Fabrication and Analysis of Mechanical Properties of Textile Waste/Glass Fiber Hybrid Composite Material

A thesis submitted by

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Under the Supervision & Guidance of

Dr. Guteta Kabeta (PhD) and
Dr. NRR Ambusahagar

Mechanical Design & Manufacturing Engineering Program
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Approved by Board of Examiners

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Internal examiner	Signature	Date
External examiner	Signature	Date

Candidate Declaration

I hereby declare that the work which is being presented in this thesis entitled **"Fabrication and Analysis of Mechanical Properties of Textile Waste/Glass Fiber Hybrid Composite Material''** in partial fulfillment of requirements for the award of the degree of Masters of Science in Manufacturing Engineering is an authentic record of my own work carried out **September to May 2018** under the supervision of **Dr. Guteta Kabeta**, Program of Mechanical Design and Manufacturing Engineering, Adama Science and Technology University, Ethiopia.

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 duty acknowledged.

Belay Taye Wondmagegnehu	_____	_____
Candidate	Signature	Date

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

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Dr. NRR Ambusahagar	_____	_____
Co-Advisor	Signature	Date

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ABSTRACT

The investigation of hybrid composite has been amalgamated and high structural performance for composite and thus it gain has attraction by many researchers. The paper presents fabrication and analysis of mechanical properties of textile waste/glass fiber hybrid composite material. In this study, the primary work was fabricated a new class of general purpose resin (resin GP) based on hybrid reinforced composites used by recycle woven textile wastes fabric composite for lower structural application and laminated with chopped glass fiber hybrid composite. In this work composite materials were fabricated by hand lay-up method and pressing strategy. Five samples were prepared which is pure resin, textile waste fiber only layer by layer (T/T/T), textile waste/glass fiber/textile waste layer by layer (T/G/T), glass fiber/textile waste/glass fiber layer by layer (G/T/G) and glass fiber only layer by layer (G/G/G). The mold was prepared locally in the workshop for test sample preparation. The specimen was cut from the manufactured test agreeing to the ASTM standard for mechanical properties test such as tensile test, flexural test, impact test and micro hardness test. Comparatively effect of textile waste fiber strengthened was observed and that created composite essentially advancement in mechanical properties from pure resin composite such as tensile strength was improved by 31.1% and modulus of elasticity was increased by 38.3%. Flexural strength of sample G/T/G is 95% greater than from separated composite of T/T/T. The flexural modulus of the pure resin is given as 45.54GPa. The flexural modulus of G/T/G is showed 32.63GPa. During impact test, the strengthened textile wastes fabric decreased by 18.6% with increasing glass fiber content in composite, while stiffness at the same time decreased. G/T/G is the highest water absorbed hybrid composite sample because of have high void content while the smallest water absorption is G/G/G composite in the salty water. When the submersion time of composites is expanded, a noteworthy amount of water absorbed; coming about within the swelling of the fiber until the cell walls is saturated with water.

Keyworks: Recycle Waste textile, Hybrid Composite, Mechanical properties, Fiber, Resin, Optical Microscopy.

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NOMENCLATURE

NOTATIONS

Symbols	Description
L_o	Original length
$T_{re}(t)$	Thickness swelling at a time
w_f	Weight of fiber
w_m	Weight of matrix
w_p	Weight of particle
ρ_{ct}	Density of composite
ρ_f	Density of fiber
ρ_m	Density of matrix
ρ_p	Density of particle
T_o	Initial thickness
T_t	Thickness at a time
B	Width
Cm	Centimeter
D	Diameter
H	Hour
HV	Vickers hardness
L	Support span length
M	Slope
Mm	Millimeter
MPa	Mega Pascal
N	Newton

T	Thickness
ΔL	Changed length
E	Strain
A	Area
P	Load
σ	Stress
w	Absorbed load (impact load)
^{o}c	Degree centigrade
Rpm	Revolution per minute
V	Impact strength

ABBREVIATIONS

3D	Three Dimensional
ASTM	American Society for Testing and Materials
HDPE	High Density Polyethylene
ISO	International Organaization for Stradardization
L	Length
D	Diametr
LDPE	Low Density Polyethylene
MTS	Mechanical Testing and Sensing
NFCs	Natural Fibers Composite
PA6	Polyamide 6 (number of chain)
PALF	Pineapple leaf fibers
PBS	Polybutylene Succinate
PBT	Polybutylene Terephthalate
PC	Polycarbonate
PE	Polyethlene
PET	Polyethlene Terephthalate
PP	Polypropylene
SEM	Scanning Electro Mycroscope
Resin GP	General Purpose resin
T/T/T	Textile waste fiber layer by layer
T/G/T	Textile/glass/textile fiber layer by layer
G/T/G	Glass/textile/glass fiber layer by layer
G/G/G	Glass fiber layer by layer

CHAPTER ONE

1. INTRODUCTION

1.1. Background of research

Straw in clay developments by Ancient Egyptians are certainly one of the most seasoned and most broadly utilized composite materials. Required of renewable fiber reinforcement composites has expanding within the last decade. Natural fibers offer both cost saving and reduction in density when compared to glass fibers. In spite of the fact that, the strength of natural filaments is not as great as glass fibers, the particular properties are comparable. Common natural fibers such as cotton, kenaf, and flex have the capacity to create a great bond between thermoplastic binder polymers. Recently, common fibers have also been utilized in exterior composite components. Car makers have been fascinated by coordination natural fiber composites into both insides and outside parts based on use of natural fiber fabrics were reported by EI Messiry M. E. (2013).

Composite item contains two or more materials that have diverse properties, where one serves as a matrix or binder material and the other as reinforcement. The properties of the composite are strong, light weight, corrosion resistant, wear resistant, and attractive in appearance (Youssef, H. A. et al. 2011). The essential capacities of matrix are to hold the fiber to create a certain shape. Other than, the functions of the matrix are moreover exchanged stress between the reinforcing fibers and secured them from mechanical and environmental harm. The function of reinforced fibers phase in matrix is improved the mechanical properties such as strength, stiffness etc. Fundamentally three major types of composite materials assigned as per the matrix material utilized. The lattice fabric can be metallic, polymeric or can indeed be ceramic. When the matrix could be a polymer, the composite is called polymer matrix composite.

