Enhancing Mechanical Properties of E-glass/Epoxy and Bagasse fiber/Epoxy Composites with Fly ash Filler

Program: MSc in Manufacturing Engineering

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ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF MECHANICAL, CHEMICAL AND MATERIAL ENGINEERING

DEPARTMENT OF MECHANICAL DESIGN AND MANUFACTURING ENGINEERING

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DECLARATION

I hereby declare that the work, which is being presented in thesis, entitled *“Enhancing Mechanical Properties of E-glass/Epoxy and Bagasse fiber/Epoxy Composites with Fly ash Filler”.* In partial fulfillment of the requirement for the award of the Degree of Masters of Science in Manufacturing Engineering is my own work carried out September 2017 to June 2019 under the supervision of Dr. Woldetinsay Gutu Jiru, and Dr. Perumula Janaki Ramulu Program of Mechanical Design and Manufacturing Engineering, Adama Science and Technology University.

The matter embodied in this thesis has not been submitted by me for the award of any other Degree or Diploma. All relevant resources of information used in this thesis have been duly acknowledge.

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This is to certify that the above declaration made by the candidate is corrected to the best of my knowledge and belief. This thesis has been submitted for examination with our approval.

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ABSTRACT

Bagasse fiber reinforced composite materials are eco-friendly materials, which do not affect the environment. Bagasse and fly ash are waste product of sugar industry and easily available. Since these byproducts were not yet commercialized for any application in material of engineering applications, this work is highly motivated to fabricate composite material that can be used for simple applications like, table's, window, door, kitchen cabinet, chairs and others. This work covers manufacturing of E-glass fiber and bagasse fiber at different compositions like E-glass fiber/Epoxy, Bagasse fiber/ Epoxy, and E-glass/bagasse fiber epoxy with 5, 10 and 15-weight % of fly ash fillers. The fabrication of this composite was done by hand lay-up method at ambient conditions. The fabricated composites were tested to obtain their microstructure and mechanical properties such as surface hardness and tensile properties. Moreover, machining property was also analyzed by performing the drilling operation. The results was optimized through various technique like Taguchi and ANOVA method. Based on the result of the work, tensile strength is noted as 135 MPa and hardness value as 32 VHN at optimum combination of parameters. Fabrication of the composite is successfully done. Effective drilling is achieved for some parameters while defects are also observed on drilled hole for optimized parameters. Machining problem is enhanced using filler materials. Machinability is improved as fly ash filler material increases.

Keywords: *composite materials, bagasse fiber, fly ash, E-glass fiber, microstructures, machining property.*

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NOMENCLATURE

ASTM	American Society of Testing and Materials
BG	Bagasse
SEM	Scanning Electron Microscope
UTS	Ultimate Tensile Strength
SBG	Sugarcane Bagasse
FA	Fly Ash
FGCMs	Functionally Graded Composites Materials
OM	Optical Microscope
PMCs	Polymer Matrix Composites
HV	Hardness Value
FGDCC	Fiber Glass Development Corporation Company

CHAPTER ONE

1 INTRODUCTION

1.1 Introduction to Composite Materials

Composite materials are widely used in industry due to their unusual properties. There are several kinds of composite materials classified according to matrix type. One of the most important types of composites materials is polymer matrix composite (PMC) materials Haider *et al*. (2017). Recently, polymer matrix composites (PMCs) have received more remarkable attention than conventional polymer materials. They have widely used for many applications in industry because of their lightness, high strength, high wear resistance and specific mechanical properties Goh *et al*. (2016).

Polymers are particularly attractive as matrix materials because they are easily process able and their density is comparatively low when compared to other materials. They exhibit excellent mechanical properties. High-temperature resins are used as composite materials are currently used in the manufacture of high-speed aircrafts, rockets and other related space and electronics. The reinforcements share the major load especially when a composite consists of fiber reinforcements dispersed in a weak matrix. The strength and stiffness of composites are controlled by the strength and stiffness of constituent fiber Durao *et al*. (2014).

1.2 Natural Fiber Materials

The major advantage of fiber-reinforced composites is to offer a high strength and modulus those are either comparable to or better than many traditional polymer materials. Because of their low specific gravity, high strength-weight ratio, and modulus - weight ratios, these composite materials are markedly superior to those of polymer materials. In addition, fatigue strength - weight ratio as well as fatigue damage tolerance of many composite laminates is excellent Ren *et al*. (2018). Fiber have two main group synthetic fiber and natural fiber. Under synthetic fiber, fiberglass is a light in weight, extremely strong, and robust. Its bulk strength, stiffness and weight properties are also very favorable when compared to metal. Natural fibers are classified into six different types. The first is bast fiber, the second is leaf fibers (abaca, sisal, and pineapple), the third is seed fiber (coir, cotton, and kapok), the fourth is core fiber (kenaf, hemp, and jute), the fifth is grass (bagasse, bamboo and corn) and the sixth is fruit fiber (wheat, corn, and rice). Bagasse fiber can be obtained by crushing sugarcane stalks. It is used as a natural fiber to develop composite materials Elanchezhian *et al*. (2018).

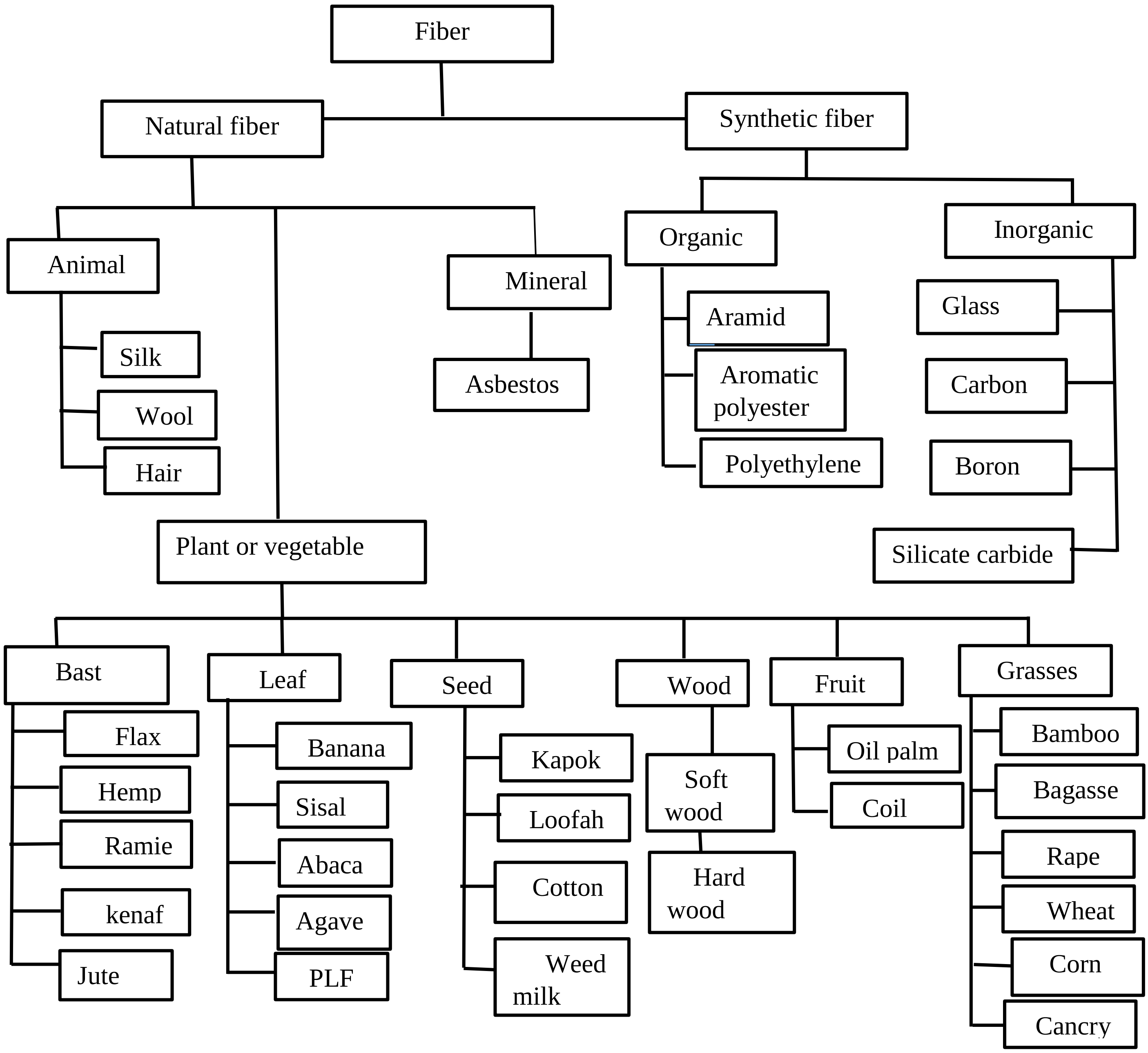


Figure 1.1 Further classification of fiber material [Elanchezhian *et al*. (2018)]

1.3 Bagasse Fiber composite materials

Sugarcane has been one of the largest and most traditional plantation crops in tropical and temperate regions around the globe for centuries. Today, both sugar for consumption and ethanol for transportation fuel are the main products from processing the juice extracted from sugarcane stalk (Mothé *et al*. 2002). The spent roll-pressed stalk, a primary industrial residue, is known as sugarcane bagasse or simply bagasse. It has a fibrous structure consisting of cellulose, hemicellulose and lignin as any natural plant fiber. It is estimated that about 700 metric tons of bagasse are produced annually throughout the world (Weber and Drelich 2016). Part of this bagasse is used as domestic fuel for steam and power in the industrial mills or as fertilizer in sugarcane plantations. However, a significant amount of bagasse is either still disposed as waste in open-air piles posing a risk to the environment or used for cogeneration of electricity with associated emissions of large CO2 volumes that contribute to the global warming effect Goh *et al.* (2016). Other alternatives such as converting bagasse waste to useful charcoal, biogas and paper pulp are also being explored Ren *et al*. (2018). An additional environmentally acceptable application is the incorporation of bagasse waste into polymer composites.

The ultimate strength of a bagasse fiber was found to be around 200 MPa, which is higher than that of any polymer Amirjan (2019). The advantages of the bagasse fiber-reinforced polymer composites are deeply discussed by Luz *et al*. (2007) related to lesser environment issues, lighter in weight and have equivalent performance with regard to aesthetic point of view, reduce environment related issues, utilization of natural fibers-reinforced composite also add up to a great chance for economic progress of developing countries.

1.4 Background of Factory

Wonji Shewa sugar factory is one of the sugar factory in Ethiopia that manufacture sugar from sugarcane with a crushing rate of 1400 tons of cane per day (TCD). It is the pioneer sugar factory in Ethiopia. Eight years after the establishment of Wonji Sugar Factory, in 1962 Shoa Sugar Factory was established with a crushing rate of 1600 TCD. Bagasse is a useful source of energy with a gross calorific value of about 9314 kJ/kg. Bagasse being a by-product of sugarcane industry has almost zero fuel cost Asaye (2016)**.** Mass and energy balance computation showed that modern sugar factories with efficient cogeneration plant crushing cane of about 14 % fiber require about 60 to 70 % of bagasse produced for steam and electricity requirement of the mills. The remaining quantity can be used as raw material for paper production, other fibrous products or for production of extra electric energy in condensing mode turbines for sale to the grid Neil *et al*. (2014).

Inert materials added to composite, called Filler materials, mainly used to decrease the resin cost and enhance its physical properties such as stiffness, hardness, and impact strength of composite materials. Generally, used fillers are calcium carbonate, hydrated alumina, clay, glass bead, etc. Now a day, fly ash is also widely used as filler material. Bagasse ash is the residual waste generated in industries by burning the processed sugarcane in boilers as a significant fuel source to produce steam for electricity cogeneration to meet up to 90% of industrial energy needs. Bagasse ash contains more than 70% of inorganic material with silica as a significant phase finds application in construction industries Singla and Chawla (2010).

1.5 Machining of composite materials

Machining of fiber-reinforced polymers (FRPs) may take place before and after layup and curing. The machining before curing involves cutting the reinforcement material to the proper size to fit the contour before it is laid in a mold and cured. The reinforcement material is either dry or resin impregnated fibers, fiber weaves, and fabrics Adekomaya and Adama (2017). Drilling represents one of the most important machining operations that are carried out on composites. Drilling, counter boring, and countersinking are often required processes for preparing composite parts for joining and assembly. Drilling also remains as one of the most challenging machining operations Durão *et al*. (2014). Among the key issues to be considered are thermal management, tool wear, and delamination.

Poor thermal conductivity of the glass fiber and the matrix favors heat buildup at the cutting region and majority of the heat generated has to be conducted away through the tool. Because the heat generated during drilling is affected by the cutting speed and the feed rate, FRPs are machined only in a limited range of process parameters in order to avoid heat damage. In some cases, approved coolant can be used in order to reduce the cutting temperatures and control machining dust. Furthermore, different thermal expansion coefficients between fiber and matrix Tate (2017).

1.6 The General Application Area of Fabricated Composites

The natural fiber composites can be very cost effective material for the following applications: Durão *et al*, (2014), Asim *et al*. (2018), Pontevedra *et al*. (2018) and Tate (2017).

- Storage devices: post-boxes, grain storage silos, biogas containers
- Furniture: chair, table, shower, bath units
- Electric devices: electrical appliances, pipes
- Everyday applications: lampshades, suitcases, helmets
- Transportation: automobile and railway coach interior, boat
- Building component such as Doors, Window, Wall partition and Ceiling
- Automotive components such as doors, roof liner, various damping and insulation parts, wheel arch, heed rest, bumper
- Furniture such as Tables, Chairs and Kitchen cabinet
- Engine intake manifolds are made from glass fiber reinforced PA 66 and
- The best results are obtained by using fly ash for low temperature applications.

In this study, fabrication and analysis of mechanical behavior of polymer composites (E-glass fiber epoxy and bagasse fiber epoxy with different weight percentage of fly ash filler) prepared. The fabrication method with hand lay-up method used due to its simplicity and in-expensiveness. Then composites was undergoing tensile, hardness and machinability test analysis in order to ensure the uniform distribution of fiber glass, fiber bagasse and filler material inside the matrix resin. Finally select composite materials, which have good performance and suggest for other relating fabrication composite material.

1.7 Organization of the Thesis

In this section, an overview of the thesis work is explained. Five chapters are done in the thesis work. In which Chapter one is introduces to composite materials.

Chapter Two is literature reviews of related works in different sections. This is to provide a information on different issues. In Chapter Three, a detailed description of experiment works are discussed. As well, testing procedures and design of experiments are illustrated. Chapter Four presents the result and discussion of the composites under study. The last Chapter provides summary of the work and recommendations for future research.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Introduction

Polymers are particularly attractive as matrix materials because they are easily processed due to density is comparatively low when compared to other materials. They exhibit excellent mechanical properties. High-temperature resins are used as composite materials for manufacturing of high-speed aircrafts, rockets and other related space and electronics. The role of reinforcements are to share the load especially when a composite consists of fiber reinforcements dispersed in a weak matrix (carbon/epoxy composite). The strength and stiffness of polymer composites materials are controlled by the strength and stiffness of constituent fiber Sundum *et al*, (2018).

2.1.1 Filler Materials

Pattanaik *et al*. (2015) studied different ratios of epoxy and fly ash sandwiched composite material for finding the flexural strength. Analyzed different ratios of epoxy and fly ash, as 65 % - 35 % (65 % fly ash and 35 % epoxy resin by weight), 60 % - 40 % and 55 % - 45 %. They found that 60 % - 40 % sample demonstrated better results in bending and compression tests. Based on the observation, they suggested composite could be used and replaced to areas where it needs a good compressive strength like wood applications, flooring, ceiling and other constructions works. Devendra and Rangaswamy (2013) investigated mechanical properties of E-glass fiber reinforced epoxy composites filled by various filler materials. Fabrication of the composite by hand lay-up technique with different weight percentage of aluminum oxide (Al_2O_3), magnesium hydroxide ($Mg\ (OH)_2$) and hematite powder. The required ingredients of resin, hardener, and fillers are mixed thoroughly in a basin and the mixture is subsequently stirred. Mechanical properties such as ultimate tensile strength, impact strength and hardness of the fabricated samples were investigated composites filled by 10% volume $Mg\ (OH)_2$ exhibited maximum ultimate tensile strength 375.36 MPa and maximum hardness number hardness 88.69 BHN. Malachy (2006) investigated effect of filler materials on mechanical properties of the particulate composite. The volume fraction of the filler materials increases stiffness, fracture toughness, high temperature load-bearing capability, decrease shrinkage and improve the appearance of composites.

