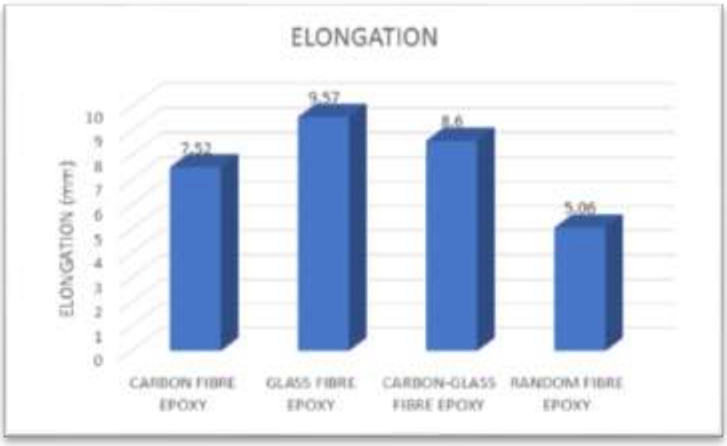
TENSILE TEST	MAX LOAD AT ELASTIC REGION	PEAK LOAD	YIELD STRENGTH	ELONGATION (PEAK LOAD)	BREAK LOAD
CARBON FIBRE EPOXY	8431 N	8819 N	195 MPa	8.32 mm	8819 N
GLASS FIBRE EPOXY	8194 N	8194 N	109 MPa	9.57 mm	2029 N
CARBON F.G EPOXY	6926 N	6926 N	135 MPa	8.6 mm	6916 N
RANDOM F.G EPOXY	2138 N	z2140 N	55 MPa	5.06 mm	2138 N



Graph. 9.1 Load achieved by composites at Elastic Region.



Graph. 9.2 Yield Strength of Composite Specimens



Graph 9.3 Elongation (mm) achieved by composite materials.

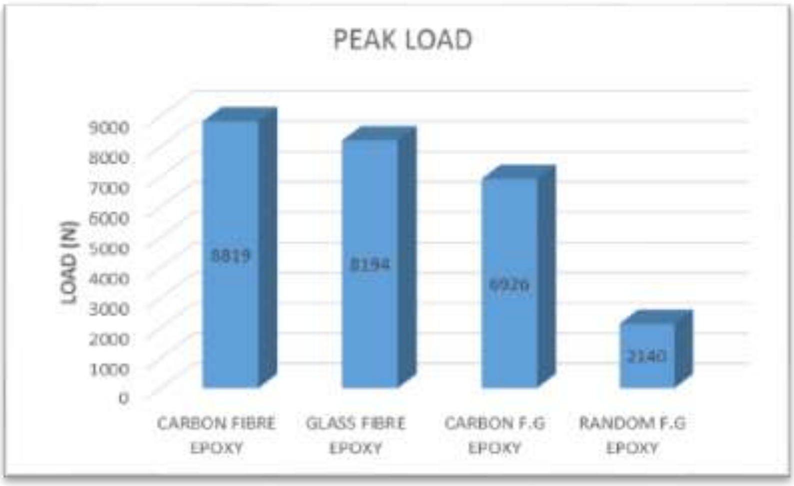


Fig. 9.4 Peak load achieved by specimens (Tensile Test)

