Mechanical Behavior of Orange Peel Reinforced Epoxy Composite

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENT FOR THE DEGREE OF

Bachelor of Technology

In

Mechanical Engineering

By

PRAVEEN KUMAR

(108ME066)

Department of Mechanical Engineering

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Under the Guidance of

Prof. S.K. Acharya

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CERTIFICATE

This is to certify that the thesis entitled, "**Mechanical Behavior of Orange Peel Reinforced Epoxy Composite"** submitted by Sri **Praveen Kumar** in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Mechanical Engineering at the **National Institute of Technology, Rourkela** (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in this thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Date:

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I feel pleased and privileged to fulfill our parents' ambition and I am greatly indebted to them for bearing the inconvenience during my M.E. course.

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CONTENTS

ABSTRACT

Over the last century, polymers have emerged as one of the most indispensible components used in everyday life, epoxy or poly-epoxide being one such example. Until recently, synthetic filler materials have been the preferred choice for reinforcement of epoxy to improve its toughness. However, natural filler and fiber materials are emerging as suitable alternatives to synthetic materials for reinforcing polymers such as epoxy due to their environment friendliness, high abundance, renewability, and cost effectiveness.

Several research efforts have been put to study the effectiveness of natural fiber based materials on the mechanical behaviour of epoxy composites, focusing mainly on fibers and their weight percent's within the composites.

The present experimental study aims at learning Mechanical behavior of orange peel reinforced epoxy composites. Composites having 5, 10, 20 and 30% weight fraction of orange peel were made using hand layup method. The fabricated composite samples were cut according to the ASTM standards for different experiments. Hardness test and density test were carried out at the samples. The maximum hardness, density, tensile, flexural and ILSS are getting for the material prepared with the 20 % reinforced orange peel epoxy composite.

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CHAPTER 1

INTRODUCTION

1.1 Overview of composites

When two or more material with different properties is combined together they form a composite material [1]. The constituents are combined in such a way that they keep their individual physical phases and are non soluble in each other or do not form a new chemical compound. That is why a composite is considered to be any multi phase material system that exhibits a combination of properties that makes the composite superior to each of the constituent phases. This criterion has provided the main motivation for the research and development of composite material worldwide. There are basically two category of constituent material, one constituent is called reinforcing phase and one in which the reinforcing phase is embedded is called matrix. The primary function of matrix is to hold the fiber to form a certain shape. Besides, the functions of the matrix are also to transfer stress between the reinforcing fibers and to protect them from mechanical and environmental damage. The function of reinforcing phase in matrix is to improve the mechanical properties such as strength, stiffness etc. As per Berghezan [2] the composite material is to be designed in such a way that the individual component retain their characteristic are so incorporated that the composite take advantage of their superior properties without compromising on the weakness of either. There are basically three major types of composite materials available designated as per the matrix material used. The matrix material can be metallic, polymeric or can even be ceramic. When the matrix is a polymer, the composite is called polymer matrix composite. Fiber reinforced polymer (FRP) composite are the most common advanced composites. These composites consist of a polymer matrix reinforced with thin diameter fibers. The reasons why they are the most common composite include low cost, high strength, and simple manufacturing processes. There are many polymer resin system used as matrices in FRP composites. They can be classified as thermo plastic (polyethylene, polypropylene, nylon etc) and thermoset (epoxies, polyesters, vinyl ester etc) polymer. Thermoplastic polymer can be repeatedly softened and formed by increasing the temperature or hardened by decreasing the temperature, while the thermoset polymers are insoluble and infusible after cure.

As far as reinforcement is concerned fibers occupy the largest weight fraction in a FRP composite and it share its major portion of the load that act on the composite structure. The reinforcing fibers can be oriented during fabrication there by giving ample opportunity to the designer to tailor down the properties in specific direction. The major fibers in use today are glass, carbon and aramid. Recently research on engineering interest have been shifting from traditional synthetic fiber composite to lignocellulosic natural fiber composite due to their advantages like high strength to weight ratio, non carcinogenic and biodegradability. The term natural fiber covers a broad range of vegetables, animal and mineral fibers. Availability of natural fibers and easy of manufacturing is tempting researcher to try locally available inexpensive natural fibers as reinforcement material in polymer matrix. The other advantages associated with natural fibers are non abrasive nature, low energy consumption, biodegradability, light weight and low cost. Careful selection of reinforcement type enables finished product characteristics to be tailored to almost any specific engineering requirement. Whilst the use of composites will be a clear choice in many instances, material selection in others will depend on factors such as working lifetime requirements, number of items to be produced (run length), complexity of product shape, possible savings in assembly costs and on the experience & skills the designer in tapping the optimum potential of composites. In some instances, best results may be achieved through the use of composites in conjunction with traditional materials.

1.2 Bio composite

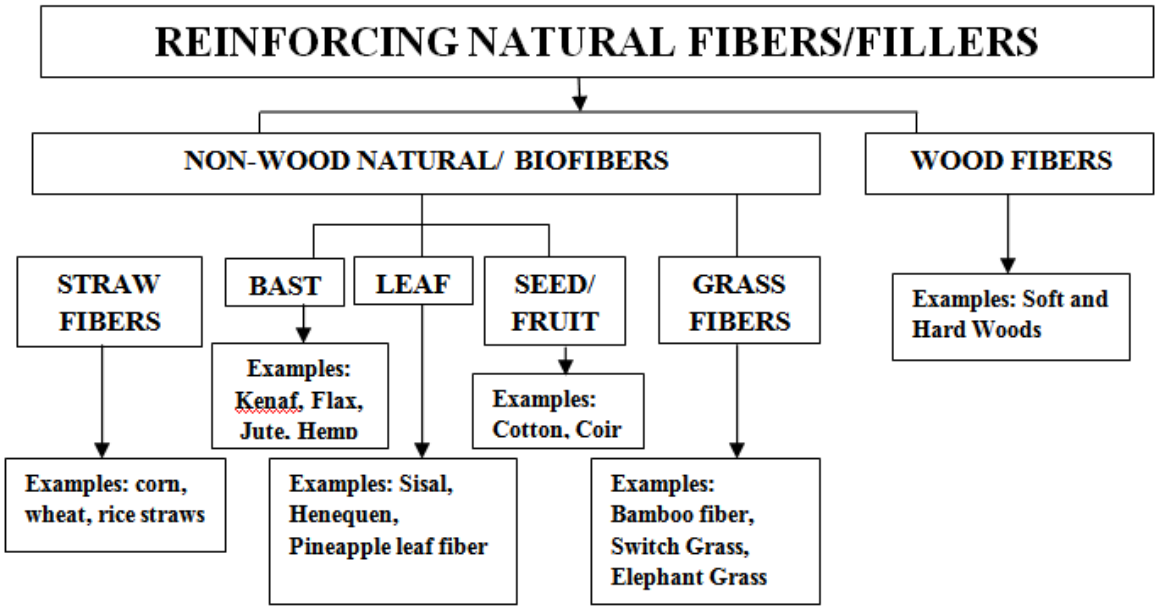
Bio composite is a material formed by a matrix and a reinforcement of a plant derived fiber. It is needed to develop novel bio based products and other innovative technologies that can reduce widespread dependence on fossil fuels. Eco-friendly bio composites from plant derived fiber and crop-derived plastics, make a great importance to the environment and is also a solution to the uncertainty of petroleum supply. Bio polymers are now moving mainstream use, and the polymers that are biodegradable or based on renewable feedstock may soon be competing with commodity plastics, as result of the sales growth of more than 20-30% per year and improvement in the economics of sales. The best examples of biopolymers based on renewable resources are: cellulosic plastics, polylactides (PLA), starch plastics and soy based plastics. Microbial synthesized biopolymers, i.e., polyhydroxy alkanoates (PHAs) polymers are also having attractive environment friendly properties. The use of materials from renewable resources is