The roles of the matrix in a fiber-reinforced composite were to (Mallick P.K., 1946):

- Keep the fibers in place,
- Transfer stresses between the fibers,
- Provide a barrier against an adverse of the environment, such as chemical and moisture, and
- Protect the surface of the fibers from mechanical degradation (e.g., by abrasion).

The matrix plays a minor role in the tensile load-carrying capacity of a composite structure. However, selection of a matrix has a major influence on the compressive; inter laminar shear as well as in-plan e shear properties of the composite material. The matrix provides lateral support against the possibility of fiber buckling under compressive loading, thus influencing to a large extent, the compressive strength of the composite material. The interlaminar shear strength is an important de sign consider action for structures under bending loads, whereas the in-plane shear strength is important under torsional loads (Mallick P.K., 1946).

1.2. Polymer matrix materials

A polymer is characterized as a long-chain molecule containing one or more rehashing units of molecules, joined together by strong covalent bonds. A polymeric material (commonly called a plastic) may be a collection of a huge number of polymer molecules of similar chemical structure (but not equal length). Polymers are divided into two wide categories, such as thermoplastics and thermosets are utilized as matrix materials for the composites. Some of the major preferences are low densities, great corrosion resistance, low thermal conductivities, low electrical conductivity, translucence, and tasteful color effects and restrictions are low transverse strength and low operational temperature. Examples of polymeric matrixes are (Mallick P.K., 1946):

Thermoset polymers:

- Epoxies: principally used in aerospace and aircraft applications
- Polyesters, vinyl esters: commonly used in automotive, marine, chemical, and electrical applications.
- Phenolics: used in bulk molding compounds
- Polyimides, polybenzimidazoles, and polyphenylquinoxaline : used for high-temperature aerospace applications (temperature range: 250^{o}C-400^{o}C).

Thermoplastic polymers:

- Nylons (such as nylon 6, nylon 6,6), thermoplastic polyesters (such as PET, PBT), polycarbonate, polyacetals: used with discontinuous fibers in injection-molded articles
- Polyamide-imide, polyester ether ketone, polysulfone, polyphenylene sulfide, polyetherimide : suitable for moderately high temperature applications with continuous fibers.

1.3. Metallic matrix materials

Metal matrix composites are had some attractive properties, when compared with natural matrices. These include:

- Strength maintenance at higher temperatures,
- Higher transverse strength,
- Better electrical conductivity,
- Superior thermal conductivity,
- Higher erosion resistance etc.

However, the major drawback of metal matrix composites is their higher densities and thus lower particular mechanical properties compared to polymer matrix composites. Another eminent trouble is the high-energy requirement for manufacture of such composites.

1.4. Ceramic matrix materials

Ceramics are known for their high temperature steadiness, high thermal shock resistance, high modulus, high hardness, high erosion resistance, and low density. However, they are brittle materials and have low resistance to crack propagation, which is showed in their low fracture toughness. The essential reasons for reinforcing a ceramic matrix are expanded its break durability (Mallick P.K., 1946).

Structural ceramics utilized as matrix materials can be categorized as either oxides or nonoxides. Alumina (Al_2O_3) and mullite (Al_2O_3-SiO_2) are the two most commonly utilized oxide ceramics. They are known for their thermal and chemical steadiness. The common nonoxide ceramics is silicon carbide (SiC), silicon nitride (Si_3N_4), etc, since ceramics had poor properties in tension and shear, most applications as reinforcement is within the particulate form (e.g. zinc and phosphate).

Fiber reinforced polymer composite is the most common advanced composites. These composites consist of a polymer matrix reinforced with thin diameter fibers. The reasons why they are the most common composite include low cost, high strength, and simple manufacturing processes (Berghezan, 1966). In order to find an application to this valuable waste, in this present work an attempt has been made to develop a polymer matrix composite (resin GP) using textile waste as reinforcement.

Textile reinforced composites have various applications in engineering science in less expensive materials, since 1970, textile reinforced composites grew attention which lead to

many global researches. As a result, in the past 30 year great attention has been given to textile reinforced composites. The main reasons for which being they are light and inflexible performing well beneath complex thermo-mechanical loads, having high strength/weight proportion or modulus/weight proportion having low expansion and great damping characteristics (Sadikoglu T.G. et al. 2003).

According to the study of Kim, S.J. et al. (2008), cotton fiber has more entanglement and way better interfacial holding happening between the matrix and fiber than the wood fiber. Subsequently, cotton fiber was found to have more potential to substitute glass in numerous applications that do not require so much stack capabilities. The cotton fibers can be getting by the waste cotton fabrics which are collected from the textile industry. Distinctive strategies and studies were carried out in arrange to utilize the waste cotton fabrics. In spite of all the advantages of utilizing natural filaments, a positive hybrid effect of synthetic reinforcements is required. By hybridization, it is possible to realize a balance between the performance and cost of the composites, which is gotten with a single type of reinforcement. Examined on the hybridization effect for the polymer matrix composites are appeared that the properties of natural filaments can be improved by making hybrid composite structures.

1.5. Characteristics of composite

Composite materials are as heterogeneous materials consisting of two or more solid phases, which are in implied contact with each other on a microscopic scale. They can be additionally considered as homogeneous materials on a microscopic scale in the sense that any portion of it will have the same physical property (Van suchtelen J, 1972).

Properties of composites are strongly subordinate on the properties of their constituent materials, their dispersion and the interaction among them. The composite properties are exceedingly influenced by volume division of the constituents may associated in a synergistic way coming around in improved or predominant properties. Separated from the nature of the constituent materials, the geometry of the reinforcement (shape, measure and measure conveyance) influences of properties of the composite is incredible extent. The concentration, dispersion and orientation of the reinforcement affect the properties. Composites were consisting of one or more discontinuous stages (reinforcement) implanted in a continuous stage (matrix). The shape of discontinuous stages (which may be circular, cylindrical, or rectangular cross-sanctioned prism or platelets), the measure and size conveyance (which controls the surface of the material) and volume division decided the interfacial zone, which

plays as critical role in extent of the interaction between the reinforcement and matrix (Agarwal B.D. et al. 1980).