Purohit *et al*. (2017) studied particulate filled polymers in large quantities in all kinds of applications and despite the overwhelming interest in advanced composite materials. Considerable research and development is done on particulate filled polymers. Fillers increase stiffness, fracture toughness, and high temperature load-bearing capability, decrease shrinkage and improve the appearance of composites. The major parameters that influence mechanical properties of the particulate composite are volume fraction or filler concentration, kind of the particles reinforcement, and particle size, shape of the particles and the interfacial adhesion between the matrix and the particles. Reddy *et al*. (2014) analyzed the impact of fly ash particle on tensile strength and flexural strength of 10% fiberglass (by weight) epoxy composites. The fly ash amount was changed from up to 10 grams in steps of 2 grams. The highest tensile strength was obtained for composite with 6-gram fly ash, the highest modulus of elasticity for composite with 8-gram fly ash and the highest flexural strength for composite with 4-gram fly ash.

Verma *et al*. (2015) found that addition of filler particles in lesser volume portions prompted the reduction in compressive strength of the fiberglass epoxy composite samples with fly ash filler. On the other hand, impact strength was improved by such addition significantly. Impact of aspect ratio of the sample on the compressive strength of the material is substantial and cannot be ignored. Sample behavior was found to change significantly with the alteration in aspect ratio; it also influenced the values of compressive strength. In event of short fiber composites, fiber length ought to be taken into account while choosing sample dimensions and aspect ratio. In event of impact mode of fracture, it incredibly relies on the interfacial strength of the filler and matrix material.

Elanchezhian *et al*. (2018) evaluated the effect of the filler additions on properties of polymer matrix composites based on the epoxy resin reinforced with glass fiber and fly ash as the fillers. Fabrication of composite materials by using the hand lay-up method with different weight percentage of fly ash particles in the epoxy matrix varied from 4-10 weight percentage in steps of 2-weight percentage. Studied microstructural, impact strength test, tensile strength test and flexural strength test. Presented the asbestos free friction materials were prepared using natural waste ingredients. A variety of banana peel and Bagasse fiber/particle content as a functional/friction additives and Nano-alumina particles as an abrasive were used to achieve an optimized friction materials composition. Investigated microstructure, density, hardness, and wear and friction behavior. The results showed an increase in natural wastes addition lead to a decrease in composites' density.

2.1.2 Polymer Composites

Goh *et al.* (2016) studied epoxy resins used widely due to their good mechanical, thermal, and electrical properties. Many types of epoxy resins have been developed, including bisphenol-aliphatic cyclic, novolac types, etc. To increase strength of epoxy resins, the use of additional phase has been a common practice. Epoxy resins modified with inorganic particles such as, titanium dioxide, silica, alumina, fly ash, clay and bagasse have shown improved performances. Pattanaik (2015) investigated inorganic/organic composites; the size of particles and the interfacial adhesion have great effect on the properties of the resin matrix. The well-dispersed inorganic fillers in polymer matrices and compatibility between inorganic and organic phases are important to achieve an overall good performance. In order to obtain the favored material properties for a particular application, it is important to know how the material performance changes with the filler content under given loading conditions.

Omrani *et al*. (2016) fabricated fiberglass reinforced polymer composites with fly ash in different weight percentage (5, 10 and 15%) using hand lay-up method. They found that mechanical properties were improved when fly ash was reinforced with the fiberglass; furthermore, the sample having 15% (highest amount of fly ash percent among all the samples) was having superior tensile strength, impact strength and hardness. Tribological behavior of unidirectional sugarcane/polyester and chopped strand mat of glass fiber reinforced polyester composites at different load tested along two different orientations at 2.5 m/s sliding speed for 2.25 km sliding distance. For unidirectional sugarcane/polyester composite in antiparallel orientation at 60 N load, the matrix support the fibers and carry out the most part of load without any fracture as evidenced

2.1.3 Treatment of Natural Fiber

Ninomiya *et al.* (2017) studied choline acetate assisted pretreatment of bagasse powder could improve properties of chemically modified bagasse/polypropylene composites. The composites had fewer voids derived from vascular bundles of bagasse tissue when using ChOAc-pretreated bagasse powder than when using untreated bagasse powder. Pretreatment of bagasse powder can enhance the compatibility and the tensile properties of modified bagasse/polypropylene composites. Verma *et al.* (2015) discussed the different surface modification techniques of bagasse fibers including alkaline, silane, acetylation, and benzoylation treatments. Studied processing techniques of bagasse fiber-reinforced composite manufacturing and its mechanical and morphological properties. It also covers advantages of bagasse fiber reinforcement in composites and future trends and applications.

Omrani *et al.* (2016) demonstrate the tribological behavior of natural fiber reinforced composite. Finds knowledge about their usability for various applications that tribology plays a dominant role. Composites reinforced with natural fibers have an improvement in tribological properties and their properties are comparable with conventional fibers. In addition, fiber treatment and fiber orientation are two important factors can affect tribological properties where treated fibers and normal oriented fibers exhibit better friction and wear behavior. Evaluated effect of test parameter including normal load and sliding speed on tribological properties, and the results vary based on type of reinforcement.

2.1.4 Fabrication of Composite Materials

Luz *et al.* (2007) evaluated compression and injection molding process for the better mixer method of fiber and matrix of composite materials. Studied mechanical tests in order to measure flexural and tensile properties. The morphological and microstructural analyses of fracture surface and specimens from composites can be easily evaluated by microscopic techniques. Mechanical properties of the composites did not have good adhesion between fiber and matrix for compression molding process and the fiber insertion improved the flexural modulus and the material rigidity. Injection molding process is the best molding process used under vacuum, which leads to materials with homogeneous distribution of fibers and free of blisters.

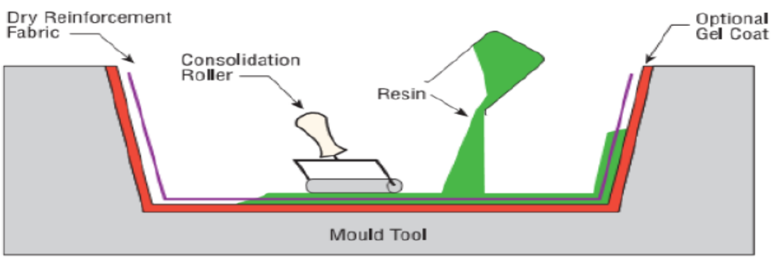


Figure 2.1 Hand layup technique of composite fabrication techniques (Luz e*t al.* (2007))

Verma *et al.* (2019) investigated composite material using fly ash and E-glass fiber. Fabrication of composite is to use industrial waste such as fly ash. Effect of fly ash filler in mechanical behavior also studied. Analyzed the evenly distribution of fly ash in E-glass matrix by help of SEM. Pattanaik *et al.* (2015) reviewed mechanical properties of natural fiber reinforced polyester hybrid composites. The effect of filler loading was evaluated on void content, tensile strength and impact strength. Void content in the hybrid composites less than 5% of pure polyester composites. Hybrid composites with filler loading show a lower tensile strength as compared to that of pure polyester.

2.1.5 Machining of Composite Materials

Babu and Philip (2014) studied the effect of the cutting speed, the feed rate, and the drill point geometry on the residual tensile strength of the drilled unidirectional glass fiber reinforced epoxy composite using the Taguchi method. Suggested the optimal conditions for maximum residual tensile strength. The maximum residual strength is found with 8-facet drill at cutting speed of 750 rpm and feed rate of 15 mm/min. Tate (2017) investigated the effect of speed, feed rate, and depth of cut on response of surface roughness, material removal rate and delamination factor. The effect of machining parameters analyzed based maximum output by Taguchi analysis method. Composite with fiber reinforcement is used to support the matrix in terms of strength and stiffness.

Durão *et al.* (2014) analyzed reduce drill thrust force can decrease the risk of delamination in drilling process. Damage assessment methods based on data extracted from radiographic images are compared and correlated with mechanical test results and analytical models. Demonstrate the importance of an adequate selection of drilling tools and machining parameters. Rahme *et al.* (2015) analyzed the difficulties of drilling operation of composite materials. Studied drilling of thick composite plates with a large-diameter drill and developed analytical model to determine the critical thrust force at delamination at the exit hole. The two considered models are used to determine the optimal cutting conditions for delamination-free drilling. Concluded large-diameter twist drill without thinning of the chisel edge always results delamination at the exit of a thick composite laminate.

2.1.6 Optimization Techniques

Tsao (2007) analyzed the Taguchi method for drilling quality associates with core drill. The thrust force and surface roughness of core drill with drill parameters is investigated. Thrust force, thickness and feed rate are the most significant factors and for surface roughness, the feed rate and spindle speed are the most significant factors in drilling glass fiber reinforced polymer composite materials (GFRP). Recommended high speed and low drilling feed rate are recommended for the production of delamination free and good surface finish holes in epoxy composites. Kishore *et al.* (2009) studied the effect of the cutting speed, the feed rate, and the drill point geometry on the residual tensile strength of the drilled unidirectional glass fiber reinforced epoxy composite. Taguchi analyzing method is used to suggest the optimal conditions for maximum residual tensile strength. The result shows increasing thrust force leads to an increase in crack nucleation inside the composite can propagate easily when tensile force is applied and cause failure of composite products.

Pontevedra *et al.* (2018) studied the electro discharging of polymer composites materials by Taguchi analysis method Analysis of variance (ANOVA). Discussed effect of input parameters like input voltage, electrolyte concentration and inter electrode gap on material removal rate (MRR). Observed each process parameters shows that MRR during electrochemical discharging machining of PMCs is directly proportional the voltage and electrolyte concentration whereas inversely proportional to the inter-electrode gap.

2.2 Research Gap

From the literature, different researchers were evaluated and examined in an elaborate manner on the effect of filler materials on polymer composite materials fabrication. Several work have been done on a variety of natural fibers polymer composites; there is a gap on the optimizing of the tensile strength and hardness property of composites materials.

1. As several scholars had reported that, the main problem of composites material was the machinability. *This work processed to increase the machinability of fabricated composites by using different combination of fiber and different weight percentage of filler materials.*
2. Most of the studies were already done on mechanical property and microstructural of E-glass epoxy composites and Bagasse fiber epoxy composite materials. However, more research work is required on the analysis of polymer composites with different weight percentage of synthetic and natural reinforcement materials.
3. Different researcher studied effect of synthetic fiber based polymer composites on the environment but there is an opportunity to replace synthetic fiber with natural fibers and particulates, which have related mechanical properties.

2.3 Statement of Problem

- Sugar factory is the factory that was established to extract sugar from sugarcane and remains with some bagasse fiber and fly ash. The byproduct from sugar industry such as bagasse fiber and fly ash are simply discharge in to the environment. It is possible to use this bagasse fiber wastage as a natural fiber and fly ash filler materials for composite material.

(a) Bagasse disposed to enviroment (b) Fly ash disposed to enviroment

Figure 2.2 Wastage of bagasse fiber and fly ash in sugar industry

- Polymer based composites materials have some disadvantages related to the matrix-dominated properties, which often limit their wide applications and increase the cost of composites materials. In the factory, the addition of filler materials to a polymer is a common practice to enhance the mechanical properties of composites materials. This addition of filler improves stiffness, toughness, hardness, heat distortion temperature, and mold shrinkage, but also reduces the cost of resin.
- Mechanical properties of fiber-reinforced composites are depending on the properties of the constituent materials (type, quantity, fiber distribution, orientation and void content). Beside those properties, the nature of the interfacial bonds and the mechanisms of load transfer at the interphase also play an important role so the addition of filler materials enhance load transfer and interfacial bond between matrix and fiber.
- The machining of composite materials is a growing problem in various fields such as aerospace, automotive, wind turbine industries, etc. This can affect the strength of the structure. Machining process can be helpful for reducing induction of stresses and preventing change in dimension of component by minimizing the defect of machining composite such as fiber pull out, matrix crack and fiber fractures. It is

possible to increase the machinability of composites materials by adding filler material.

2.4 Objectives

The main objective of this work is “to fabricate composite materials, analyze and optimize mechanical behavior and machinability of E-glass and bagasse fiber composites with different weight percentage of fly ash”.

2.4.1 Specific Objectives

1. To fabricate composite materials with different combinations of E-glass and bagasse fiber with different weight percentage of fillers. The fabrication method used is hand lay-up technique.
2. To evaluate and optimize mechanical properties of fabricated composite like tensile strength and hardness.
3. To observe machinability using drilling process in order to check effect of different combination of fly ash filler.
4. To optimize the parameters like weight percentage of fly ash, type of fiber and weight percentage of epoxy resin using Taguchi and ANOVA method.

2.5 Scope of the study

The scope of this study is analyzing the behavior of chopped E-glass epoxy composites with fly ash and bagasse filler. This studies covers fabrication of E-glass fiber and bagasse fiber with fly ash filler (E-glass fiber, E-glass/bagasse fiber and bagasse fiber with 5, 10 and 15-weight % of fly ash). Analyzing mechanical behavior of composites like microstructures, hardness value, tensile strength. Machinability has been conducted using drilling operation.

2.6 Research Motivation

Different filler materials are used to enhance mechanical properties of composites materials. Fly ash filler obtained from different sugar industry as waste product during manufacturing sugar from sugarcane. In Ethiopia Wonji sugar factory is the biggest factory that produce maximum tones cane per day (TCD) of fly ash filler and bagasse fiber as a waste product. Disposal of fly ash and bagasse fiber to the environment affect the environment and loss of the resource without usage. Synthetic composites material has the problem of environmentally unfriendly since they are not degradable to the soil, to overcome this problem natural fiber is the best alternatives fiber.

The other main problem of composite materials are the problem with machinability of the materials Durão *et al.* (2014). Use of the filler can be increase the machinability of the composites materials. Several part of composite material fabricated individually and require assemble different parts together, assembling composite materials is difficult to control and often leads to delamination at the exit of the laminates so addition of filler material improve this property.

2.7 Significance of the Research

The importance of the study have many advantage such as in the academic context the study will expand on the further research relative to the composites materials with their application areas including aerospace, automobile, ship and building applications. Objective behind fabricating a composite is to use industrial waste such as fly ash and bagasse. In addition, its outcome provides a great contribution for manufactures to achieve the green development without loss of material. Due to highly increasing of the demand of light materials for consuming energy composite material is the promising material.

CHAPTER THREE

3 MATERIALS AND METHODOLOGY

3.1 Introduction

This chapter describes the materials and methods used for the fabrication of composites. For this study, the materials such as E-glass fiber, bagasse fiber, fly ash and epoxy resin with hardener are utilized in order to manufacture the composite material specimen. Sodium hydroxide (NaOH) and distilled water have been mixed to treat the bagasse fiber to maximize the efficiency of the fiber as reinforcement.

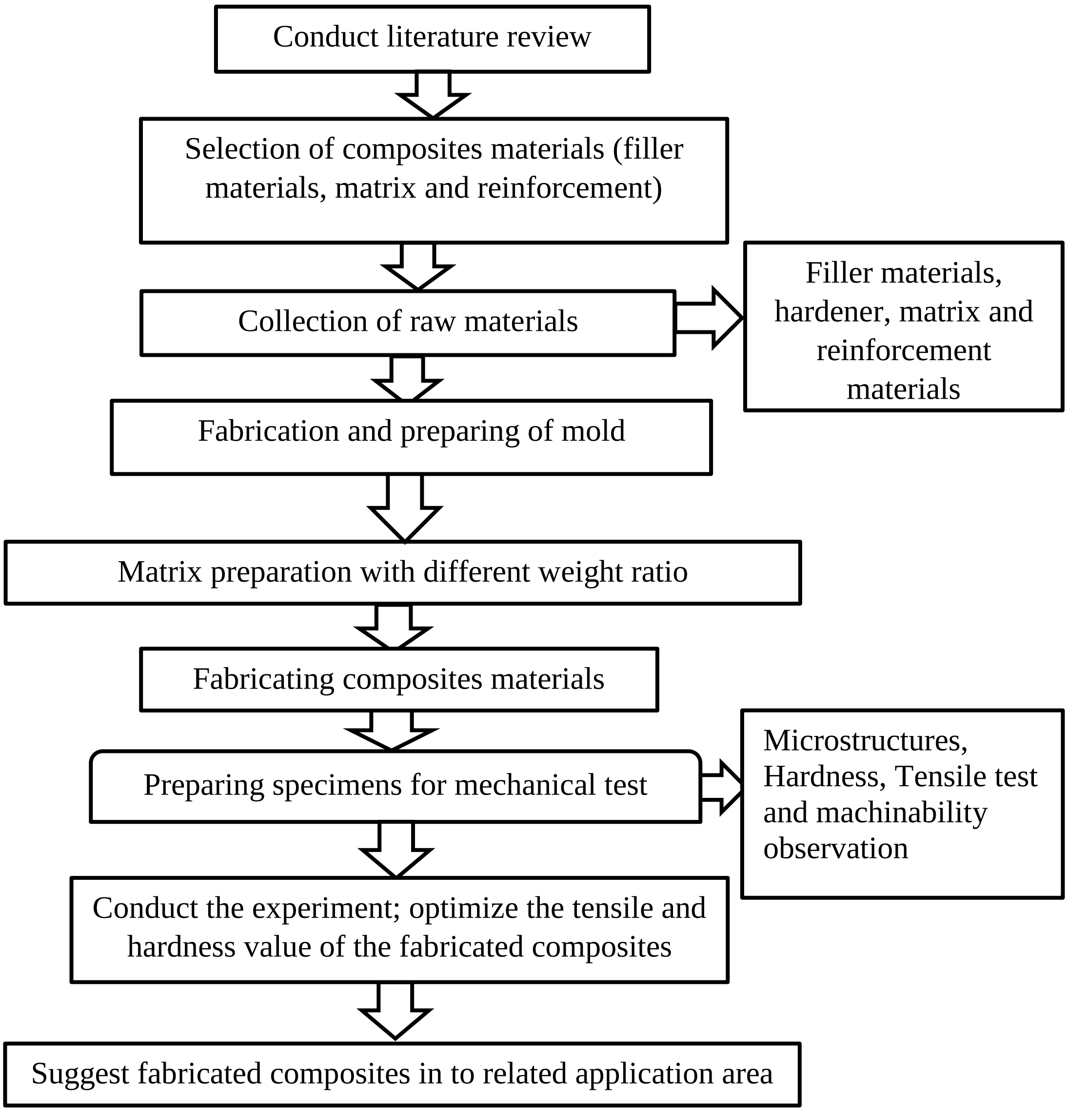


Figure 3.1 Procedure of the thesis experiment work and testing step

3.2 Material

In this section, different materials used for fabrication of composite material was discussed. The materials included in this section are epoxy resin, hardener, fiber, fly ash and other has been discussed in elaborate manner.