being popular and the world's leading industries are looking forward to use more and more composite materials derived from natural fibers and bio-polymers in place of petrochemical-based feedstock.

1.3 Classification of Natural/Bio-fibers

Natural/bio-fibers can be broadly divided into two categories: non-wood fibers and wood fibers shown in the table 1.1. At present level of technology non wood fibers like hemp, kenaf, flax and sisal find commercial success in the design of bio-composites from polypropylene for automotive applications. Increase use of biopolymers would result in more eco-friendly bio-composites for twenty first century green automotive parts applications. All the natural reinforcing fibers are lingo-cellulosic, having cellulose and lignin as principle components.

Table 1.1 Classification of Natural fibers



1.4 Application of natural fiber composites

The natural fiber composites can be very cost effective material for following applications:

- Building and construction industry: panels for partition and false ceiling, partition boards, wall, floor, window and floor frames, roof tiles, mobile pre-fabricated buildings which can be used in times of natural calamities such as floods, cyclone, earthquakes etc.
- Storage devices: post boxes, grain storage silos, bio gas containers etc.

- Furniture: chair, table, shower, bath units etc.
- Electric devices: electrical appliances, pipes etc.
- Everyday applications: lampshades, suitcases, helmets etc.
- Transportation: automobile and railway coach interior, boat etc.
- Toys

The reason for the application of natural fiber composites in the automotive industry includes:

- Low density: which may lead to a weight reduction of 10 to 30%
- Acceptable mechanical properties, good acoustic properties.
- Favorable processing properties, for instance low wear on tools, etc.
- Options for new production technologies and materials.
- Favorable accident performance, high stability, less splintering.
- Favorable eco balance for part production.
- Favorable eco balance during vehicle operation due to weight savings.
- Occupational health benefits compared to glass fibers during production.
- No off-gassing of toxic compounds (in contrast to phenol resin bonded wood and recycled cotton fiber parts.)
- Reduce fogging behavior
- Price advantage both for the fibers and the applied technologies.

Composite materials due to their low density, excellent stiffness and good thermal and mechanical properties are particularly superior to many traditional materials such as metals. Recent developments on various applications of polymer composite are well documented in many literatures. Different types of polymer show different Mechanical and tribological behavior. However neat polymers is very rarely used as bearing materials and wear resistance material because unmodified polymer could not satisfy the demands arising from the situations wherein a combination of good mechanical and tribological properties is required [3]. Visualizing the importance of polymer composite reinforced with cellulosic fibers like sisal, coconut(coir), bamboo, banana in their natural form as well as several waste cellulosic products

such as shell flour, wood flour and pulp have been used as reinforcing agents of different thermosetting and thermoplastic composites.

However as per the information of the investigator there is no information available on the mechanical behavior of fruit waste. There is little work done by Abdul Khalil *et.al* [4] to characterize the epoxy composite filled with the bio-based fillers like bamboo stems, coconut shells and oil palm fiber bunches. Their results showed that there was improvement in thermal stability of the carbon black filled composite compared to the neat epoxy. Christian J.Espionze Santos [5] performed details characteristics studies on coconut fibers. He observed that increase in weight percent of fiber reinforcement increase the flexural strength of the composite. Keeping all these in view in the present work an attempt has been made to study the mechanical and flexural behavior of orange peel reinforced epoxy composite.

Thesis outline

The remainder of this thesis is organized as follows:

Chapter 2: Previous work relevant to the present investigations available in literatures is described in this chapter

Chapter 3: This chapter describes the details of materials required, fabrication techniques and Experimental investigation in to Mechanical properties of the composite.

Chapter 4: This chapter deals with the results and their interpretation.

Chapter 5: Recommendations for future work are presented in this chapter.

CHAPTER 2

Literature survey

2.1 Introduction

Literature survey is carried out to get the background information on the issues to be considered in the present research work and to focus the relevance of the present study. The purpose is also to present a thorough understanding of various aspects of bio polymer composite with special emphasis on their mechanical properties. In fiber reinforced polymer composites, the fibers can be either synthetic fibers or natural fibers. Natural fibers constituents are mainly of cellulose fibers, consisting of helically wound cellulose micro fibrils, bound together by an amorphous lignin matrix. Lignin keeps the water in fibers; acts as a protection against biological attack and as a stiffener to give stem its resistance against gravity forces and wind. Hemicellulose found in the natural fibers is believed to be a compatibilizer between cellulose and lignin [6].The use of lignocellulosic fibers as reinforcements for polymeric materials has been growing during the last decade or so to replace synthetic fibers, especially glass fibers in composites, for different industrial sectors, such as packaging, automobiles [7, 8] and even in the building sector [9]. This is mainly due to their unique characteristics, such as availability, biodegradability, low density, non-toxic nature, less abrasiveness to plastic processing equipment, useful mechanical properties and low cost [10]. The chemical composition of natural fibers may differ with the growing condition and test methods even for the same kind of fiber. The physical mechanical properties of natural fibers are greatly influenced by their chemical compositions.

Natural fibers in general can be classified based on their origin, and the plant-based fibers can be further categorized based on part of the plant they are recovered from. An overview of natural fibers is presented in Figure-2.1 [11].