Concentration, ordinarily measured as volume or weight division, determines the contribution of the single constituent to the generally properties of the composites. It is not only the single most critical parameter affecting the properties of the composites, but also an easily controllable fabricating variable utilized to change its properties.

1.6. Classification of composite materials

Composite materials can be classified in several ways (Agarwal B.D. et al. 1980). Classification based on the geometry of a representative unit of reinforced was supportive since it is the geometry of the reinforcement which is competent for the mechanical properties and high execution of the composites. A typical classification is displayed in Figure 1.1. The two wide classes of composites are:

- Particulate composites and
- Fibrous composites

1.6.1. Particulate composites

As the name itself shows, the reinforcement is particle nature (platelets are also included in this class). It may be round, cubic, tetragonal, a platelet, or of other customary or unpredictable shape, but it was around equiaxed. In general, particles are not very successful in improving break resistance but they upgrade the stiffness of the composite to a restricted extent. Molecule fillers are broadly utilized improved the properties of matrix materials to modify the thermal and electrical conductivities, improve performance at hoisted temperature, decrease friction, increment wear and abrasion resistance, improve machinability, increase surface hardness and diminish shrinkage.

1.6.2. Fibrous composites

A fiber was characterized by its length being much more noteworthy compared to its cross-sectional measurements. The measurements of the reinforcement decide its capability of contributing its properties to the composite. Filaments are very effective in making strides the break resistance of the matrix since a reinforcement having a long measurement discourages the growth of beginning cracks typical to the reinforcement that might something else lead to failure especially with brittle matrices.

Man-made fibers or strands of non polymeric materials display much higher strength along their length sine large flows, which may be present in the bulk material, are minimized because of the small cross-sectional dimension of the fiber. Within the case of polymeric materials orientation of the atomic structure is dependable for high strength and stiffness.

Fibers, because of their small cross-sectional dimensions are not directly usable in engineering applications. They are therefore, embedded in matrix materials to form fibrous composites. The matrix serves to bind the fibers together, transfer loads to the fibers, and protect them against environmental attack and damage due to handling. In discontinuous fiber reinforced composites, the load transfer function of the matrix is more critical than in continuous fiber composites.

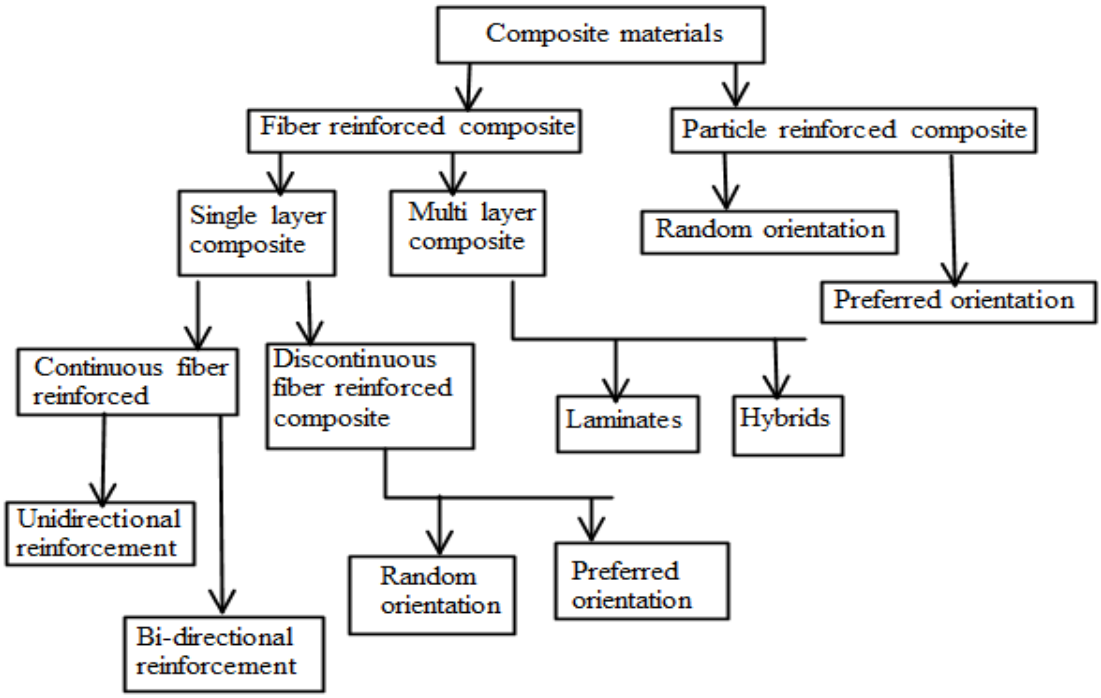


Figure 1.1. Classification of composite (Agarwal B.D. et al. 1980)

Natural fiber is subdivided, based on their roots, viz. plants, animals, or minerals. All plant filaments are composed of cellulose whereas animal fibers consist of proteins (hair, silk and wool). Plant filaments incorporates bast (or stem or delicate sclerenchyma) fiber, leaf or hard fiber, seed, fruit, wood, cereal straw and other grass filaments. A diagram with a classification of the different natural fibers was shown in Figure 1.2. Over the final few years, a number of analysts have been included in examined the exploitation of natural fiber as composite materials.