3.2.1 Epoxy Resin

Among main group of the matrix material, thermoset resin is the major one, which includes polyester, phenolic, polyurethanes and epoxy. Epoxy resin belonged to a family of polymeric materials under the group of thermoset. The epoxy resin is used for this study, which is manufactured by Fiber Glass Development Corporation Company (FGDCC).

(a) (b)

Figure 3.2 a) Epoxy resin LY552 and b) Hardener HY951

Table 3.1 Properties of epoxy resin LY552 [Singla and Chawla (2010)]

Properties	Unsaturated polyester resin
Tensile strength (MPa)	40
Elongation (%)	1.0
Flexural strength (MPa)	45
Modulus of Elasticity (GPa)	3.30
Temperature (^{o}C)	90
Specific gravity at 25°C	1.114
Density (g/cm^3)	1.09

Epoxy resin has better properties than other types of resin like - adhesive properties, mechanical properties, and degradation properties of materials. In general epoxy resin have the following advantage over the other resin type Singla and Chawla (2010).

- Better adhesive properties (the ability to bond reinforcement)
- Superior mechanical properties (particularly strength and stiffness)
- Improve resistance to fatigue and micro cracking.

3.2.2 Glass Fiber

Fibers have been manufactured from glass since the 1930s. Glass fibers are manufactured by melt spinning method. Glass fiber is a material, which consists innumerable extremely fine fibers of glass. E-glass is also known as electrical grade glass and it was developed to work as an insulator for electrical wires. However, because of its excellent fiber forming capabilities, it was started using as reinforcing materials in composites. The most commonly used glass fiber type for composite applications is E-glass, due to its relatively good mechanical properties and high electrical insulation.

3.2.3 Bagasse Fiber and Fly Ash

Bagasse fiber can be obtained by crushing sugarcane stalks in Wonji sugar factory. It is natural fiber and filler materials used to develop composite materials. Sugarcane is crushed in a series of mills with heavy rollers to extract the juice, which is then processed for sugar production. The remaining crushed and broken cane stalks or bagasse fibers are the by-product (or waste) from sugar factories. Bagasse contains short fiber, water and small amounts of soluble solids. Bagasse sugarcane is waste product of the sugar industry, mainly burned as fuel in sugar mill boilers and the rest part removed as waste product of the factory. The bagasse fiber in this study collected from Wonji sugar factory in Adama. Fly ash was obtained from burned bagasse fiber and it is used as filler material for making composite material.

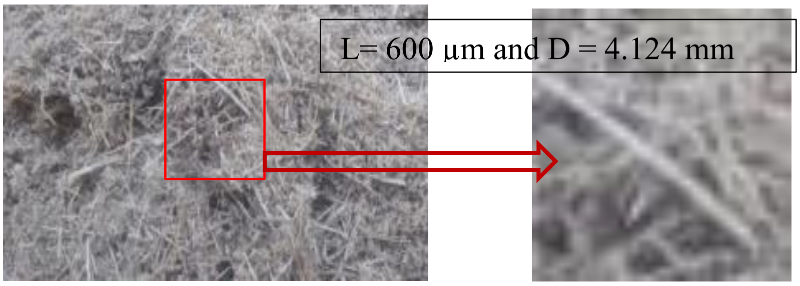
(a) Fly ash (b) Sieve with 75 µm mesh size

Figure 3.3 Fly ash collected from sugar industry and sieve mesh with 75 µm

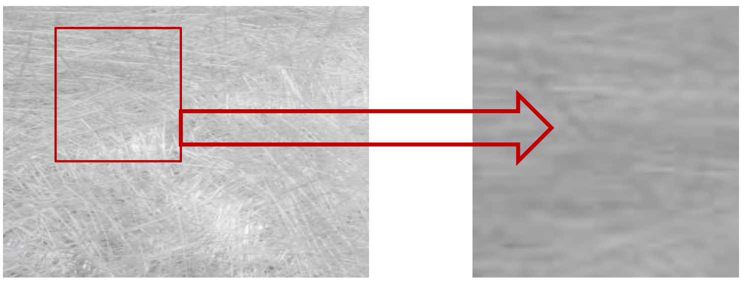
The diameter of fly ash for this work is filtered by using 75-micrometer mesh size sieve to get average diameter of 75-micrometer particle size of fly ash. To minimize the particle size mechanically grinding fly ash is very important.

(a) Micrometer (b) Vernier calliper

Figure 3.4 Micrometer and Vernier caliper



(a)



(b)

Figure 3.5 Bagasse fiber and chopped E-glass fiber

The average measurement of diameter and length of bagasse is collected by measuring the mean of 20 single bagasse fiber by using micrometer and Vernier caliper with precision of 0.01 and 0.05 respectively. The average diameter and length used for this work is 600 μm and 4.124 mm respectively.

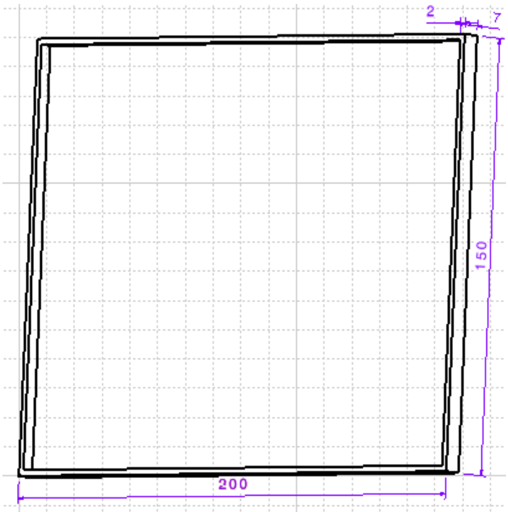
3.2.4 Hardener

The hardener used in this study will be HY951 and it is available in liquid form. The hardener purchased from market. When epoxy resin and hardener mixed, chemical reaction takes place and mixture starts to harden the matrix material. The curing agent applied in this work for the liquid epoxy resin is hardener manufactured by fiberglass development Corporation Company. Here, in proper amount of epoxy and fly ash is mechanically stirred for 15 minutes at 300 rpm. Additionally hardener poured after epoxy and fly ash mixed properly and stirred using deep stick material for 15 min. Epoxy resin is cured by mixing with hardener in ratio of 1 to 10 weight ratio of hardener to epoxy resin [Singla and Chawla (2010)].

3.2.5 Mold, Roller and Brush

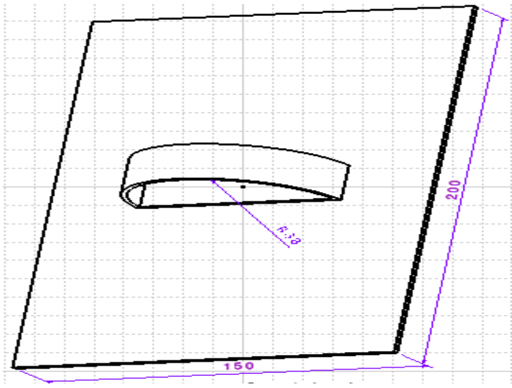
3.2.5.1 Mold

Open mold system was selected for fabrication of composite since the advantage of easy fabrication system and less cost. The open mold used for this work has the dimension of length (200mm) X width (150mm) X height (5mm) so the mold volume is 150000 mm^3. The sketch of mold is drawn with help of CATIA V5 R20 software and manufactured from 2 mm thickness sheet metal by automatic bending machines. In order to remove easily the composite materials from the mold, avoid sticking behavior composite materials to mold, to provide good dimensional stability and good surface finish, the mold was coated by coating gel or by wax.

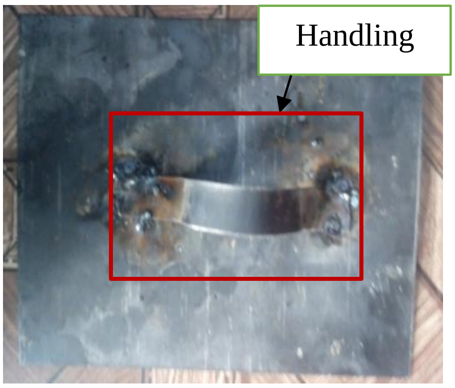


(a) Drawing of drag part of mould

(b) Fabricated drag part of mould



(c) Drawing of cope part of mould



(d) Fabricated cope part of mould

Figure 3.6 cope and drag part of fabricated mold

3.2.5.2 Roller and Brush

During pouring matrix and placing fibbers in mold cavity, the atmospheric air directly entrapped composite materials in the mold cavity. The brush used in fabrication of composites by hand layup method to distribute the poured matrix on the fiber uniformly and the roller rolled over evenly spread composite to remove entrapped air from the composites to increase manufactured composites surface quality, minimizing porosity on composites and for equally spread epoxy on the fiber. Finally, the mold covered by cope of the mold part and curing composite is followed for 24 hrs.

3.2.6 Marble Cutter

The fabrication of composites materials starts from the preparation of matrix to cutting specimen of fabricated composites. Once the prepared matrix and reinforcement fully cured to prepared mold cavity, the fabricated composites removed from mold cavity after 24 hour Haider *et al.* (2007). Composites material cut in to different dimension of experimental specimens according to ASTM standard of specimen. To cut the composites sheet in to actual sample size marble cutter and grinding cutter is mainly used.

3.2.7 Universal testing machine (UTM) and Vickers hardness tester

Tensile strength and surface hardness are the important mechanical properties carried out in this work for fabricated composites materials. Universal tensile testing machine used for testing mechanical properties of the fabricated composite material such as tensile, flexural and other tests. The Vickers hardness tester for determining surface hardness of fabricated composite material.

3.3 Methods

3.3.1 Process Parameters

The most important parameters for fabrication of composite to determine strength of materials and mainly studied in this thesis work are weight percentage of fly ash, fiber volume fraction and type of fiber.

3.3.1.1 Fiber, Filler and Matrix mass Fraction

The mass of composite material was the sum of mass of each constituent in composites materials. Total mass of composite is equal to the summation of mass of filler, fiber, matrix and hardener. Mass fraction of each constituent is equal to mass of constituent divided by total mass of composite materials and mass of individual was conducted by mass balancing with precision of 0.01mg.

$$M_c = M_F + M_f + M_m + M_H \quad 3.1$$

where; M_c = mass of composites material

M_f = mass of filler materials

M_F = mass of fiber and

M_m = mass of matrix

M_H = mass of hardener

Fiber mass fraction = $\frac{mass\ of\ fiber}{total\ mass}$

$$M_F = \frac{Mf}{Mm} \quad 3.2$$

Filler mass fraction = $\frac{mass\ of\ filler}{total\ mass}$

$$M_f = \frac{Mf}{Mm} \quad 3.3$$

Matrix mass fraction = $\frac{mass\ of\ matrix}{total\ mass}$

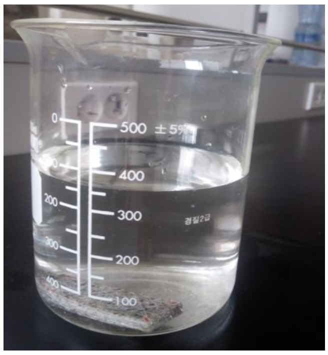
$$M_M = \frac{Mm}{total\ mass}, \quad 3.4$$

$$M_F + M_f + M_m + M_h = 1 \quad 3.5$$

3.3.1.2 Density Measurement of Bagasse Fiber and Fly Ash

Density of an object determine the degree of compactness of the substances. Natural reinforcement materials has advantage of low density and low weight in composite materials compared to synthetic constituent. For this work density of bagasse and fly ash conducted by "Archimedes principle". Archimedes principle can verify in experimental procedures and determine mass and density of using immersed composites. This is demonstrated by simple experiments using graduated beakers Marian. (2015).

(a) Before immersed composites



(b) After immersed composites

Figure 3.7 Measuring density of immersed object

Density of composite materials was measured depend on the density of water and volume of water as follows.

$$\mathcal{P} = \frac{M}{V} \quad 3.6$$

$$\mathcal{P}f = \frac{Mf}{Vf - Vi} \qquad 3.7$$

Where; $\mathcal{P}f$ = density of fiber

M_f = mass of fiber

V_i = initial volume of water before immersed composites

V_f = final volume of water with immersed composites

Density of the constituent in g/cm^3 (Density= Mass/volume)

- Density of Bagasse fiber = 0.35 g/cm^3
- Density of E-glass fiber = 2.54 g/cm^3
- Density of Epoxy resin =1.25 g/cm^3
- Density of Fly ash = 0.6 g/cm^3
- Density of Hardener = 0.98 g/cm^3

Table 3.2 Calculated mass of constituents in each sample

Samples	**Composition (Wt %)**					**Mass (gms)**				
	Epoxy	Fiber (B/E)	Fly ash	Hardener	Total	Epoxy	Fiber (B/E)	Fly ash	Hardener	Total
S1	55	34.5	5	5.5	100	52.71	33.10	4.79	5.27	95.84
S2	65	23.5	5	6.5	100	127.90	46.25	9.84	12.79	196.80
S3	75	12.5	5	7.5	100	115.84	19.31	7.72	11.58	154.45
S4	65	18.5	10	6.5	100	76.10	21.65	11.70	7.61	117.00
S5	75	7.5	10	7.5	100	128.90	12.89	17.19	12.89	171.88
S6	55	29.5	10	5.5	100	72.20	38.74	13.13	7.22	131.32
S7	75	2.5	15	7.5	100	112.73	3.76	22.55	11.27	150.30
S8	55	24.5	15	5.5	100	97.90	43.62	26.7	9.78	178.00
S9	65	13.5	15	6.5	100	92.40	19.18	21.31	9.24	142.10
Total mass required for experiment						876.68	238.5	134.93	87.65	1337.69

For sample-S1

Epoxy resin = 55 wt% = 0.55

Hardener = 1:10 ratio of epoxy = .055

Bagasse fiber= 30 wt% =0.345

Fly ash filler = 5 wt% = 0.05

$\mathcal{P}c = 0.64\ g/cm^3$ (density of composites S1)

$Mc = \mathcal{P}c\ Vc = 0.64\ g/cm^3 * 150\ cm^3$

Mc = 95.84 g (mass of composites S1)

Mass of Epoxy resin = 95.84 g x 55 % = 52.71 g

Mass of bagasse = 95.84 g x 34.5 % = 33.1 g

Mass of fly ash = 95.84 g x 5 % = 4.79 g

Mass of hardener = 95.84 g x 5.5 % = 5.27 g

3.3.1.3 Fiber, filler and matrix volume fraction (V_p, V_F, V_M)

Volume fraction of composite materials constituent measured using dividing mass of constituent to density of constituent.

$$\text{Volume of constituent} = \frac{\text{mass of constituent}}{\text{density of constituent}}$$

$$V_f = \frac{Mf}{\mathcal{P}f} \qquad 3.8$$

$$V_c = V_m + V_f + Vp \qquad 3.9$$

$$\text{Fiber volume fraction} = \frac{volume\ of\ fiber}{total\ volume}$$

$$V_F = \frac{vf}{vf+vm+vp} \qquad 3.10$$

$$\text{Filler volume fraction} = \frac{volume\ of\ particulate}{total\ volume}$$

$$V_p = \frac{vp}{vp+vm+vp} \qquad 3.11$$

$$\text{Matrix volume fraction} = \frac{volume\ of\ matrix}{total\ volume}$$

$$V_m = \frac{v_m}{v_f + v_m + v_p} \qquad 3.12$$

3.3.1.4 Calculation to find the Volume of the Fiber, particulate and matrix

For sample S1

$$\text{Volume of fiber} = \frac{\text{mass of fiber}}{\text{density of fiber}}$$

$$V_b = \frac{M_b}{\mathcal{P}_b} = \frac{33.1}{0.35} = 94.57\ cm^3$$

$$V_e = \frac{52.71}{1.25} = 42.2\ cm^3$$

$$V_{fl} = \frac{4.79}{0.6} = 7.98\ cm^3$$

$$V_{ha} = \frac{5.27}{0.98} = 5.38\ cm^3$$

where;

$\mathcal{P}f$: Density of fiber (gm/cm^3)

$\mathcal{P}m$: Density of matrix (gm/cm^3)

V_F: Fiber volume fraction

VM: Matrix volume fraction

Vf: volume of fiber (cm^3)

V_m: Volume of matrix (cm^3)

V_{fl} : Volume of fly ash (cm^3)

M_M: Matrix mass fraction

M_f: fiber mass fraction

M_f: Mass of fiber (gm)

Mm: Mass of matrix (gm)

Mc: Mass of composite (gm)

V_e : Volume of epoxy (cm^3)

V_{ha} : Volume of hardener (cm^3)

Table 3.3 The calculated volume of constituents in each sample

Samples	Composition (Wt %)					Volume (cm^3)				
	Epoxy	Fiber(B/E)	Fly ash	Hardener	Total	Epoxy	Fiber(B/E)	Fly ash	Hardener	Total
S1	55	34.5	5	5.5	100	42.20	94.57	7.98	5.38	150.13
S2	65	23.5	5	6.5	100	102.40	18.20	16.40	13.05	150.05
S3	75	12.5	5	7.5	100	92.67	31.39	12.87	11.82	148.75
S4	65	18.5	10	6.5	100	60.88	61.86	19.50	7.76	149.30
S5	75	7.5	10	7.5	100	103.12	5.10	28.65	13.15	150.02
S6	55	29.5	10	5.5	100	57.76	64.10	21.88	7.37	151.10
S7	75	2.5	15	7.5	100	90.18	10.74	37.58	11.50	150.00
S8	55	24.5	15	5.5	100	78.32	17.70	44.50	9.99	149.98
S9	65	13.5	15	6.5	100	73.92	31.18	35.52	9.43	150.05
Total volume						701.45	334.84	224.88	89.45	1349.38

3.3.2 Optimizing parameters of composite materials

In this subsection, design of experiment (DOE) has been used to find out the parameters optimum composite, which give good results.