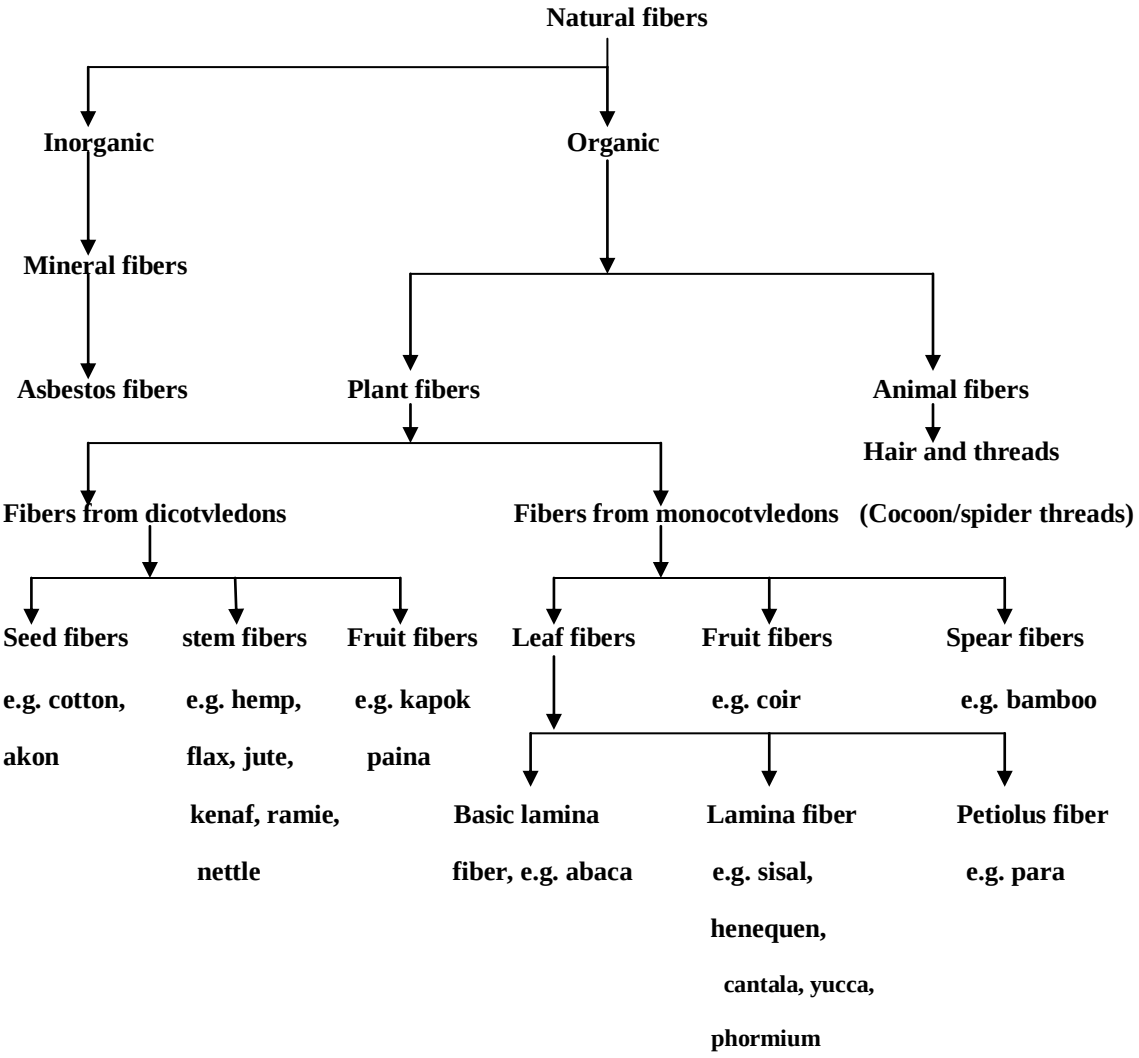


Figure 2.1 Overview of Natural fibers

Epoxy resins (ER) are one of the most important classes of thermosetting polymers which are widely used as matrices for fiber-reinforced composite materials and as structural adhesives [12–17]. They are amorphous, highly cross-linked polymers and this structure results in these materials possessing various desirable properties such as high tensile strength and modulus, uncomplicated processing, good thermal and chemical resistance, and dimensional stability [12]. However, it also leads to low toughness and poor crack resistance, which should be upgraded before they can be considered for many end-use applications [12-13]. One of the most successful methods of improving the toughness of epoxy resin is to incorporate a second phase of dispersed rubbery particles into the cross-linked polymer [18-20].

Luo and Netravali [24] studied the tensile and flexural properties of the green composites with different pineapple fiber content and compared with the virgin resin. Sisal fiber is fairly coarse and inflexible. It has good strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in seawater. Sisal ropes and twines are widely used for marine, agricultural, shipping, and general industrial use.

Belmeres et al. [25] found that sisal, henequen, and palm fiber have very similar physical, chemical, and tensile properties. Cazaurang et al. [26] carried out a systematic study on the properties of henequen fiber and pointed out that these fibers have mechanical properties that are suitable for reinforcing thermoplastic resins.

Ahmed et al. [27] carried out research work on filament wound cotton fiber reinforced for reinforcing high density polyethylene (HDPE) resin. Khalid et al. [28] also studied the use of cotton fiber reinforced epoxy composites along with glass fiber reinforced polymers. Fuad et al. [29] investigated the new type wood-based filler derived from oil palm wood flour (OPWF) for bio-based thermoplastics composites by thermo gravimetric analysis and the results are very promising.

Schneider and Karmaker [30] developed composites using jute and kenaf fiber and polypropylene resins and they reported that jute fiber provides better mechanical properties than kenaf fiber. During leaf defibration of heneque ´n fibres and also during the transformation of the raw fibers into cordage, approximately 10% of waste fibres are produced. These waste fibers could be profitably used in the manufacture of fiber polymer reinforced composites because they posses attractive physical and mechanical properties [31].

2.2 Summary of the previous work done

The literature survey above reveals the following facts:

Plenty of work has been done on a number of natural fibers combining with polymer matrices, resulting in improvement in mechanical properties of the composites compared with the matrix material.

The major disadvantage of natural fiber reinforced composites is their property to absorb moisture. Accordingly number of researches has been done to understand and improve this quality of natural fiber reinforced composites.

Various studies have been done to understand the mechanical properties of different fibers reinforced composites. However orange peel reinforced composite mechanical properties studies have not been done so far.

2.3 Objectives of the Present Work

The objectives of the present work are:

- To prepare the orange peel particulates of desired particle size.
- To fabricate the particulate with different weight percentage in the epoxy matrix.
- To study the density of different samples.
- To check the micro-hardness of different samples.
- To perform the tensile and flexural tests on the composite samples.
- To conduct the SEM for the tensile and flexural tested samples to study the nature of failure at the microscopic level.

CHAPTER 3

Materials and Method

3.1 Materials And Method

Raw materials used in this experimental work are listed below

1. Natural fiber (Orange peel)
2. Epoxy Resin
3. Hardener

3.1.1 Orange peel:

Orange is a citrus fruit mainly originated in Southeast Asia. It is the most commonly grown tree fruit in the world. Like all citrus fruits, the orange is acidic having pH range 2.9-4.0.