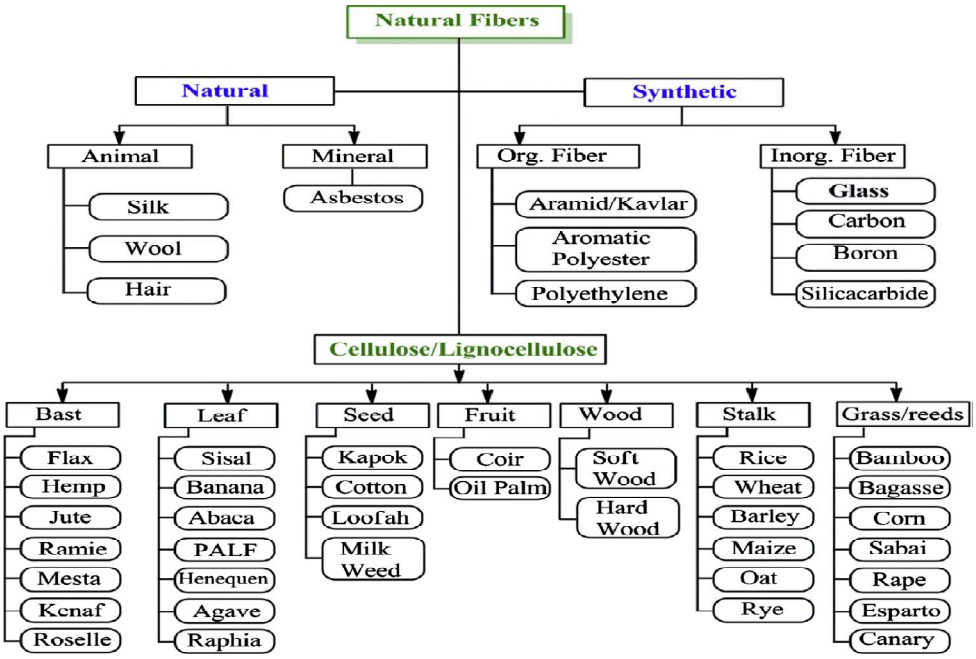


Figure 1.2. Classification of natural and synthetic fibers (Azwa ZN et al, 2013)

1.7. Hybrid bio composite materials

Hybrid bio composites can be outlined by the combination of a synthetic fiber and natural fiber in a matrix. Hybridization with glass fiber provided a strategy moved forward the mechanical properties of natural fiber composites and its effect in several modes of stress depends on the design and construction of the composites (John M.J. et al (2002).

The joining of several diverse types of fibers into a single matrix has driven to the improvement of hybrid bio composites. The behavior of hybrid composites could be a weighed sum of the individual components in which there is more favorable balance between the inherent advantages. Also, using a hybrid composite that contained two or more types of fiber, the advantage of one type of fiber might be complement with what are missing within the other. As the consequence, a balance in cost and performance can be achieved through proper material design.

The concept of hybrid systems improved material or structural performance is well-known in engineering designs. However, it is the motivation from natures' possesses materials that are recently motivating the way towards inventive material and structural designs. Considered on characteristic materials appeared how high basic execution can be accomplished with non-exotic materials through hybrid combination assembled in optimized hybrid various leveled setups were detailed by John M.J. et al. (2002).

In spite of the fact that hybrid fiber strengthened polymer composites are gaining interest, the challenge was replaced customary glass reinforced plastics with bio composites that display basic and functional stability during storage and use and yet are susceptible to environmental degradation upon disposal.

1.8. Research motivation

Composite is considered to be any multi stage fabric framework that shown a combination of properties that makes the composite superior for each of the constituent phases. This criterion has provided the main motivation for the research and advancement of composite fabric around the world. Different constituents phase are stay own properties and hybridize with another phase to improve the properties of composite materials. Textile waste material was selected for this research work because of resource availability around us and in garment industry.

1.9. Significance of research

Each year, due to fabricate process of industrial activities; wide run of wastes produced within the world. This not only poses a danger to the environment but also represents wastes of valuable assets. Hence, in later decades, most of the efforts have been conducted to reusing and reutilization exercises to diminish waste materials utilized to save a modern asset. One of the waste materials is textile wastes. As a result of these improvements material strengthened composites have been an important elective for the conventional engineered materials in low structural application (interior car body, kitchen cabinet, furniture, etc). Therefore, the important of this study is reduce the usage of new raw materials, decrease cost of materials, and improved mechanical properties of composite.

1.10. Statement of problem

Nowadays, increasing a new row material cost and shortage of supply because of these problems, increased emphasis has been placed on developing recycling techniques of waste product, with the goals of protecting the environment. However, relatively little investigation was conducted from waste textile fiber produced a composite material and most these waste products are destroyed by fixing or buried underground.

In this work, a new product produced from the textile waste spin by changed twisted strand for manufacturing 3D woven preforms in order to determine its usefulness as a new composite material and analyzed their mechanical characteristics. In addition, this work is

aiming to contribute for the scarcity of literature. Textile waste cotton is used in blanket factory for blanket and carpet mat production in Ethiopia. Therefore, this study added the value of textile waste application and hybridized with fiber glass improved those properties.

1.11. Objectives of research

1.11.1. General objective

The major objective of this research is to fabricate and analysis hybrid composite material from textile waste fabric and glass fiber reinforcement based on polyester as a matrix.

1.11.2. Specific objectives

The specific objectives of this research are to:

- Fabricate new class of resin GP based hybrid composites reinforced with oriented glass fiber and twisted textile waste fabrics;
- Evaluate mechanical properties such as tensile strength, flexural strength and impact strength;
- Analyze the influence of fiber content on the mechanical behavior of the composites and
- Analyze the microstructure of the composites using optical microscopy

1.12. Scope of Research

This research work is to manufacture textile waste hybrid glass fiber composite materials and analyze tensile, impact load and flexural strength using nonwoven web to change twist strand for manufacturing 3D woven be used in composite material. Table 1.1 depicted the sample size and the fiber contents in the matrix.

Table 1.1. Numbers of fabricating sample

Number of samples	Sample type
1	Pure resin
2	-T/T/T-
3	-T/G/T-
4	-G/T/G-
5	-G/G/G-

Note: *T-textile waste, G-glass fiber*

1.13. Research methodology

The composite plate was fabricated by hand lay-up method. Raw materials of textile waste and glass fiber based on unsaturated polyester resin are used specimen preparation.

Textile waste is a material that is deemed unusable for its original purpose by the owner. Textile waste can include textile industry waste, created during fiber, textile and clothing production, and consumer waste, created during consumer use and disposal.

Chopped strands are produced by cutting continuous strand s into short lengths. The ability of the individual filaments to hold together during or after the chopping process depends largely on the type and amount of the size applied during fiber manufacturing operation. Strands of high integrity are called ‘‘hard’’. These mats are used mostly for hand layup moldings and provide nearly equal properties in all directions in the plane of the structure (Mallick P.K., 1946). E-glass fiber is used in this present work of hybrid composite. E-glass has the lowest cost of all commercially available reinforcing fibers.