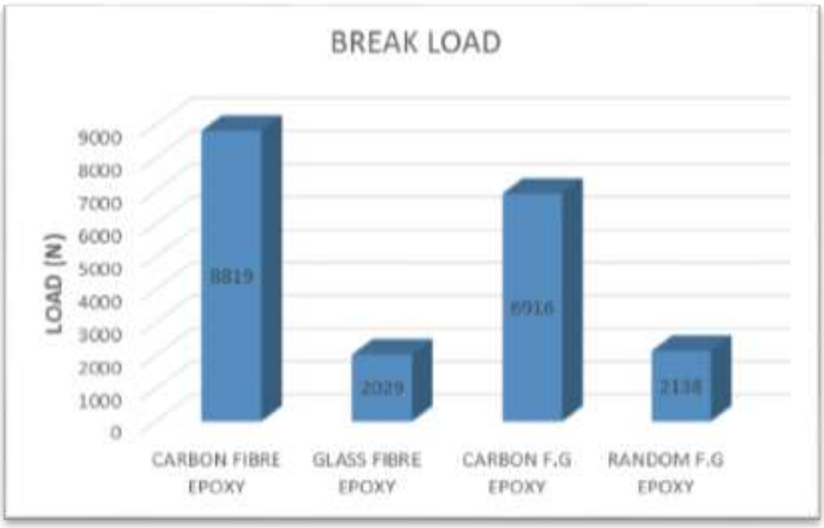
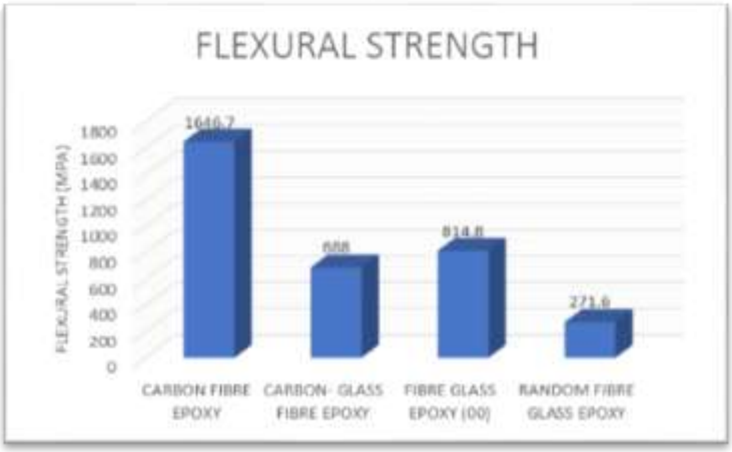


Fig. 9.5 Break load achieved by specimens (Tensile Test)

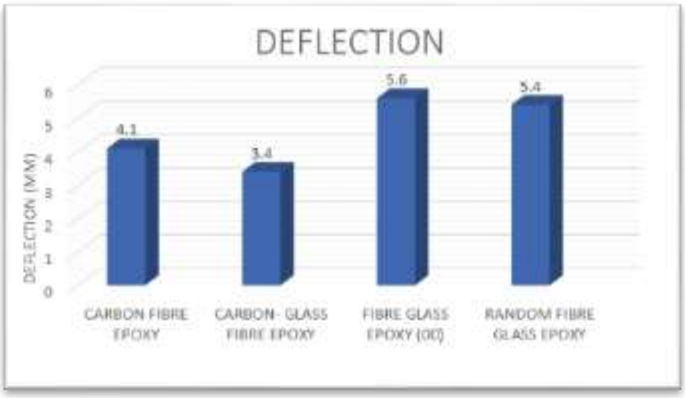
9.2 FLEXURAL TEST: specimen is prepared according to ASTM D-7264, in which specimen is a flat section having width 13 mm, standard specimen thickness is 4mm, and support span length 64mm, though specimen length is set to 120 mm. Results and values obtained shown below.



Graph 9.6 Flexural Strength for Composite Materials

Table 9.2. Results obtained from Flexural Test

FLEXURAL TEST	LOAD AT ELASTIC REGION	DEFLECTION	FLEXURAL STRENGTH	CROSS-S AREA
CARBON FIBRE EPOXY	892 N	4.2 mm	1646.7 MPa	55 mm^2
CARBON-GLASS FIBRE EPOXY	372.78 N	3.3 mm	688 MPa	55 mm^2
FIBRE GLASS EPOXY (0^0)	441.4 N	5.6 mm	814.8 MPa	55 mm^2
RANDOM FIBRE GLASS EPOXY	147.15 N	5.4 mm	271.6 MPa	55 mm^2