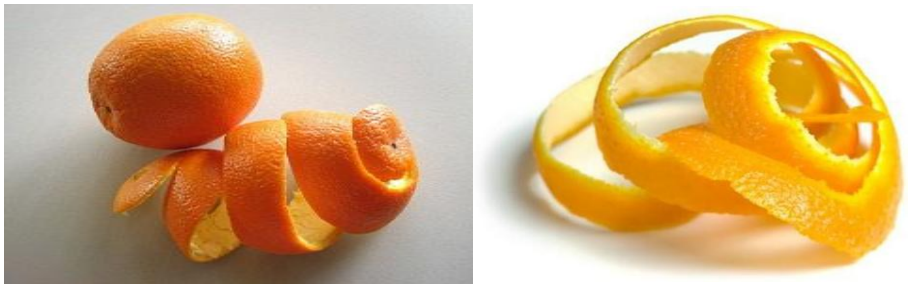


Figure 3.1 (a) Orange peels

(b) Sun dried orange peels (c) Powdered orange peels

Orange peel, the outer cover part of an orange, mainly consists of cellulose, essential oils, proteins and some simple carbohydrates.

The orange peels were collected locally and were sun dried for 5 days. Sun drying was necessary to remove the moisture from the peels. The fibers were then grinded into fine powder as shown

in figure 3.2. The collected powders were sieved and a particle size distribution in a sample is given in Table-3.1. Since the wt% of 212+ microns was around 74.6grams, for the present investigation we have taken this particle size for further experimentation.

Table 3.1 Particles Size

Sample No.	Size range - micron	Size range + micron	Weight grams approx.	Weight %
1.	------	1700	22.25	18.12
2.	------	212	74.60	67.16
3.	212	150	4.87	4.38
4.	150	106	4.17	3.75
5.	106	-----	5.18	4.66
		Total	111.07	

3.1.2 Epoxy Resin

The type of epoxy resin used in the present investigation is araldite LY556 which is chemically belongs to epoxide family. Its common name is BisPhinol-A-Diglycidyl-Ether. It is supplied by CIBA GUGYE India Limited.

3.1.3 Hardener

The hardener with IUPAC name NNO-bis (2aminoethylethane-1,2diamin) has been used with epoxy designated as HY951. This has a viscosity of 10-20 MPa at 25ºC.

3.2. Composite preparation

A Per-pex sheet mould (dimension 130X100X6mm) figure-3.2 was used for casting the composite sheet. A mould release spray was applied at the inner surface of the mould for quick and easy release of the composite sheet. A calculated amount of epoxy resin and hardener (ratio of 10:1 by weight) was taken and mixed with orange peel particulate with gentle stirring to minimize air entrapment. After keeping the mould on a glass sheet (coated with wax) the mixture is then poured into it. Care was taken to avoid formation of air bubbles. Pressure was then applied from the top and the mould was allowed to cure at room temperature for 72 hrs. During application of pressure some amount of epoxy and hardener squeezes out. Care has been taken to consider this loss during manufacturing so that a constant thickness of sample could be manufactured. This procedure was adopted for preparation of 5, 10, 20 and 30% weight fractions of orange peel. After 72 hrs the samples were taken out of the mould, cut into different sizes and kept in air tight container for further experimentation.

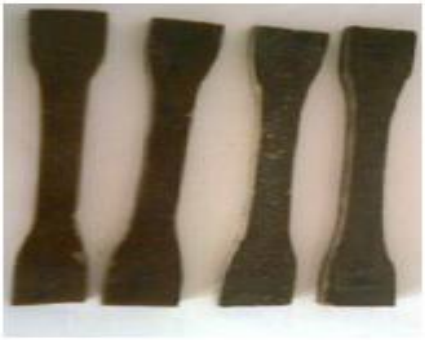


Figure 3.2 (a) Mould used for making the composite (b) Tensile test specimen

(c) Flexural test specimen

3.3 Experimental Procedure

The following tests were conducted on the samples:

a. Density measurement
b. Hardness test
c. Tensile test
d. Flexural test

3.3.1 Density Measurement

The density of composite materials in terms of volume fraction is found out from the following equations

$$s_{ct} = \frac{w_0}{(w_o) + (w_a - w_b)} \tag{3.1}$$

Where ''ρ_{ct}' represents specific gravity of the composite,

W_0 represents the weight of the sample; W_a represents the weight of the bottle + kerosene,

W_b represents the weight of the bottle + kerosene + sample,

Density of composite = S_{ct} * density of kerosene. (3.2)

The theoretical density of composite materials in terms of weight fraction is found out from the following equations as given by Agarwal and Broutman [32].

$$\rho_{ct} = \frac{1}{\left(\frac{W_f}{\rho_f}\right) + \left(\frac{W_m}{\rho_m}\right)} \tag{3.3}$$

Where '*W'* and 'ρ' represents the weight and density respectively. The suffix *f, m* and *ct* stand for the fiber, matrix and the composite materials.

The void content of composite sample has been determined as per ASTM D-2734-70 standard procedure respectively. The volume fraction of voids (V_v) in the composites was calculated by using equation:

$$V_v = \frac{\rho_t - \rho_a}{\rho_t} \quad (3.4)$$

where ρ_t and ρ_a are the theoretical and actual density of composite respectively

3.3.2 Hardness Test

Leitz Micro –hardness tester was used for Hardness measurement. This tester had a diamond indentater, in the form a right pyramid with a square base and an angle 136° between opposite faces, is forced in to the material under a load ranging from 0.3 to 3 N. Vickers hardness number is calculated by using the following equations.

$$L = (X+Y)/2 \quad (3.5.a)$$

$$Hv = 0.1889\ F/L^2 \quad (3.5)$$

Where 'F' is the applied load, 'L' is the diagonal of square impression (mm), 'X' is the horizontal length (mm), and 'Y' is the vertical length (mm).

3.3.3 Tensile Test

The tension test is generally performed on flat specimens. The most commonly used specimen geometries are the dog-bone specimen, figure-3.3, and straight-sided specimen with end tabs. The standard test method as per ASTM D3039-76 has been used. The length of the test specimen used is 150 mm. The tensile test is performed in universal testing machine (UTM). The tests were performed with a cross head speed of 0.5mm/min. For each test composite of four samples were tested and average value was taken for analysis. Figure 3.4(a, b) shows the machine used for the test and the sample in loading condition.