Unsaturated polyester resins can be formulated in a variety of properties ranging from hard and brittle to soft and flexible. Its advantages are low viscosity, fast cure time, and low cost. Although this allows easier release of parts from the mold, the difference in shrinkage between the resin and fibers results in uneven depressions (called sink marks) on the molded surface. The sink marks are undesirable for exterior surfaces requiring high gloss and good appearance. One way of reducing these surface defects is to use low-shrinkage (also called low-profile) polyester resins that contain a thermoplastic component (Pickering K.L. et al. 2016). As curing proceeds, phase changes in the thermoplastic component allow the formation of micro voids that compensate for the normal shrinkage of the polyester resin.

Hand lay-up molding is the of laying down fabrics made of reinforcement and painting with the matrix resin layer by layer until the desired thickness is obtained. The method is quite simplest; there is virtually no limit to the size of the part that can be made higher fiber content and longer fibers, low cost tooling, room temperature cure resins are used and simple principle. Figure 1.1 represents the process plan of a studied of this research.

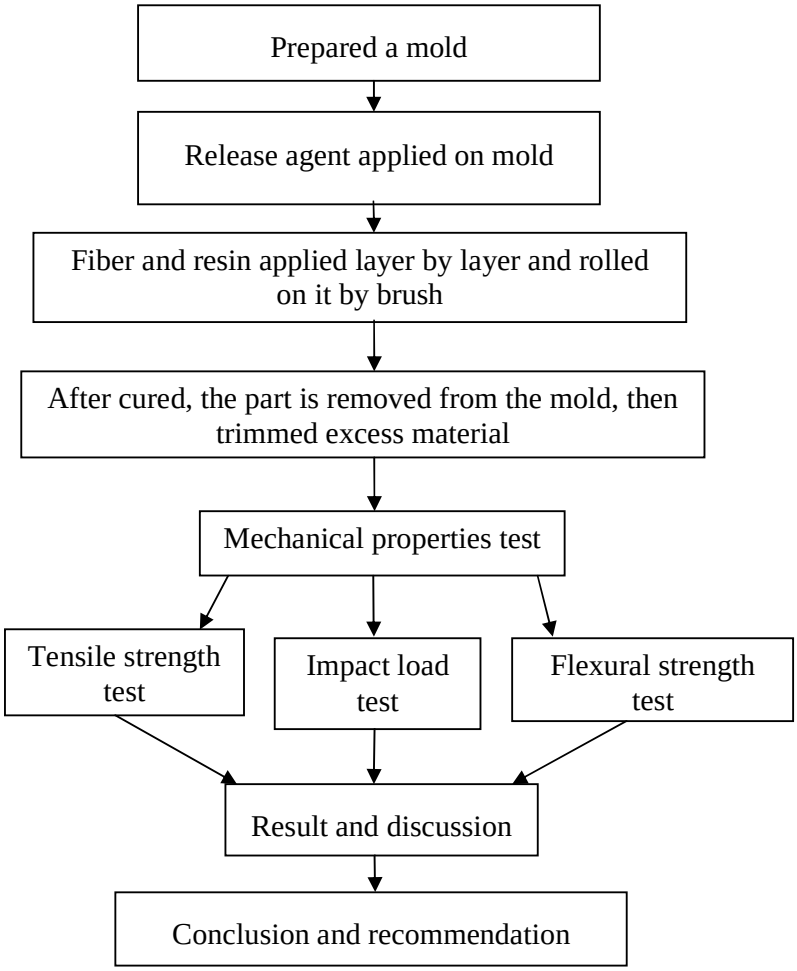


Figure 1.3. Manufacturing process of sample

1.14. Limitation of the research

Although this research was carefully prepared, there were some limitations. First, lack of previous studies in this research area, literature review findings is used as the foundation for built upon to achieve research objectives. Secondly, formulated the research aim and objective, this is fabrication and analysis of mechanical properties. Thirdly, sample size, sample size was small; this study in larger sample size could have generated more accurate results.

1.15. Layout of the research

In this section, an overview of the tasks involved to accomplishing the overall objective of the study and summary of the contents are given. These tasks are described in detail in the subsequent chapter.

Following the introductory chapter, comprehensive literature survey has been laid down in chapter 2, which described the raw materials, method, parameters and composite that is relevant to this research (such as polymer matrix composite, natural fiber, textile waste fabrics and hybrid composite).

Chapter 3 contains the material used in this research. The process including the preparation of sample and methods which is hand-layup technique for the examined mechanical properties of tensile strength, flexural strength, impact force, micro hardness and for water absorption properties and for surface micro structure were the specimen prepared according to ASTM standard.

The data have been collected, analyzed and then presented graphically in chapter 4. This chapter also discusses the experimental data with the theoretical data, which was calculated using the rule of mixture in chapter 2. The best manufactured sample of this research is compared with other researcher's results. Finally, conclusion and recommendations are presented in chapter 5.

CHAPTER TWO

2. Literature Review

Literature review is carried out to get the background information on the issues to be considered in this research work and to focus the relevance of the present study, in addition to present a thorough understanding of different aspects of natural fiber polymer composite with a special awareness to their fabrication and mechanical properties.

2.1. Natural Fibers Composite

Gassan J., (2002) studied the effects of fiber-matrix adhesion and fiber properties on the fatigue behavior and for study used ware made of flex, and jute yarns and woven as reinforcements for epoxy resins, polyester resins and polypropylene. All of the fatigue tests were achieved on a servo-hydraulic MTS test machine. The research shown due to difference in fiber fine structure and surface morphology, significant differences in composite damping ware were measured between unidirectional flex and jute epoxy composites, with an approximately, two-fold increase in damping for the flex-epoxy composites. Damage propagation was quite similar for both types of composites; the influence of textile structural design was examined by use of unidirectional and woven reinforced jute-epoxy composites. Critical load for damage initiation and load into failure was lower and damage propagation was more rapid for the composites based on woven reinforcements, fiber strength and modules were found to influence the critical load for damage initiation, the rate of damage propagation and the load at failure in unidirectional flax-epoxy composites. Increasing mechanical fiber properties increases the critical load and the failure load. While damage propagation was reduced; composite damping was reduced with increasing fiber volume fraction below and above the critical load for damage initiation, with comparable rates for damage propagation.