3.3.2.1 Design of Experiment

In the design of experiment, (DOE) Taguchi method is commonly used because it is a problem-solving tool, which can improve the performance of the product, process design and system. Design of experiment is a technique of defining and investigating all possible conditions involving multiple factors, parameters and variables in an experiment to observe the most influential process parameters [Meet Minitab 15 (2007)].

3.3.2.2 Selection of Oorthogonal array (OA) and Column Assignment

The selection of a particular orthogonal array was based on the number of levels of various factors. Here, to conduct the experiments 3 factors each at 3 levels have been selected. Now the Degree of Freedom (DOF) fabrication of composites can be calculated by the formula given below.

$$DOF = P \times (L - 1) \qquad 3.13$$

where, P = number of factors and L = number of levels

DOF = 3(3 – 1) = L9, However, total number of experiment of the orthogonal array (OA) should be greater than or equal to the total DOF required for the experiment. Thus, L9 orthogonal array has been selected to perform the further experiments as shown in Table 3.7.

3.3.2.3 Data Analysis and Optimal setting

The optimal setting of factors is obtained by drawing main effect. The data obtained is analyzed by raw data of the S/N ratio (Signal to Noise Ratio) and analysis of variance (ANOVA). For S/N ratio analysis, the conversion of raw data to S/N ratio is based on the maximizing the value of tensile strength and hardness have been selected as larger is the better type of characteristic. Nine different fabrication of composite with different parameters and at different levels have been taken. In the Taguchi method, the response variation has been studied using signal-to-noise ratio and maximizing by optimizing the responses parameters. The larger is the better S/N ratio used for this response.

3.3.2.4 Analysis of variance (ANOVA)

The purpose of the analysis of variance (ANOVA) has been to find which parameters significantly affect the property of composite materials. ANOVA is the statistical technique used to find the influence of all control parameters. In the analysis of variance, the percentage contributions of each control factor were used to measure the corresponding effects on the performance characteristics. The significance level of 5 %, i.e. for 95 % level of confidence was considered in this analysis. ANOVA results indicate whether there is statistically significance in difference or not in output characteristics. When α values is below 0.05 is significant and above 0.05 is not significant. From analysis of variance, percentage contribution of each influential parameter was calculated by:

$$P\ (\%) = \left(\frac{SSTR - DOF \times MSE}{SST}\right) \times 100 \qquad 3.14$$

where, P: Percentage contribution of individual factor, SSTR (Adj SS): Sum of squares or treatment sum of squares, DOF: Degree of freedom, MSE (Adj MS): Mean square Error and SST: Total sum of squares.

3.3.2.5 Confirmatory Experiment

Taguchi suggested that if the optimal setting is not among the trials of the experiments, then confirmatory experiment should be done to verify the results. A confirmatory experiment is done considering the predicted optimal setting of the factors to verify the results. Many researchers have worked to get various UTS under several control parameters. The objective is to get optimum parameters to obtain maximum strength and hardness of the composite. For this, three parameters (weight percentage of fly ash, fiber volume fraction and type of fiber) are selected as input parameters or independent variable. To get optimum parameters by fixing three factors with three levels (i.e. fly ash weight percentage (5%, 10% and 15%), fiber volume fraction (55%, 65% and 75%) and types of fiber (Bagasse (natural fiber), E-glass (synthetic fiber), and Bagasse/E-glass (natural and synthetic fiber)). The layout of experiment has been given by Taguchi method is listed in the Table 3.4 and optimizing method of the parameters has been done by both Taguchi method and ANOVA method by using Minitab 17.

Table 3.4 Experiment lay out of Taguchi L9

No. of experiment	Filler	Fibre	Epoxy
S1	5%	Bagasse	55%
S2	5%	E-glass	65%
S3	5%	E-glass/Bagasse	75%
S4	10%	Bagasse	65%
S5	10%	E-glass	75%
S6	10%	E-glass/Bagasse	55%
S7	15%	Bagasse	75%
S8	15%	E-glass	55%
S9	15%	E-glass/Bagasse	65%

3.3.3 Matrix preparation

Epoxy resin will be used as matrix since epoxy resin has low molecular weight oligomer that contains one or more epoxy groups per molecule (more than one unit per molecule is required if the resultant material is to be cross-linked). Epoxy resins can be cross-linked through a polymerization reaction with a hardener at room temperature or at elevated temperature. Epoxy resin will mix with varies amount of fly ash filler materials and hardener by using mechanical mixer with 300rpm speed to mix epoxy to ash filler. Step followed to prepare matrix is

- First measuring weight percentage of Epoxy resin, fly ash and hardener
- Next step is mixing proper amount of epoxy and fly ash is mechanically stirred for 15 minutes at 300 rpm.

- Epoxy resin is cured by mixing with hardener in ratio of 1 to 10 weight ratio of hardener to epoxy resin
- Finally, hardener poured after epoxy and fly ash mixed properly and stirred using deep stick material for 15 min.

3.3.4 Alkaline-Based (Sodium Hydroxide) Treatment

Treatment of natural fiber (Bagasse fiber) using sodium hydroxide (NaOH) is broadly applied for composites for bleaching and cleaning the surface of the natural fibers to maximize the efficiency of the fiber as reinforcement. This handling alters the direction of extremely packed crystalline cellulose arrangement and creates an unstructured region by enlargement of fiber cell wall. This process offers more access to penetration of chemicals. Alkali-sensitive hydrogen bonds existing among the fibers are agitated and new hydrogen bonds form between the chains of cellulose molecules and increase surface roughness. Alkaline-based treatment removed the waxy substances on the surface of the fiber thereby improving the close contact of matrix of fibers. Chemical treatment of bagasse fibers performed by soaking in 5 % (w/w) NaOH solution at atmospheric temperature Acharya et al. (2011). The bagasse fibers have been kept plunged in the solution for 6 hour and there after the fibers were cleaned by the fresh clean water for several times to remove NaOH contents from the fibers.

a) Bagasse before treated b) Bagasse under treatment c) Bagasse after treated

Figure 3.8 Bagasse treatment in NaOH solution

3.3.5 Hand Laminating method (or Wet Layup)

The hand layup method is a very simple and low cost method for the fabrication of composite material. As a part requirement for the hand layup process, a mold must be used unless the composite has to be fixed right to the next structure. The mold should not be complicated and can be a flat sheet or have unlimited curves and edges. For few typical sizes/shapes, molds should be joined in sections/parts so that after curing they can be separated. A release agent can be used and applied on the surfaces of the molds so that the part will not be able to stick to the mold surfaces. The fibers (for reinforcement) can also be laid in the mold as desired by the designer. After that, resin should be added to the fibers.

3.3.6 Fabrication of composite

Fabrication of the composites is done at room temperature by hand lay-up techniques. The required ingredients are Epoxy resin, hardener, and fillers are mixed thoroughly in a basin and the mixture is subsequently stirred mechanically at 300-rpm speed constantly up to 15 minutes for chemically bonded epoxy resin with hardener and filler material. The chopped type E-glass fiber and bagasse fiber cut in to dimension of mold (200 mm X 150 mm) and positioned manually in the open mold. The mixture of Epoxy, hardener and filler material (fly ash) poured in to prepared mold over the glass placed in the mold box layer by layer and brushed uniformly. During pouring of mixtures to the mold box atmospheric air entrapped in to the composites material. To remove entrapped air manually with squeezes or rollers to complete the laminates structure and the composite is cured at room temperature. To remove the developed composite from the mold easily, a wax well spread over the mold surface before the material has been poured into it.

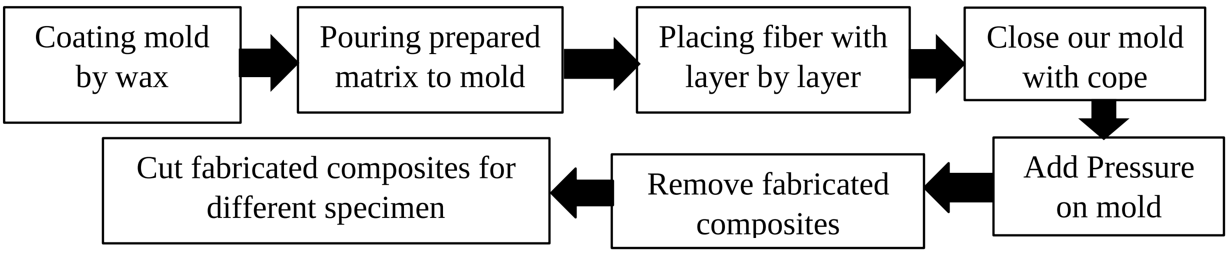


Figure 3.9 Procedure to fabricate composites samples

a) Fabricated E-glass composite	b) Fabricated E-glass/bagasse composite	c) Fabricated bagasse

Figure 3.10 Fabricated composites with different weight percentage of fly ash

where, I, II and III indicates fabricated composites with 5%, 10% and 15% weight of fly ash respectively.

3.3.7 Specimen preparation

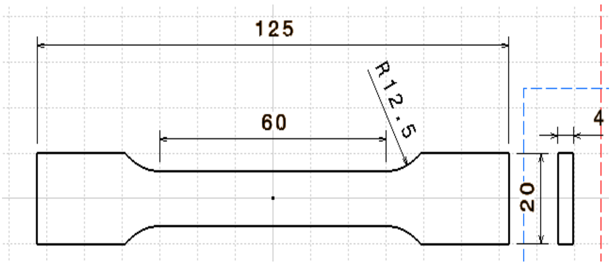
Commercially available E-glass fiber, bagasse fiber, fly ash and epoxy had been used for making specimen. The specimen had been cut and prepared as per the assumed dimensions for tensile, microstructures and hardness tests.

3.3.7.1 Specimen preparation for tensile testing

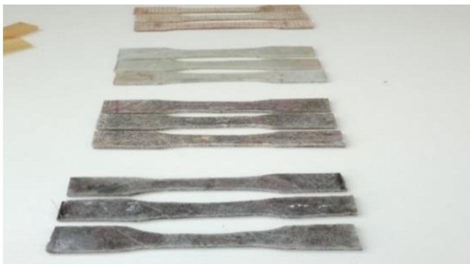
The composite material fabricated for the mechanical prosperity test, the tensile test specimen was prepared according to the ASTM. The dimension, gauge length has been chosen according to the ASTM D638 standard Aladdin *et al.* (2011). A tensile test involves mounting the specimen in a machine and subjecting to the tension until it fracture. The tensile force recorded as a function of the increasing in gauge length. During the applied force. The dimension of specimen is length 125 mm, width 20 mm and thickness 4 mm.

Table 3.5 Specimen specifications for tensile testing

Parameter for Specimen	Specimen for tensile testing
Length	125 mm
Width	20 mm
Thickness	4mm



(a) Tensile specimen according to standard



(b) Tensile specimen prepared for testing

Figure 3.11 Specimen for tensile test

3.3.7.2 Specimen preparation for analysis of microstructures and hardness

The hardness of the polymeric composite is a critical parameter that influences the durability and lifespan of the material. Hardness test was conducted using the Vickers hardness machine. Vickers hardness test can test hardness material by indenting the material by using diamond indenter tool and conduct the hardness of material. Size of specimen is length 10 mm, width 10 mm and thickness 4 mm.

3.3.7.3 Specimen preparation for machining

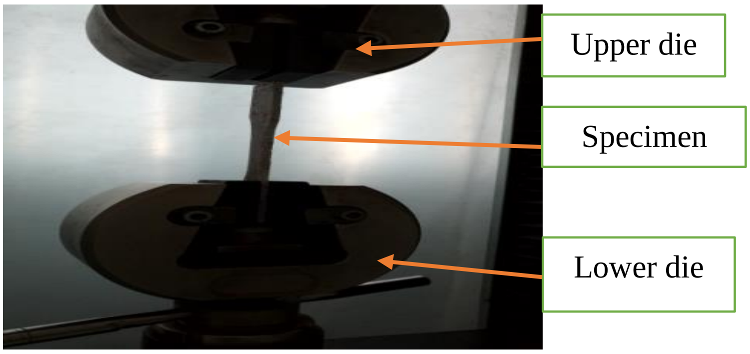
The prepare E-glass and bagasse fiber reinforced epoxy composite with ash filler composite will take out from the mold and then specimens of suitable dimensions will prepare from the composite slabs for different mechanical tests according to ASTM standards. The test specimens will cut by using marble cutter and different tools in the workshop. Three identical test specimens will prepare for different test.

3.3.8 Mechanical test

Mechanical properties of composites will be evaluate by tensile, microstructure, machining measurement and hardness measurements. Tensile tests carried out using Universal tensile testing machine, study of microstructure carried out by optical microscope and Vicker hardness tester used for conducting hardness test.

3.3.8.1 Tensile test

The tensile strength testing was done on universal testing machine shown in Figure 3.10. The gauge length was 55mm. The crosshead speed was 100mm/min, at room temperature the specimens were subjected to a controlled tension until they failed. The elongation up to the breaking point, the load taken by the specimens until the point of breaking and the ultimate tensile stresses were calculated by the machine. Thereafter, strain and Young’s modulus were calculated according to the formula using the data obtained from the machine.



a) Tensile test machine during experiment conducting

b) Tensile test specimen

Figure 3.12 Tensile test machine and specimen prepared for tensile test

3.3.8.2 Microstructure Observation

Determining grain size, shape and distribution of various phases and inclusions was important as these effects of the mechanical properties of the composite materials. The specimen preparation of sample to examine microstructure were cutting of specimen, grinding, polishing, etching and observing microstructure by optical microscopy. The procedure of specimen preparation metallographic test was as follows.