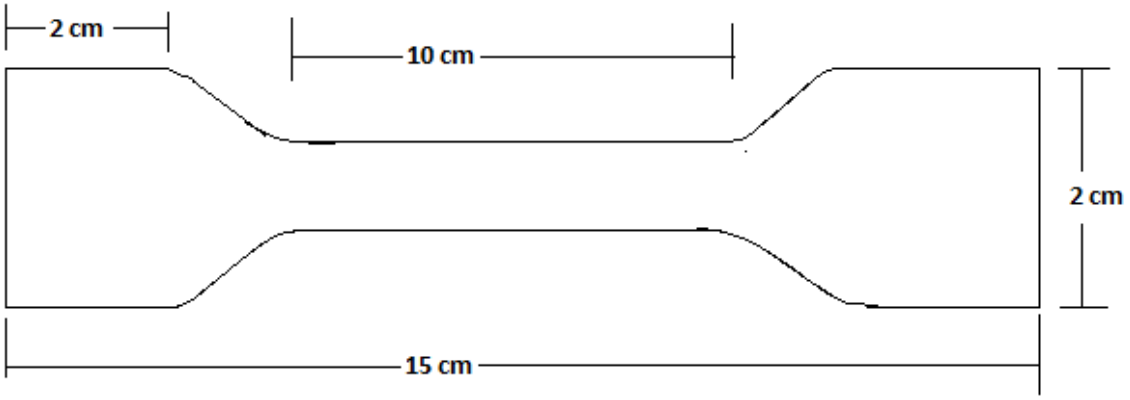


Figure 3.3 Dog bone shape of the tensile testing sample

Figure 3.4 (a) UTM Machine Sample holder **(b)** UTM Machine Sample Loaded

3.3.4 Flexural Strength

The three point bend test was carried out in UTM machine in accordance with ASTM D2344-84 to measure the flexural strength of the composites. The loading arrangement for the specimen and the photograph of the machine used are shown in Figure-3.5(a) and (b) respectively. The entire specimens were of rectangular cross section of (150x20x5) mm. A span of 100 mm was

used for the test specimen. The specimens were tested at a crosshead speed of 0.5mm/min. The flexural stress in a three point bending test is found out by using equation (3.6)

$$\sigma = \frac{3FL}{2bt^2} \tag{3.6}$$

Where F is the load, b is the width and t is the thickness of the specimen under test.

The short beam shear tests (SBS) are performed on the composite samples at room temperature to evaluate the value of inter-laminar shear strength (ILSS). It is three point bending test which generally promotes failure by inter-laminar shear. The SBS test is conducted as per ASTM standard using the same UTM, span length 100mm and cross head speed 0.5mm/min.

The inter-laminar shear strength (ILSS) is found out by using the equation (3.7)

$$\text{ILSS} = \frac{3F}{4b.t} \tag{3.7}$$

Where F is the maximum load, b the width of the specimen and t is the thickness of the specimen.

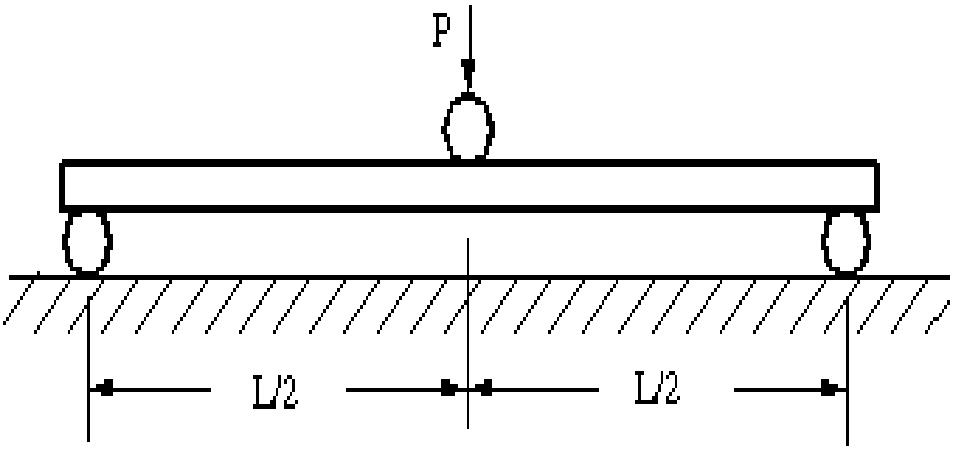


Figure 3.5(a) the loading arrangement for the flexural testing

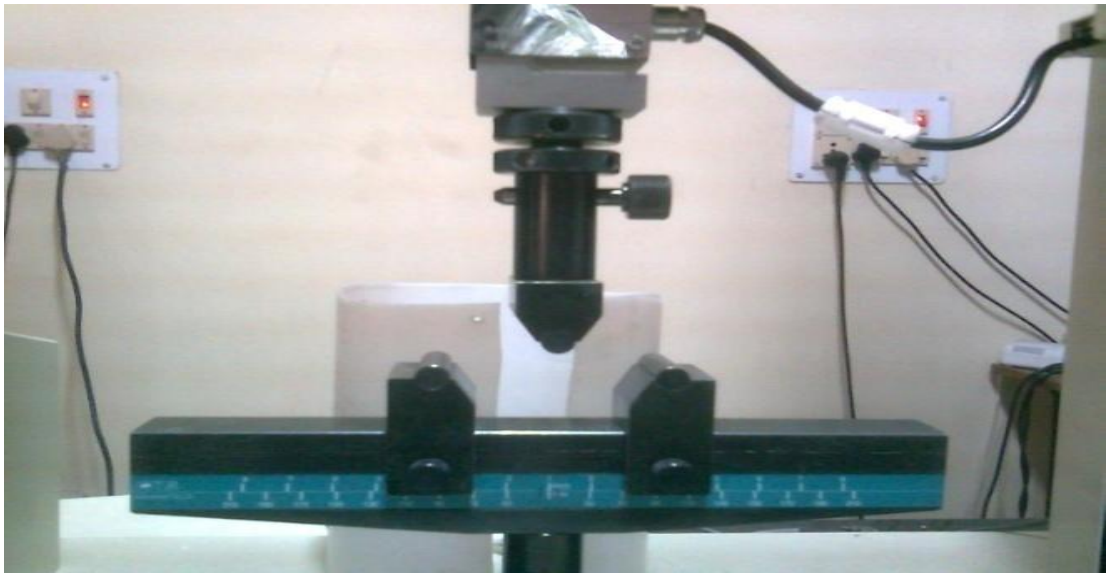


Figure 3.5 (b) Flexural specimen loading position

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Density Measurement

From the table 4.1 it is observed that the void fraction percentage of composite increases as the percentage of reinforcement increases still the void content is very less so it shows that the composite fabrication is done properly.

Figure 4.1 is drawn between the measured densities of the composites and weight fraction of the composite. It is observed that as the reinforcement percentage increases in the epoxy the density increases gradually up to 20 % and suddenly decreases at 30 % due to void percentage increases the void content increase due to the weight percentage of fiber increases.