Mishra S. et al. (2003) studied the mechanical properties of pineapple leaf fibers (PALF)/glass and sisal/glass fiber hybrid polyester composites which are tensile, impact and flexural properties as a function of relative weight fractions of the two fibers (total fiber 25 w.t % and 30 wt.% respectively). In addition to this, sisal/glass hybrid polyester composites of sisal fiber were fiber treatment, fabricated and mechanical properties was assessed. The effect of glass fiber hybridization on water absorption tendencies towards the biofiber-reinforced polyester composite was studied. The specimens of composites were prepared in

the laboratory and used hydraulic press. The tensile, impact and flexural properties of PLAF and sisal reinforced polyester composites were observed to have improved by the incorporation of small amount of glass fiber in these composites, shown positive hybrid effect. Among the different chemical modifications of the sisal fibers, 5% alkali treatment produced optimum tensile and impact strength while cyanoethylation resulted in the maximum increases the flexural strength. It was also observed that water absorption tendency towards composites decreases by the process of hybridization and surface treatment of biofibres. The SEM micrographs of tensile fractured specimens reveal that glass/alkali-treated biofiber-polyester hybrid composites were shown better fiber-matrix adhesion over glass/untreated biofiber-polyester composites.

Kalaprasad G. et al. (2004) evaluated the tensile properties of intimately mixed sort sisal/glass hybrid fiber reinforced LPDE as a function of fiber length and various surface chemical modifications on the fiber as well as the matrix. The composite was prepared the fibers mixed with slurry of LPDE used toluene as the solvent, through a ram type hand extruder then exerted pressure by compression mould. The fiber length was increased the tensile length and young's modulus ware increased and also chemical modification was improved fiber-matrix compatibility through mechanical anchoring, physical and chemical bonding. Furthermore, Rong M. Z. et al. (2001) studied the effect of fiber treatment on the mechanical properties of unidirectional sisal-reinforced epoxy composite. It was presented a treatment of sisal fibers which increase fiber strength and adhesion between the fiber bundles and the matrix, while an overall improvement of mechanical properties (especially tensile properties) of sisal laminates.

Junior C.Z.P et al. (2004) studied the tensile strength of ramie-cotton hybrid polyester resin matrix composites, as a function of the volume fraction (52%, 56%, 72%, and 83%) and orientation of the ramie fibers (longitudinal 0 and transverse 90) ware made by compression molding. The fibers were used threaded classified as 2.70 and 3.10. Composites with 45% of ramie fibers were shown an increase on the tensile strength over the bare polyester resin of up to 338%. Neither the fabric nor the diameter of the thread was utilized a critical part within the tensile properties of the composites analyzed, but was dominated by volume division of ramie fibers with fibers introduction. Cotton had a minor reinforcement effect was attributed to the week cotton-polyester interface as well as poor cotton alignment. The ramie fiber was disposed transversely to the test direction had a deleterious effect on the tensile behavior of the composites.

The mechanical properties and physical properties of natural fibers vary considerably depending on the chemical and structural composition, fiber type and growth conditions. Mechanical properties of plant fibers are much lower compared to those of the most widely used competing reinforcing glass fibers (Table 2.1).

Table 2.1. Mechanical properties of natural fibers as compared to conventional reinforcing fibers (Taj S. et al. (2007)

Fiber	Density (g/cm^3)	Elongation (%)	Tensile Strength (MPa)	Young's Modulus (Gpa)
Cotton	1.5-1.6	7.0-8.0	287-597	5.5-12.5
Jute	1.3	1.5-1.8	393-773	26.5
Flex	1.5	2.7-3.2	345-1035	27.6
Hemp	---	1.6	690	---
Ramie	---	3.6-3.8	400-938	61.4-128
Sisal	1.5	2.0-2.5	511-635	9.4-22.0
Coir	1.2	30	175	4.0-6.0
Viscose (cord)	---	11.4	593	11
Soft Wood Karaft	1.5	---	1000	40
E-glass	2.5	2.5	2000-3500	70
S-glass	2.5	2.8	4570	86
Aramid (normal)	1.4	3.3- 3.7	3000-3150	63.0-67.0
Carbon (standard)	1.4	1.4-1.8	4000	230-240

Many fibers such as jute, ramie, hemp, sisal, jute, etc were examined as the nature fibers in polymer matrix composite. However, cotton fibers can be considered as the promising fiber compared to traditional reinforcements.

Kim S.J. et al. (2008) studied the mechanical properties of polypropylene (PP)/cotton fiber composites were compared with those of PP/wood fiber composites. The wood and cotton fibers were dried in an oven before used. The PP, natural fiber and compatibilizer were mixed in a plasticorder used a rotor speed of 50 rpm at 170^{o}C for 10min. Then, the obtained mixture was compression molded at 170^{o}C for 20min, the composite was prepared. According the study, the tensile strength depends on the weakest part of the composites and the interfacial interaction between PP and wood fiber is weak, the tensile strength of the PP/wood fiber composites decreases to increase wt% of wood fibers. However, the tensile strength of the PP/cotton fiber composites was displayed different behavior. With the addition of 10 wt% cotton fibers, the tensile strength decreased, but with the addition of 20 and 30 wt% cotton fiber it increased because of the entanglement of the cotton fibers, as confirmed by the SEM micrographs.

Ahmed K. S. and Vijayarangan S. (2008) studied the effect of hybridization of glass and layering sequence effect on tensile, flexural and interlaminar sheer properties of woven jute-glass fiber hybrid composite. Samples of hybrid laminates were prepared by simple hand lay-up technique in a mold at laboratory temperature. According to the study, layering sequence significantly affects the flexural and interlaminar shear strength. For the same relative weight fraction of jute and glass fiber, layering sequence has little effect on tensile properties.