Cutting specimen → Mounting specimen → Grinding specimen → Etching specimen → Analysis of microstructures

Figure 3.13 Procedure of specimen preparation metallographic test

a) Cut Specimen from the Sample

The first step of any microstructural test is to; cut the specimen from the sample accurately to the required testing size. For this work nine sample with dimension of one-centimeter length specimen were cut from each sample by using consumable high speed rotating disc abrasive cutter to examine microstructures

b) Mounting Specimen for Microstructural test

The second step of specimen preparation was mounting specimen for microstructural. Specimens cut from each sample were fixed in a holder to be handled easily during polishing, which is necessary to examine microstructure. The mounting operation was done by RB 206 Met press-A machine using two-cup MC-PRC/phenolic resin conductive powder. The maximum heating temperature was 250°C and took 1020 seconds/17 minutes (i.e. 300sec for heating time, 300sec holding time and 420sec for cooling time) for each samples. The machine consists of upper ram, lower ram, heating part and cooled by water controlled by solenoid valve. A small piece of specimen increased in to a 32 mm diameter pellet before grinding and polishing.

c) Grinding of Specimen

After a mounting operation, two grinding process were applied on each specimen. The first one was a rough grinding using silicon carbide paper and second one intermediate grinding process using RB 204 Metpol-II machine. All the specimen were grinded by the same method and procedure. First grinded by 400 grit size silicon carbide paper for about two minute. Again grinded by the following carbide papers 800, 1200 and 2000 grit size respectively. After each step of grinding dust particle is washed by water and removed by compressor. The rough grinding of sample was continued until the surface in flat and free from nicks, burrs, etc.

d) Polishing of specimen

The success of fine polishing depends largely upon the care that was worked during a previous grinding operation step. The final approximation to a flat scratch-free surface was obtained by using of the wet rotating wheel covered with a special cloth that charged with carefully sized abrasive particles. In this step of specimen preparation, the specialized liquid spray on the surface of polishing cloth was diamond suspension liquid is used as spray form. Nine specimen of sample of each test polished four times before the etching. In each of the polishing step, the specimen is washed with water and dried using pressurized compressor. The process continued up to four times until the specimen is free from any scratch and shine surface is obtained.

e) Etching

Etching was the final step of specimen preparation to make the sample visible to many structural characteristics of the metal. This was accomplished by using an appropriate reagent, which subjects the polished surface to chemical action. All sample was etched by 25 ml hydrochloric acid and 5 ml ethanol combination. The duration of time of each sample etching was 12 second. Then the shine surface of specimen put on the table of optical microscopy and examine its microstructure properties. The optical microscopy was having five magnification ranges, which are 50×, 100×, 200×, 500× and 1000×. The scanning area covers 104 mm × 102 mm. Microstructural properties observed by 20-micrometer label.

3.3.8.3 Hardness test

Hardness is the properties of material that allows to resist a plastic deformation, usually measured by penetration. The value of this property was the result of a defined dimension procedure, thus depending on the hardness method used; the hardness value will be different. All hardness tests contain the use of a specifically shaped indenter, significantly harder than the test sample. This indenter is pressed into the external surface of the sample using a specific force. Either the size or depth of the indent is measured to determinate a hardness value. Hardness measurements were extensively used for the superiority control of materials because they are rapid and considered nondestructive tests when the marks or indentations produced by the test are in low stress areas.

There are many methods to determine the hardness, among those Brinell, Vickers and Rockwell hardness tests are frequently used. In this experiment Vickers's hardness test was used to measure the sample extrudes qualities. Vickers hardness test was measured to determine the hardness of a material, calculated from the size of an impress produces under load by a pyramid shaped diamond indenter. The diamond was pressed on the surface of material at measuring range up to approximately 5 kgf (kilogram force) and the size of the impression was measured with the help of a calibrated microscope. The Vickers hardness number (HV) was calculated using the following formula:

$$\mathrm{HV} = \frac{(\mathrm{constant} * \mathrm{testforce})}{\mathrm{surface\ area\ of\ indentation}} \qquad 3.15$$

$$= \ 0.102 * 2F\ (sin1360/2)/d1d2$$

Square-based pyramid diamond indenter with an angle 1360 between the opposite faces at the vertex. Where F being the applied load (measured in kilogram force) and d1d2 the area of the indentation (measured in square millimeters). The Vickers hardness should be reported like 400 HV/5, which means a Vickers hardness of 400, was obtained using a 5 kg force. Very accurate readings can be observed in this test, which is one of the main advantages of the Vickers hardness test and just single type of indenter is used for each and every type of specimen. From nine sample for each test, 10 mm × 10 mm × 4 mm specimen were cut at the cross section for microstructural study and micro-hardness measurement from each sample. Micro-hardness was measured with Vickers micro-hardness tester HVS-50 machines just after microstructural test by using both 5Kgf and

10Kgf.

Figure 3.14 Vickers hardness-testing machines

3.3.8.4 Machinability test

The mechanical behaviour of fibre-reinforced composites at a macro level is influenced by the properties of the matrix and the fibres. In general, fibres contribute high modulus, high strength and brittleness, whereas resins contribute toughness, low density, low strength, low stiffness, high thermal expansion and low thermal stability. Polymer matrix composites exhibit a wide variety of failure modes including fibre fracture, fibre pull out from the matrix, plastic flow in the matrix, delamination. After fabricating composites materials different machining operation is required. Drilling, counter boring, and countersinking are often required processes for preparing composite parts for joining and assembly. Performing machinability test after fabrication of the polymer based composites material is very important to minimize the failures on composite material during machining operation. Machining of Composite material has challenges due the following points:

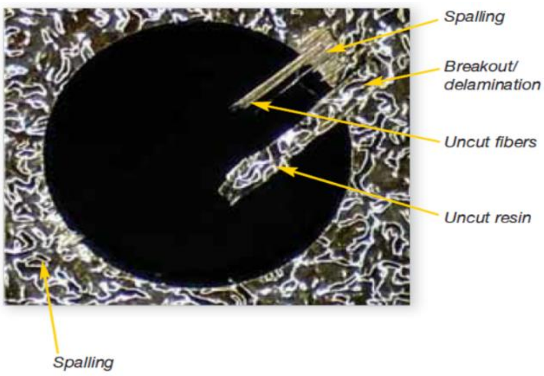


Figure 3.15 Defect on composite during drilling operation Jalumedi Babu *et al.* (2016)

3.3.8.4.1 Drilling of composite materials

Because the heat generated during drilling is affected by the cutting speed and the feed rate, FRPs are machined only in a limited range of process parameters in order to avoid heat damage. In this work the drilling operation, take place with radial drill, with diameter of 6 mm two flute twist drill bit at 200 rpm, 2 mm per second speed and 0.5 revolution per minute feed rate of the drilling machines.

Figure 3.16 Radial drilling machine

CHAPTER FOUR

4 RESULTS AND DISCUSSION

4.1 Introduction

In this chapter the result of experimental works have been discussed in detail. In different sub sections hardness test result, tensile strength test result, microstructure results and machinability test result are explained.

4.1.1 Hardness Testing Result

Hardness is the resistance of a material to deformation, indentation or scratching. The basic goal of hardness testing is to quantify the resistance of a material to plastic deformation. Load used during hardiness test was 49.05 N (5 kgf) on three trails on a sample. For each test, three reputations are followed and an average value was taken. All the experimental data is tabulated in the Table 4.1.

Table 4.1 Experimental result for mean value of Hardness

Samples	Filler (%)	Fibre type	Epoxy (%)	Hardness value (HV)			Avg. HV	S/N ratios
				Trial 1	Trial 2	Trial 3		
S1	5%	Bagasse	55%	16.30	17.00	16.70	16.67	24.43
S2	5%	E-glass	65%	17.90	17.80	19.50	18.40	25.27
S3	5%	E-glass/Bagasse	75%	19.50	19.00	22.00	20.17	26.04
S4	10%	Bagasse	65%	16.30	17.80	18.00	17.37	24.77
S5	10%	E-glass	75%	24.10	19.40	23.70	22.40	26.88
S6	10%	E-glass/Bagasse	55%	24.10	24.00	22.00	23.37	27.35
S7	15%	Bagasse	75%	19.60	23.70	19.00	20.77	26.23
S8	15%	E-glass	55%	24.60	24.90	23.70	24.40	27.74
S9	15%	E-glass/Bagasse	65%	34.00	32.00	29.00	31.67	29.96
Average performance mean value							21.69	26.52

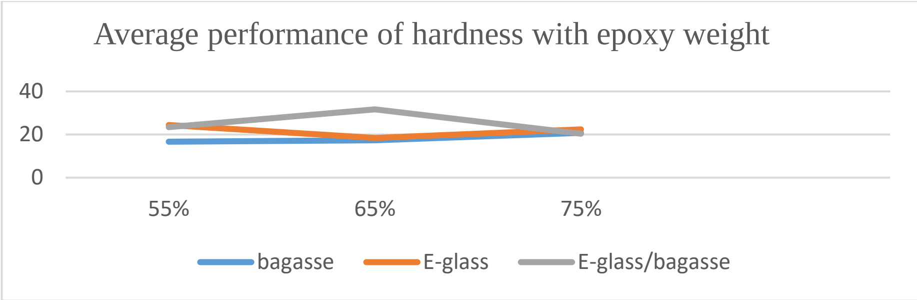
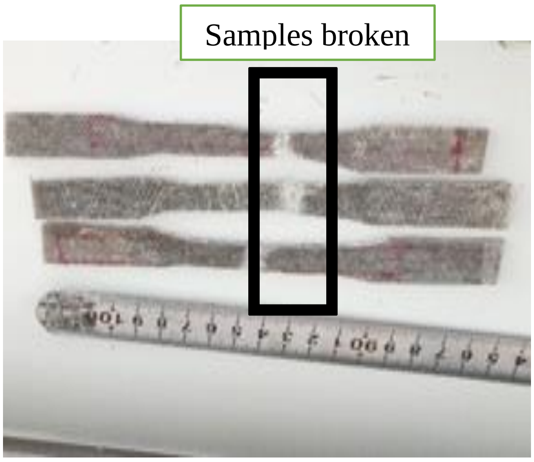


Figure 4.1 Average performance of HV with weight percentage of epoxy

Table 4.1 and Graph 4.1 shows that the result of hardness value of fabricated composites materials according to orthogonal array given in Table 3.3. The hardness value of bagasse composite materials increases from 17 HV to 20 HV as weight percentage of fly ash increases from 5 to 15%. The hardness value of E-glass composites materials also uniformly increase from 18 HV to 24 HV as fly ash weight percentage increases from 5 to 15%. Finally, the bagasse + E-glass composite materials hardness value is also increase uniformly increases from 20 HV to 32 HV for weight percentage of fly ash increases from 5 to 15%. From the result given above also the hardness value of bagasse/E-glass, composites are higher than that of E-glass composites that is greater than bagasse composites materials in each weight percentage of fly ash. Increasing fly ash weight percentages increases the hardness value of composite materials due to increasing load transfer and interfacial bond between matrix and fiber.

4.1.2 Analysis of Tensile Test Results

The tensile strength testing was done using universal testing machine and samples are shown in Figure 4.1. The gauge length was 55mm. The crosshead speed was 1mm/min, in room the specimens were subjected to a controlled tension until they failed. The elongation up to the breaking point, the load taken by the specimens until the point of breaking and the ultimate tensile stresses were calculated by the machine.



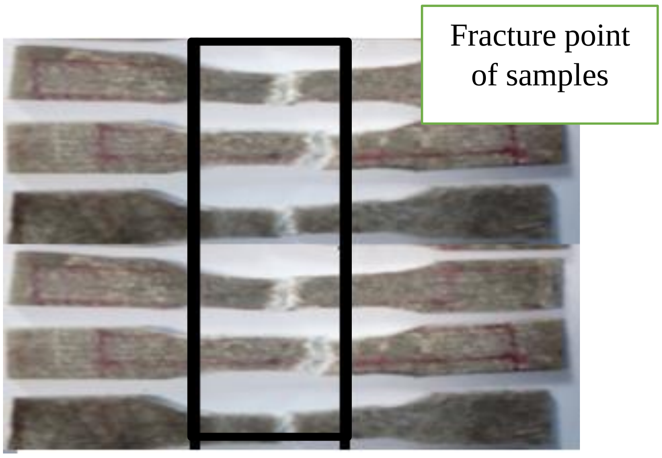


Figure 4.2 Specimen after tensile testing

There are several failure are incorporated to the tensile specimen. Some failure type observed in the specimen are explosive of fiber failure in the E-glass composite with fly ash of 5%, 10% and bagasse/E-glass composites with fly ash of 5%. Additionally, lateral gage middle type of failure is observed on bagasse composite with 10% and 15% of fly ash weight percentage. Most of the sample are failed in the gage area of sample that is nearest to the center of the sample, but some of sample also failed at various gage area that need the additional experiment to get the acceptable tensile strength of samples.

Table 4.2 Experimental result for mean value of tensile strength

Samples	Filler (%)	Fibre type	Epoxy (%)	Tensile Strength (MPa)			Avg. UT (MPa)	Strain (mm)	S/N ratios
				Trial 1	Trial 2	Trial 3			
S1	5%	Bagasse	55%	92.90	91.70	92.90	92.50	6.41	39.32
S2	5%	E-glass	65%	127.50	116.30	104.30	116.03	3.13	41.20
S3	5%	E-glass/Bagasse	75%	104.30	100.30	69.70	91.43	2.88	38.78
S4	10%	Bagasse	65%	72.40	92.10	91.70	85.40	5.70	38.46
S5	10%	E-glass	75%	90.30	91.20	80.60	87.37	5.54	38.79
S6	10%	E-glass/Bagasse	55%	139.60	136.30	129.20	135.03	2.09	42.60
S7	15%	Bagasse	75%	69.90	59.10	68.70	65.90	5.14	36.30
S8	15%	E-glass	55%	105.80	92.90	99.30	99.33	6.31	39.91
S9	15%	E-glass/Bagasse	65%	111.30	116.30	100.20	109.27	3.46	40.72
Average performance mean value							98.03	4.52	39.56

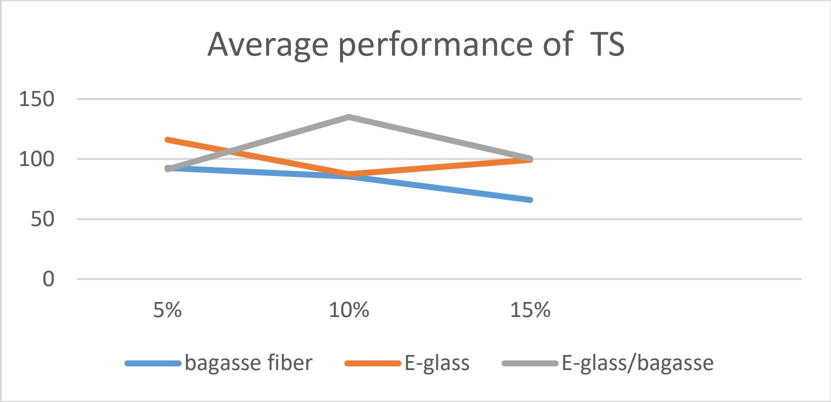


Figure 4.3 Average performance of HV with weight percentage of fly ash

Table 4.2 and Graph 4.3 shows that the result of tensile strength fabricated composites materials according to orthogonal array given in Table 3.3. The tensile strength of bagasse composite materials decreases from 92 MPa to 66 MPa as weight percentage of fly ash increases from 5% to 15%. The tensile strength of E-glass composites materials is maximum (116 MPa) at fly ash weight, percentage is 5% and minimum (87.37 MPa) for sample of weight, percentage of fly ash is 10%. The tensile strength of bagasse/E-glass composite materials is maximum (135.03 MPa) at weight percentage of fly ash is 10% and minimum (91.43 MPa) for sample of weight, percentage of fly ash is 5%.

From the result given above also the tensile strength of bagasse/E-glass composites, attain maximum value at 10% of fly ash, 55% of epoxy resin and 5.5% of hardener weight percentage. The reason behind maximum tensile is attain for sample S6 is the volume of fiber is higher than the volume of fiber in sample S3 and sample S9. Increasing the fiber volume in the composites materials increases the ability to carry maximum load. The main advantages of fiber in the composites materials are sharing load and increase the bond between constituent of composite materials.

4.1.2.1 Analysis of Mean for Hardness and Tensile Test Results

The average main effect of mean value for hardness and tensile strength given as weight of fly ash (A), type of fiber (B), and weight of epoxy resin (C) calculated using the Minitab 17 design of experiments. Table 4.1 and Table 4.2 presents the experimental results of Vickers hardness test machines for each specimen and their mean values and the experimental results of UTS machines for each specimen and their mean values respectively. Vickers hardness test result and tensile test result is conducted with mean value of the three-trial reading average.

4.1.2.2 Analysis of Mean for Hardness

The mean value of hardness for each factor weight of fly ash (A), type of fiber (B), and weight of epoxy resin (C) at each level1, 2 and 3 are obtained and the result is listed in response Table 4.3.