Table 4.1 Density of different Samples

Fiber content (%)	Measured Density (gm/cm^3)	Theoretical Density (gm/cm^3)	Volume fraction of voids (%)
0	1.082	1.100	1.636
5	1.0991	1.118918	1.7712
10	1.113	1.138498	2.239613
20	1.143	1.179788	3.118215
30	1.1398	1.224186	6.893266

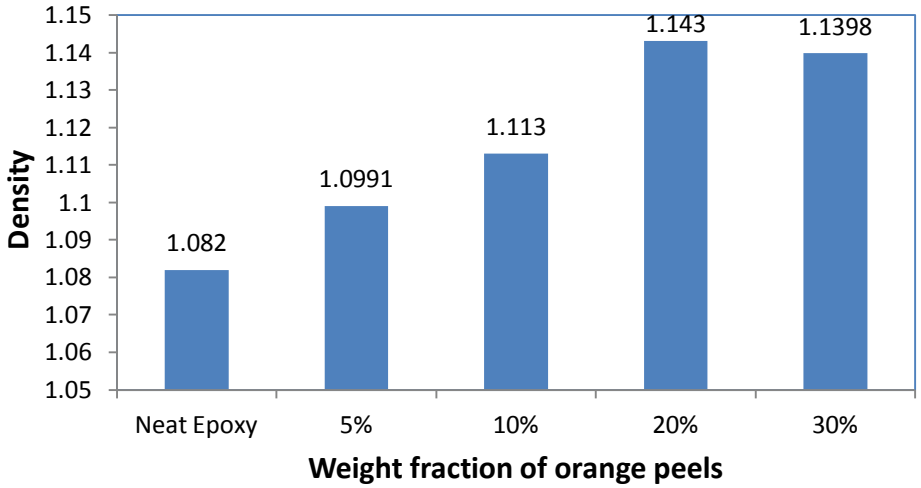


Figure 4.1 The variation of density with different fiber contents

4.2 Hardness Test

Vickers hardness number is measured by Leitz Micro –hardness tester. The results are tabulated in the table 4.2. Figure 4.2 drawn between the harness values of composite and the weight percentage of composite. It is observed that as the reinforcement increases the hardness increases the maximum value is obtained for composite prepared with the 20% composite.

Table 4.2 Hardness of different samples

Weight fraction of particulates (%)	Vicker Hardness value
Neat epoxy	17.894
5	18.28
10	19.68
20	20.72
30	18.95

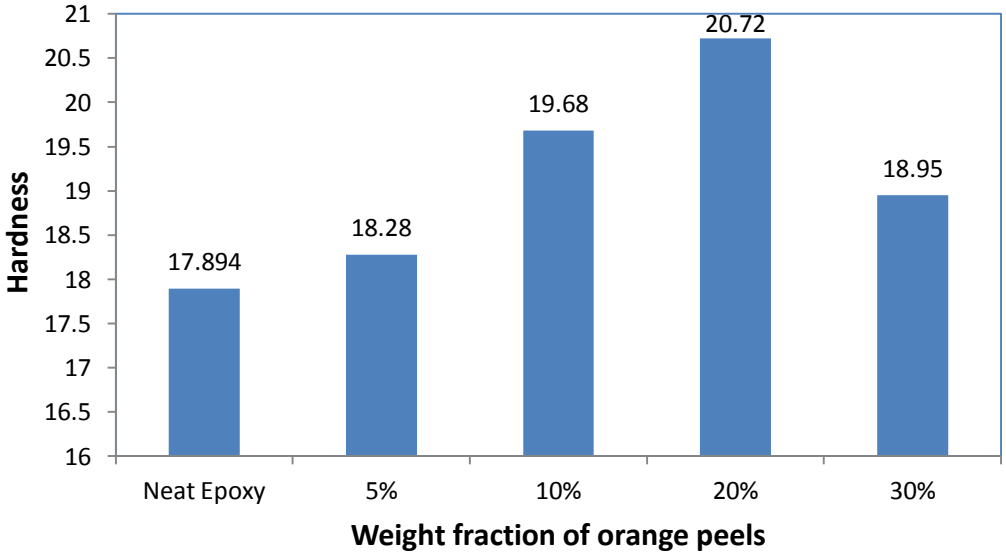


Figure 4.2 Variation of Vicker Hardness value with different fiber contents

4.3 Tensile Test

The results of tensile test using UTM are tabulated in Table 4.3. From figure 4.3 it is observed that the tensile strength is maximum for the composite prepared with 20% fiber However, for 30% fiber composite the tensile strength decreases because of the void content.

Table 4.3 Tensile Stress and Tensile Modulus of composites

Weight percent of fiber	Tensile Stress (MPa)	Tensile Modulus (MPa)
Neat epoxy	18.031	648.23
5%	19.25	742.46
10%	22.69	1313.63
20%	25.85	1271.69
30%	21.34	938.96

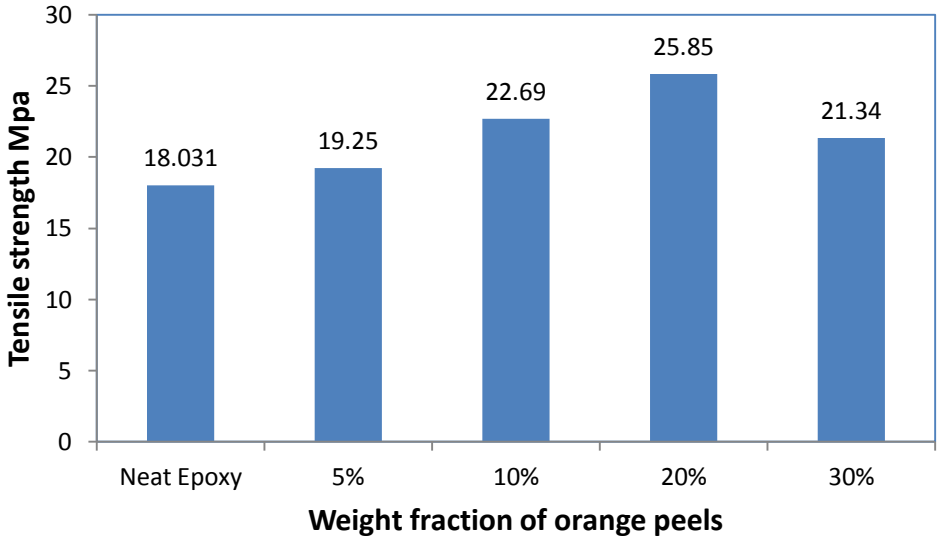


Figure 4.3 Variation of Tensile strength with different fiber contents

4.4 Flexural Test

The three point bend test was carried out in UTM 201 machine in accordance with ASTM D2344-84 to measure the flexural strength of the composites. The flexural strength, flexural modulus and ILSS values are tabulated in Table 4.3. From the table, it is observed that the composite having 20% fiber content has the highest values of flexural strength, flexural modulus and ILSS. Figure 4.4 and 4.5 it is observed that the flexural and ILSS values are getting maximum for the composite prepared with 20 % fiber.