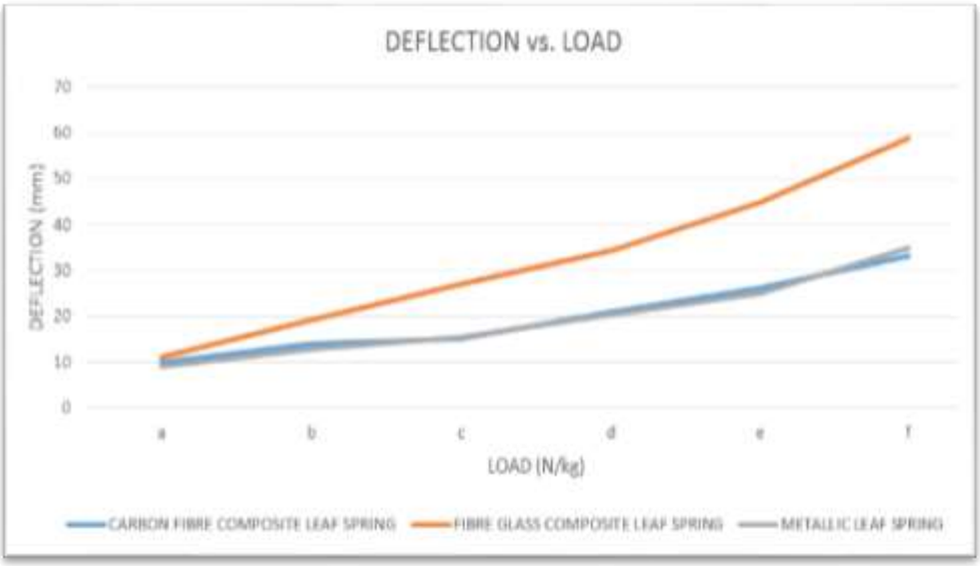
Graph 9.7 Deflection (Flexural Test)

9.3 Leaf Spring Testing for Load vs. Deflection:

Load vs. Deflection were performed in Universal Testing Machine, the mono-leaf spring was mounted in a mild-steel channel for support

Table 9.3. Results obtained from Mono-Leaf Spring Testing

EXPERIMENTAL DEFLECTION FOR LEAF SPRING (mm)			
LOAD APPLIED (kg/N)	CARBON FIBRE COMPOSITE LEAF SPRING	FIBRE GLASS COMPOSITE LEAF SPRING	METALLIC LEAF SPRING
50 kg (490 N)	10.0 mm	11.0 mm	9.0 mm
100 kg (98.1 N)	14.1 mm	19.3 mm	12.7 mm
150 kg (1471 N)	15.0 mm	27.0 mm	15.5 mm
200 kg (1962 N)	21.0 mm	34.3 mm	20.3 mm
250 kg (2453 N)	26.3 mm	45.0 mm	25.1 mm
300 kg (2943 N)	33.1 mm	59.0 mm	35.0 mm

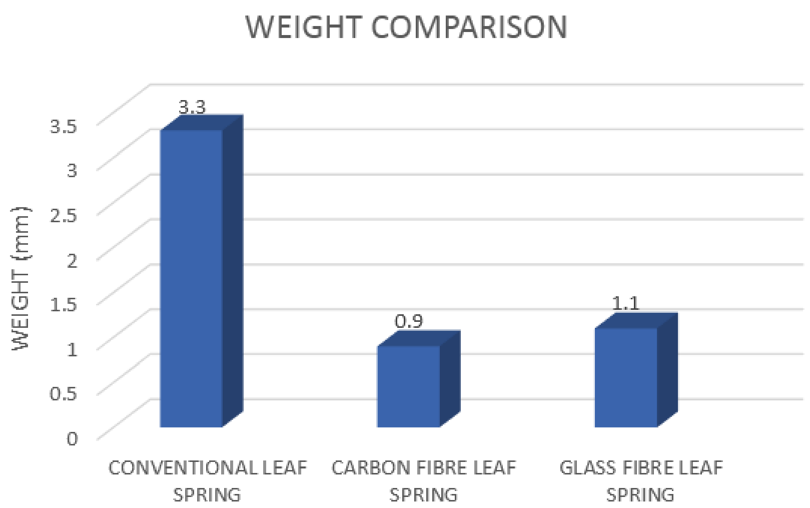


Graph. 9.8 Deflection vs. Load for different material

Weight were compared for fabricated mono-leaf spring with conventional steel material

9.4 Table for weight comparison for Leaf Spring:

TYPE OF LEAF SPRING	WEIGHT OF MONO - LEAF SPRING
CONVENTIONAL LEAF SPRING	3.3 kg
CARBON FIBRE LEAF SPRING	0.9 kg
GLASS FIBRE LEAF SPRING	1.1 kg