Table 4.3 Response Table for means of Larger is better

Level	Weight of fly ash	Type of fiber	Weight of epoxy
	Symbol		
	A	B	C
1	18.41	18.27	21.48
2	21.04	21.73	**22.48**
3	**25.61**	**25.07**	21.11
Delta	7.20	6.80	1.37
Rank	1	2	3

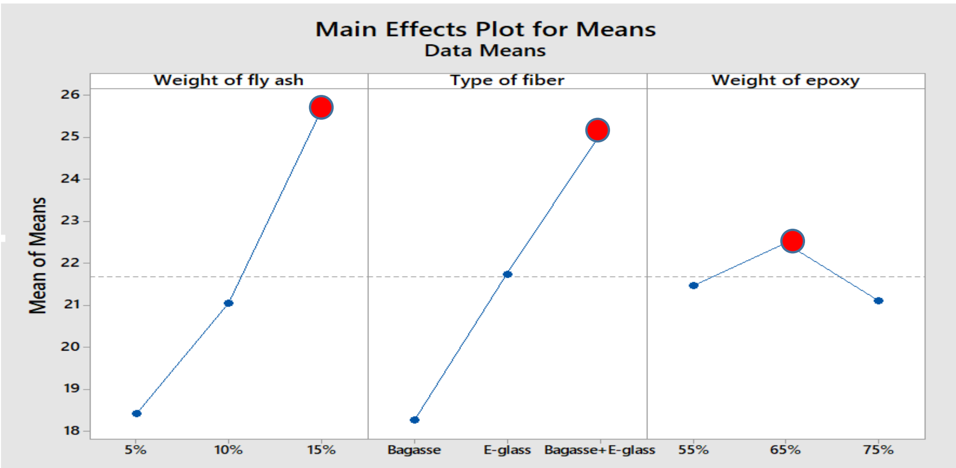


Figure 4.4 Main effect plot of means

Table 4.3 and Figure 4.2 shows the effect of each parameters on mean value of the expriment where A, B and C represents the weight of fly ash, type of fiber and weight of epoxy in composite materials. The maximum mean attained at weight fly ash at level three (15% of fly ash), type of fiber at level three (Bagasse/E-glass fiber) and weight of epoxy at level two (65% of epoxy). The result taken from the above data shows main effect of mean, as lager is better is selected for hardness value output. Delta = (maximum mean – minimum mean). Table 4.3 and Figure 4.2 show that the factor with the greatest effect on the mean is weight of fly ash weight percentage (Delta 7.20 =, Rank = 1). The factor with the least effect on the mean is weight of epoxy (Delta = 1.37, Rank = 3). Since main effect plots for means is helpful for adjusting the mean on better value. Those parameter levels with better hardness value of specimens that means A3B3C2 will be taken as a possible parameter combination for better values. The hardness value of fabricated composites materials in all specimen increases as weight of fly ash filler increase up to 15% within 5% ranges. The result shows as addition of fly ash increase the load distribution between matrix and fiber, also increase bond of composites materials.

4.1.2.3 Analysis of Mean for tensile strength

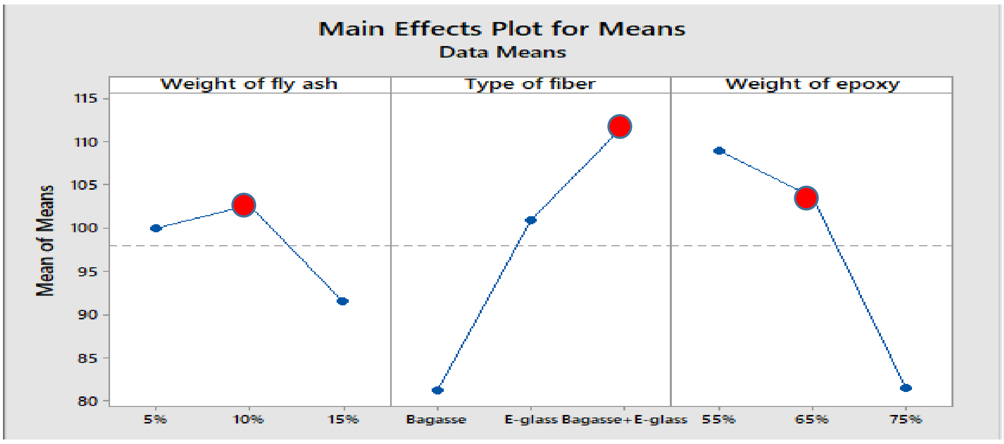


Figure 4.5 Main effect plot for Means

Table 4.4 Response Table for mean effect of Larger is better

Level	**Weight of fly ash**	**Type of fiber**	**Weight of epoxy**
	Symbol		
	A	**B**	**C**
1	99.99	81.27	**108.96**
2	**102.60**	100.91	103.57
3	91.5	**111.91**	81.57
Delta	11.10	30.64	27.39
Rank	3	1	2

Table 4.4 and Figure 4.3 shows the effect of each parameters on mean value of the expriment in tensile streength where A, B and C represents the weight of fly ash, type of fiber and weight of epoxy in composite materials. The maximum mean attained at weight fly ash at level two (10% of fly ash), type of fiber at level three (Bagasse/E-glass fiber) and weight of epoxy at level one (55% of epoxy). The result taken from the above data shows main effect of mean, as lager is better is selected for tensile strength output. Delta = (maximum mean – minimum mean). The result shows that the factor with the greatest effect on the mean is type of fiber weight percentage (Delta 30.64 =, Rank = 1). The factor with

the least effect on the mean is weight of fly ash (Delta = 11.10, Rank = 3). Since main effect plots for means is helpful for adjusting the mean on better value. Those parameter levels with better tensile strength of specimens that means A2B3C1 will be taken as a possible parameter combination for better values. The tensile strength of fabricated composites materials in all specimen increases as volume fraction of fiber increase in each composite materials.

4.1.3 Predict the Performance at Optimal Levels the Mean Value

4.1.3.1 Analysis of Mean for Hardness

For predicting the optimum response, three factors of parameters are selected by mean value. A3B3C2 is the optimum levels of parameters mean value for hardness value. To find out predicted value of the responses (hardness value) the following regression equation is used:

$$Ypqt = m + (m\text{A3} - m) + (m\text{B3} - m) + (m\text{C2} - m) \quad 4.1$$

where, m = Average performance mean value for hardness value, mA3 = optimum level value for parameter A, mB3= optimum level value for parameter B, mC2= optimum level value for parameter C.

$Ypqt$ = 21.69+ (25.63-21.69) + (25.07-21.69) + (21.11-21.69)

$Ypqt$ = 28.43 (predict mean value for hardness value).

4.1.3.2 Analysis of Mean for tensile strength

For predicting the optimum response, three factors of parameters are selected by mean value. A2B3C1 is the optimum levels of parameters mean value for tensile strength. To find out predicted value of the responses (tensile strength) the equation 4.1 is used:

$Ypqt$=98.03+ (102.6 - 98.03) + (111.91 - 98.03) + (108.96 - 98.03)

$Ypqt$= 127.41 (predicted mean value for tensile strength).

4.1.4 Analysis of S/N Ratios for Hardness and Tensile Strength

The Taguchi method uses S/N ratio to measure the variations of the hardness value and tensile strength value in experimental design. The equations for calculating the signal to noise ratios are based on the characteristics of the response variables being evaluated. In the case of this study, the response variables are larger-the-better. Therefore, larger-the-better characteristic was used and S/N equation for this characteristic is given in Maximizing performance characterstic equation below (4.2).

$$\frac{S}{N} = -10log(\frac{1}{n}\sum_{j=1}^{n}\frac{1}{yij2}) \quad 4.2$$

4.1.4.1 S/N Ratios for Hardness

Table 4.5 and Figure 4.4 presents the calculations of S/N ratios for hardness value results using the Minitab 17 design of experiments. Effect of each parameters on signal to noise ratios of the expriment where A, B and C represents the weight of fly ash, type of fiber and weight of epoxy in composite materials. The maximum signal to noise ratio attained at weight fly ash at level three (15% of fly ash), type of fiber at level three (Bagasse/E-glass fiber) and weight of epoxy at level two (65% of epoxy).

Table 4.5 Response Table for Signal to Noise Ratios Larger Is Better

Level	**Weight of fly ash**	**Type of fiber**	**Weight of epoxy**
	Symbol		
	A	**B**	**C**
1	25.25	25.14	26.51
2	26.33	26.63	**26.67**
3	**27.97**	**27.78**	26.38
Delta	2.73	2.64	0.29
Rank	1	2	3

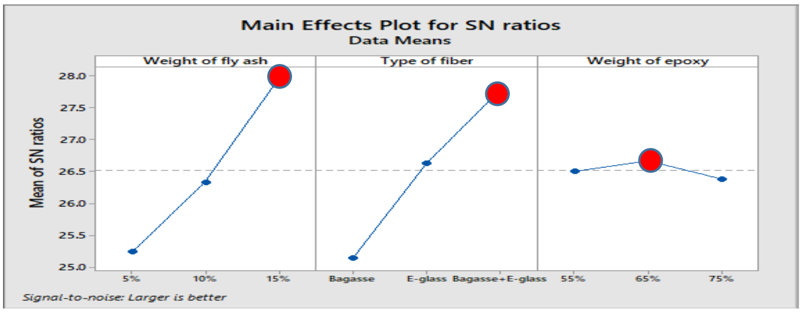


Figure 4.6 Main effect plot for SNR of hardness

The control factors main effect plot for SNR of hardness value variations is as shown in the Figure 4.4. The result taken from the above data shows signal to noise ratio, as lager is better is selected for hardness value output. Delta = (maximum mean – minimum mean).

Table 4.5 and Figure 4.4 show that the factor with the greatest effect on the mean is weight of fly ash weight percentage (Delta 2.73 =, Rank = 1). The factor with the least effect on the mean is weight of epoxy (Delta = 0.29, Rank = 3). Since main effect plots for means is helpful for adjusting the mean on better value. Those parameter levels with better hardness value of specimens that means A3B3C2 will be taken as a possible parameter combination for better values.

4.1.4.2 S/N Ratios for tensile strength

Table 4.6 and Figure 4.5 presents the calculations of S/N ratios for tensile strength results using the Minitab 17 design of experiments. The result shows effect of each parameters on SNR value of the expriment in tensile streength where A, B and C represents the weight of fly ash, type of fiber and weight of epoxy in composite materials. The maximum mean attained at weight fly ash at level two (10% of fly ash), type of fiber at level three (Bagasse/E-glass fiber) and weight of epoxy at level one (55% of epoxy).

Table 4.6 Response Table for Signal to Noise Ratios Larger Is Better

Level	Weight of fly ash	Type of fiber	Weight of epoxy
	Symbol		
	A	B	C
1	39.77	38.03	**40.61**
2	**39.95**	39.96	40.13
3	38.98	**40.70**	37.96
Delta	0.97	2.67	2.65
Rank	3	1	2

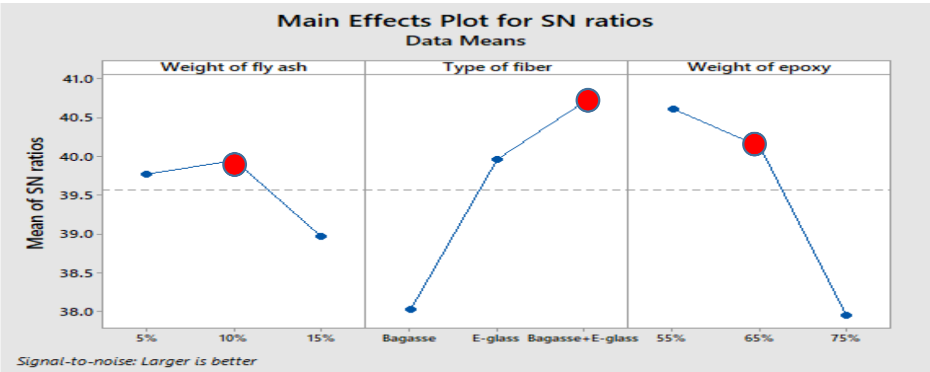


Figure 4.7 main effect plot for SNR of tensile

The control factors main effect plot for signal to noise ratio of tensile strength variations is as shown in the Figure 4.5. The result taken from the above data shows signal to noise ratio, as lager is better is selected for tensile strength output. Delta = (maximum mean – minimum mean). Table 4.6 and Figure 4.5 show that the factor with the greatest effect on the signal to noise ratio is type of fiber weight percentage (Delta 2.2.67 =, Rank = 1). The factor with the least effect on the mean is weight of fly ash (Delta = 0.97, Rank = 3). Those parameter levels with better tensile strength of specimens that means A2B3C1 will be taken as a possible parameter combination for better values.

4.1.5 Predict the Performance at Optimal Levels the Mean Value of SNR

4.1.5.1 Analysis of SNR for Hardness

For predicting the optimum response, three factors of parameters are selected by SNR value. A3B3C2 is the optimum levels of parameters SNR value for hardness value. To find out predicted value of the responses (hardness value) the following equation is used:

$Ypqt$=26.51826 + (27.97-26.51826) + (27.78-26.51826) + (26.67-26.51826)

$Ypqt$=29.38 (predict SNR value for hardness value).

4.1.5.2 Analysis of SNR for Tensile Strength

For predicting the optimum response, three factors of parameters are selected by mean value. A2B3C1 is the optimum levels of parameters mean value for tensile strength. To find out predicted value of the responses (tensile strength) the following equation is used:

$Ypqt$ = 39.56 + (39.95 - 39.56) + (40.70 - 39.56) + (40.61- 39.56)

$Ypqt$ = 42.13 (predict SNR value for tensile strength).

4.1.6 Analysis of Variance (ANOVA) for Hardness and Tensile Strength

ANOVA results DOF = degree of freedom, SSTR = Sum of squares, MSE = Mean square error and F = F- Ratio calculated by using Minitab 17 software were shown in table 4.7. From analysis of variance Percentage, contribution of each influential parameter was calculated by the following formula:

$$P\ (\%) = \left(\frac{SSTR}{SST}\right) X\ 100 \qquad 4.3$$

where, P: Percentage contribution of individual factor; SSTR (Adj SS): Sum of squares or treatment sum of squares; DOF: Degree of freedom; MSE (Adj SS): Mean square Error; and SST: Total sum of squares.

4.1.6.1 Analysis of Variance (ANOVA) for Hardness

Table 4.7 presents tensile strength percentage contribution variation of factors A, B, and C. From the table 4.7 it is clearly observed that none of the p-values was below 0.05, in this case, it is impossible to reject the null hypothesis, or cannot conclude that the all parameter has significant effect on the hardness effect at 95% confidence level. The analysis can stop here (there is no need of further analysis for validating and interpreting ANOVA results). Additionally the above results shows as the weight of fly ash take greater percentage contribution on the hardness of the composites materials by 48.28%, the second percentage contribution is taken by type of fiber that is 44.88% and the least percentage contribution is attained by weight of epoxy is 0.52%. Increasing weight percentage of fly ash highly affect the result of hardness value of composite materials, but weight of epoxy has the least effect on hardness value Meet Minitab 15 (2007).

Table 4.7 Analysis of Variance for hardness value

Source	DF	SST	SSSTR	MSE	F	P	Percent contribution	Significance (α=0.05)
Weight of fly ash	2	11.30	11.30	5.65	7.65	0.12	48.28%	In signif.
Type of fiber	2	10.50	10.50	5.25	7.11	0.12	44.88%	In signif.
Weight of epoxy	2	0.12	0.12	0.06	0.08	0.92	0.52%	In signif.
Residual error	2	1.48	1.48	0.74			6.30%	
Total	8	23.40					100%	

4.1.6.2 Analysis of Variance (ANOVA) for Tensile Strength

Table 4.8 presents tensile strength percentage contribution variation of factors A, B, and C. From the table 4.8 it is clearly observed that none of the p-values was below 0.05, in this case, it is impossible to reject the null hypothesis, or cannot conclude that the all parameter has significant effect on the hardness effect at 95% confidence level. The analysis can stop here (there is no need of further analysis for validating and interpreting ANOVA results).

Table 4.8 Analysis of Variance for tensile strength

Source	DF	SST	SSSTR	MSE	F	P	% contribution	Significance (α=0.05)
Weight of fly ash	2	1.61	1.61	0.80	1.10	0.48	6.07%	In signif.
Type of fiber	2	11.41	11.41	5.71	7.80	0.11	43.14%	In signif.
Weight of epoxy	2	11.97	11.97	5.99	8.18	0.11	45.25%	In signif.
Residual error	2	1.46	1.46	0.73			5.53%	
Total	8	26.45					100%	

4.1.7 Determining the Optimum Condition for Hardness

From above discussion, the optimum level value of fly ash is 15%, for type of fiber is Bagasse/E-glass and for weight of epoxy is 65% make the response S/N ratio values highest. Therefore, the optimum processing parameters signal to noise (S/N) ratio is selected. Table 4.9 presents the optimum parameters setting selected for hardness value obtained from the design of experiment and experimental results.

Table 4.9 show as the 15% of fly ash weight, Bagasse/E-glass fiber type and 65% weight of epoxy give the optimum value of tensile strength of 31.67 HV. Hardness value of fabricated composite materials highly affect with weight of fly ash and the second rank is taken by the type of fiber constituent in the composite materials. Finally, weight of epoxy has least effect on the hardness value of the composite materials. Volume fraction of fly ash share load and interaction bond between constituent of composite material than epoxy and type of fiber that results for optimizing hardness value of fabricated composite materials

Table 4.9 Optimum parameters setting levels and their values

Controllable factors	Level selected	Value of the level	Rank of affecting the response
Weight of fly ash	3	15%	1
Type of fiber	3	Bagasse/E-glass	2
Weight of epoxy	2	65%	3

4.1.8 Determining the Optimum Condition for Tensile Strength

From above discussion, the optimum level value of fly ash is 10%, for type of fiber is Bagasse/E-glass and for weight of epoxy is 55% make the response S/N ratio values highest. Therefore, the optimum processing parameters signal to noise (S/N) ratio is selected.