Table 4.4 Flexural properties of the composites

Weight fraction of particulates(%)	**Flexural Strength(MPa)**	**Flexural modulus(GPa)**	**ILSS (MPa)**
Neat epoxy	45.519	5.046	1.137
5%	48.23	5.146	1.425
10%	56.98	9.631	1.653
20%	62.35	10.970	1.808
30%	57.89	8.334	1.765

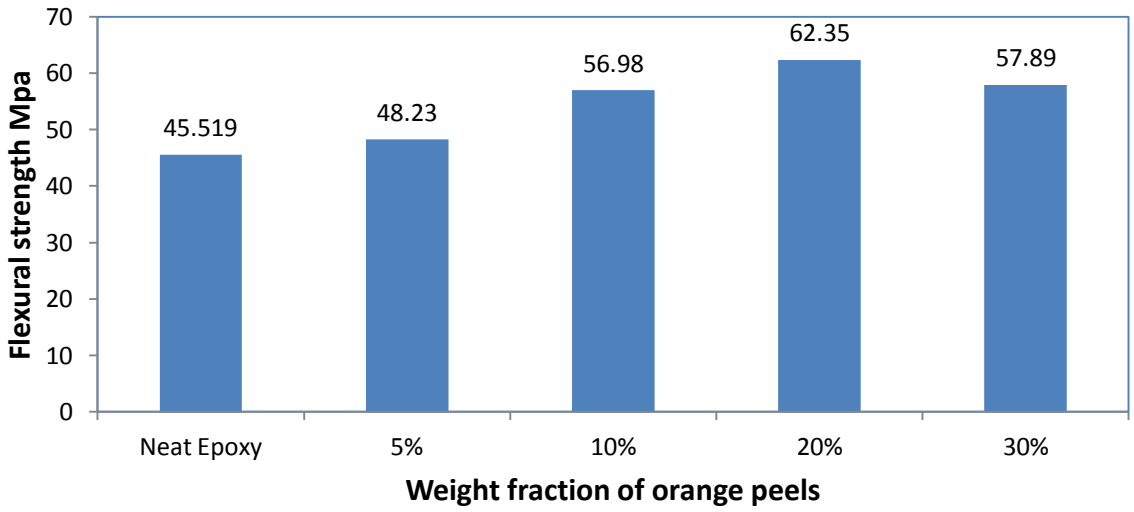


Figure 4.4 Variation of flexural strength with different fiber contents

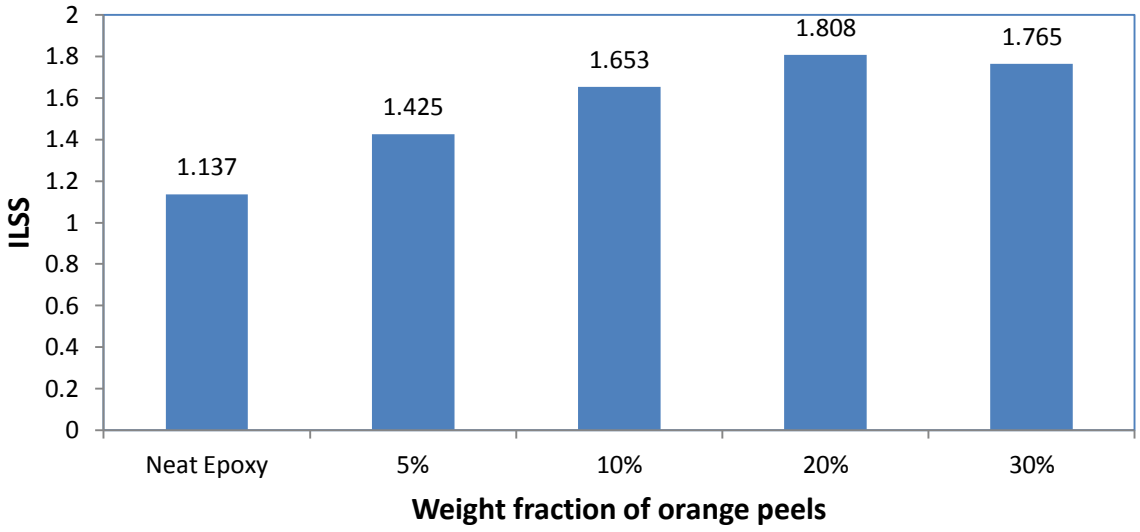
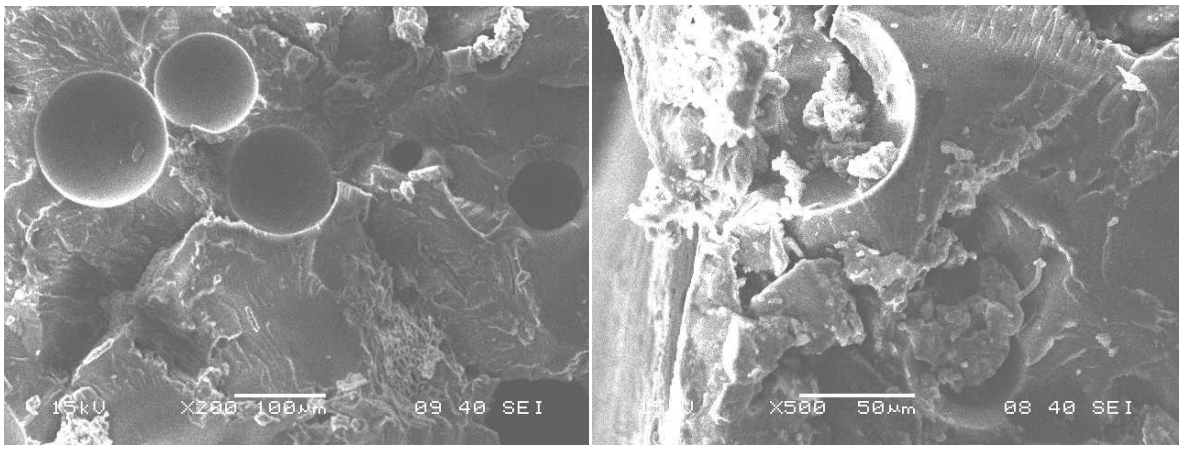


Figure 4.5 Variation of ILSS with different fiber contents

4.5 SEM Analysis

Scanning electron micrographs (SEM) of resin sample and its respective composites were taken on Leo 435 VP. Figure 4.6 is the micro graphs of the 20 % orange peel reinforced epoxy composite which is subjected to tensile test. Micrographs clearly show that no debonding, no fiber chipping out and no crack formation it shows that the bonding is strong between the matrix and reinforcement.