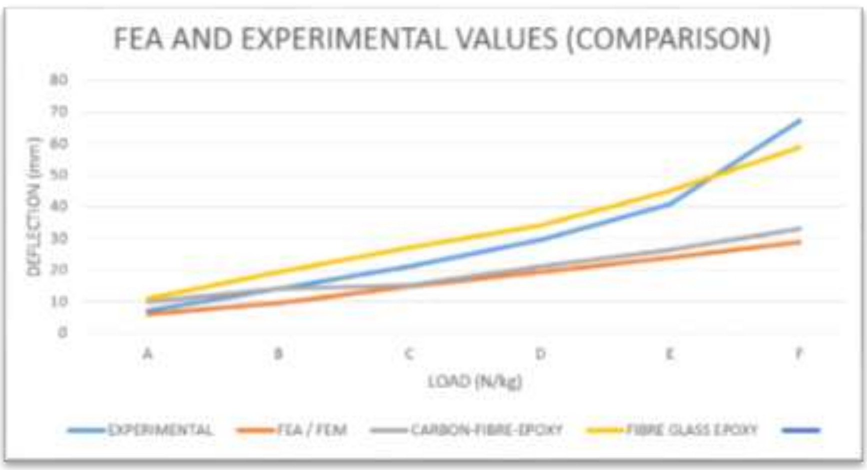


Graph 9.9 Overall Weight Comparison

9.4 Validation: For validation, experimental results were compared with FEA and analytical results, performed by other authors, references and publication having similar configurations and experimental procedures.

Table 9.5. Results obtained and comparison with reference for validation

VALIDATION FROM FEA AND REFERENCES				
LOAD APPLIED (kg/N)	CARBON FIBRE COMPOSITE LEAF SPRING	FIBRE GLASS COMPOSITE LEAF SPRING	EXPTL. VALUE	FEA (FIBRE GLASS EPOXY)
50 kg (490 N)	10.0 mm	11.0 mm	7.0 mm	6.0 mm
100 kg (98.1 N)	14.1 mm	19.3 mm	14.0 mm	9.60 mm
150 kg (1471 N)	15.0 mm	27.0 mm	21.0 mm	14.9 mm
200 kg (1962 N)	21.0 mm	34.3 mm	29.6 mm	19.20 mm
250 kg (2453 N)	26.3 mm	45.0 mm	41.0 mm	24.0 mm
300 kg (2943 N)	33.1 mm	59.0 mm	67.4 mm	28.80 mm



Graph 9.10 Result Validation from Reference Paper and Experimental Work

CHAPTER 10

SUMMARY AND CONCLUSIONS

Specimens were prepared and tested according to ASTM standards, flexural as well as tensile test were performed, results from tensile as well as flexural test for carbon fibre was found to be better when compared to glass fibre epoxy. After performing experiment it was observed that deflection for carbon-fibre epoxy mono-leaf spring was almost same as conventional steel leaf spring material. Deflection for fibre-glass epoxy mono-leaf spring was higher when compared to carbon-fibre epoxy mono-leaf spring.

Moreover it was observed that the deflection was more for composite leaf spring having the same thickness when compared to conventional material. Reference were taken from research paper. **[3][2016 Suhas V. Gaikwad],** earlier research performed on FEA and research on glass fibre epoxy that having high thickness, so experimental values from research performed, showed deflection was lesser for glass fibre epoxy. Due to higher thickness of glass fibre epoxy has less deflection, as we have learnt that deflection increases with decreasing thickness, leaf spring made of composite material having high thickness has less deflection,

It was observed that under same loading conditions, leaf spring made of carbon fibre epoxy can bear more lead when compared with fibre glass epoxy leaf spring material.

Moreover, weight of the leaf spring was drastically reduced, weight optimization by using glass fibre epoxy for leaf spring found to be 69.4%. Carbon fibre reduced the weight by 75%.

So, we can say that it is useful to manufacture leaf spring with carbon-fibre-epoxy composite material rather than fibre-glass-epoxy material.

REFERENCES

[1] "Design and Analysis of Leaf Spring with Different Arrangements of Composite Leaves with Steel Leaves" by Ajay B.K. (1), Mandar Gophane (1), P Baskar (2)"

SMBS, VIT University, Vellore, India. **(ISSN: 2231-5381)**

[2] "DESIGN AND FINITE ELEMENT ANALYSIS OF LEAF SPRING USING DIFFERENT MATERIAL PROPERTIES" by Sagar Manchanda, Beant Singh and Gurmeet Singh, **(JAIR) Volume 4, Issue 7 December 2015 ISSN: 2278-5213**