Table 4.10 presents the optimum parameters setting selected for hardness value obtained from the design of experiment and experimental results. Table 4.10 show as the 10% of fly ash weight, Bagasse/E-glass fiber type and 55% weight of epoxy give the optimum value of tensile strength of 135.03 MPa. The type of fiber used for fabricating composite materials highly affect the tensile strength composite materials than weight of epoxy. Finally, weight of fly ash has least effect on the tensile strength of the composite materials. Volume fraction of fiber can hold maximum load than epoxy and fly ash that results for optimizing tensile strength value of fabricated composite materials.

Table 4.10 Optimum parameters setting levels and their values

Controllable factors	**Level selected**	**Value of the level**	**Rank of affecting the response**
Weight of fly ash	2	10%	3
Type of fiber	3	Bagasse/E-glass	1
Weight of **epoxy**	1	55%	2

4.1.9 Confirmation Test

Once the optimal combination of process parameters and their levels was obtained, the final step was to verify the predicted result against experimental result. If the optimal combination of parameters and their levels coincidently match with one of the experiments in the OA, then no confirmation test is required.

4.1.9.1 Confirmation test for hardness value

By considering this, Confirmation test was not required in this case study because the optimum combination of parameters and their levels (A3B3C2) have a correspondent to an experiment of the orthogonal array of the trail condition (trial 9) of the experiment. The obtained optimal factor combination is one of the trial conditions (Trial 9) of the experiment. Thus, the mean is calculated by averaging the response values of that trial. The Optimum combination of parameters obtained from above at 15% of fly ash, Bagasse/E-glass fiber and 65% of epoxy resin. Optimized parameters hardness value has been observed as 24 HV.

4.1.9.2 Confirmation test for tensile strength

By considering this, Confirmation test not was required in this case study because the optimum combination of parameters and their levels (A2B3C1) have a correspondent to an experiment of the orthogonal array of the trail condition (trial 6) of the experiment. The obtained optimal factor combination is one of the trial conditions (Trial 6) of the experiment.

Thus, the mean is calculated by averaging the response values of that trial. The Optimum combination of parameters obtained from above at 10% of fly ash, Bagasse/E-glass fiber and 55% of epoxy resin. Optimized parameters hardness value has been observed as 135 MPa. Table 4.11 presents the confirmation experiment and predicted results comparison for both tensile strength and hardness.

Table 4.11 Comparison between predicted and experimental confirmation

	Combination	Tensile strength (MPa)	Combination	Hardness (HV)
		S/N ratio		S/N ratio
Predicted	A2B3C1	**42.8**	A3B3C2	**29.95**
Experiment		**42.13**		**29.4**

The results of confirmation experiment mean and S/N obtained from the experiment were then compared with the predicted mean and S/N results as shown in Table 4.11 for both tensile strength and hardness. By comparing the predicted result that calculated by regression equation and the output value of Taguchi result by Minitab 17 software. The difference between experimental results and the predicted results are 1.84% for hardness value and 1.56% for tensile strength. The values of predicted by using Taguchi approach is approximately near to the value which is experimentally obtained. These verify that the experimental results of both tensile strength and hardness are strongly correlated with the predicted results.

4.1.10 Analysis of Microstructure

The microstructure analysis of fabricated composite material can be analyzed by the help of optical microscope that available in Adama Science and Technology University in department of material engineering with magnification power 5X, 10X, 20X, 50X, 100X, 200X and 500X. The result shows that the microstructure of all fabricated composite materials within the respective orthogonal array given in table 3.3. Figure 4.6 (a), (b) and (c) shows the microstructures of fabricated bagasse fiber composites materials with 5%, 10% and 15% fly ash respectively. The result shows that fiber distribution is high in bagasse composites material with 5% fly ash and comparatively low in the composites with 15% fly ash.

The maximum distributed particle of fly ash is shown in composite material with 15% weight percentage of fly ash. Evenly distributed fly ash in composite materials increase the hardness value of composite materials. Figure 4.6 (e), (f) and (g) also shows the microstructures of fabricated bagasse fiber/E-glass fiber composites materials with 5%, 10% and 15% fly ash respectively. The result shows that the fiber distribution is high in composites material with 10% fly ash and comparatively low in the composites with 15% fly ash. Evenly distributed fiber in composite materials is increases the tensile strength of composite materials. Finally, figure 4.6 (h), (i) and (j) shows the microstructures of fabricated E-glass fiber composites materials with 5%, 10% and 15% fly ash respectively. The result shows that the E-glass fiber distribution is high in E-glass composites material with 5% fly ash and comparatively low in the composites with 10% fly ash.

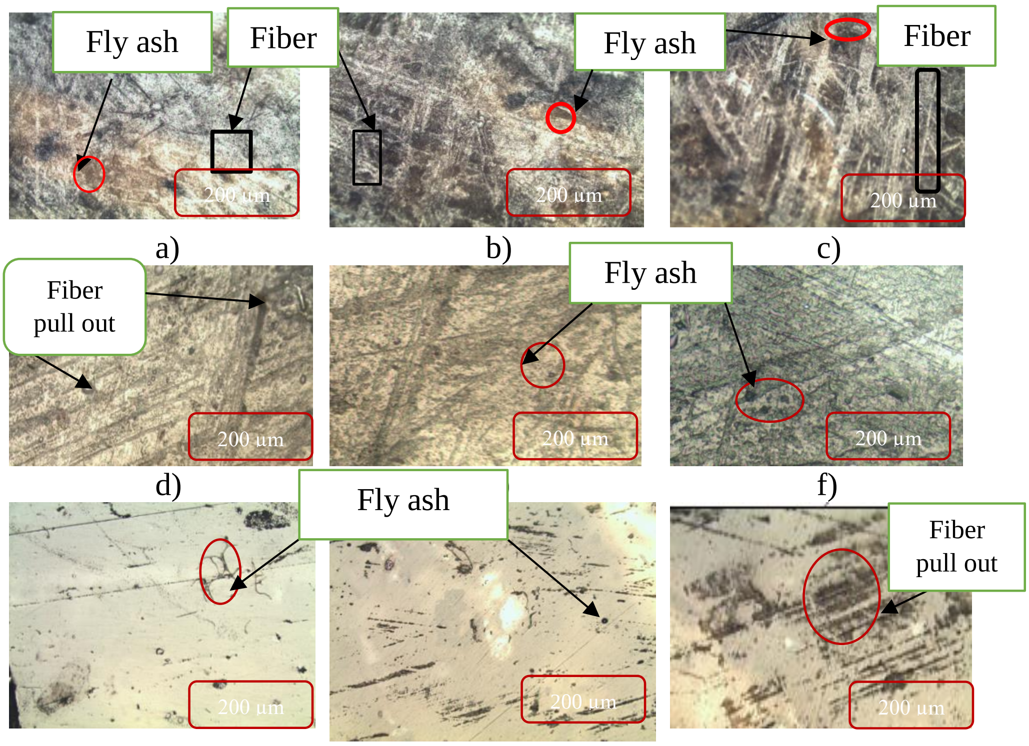


Figure 4.8 Microstructures of fabricated composites materials (a) bagasse with 5% fly ash, (b) bagasse with 10% fly ash, (c) bagasse with 15% fly ash, (d) bagasse/E-glass with 5% fly ash, (e) bagasse/E-glass with 10% fly ash, (f) bagasse/E-glass with 15% fly ash, (g) E-glass with 5% fly ash, (h) E-glass with 10% fly ash and (i)) E-glass with 15% fly ash,

4.1.11 Machinability test result

The drilled hole of fabricated composite materials analyzed by visual inspection method. The result shows that the different future of machined fiber pull out and fibre fracture occurred around the drilled hole of composite materials of all fabricated composite materials within the respective orthogonal array given in table 3.3.

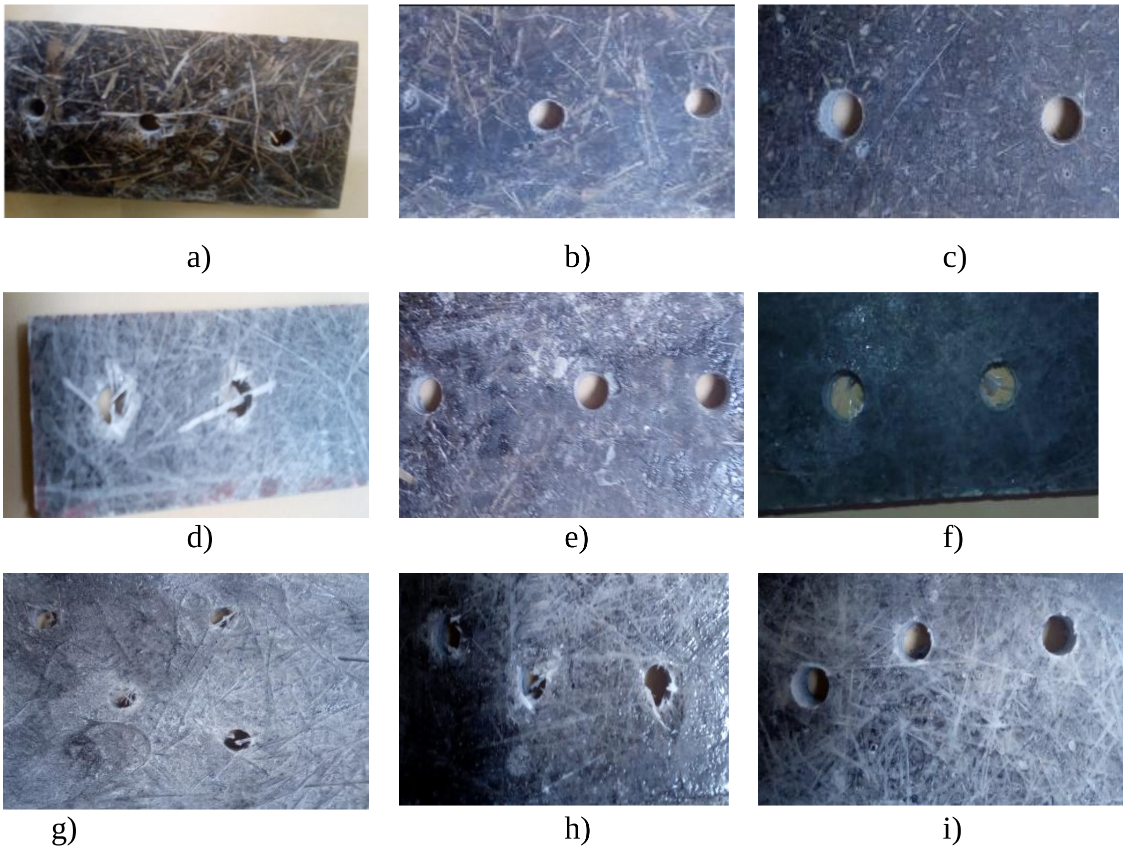


Figure 4.9 Image of drilled surface (a) bagasse with 5% fly ash, (b) bagasse with 10% fly ash, (c) bagasse with 15% fly ash, (d) bagasse/E-glass with 5% fly ash, (e) bagasse/E-glass with 10% fly ash, (f) bagasse/E-glass with 15% fly ash, (g) E-glass with 5% fly ash, (h) E-glass with 10% fly ash and (i)) E-glass with 15% fly ash

Fabricated composite material with minimum weight percentage of fly ash (5% like (a), (d) and (e)) defected with fiber pull out, fibre fracture and matrix break. The result shows as the bagasse fiber defected with minimum fiber fracture is occurred at minimum weight percentage of fly ash and the defect omitted by increasing weight of fly ash from 5% to15%

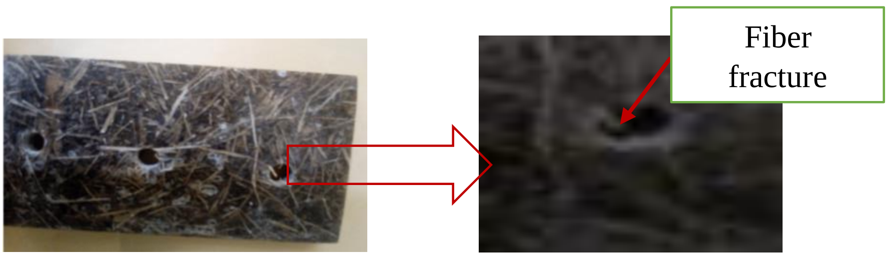


Figure 4.10 Defect on bagasse composite materials

The defect of drilled hole high in E-glass composite materials, this composite material defected with fiber pull out, fibre fracture and matrix break. Similarly the increasing weight percentage of fly ash improve the machinability of composite materials

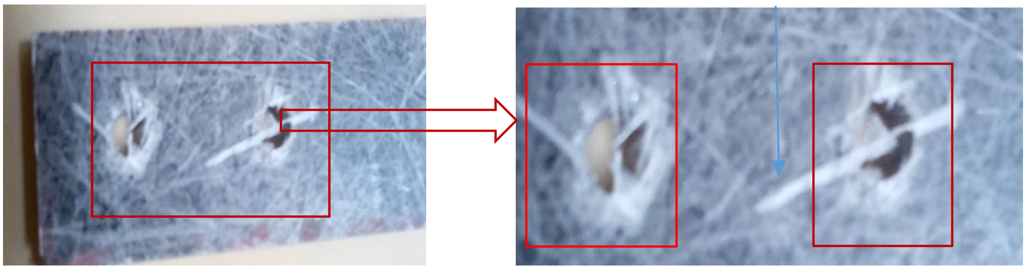


Figure 4.11 Defect on E-glass composites material

The better surface finish obtained for bagasse composite material with fly ash 10% and 15%, for bagasse/E-glass fiber composite with 10% and 15% and E-glass fiber composite with fly ash 15% weight percentage. The machining of fabricated composite is successfully done. The machined edge of the fabricated composite is improved as the weight of fly ash increased from 5% to 15% of the composite materials in all type fiber (bagasse fiber, E-glass fiber and bagasse/E-glass fiber composite materials). The result shows that the different problem of machining composite like: - fibre fracture, fibre pull out from the matrix, plastic flow in the matrix and delamination is improved by enhancing the filler material to composite materials.

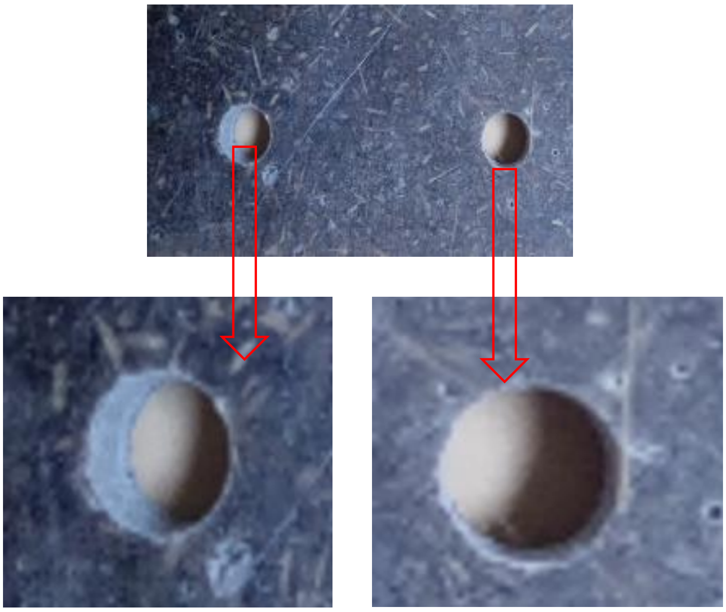


Figure 4.12 Surface finish of bagasse with 15% weight percentage of fly ash

4.1.12 Verification of the machining test

Verification describes the validity of the performed task by comparing with other related work as well as tasks performed before. Different literatures reports the problem related to machining of composites materials.

1. Luiz *et al.* (2018) represent and analysis the delamination occurred on composite materials during drilling operation.

2. Tate (2017) shows the delamination of composite materials

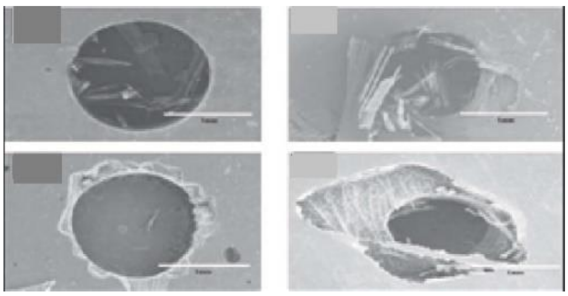


Figure 4.13 Delamination during drilling operation of composite materials.

The delamination occur during machining operation is discussed by different authors. The addition of fly ash as filler material for E-glass epoxy composite materials improve the machining operation of the composite materials. As shown above the composite with 15% fly ash filler improved the drilling operation of fabricated composite materials.