Ramesh M. et al. (2014) prepared banana fiber reinforced epoxy composite and mechanical properties of these composite was evaluated. The composite samples of different volume fractions were prepared by using the hand lay-up process and applied pressure in room temperature. The result shown Table 2.2, the banana fibers exhibited excellent mechanical properties

Table 2.2. Experimental findings of the composite samples (Ramesh M. et al. 2014)

Samples	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (joules)
40% banana fiber+60%epoxy resin	108.42	71.28	8.62
50% banana fiber+50% epoxy resin	112.58	76.53	9.48
60% banana fiber+40% epoxy resin	98.3	66.18	11.22

Ramesh M. et al. (2013) evaluated mechanical properties such as tensile and flexural properties of hybrid glass fiber-sisal/jute reinforced epoxy composites and the result was compared. The samples of hybrid composites were prepared by hand lay-up technique. Therefore, the jute/glass fiber reinforced polymer composite is holding the maximum flexural load slightly higher than sisal/ glass fiber reinforced polymer composite and the failure morphology of the tested samples was examined by using SEM. From the results, sisal/ glass fiber reinforced polymer composite performing better for tensile loading and jute/ glass fiber reinforced polymer composite performing better for flexural loading.

Shah D. U. et al. (2014) evaluated various mechanical properties of nonwoven and plain woven silk fiber composite. According to this study, Woven composites performed better than nonwoven composite shown in figure 3.2.

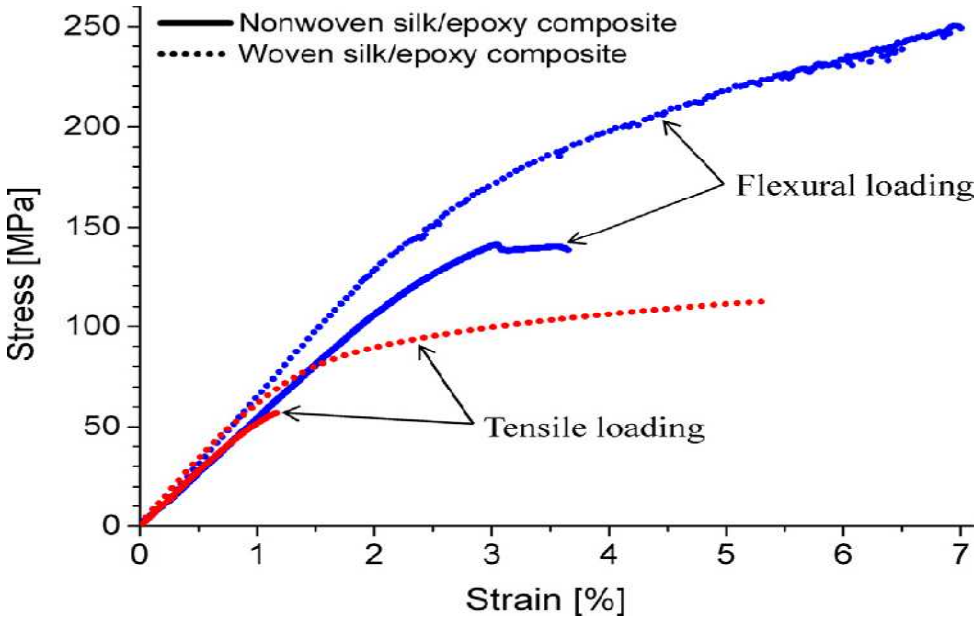


Figure 2.1. Nonwoven (solid line) and plain woven (dotted line) silk composite subject to tensile and flexural loads (Shah D. U. et al. 2014)

2.2. Recycled Natural Composite

Stuart A. et al. (2001) studied reuse of waste textiles whereby carpet fibers were utilized to reinforced polyethylene, the method of compounding of the carpet fiber-LDPE composite material was carried out on a single-screw extruder with a vent stage using 32 L: D ratio screw and different temperature profile and were dried at 60^{o}C for more than12h. Increasing the fiber loading increased the tensile modulus. The SEM results confirm that was improved interfacial compatibility and interactions resulted from the addition of the compatibilizer. The composite materials containing of compatibilizer were provided improvements in tensile strength and strain values except PE-g- maleic anhydride compatibilizer. The water absorption and strength properties of composite were investigated by Sadikoglu T. G. et al. (2003). Matrix material was prepared by mixing urea formaldehyde resin, ammonium sulfate and flour in a weight ratio of 100:5:10 consecutively. PET wastes were sunk in this matrix first and were immersed thoroughly by the matrix material. After squeezing, were laid in a mould and closed, then applied 700N pressure was prepared a composites. The new textile-reinforced composite absorbs less water than fiberboard and medium density fiberboard was compared, and also the specific bending strength of the new composite less than fiberboard and medium density fiberboard.

Dobircau L. et al. (2009) studied characterization of mechanical and thermal properties of 100% of cotton fiber as reinforcement of wheat flour based thermoplastic matrix was prepared

by extrusion method. Fiber contents in the composite 0%, 5%, 10% and 15%. Fiber content in the matrix shown does not change the thermal stability of the composites. Tensile modulus and stress at failure increased as a function of fiber content increase and a fiber loading beyond 10% w/w was decreased. The increment of fiber contents, given a good dispersion of the fibers in the matrix which resulted in a good stress transfer between the interfaces.

Bakkal U.et al. (2012) studied the effect of reprocessing on the mechanical properties of the waste fabric reinforced composites; it processed by a custom-made recycling extrusion. Two different (12.5% and 25% fibers by weight) waste fabrics reinforced composite plates were produced and reprocessed six times to assessed repetition effect of processing on the mechanical and rheological properties on plates. And also effect of fiber orientation was studied. Then, experimental results introduced tensile strength of the composites was increased with the number of reprocessing steps due to the improvement of fabric dispersion and decrease of the void volume. On the other hand, tensile strength of low density polypropylene was found to decrease consequently by reprocessing. Optimum mechanical properties were obtained at the 3rd reprocessing step for 12.5 wt% composites and at the 4th reprocessing step for 25 wt% composite material. Impact strength of the polymer was found to be drastically decreased from 450 to 194kJ/m^2 and from 450kJ/m^2 to 122kJ/m^2 by the addition of 12.5 wt% and 25 wt% cotton fabrics, respectively as a result of agglomeration of the fabrics. In addition, reprocessing steps brought a constant decrease in impact strength of both polymer and composites. The effect of orientation on the tensile properties was shown that the specimens parallel to the extrusion direction has maximum tensile strength compared to specimens' perpendicular to extrusion direction.