[3] "DESIGN AND ANALYSIS OF MONO COMPOSITE LEAF SPRING FOR LIGHT VEHICLE" by Suhas V. Gaikwad[1], Prof. V. J. Shinde[2]. **(Vol-2, Issue-7, 2016 ISSN: 2454-1362)**

[4] "DESIGN AND DURABILITY TESTING OF COMPOSITE MONO LEAF SPRING" by Subhash Khamkar, Prof. P.A. Narwade. Department of Mechanical Engineering, PDVVP College of Engineering, Ahmednagar, Maharashtra, India. **(ISSN: 2319-6890)** (Online), **2347-5013**(print) (**1 May 2016**), Email Id: khamkarsp@gmail.com

[5] "DESIGN AND EXPERIMENTAL ANALYSIS OF LEAF SPRING USING COMPOSITE MATERIALS" By E. Janarthan, M Venkatesan[2]**. (ISSN: 2278-0181 Vol. 2 Issue 12, December – 2013)**

[6] "WEIGHT OPTIMIZATION OF MONO LEAF SPRING USED FOR LIGHT PASSENGER VEHICLE" by Atul J. Parwar, Prof.S.N.Bansode. **(ISSN: 2321-8169)**, K.J. Somaiya College of Engineering, Vidyavihar, Mumbai, India,Email: sangeetabansode@yahoo.com

[7] "DESIGN AND ANALYSIS OF COMPOSITE LEAF SPRING" by Y. N. V. Santhosh K, M. Vimal Teja. Dept. of Mechanical Engineering, Nimra College of Engineering & Technology, Ibrahimpatnam, Vijayawada.

(IJMIE), ISSN No. 2231–6477, Vol-2, Issue-1, 2012, E-mail: santhosh.nagarjuna@gmail.com

[8] "ANALYSIS OF EPOXY CARBON COMPOSITE MATERIAL MONO LEAF SPRING", COMPARISION WITH STEEL LEAF SPRING Prof. N.D. Patil[1], Prof. V.P. Patil[2], Prof. S.P. Shinde[3], The International Centre Goa, Panjim, Goa (India) (9/10/2016) **(ISBN: 978-93-86171-09-2)**

[9] "ANALYSIS OF STEEL AND COMPOSITE LEAF SPRING FOR VEHICLE" Ghodake A. P.*, Patil K.N. Department of Mechanical Engineering, SND COE,RC Yeola, Nashik, India.

(E-ISSN: 2278-1684 Volume 5, Issue 4 (Jan. - Feb. 2013), PP 68-76)

[10] "ANALYSIS OF LEAF SPRING USING COMPOSITE MATERIAL" by Y.Phaneendra, Hari Sankar Vanka

[11] "DESIGN AND ANALYSIS OF MONO COMPOSITE LEAF SPRING BY VARYING THICKNESS USING FEA" Sagar B Mahajan[1], Prof.M.C.Swami[2], Permeshwar Patil[3], (Mechanical Engineering Department, G. N. D. Engineering College, Bidar, Karnataka, India), IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)

[12] "PERFORMANCE ANALYSIS OF COMPOSITE LEAF SPRING IN A DEFENCE SUMO VEHICLE" by M. VENKATESAN, V. C. SATHISH GANDHI

(Vol. 10, No. 5 (2015) 680 - 691)

[13] "DESIGN AND ANALYSIS OF LEAF SPRING BY USING COMPOSITE MATERIAL FOR LIGHT VEHICLES" by Syambabu Nutalapati, B. Tech (Mechanical Engineering), M.E (Machine Design) Andhra University, Andhra Pradesh, India. **Article ID: IJMET_06_12_005**

[14] "DESIGN AND FINITE ELEMENT ANALYSIS OF LEAF SPRING USING DIFFERENT MATERIAL PROPERTIES" by Sagar Manchanda, Beant Singh and Gurmeet Singh.

(JAIR) Volume 4, Issue 7 December 2015 ISSN: 2278-5213

[15] "MODELLING AND ANALYSIS OF A MOTORCYCLE WHEEL RIM"

S. Rajesh * and Sameer J Deshmukh

[16] "DESIGN AND ANALYSIS OF MULTI LEAF SPRINGS USING COMPOSITE MATERIALS" by Ganesh K, Gembiram.M, Elayaraja.R,

Vol. 2 Issue IV, April 2014 ISSN: 2321-9653