CHAPTER FIVE

5 CONCLUSION AND RECOMMENDATION

5.1 Conclusions

This experimental investigation of mechanical behavior of fabricated composites leads to the following conclusions:

1. This work shows that successful fabrication of glass fiber and bagasse fiber with random oriented reinforced epoxy composites with different fly ash contents.
2. It was found that the tensile strength varies from 59.1 MPa for bagasse fiber composite materials with 15% fly ash filler to 139.6 MPa for bagasse/E-glass composite materials with 10% fly ash filler.
3. The hardness value will also vary from16.3 VHN for bagasse composites with 5% and 10% fly ash to 34 VHN for bagasse/E-glass fiber with 15% fly ash. The hardness value of fabricated composites increases with increasing the weight of fly ash in all fiber types.
4. The Optimum combination of parameters obtained from the main effect plot for the S/N ratio and mean with the best combination at A3B3C2 for hardness value and A2B3C1 for tensile strength.
5. The Optimized E glass/Bagasse epoxy composite material have been the tensile strength and hardness were 135 MPa with 5% weight percentage of flay ash and 32 VHN with 15% weight of fly ash respectively.
6. The bagasse fiber distribution was high in bagasse composites material with 5% fly ash and comparatively low in the composites with 15% fly ash.
7. The bagasse/E-glass fiber distribution is high in composites material with 10% fly ash and comparatively low in the composites with 15% fly ash and
8. E-glass fiber distribution is high in E-glass composites material with 5% fly ash and comparatively low in the composites with 10% fly ash.
9. Drilling fabricated composite is successfully done and the polymer composite machining problem can be minimized by using filler materials. As filler, material increase the machinability of the composite materials can be increased.

5.2 Recommendation

Bagasse fiber reinforced composite materials are eco-friendly materials that do not contribute side effect to environment. Bagasse and fly ash are waste product of sugar industry and they are highly abundant in the earth. In order to be highly profitable from those by-product and mostly abundantly occurring resource materials the following points are raised as recommendation.

1. To introduce byproduct of sugar industry like bagasse fiber and fly ash products to community it is important fabricate composite from it.
2. Joining of composites materials will be conducted.
3. To minimize machining defect of composite materials additional of filler materials is the best option.
4. The future researcher can further extend on the effect of drilling parameter on machining of polymer based composite materials, compression test, wettability test, delamination.
5. The matrix material used for this study (epoxy resin) is thermos set matrix its recommended that substituting with natural matrix, since thermos set materials are eco friendliness and not easily degradable to the soil to minimize the pollution rate of environment.
6. The fabricated composites can be used for chair, table, shower, bath units, Doors, Window, Wall partition.

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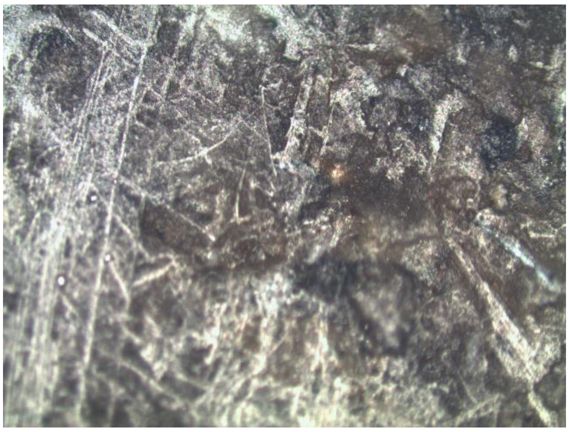
APPENDIX

Appendix A

Microstructure of fabricated composite



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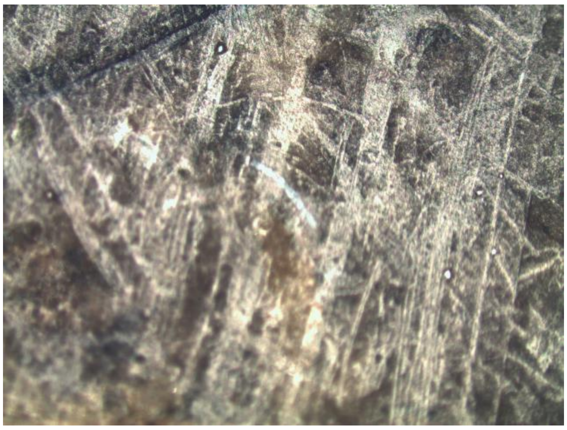

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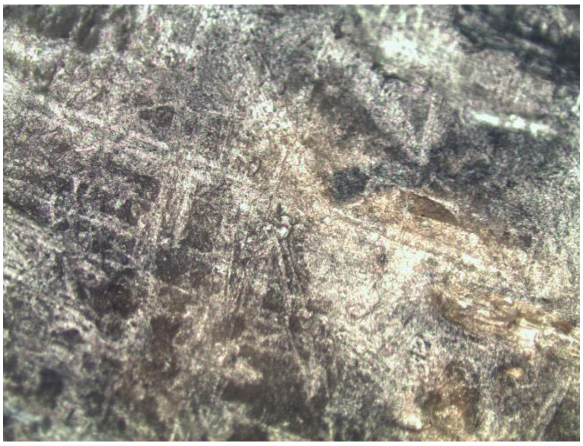

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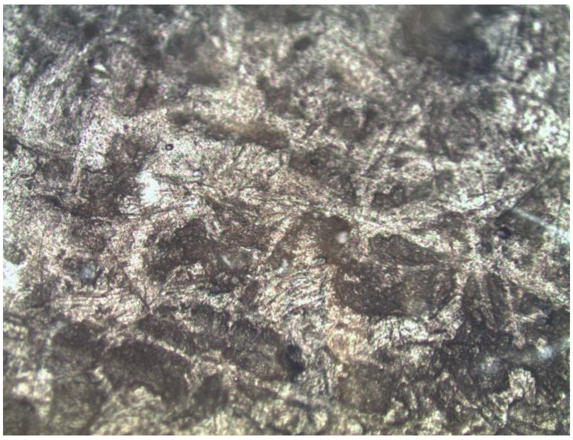

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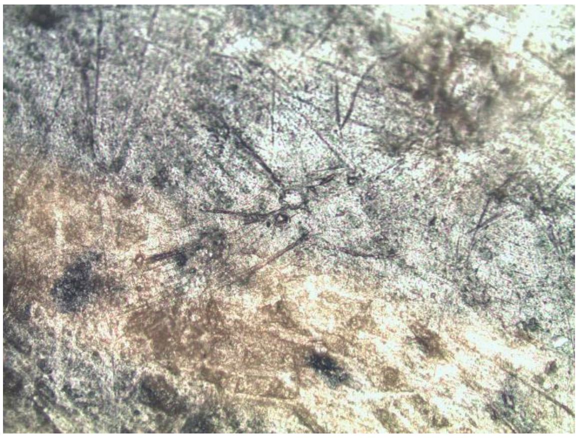

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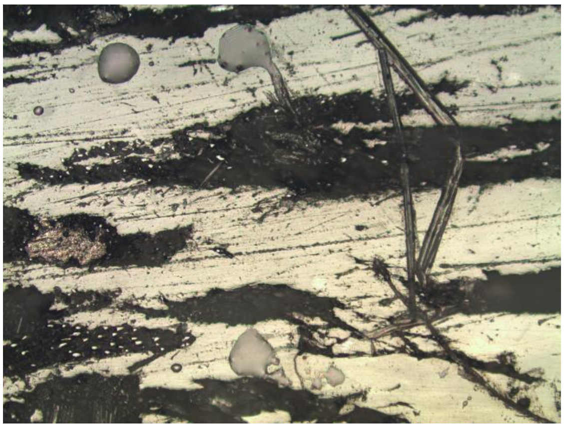

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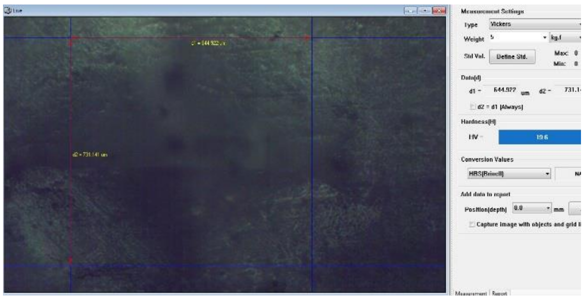
Appendix B

Hardness result



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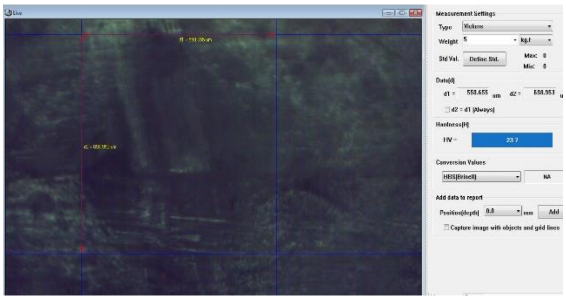

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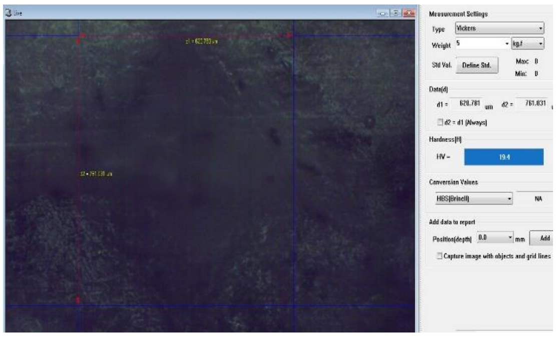

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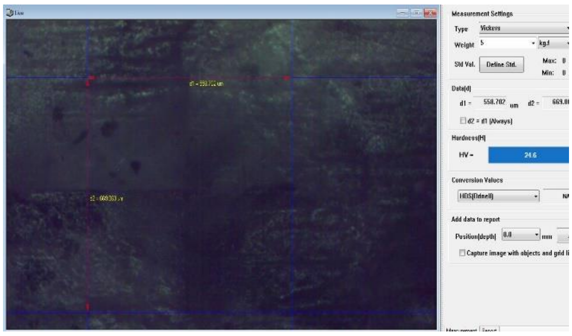

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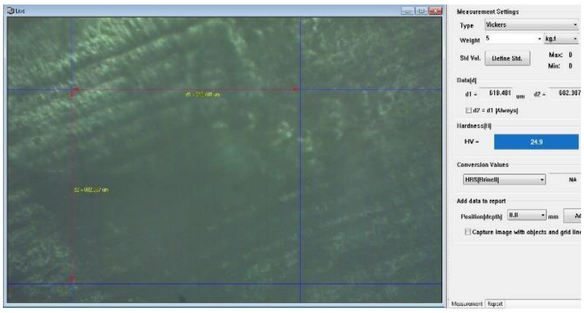

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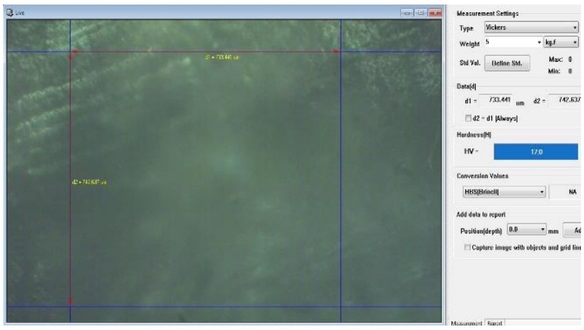

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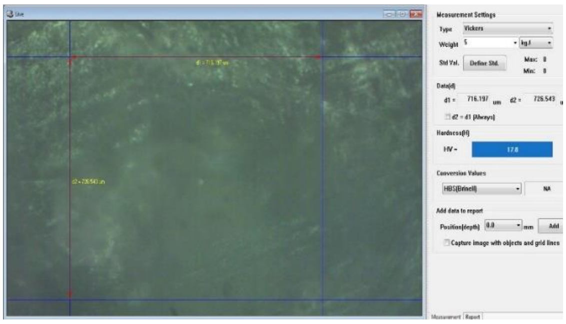
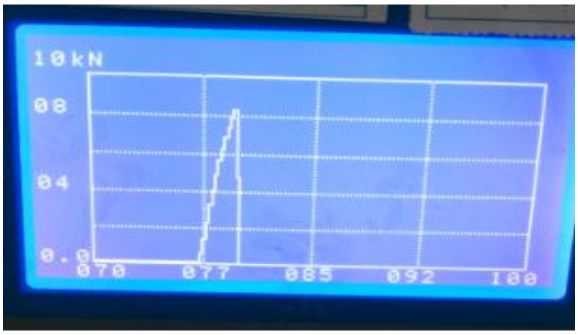


h)

Appendix C

Tensile test result

a)



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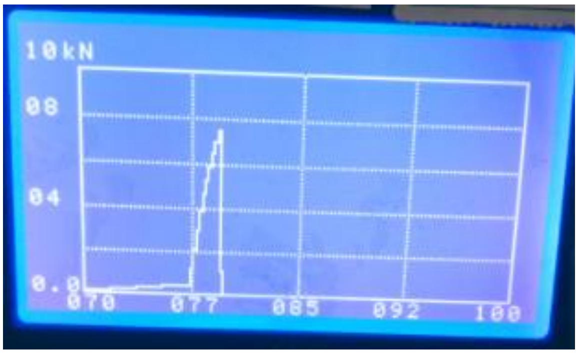

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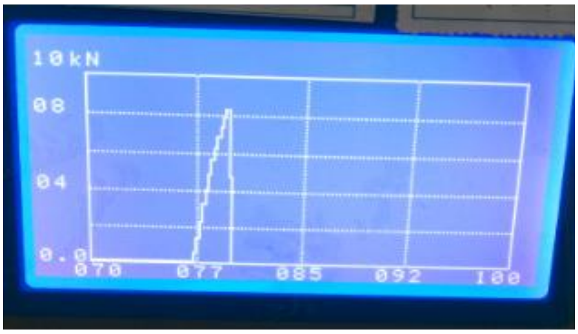

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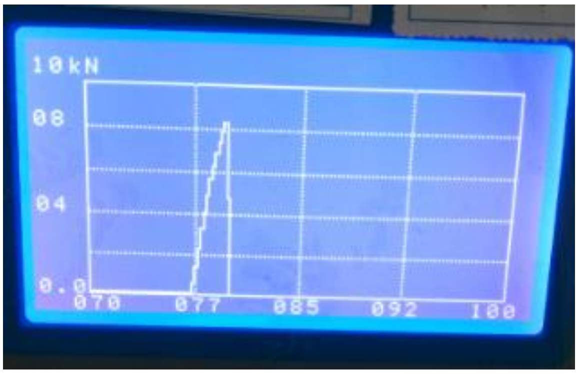

Appendix D

Minitab 17 results

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Weight of fly ash	2	11.3004	11.3004	5.65020	7.65	0.116
Type of fiber	2	10.5040	10.5040	5.25200	7.11	0.123
Weight of epoxy	2	0.1225	0.1225	0.06127	0.08	0.923
Residual Error	2	1.4771	1.4771	0.73857		
Total	8	23.4041				

Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Weight of fly ash	2	79.629	79.629	39.814	4.94	0.168
Type of fiber	2	69.369	69.369	34.684	4.30	0.189
Weight of epoxy	2	3.002	3.002	1.501	0.19	0.843
Residual Error	2	16.116	16.116	8.058		
Total	8	168.116				

Response Table for Signal to Noise Ratios
Larger is better

Level	Weight of fly ash	Type of fiber	Weight of epoxy
1	25.25	25.14	26.51
2	26.33	26.63	26.67
3	27.97	27.78	26.38
Delta	2.73	2.64	0.29
Rank	1	2	3

Response Table for Means

Level	Weight of fly ash	Type of fiber	Weight of epoxy
1	18.41	18.27	21.48
2	21.04	21.73	22.48
3	25.61	25.07	21.11
Delta	7.20	6.80	1.37
Rank	1	2	3

For tensile test results

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Weight of fly ash	2	1.606	1.606	0.8031	1.10	0.477
Type of fiber	2	11.414	11.414	5.7071	7.80	0.114
Weight of epoxy	2	11.972	11.972	5.9862	8.18	0.109
5Residual Error	2	1.463	1.463	0.7317		
Total	8	26.456				

Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Weight of fly ash	2	202.1	202.1	101.0	0.70	0.589
Type of fiber	2	1446.0	1446.0	723.0	4.99	0.167
Weight of epoxy	2	1263.2	1263.2	631.6	4.36	0.187
Residual Error	2	289.7	289.7	144.9		

Total	8	3201.0

Analysis of Variance for StDevs

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Weight of fly ash	2	21.44	21.44	10.72	0.26	0.791
Type of fiber	2	35.92	35.92	17.96	0.44	0.693
Weight of epoxy	2	75.72	75.72	37.86	0.93	0.518
Residual Error	2	81.26	81.26	40.63		
Total	8	214.34				

Response Table for Signal to Noise Ratios
Larger is better

Level	Weight of fly ash	Type of fiber	Weight of epoxy
1	39.77	38.03	40.61
2	39.95	39.96	40.13
3	38.98	40.70	37.96
Delta	0.97	2.67	2.65
Rank	3	1	2

Response Table for Means

Level	Weight of fly ash	Type of fiber	Weight of epoxy
1	99.99	81.27	108.96
2	102.60	100.91	103.57
3	91.50	111.91	81.57
Delta	11.10	30.64	27.39
Rank	3	1	2