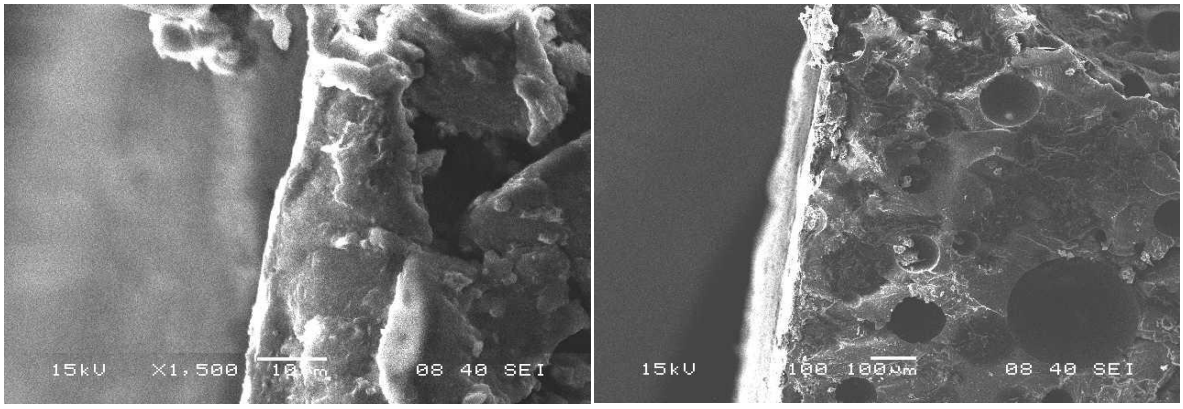


Figure 4.6 SEM micrograph of 20% orange peel composite after tensile test

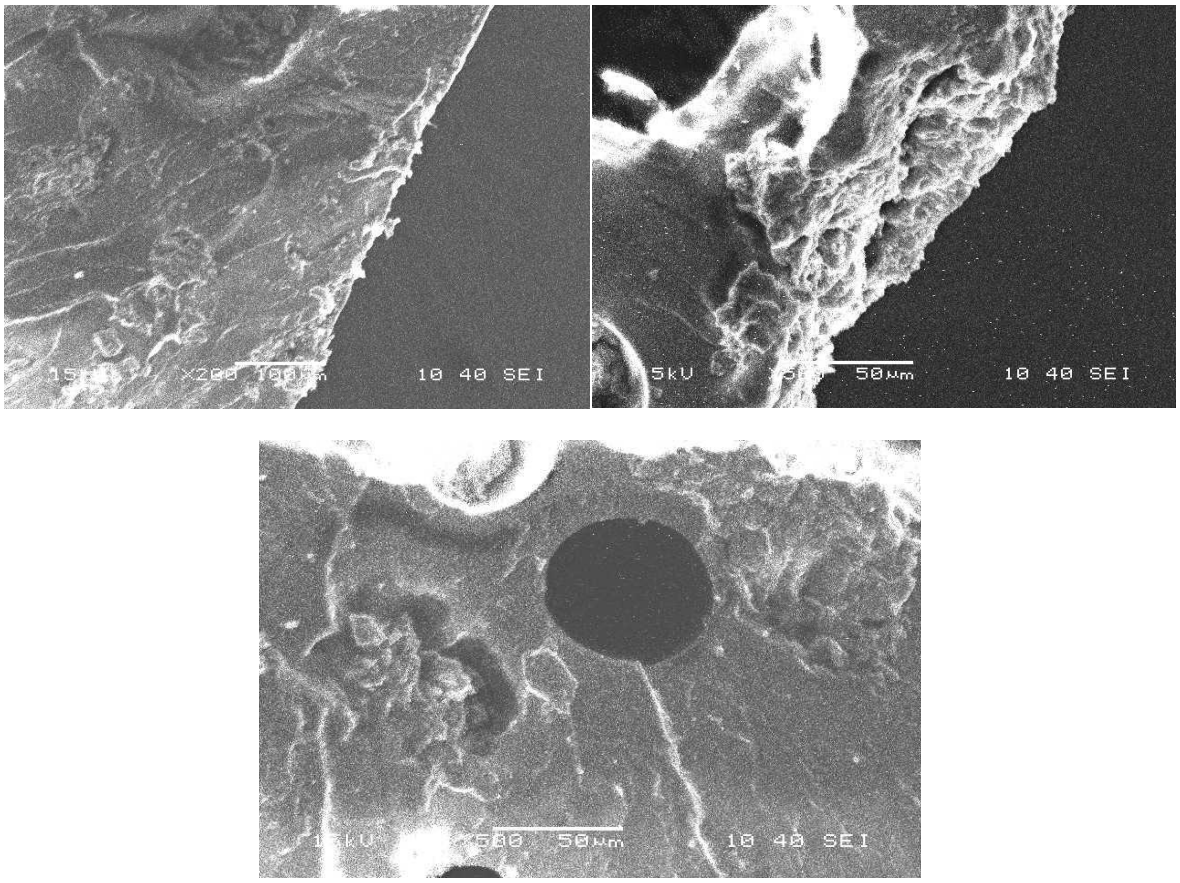


Figure 4.7 SEM micrograph of 20% orange peel composite after flexural test

Figure 4.7 is the micro graphs of the 20 % orange peel reinforced epoxy composite which is subjected to flexural strength micrographs clearly show that some bending of fibers are taken place but the fibers are not come out from the epoxy it shows that the bonding is more between the epoxy and orange peel fiber.

CHAPTER 5

5.1 CONCLUSIONS

The present work deals with the preparation of characterization of waste orange fiber reinforced epoxy composite. The mechanical behavior of the composite lead to the following conclusions

1. With the successful fabrication of a new class of epoxy based composites reinforced with orange fiber.
2. The flexural strength and ILSS of the composite is found to be maximum with 20% weight percent of orange fiber.
3. The tensile strength of the composite is found to be maximum for the 20 % weight percentage of the orange fiber.
4. The hardness value of the composite increases with increasing of the fiber content.
5. SEM observation reveals that most of the fibers were broken instead of pulling out from the matrix. This indicates a good bonding between fiber and the matrix.

5.2 RECOMMENDATION FOR FURTHER RESEARCH

- In this study fiber weight fraction of 30% has been used. This can be further increased to higher weight fraction of fiber using other manufacturing methods.
- The current study is limited to mechanical study only. It can be extended to tribological tests.
- The same work could be extended to different treated fiber composite.

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