Alamri H. and Low I.M. (2012) studied a mechanical properties and water absorption behavior of recycled cellulose fiber reinforced epoxy composite with different fiber contents (19, 28, 40 and 46) wt%. The composite sample prepared by initially pre-drying the paper sheet for 60min at 70^{o}C, and immersed in epoxy resin system and after that, epoxy soaked sheet were laid down in a closed silicone mould under 8.2kPa compressive pressure and left for 24h at room temperature. According to the study, the flexural strength, flexural modulus, fracture toughness and impact toughness tests were found to increase as the fiber contents increased. And also, the water absorption was observed to increase with increase fiber content. Because of this, flexural strength, flexural modulus and fracture toughness was decreased due to the degradation of bonding at the fiber-matrix interface. However, impact strength was found to increase slightly after water absorption.

Bodur M.S. et al. (2017) studied the effect of hybridization on the mechanical and rheological properties of the glass fiber/waste cotton fabric-reinforced hybrid composite. According to the study, waste cotton fabric and glass fiber have better interfacial bonding between them and increase the effectiveness of glass fiber on the mechanical properties.

Kocak D. et a.l (2008) studied the composite structures produced using high density polyethylene (HDPE) polymer with silk and cotton waste as reinforcement fibers in different ratios. Cotton and silk wastes were mixed in the ratio of HDPE/silk or cotton waste 100/0, 97/3 and 94/6. This mixture was prepared with double-screwed extruder. Addition of 3% and 5% cotton and silk fibers to HDPE polymer increased the elasticity module value of mechanical characteristics of the composite. When the waste textile fibers are compared to each other, the elongation values of the composite formed from the addition of cotton fibers are lower than those of silk fibers. When the morphological structure of the composite showed that the segments of silk fibers were closer to each other. Izod impact values seem to decrease. Breaking faces has seen to have big gaps and polar fibers hold nonpolar fibers weakly as a result of which fibers are pulled out of the matrix.

When differential scanning calorimetry thermal analysis results is considered, the melting behaviors of the composites differed due to the use of two different waste fibers added to the HDPE polymer matrix. When scanning electron microscope (SEM) photographs were analyzed, it was clearly seen that fiber has not well dispersed within the structure. As a result, the existence of the waste fibers does not contribute to durability. Elongation characteristic of the composite made from textile waste is suitable for the material with little elongation values and can be considered to lead to a decrease in production costs.

Petrucci R. et al. (2015) studied tensile and fatigue characterization of textile cotton waste/polypropylene laminates by using jeans short fiber based flocks, coming from different waste collection around 16%. The composite products were prepared by using injection molding. Their result showed that, tensile strength and modulus are improved with respect the neat PP matrix to 16% cotton fiber content; also fatigue tasting up to 5000 cycles demonstrated a limited amount of degradation during loading at a maximum stress around 70% of ultimate tensile strength.

The teams of researchers Seong et al. (2006) investigated the mechanical and thermal properties of polybutylene succinate (PBS) biocomposites reinforced with industrially available waste silk fibers, fabricated with varying fiber contents and lengths. Figure 2.2

shows the microstructure of single filaments in waste silk fibers. To investigate the waste silk fiber length effect, the as separated waste silk fibers ware chopped to approximately 25.4mm, 12.7mm, 6.4mm, and 3.2mm in average length. The fiber contents used are 0, 20, 30, 40, and 50% by weight. The biocomposite molding was performed by compressed method. The tensile strength was gradually increased with the increase in the waste silk fiber loading up to 40 wt%, compared with that of the unreinforced PBS control. The decrease of the tensile strength in 50 wt% waste silk/PBS biocomposite was due to insufficient filling of melted PBS matrix resin into such a high fiber loading. The flexural properties were gradually increased with the fiber loading up to 40wt. %. With the addition of 50wt. % waste silk fibers, the flexural properties were somewhat decreased.

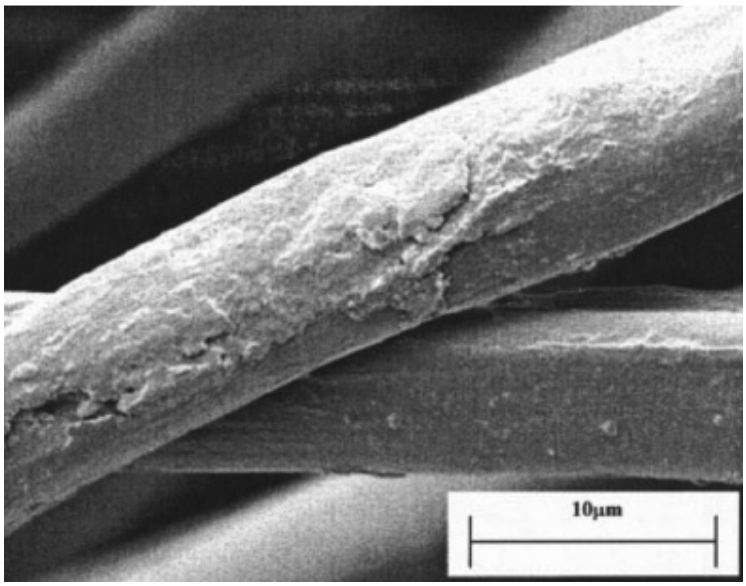


Figure 2.2. Scanning electron micrograph of single filament in waste silk fibers (Seong et al. 2006)

This is due to the insufficient filling of the melted PBS resin into the reinforcing natural fibers during composite processing. The flexural result also indicted that the strength of the biocomposites does not significantly depend on the variation of chopped waste silk fiber length, whereas the modulus was more or less greater than that reinforced with as-separated waste silk without chopping. The glass transition temperature, the storage modulus of all the waste silk fiber-reinforced PBS biocomposites studied was significantly greater than that of PBS resin, especially in the higher temperature region. The storage modulus of the biocomposite was increased with increase in the loading of waste silk fibers, and the greatest value was obtained with the chopped waste silk fibers of 12.7 mm length. The thermal

stability of waste silk/PBS biocomposite was observed to be intermediate between the PBS resin and the waste silk fiber depending on the fiber content.

The mechanical and thermal properties of a silk fiber/polylactic acid (PLA) biocomposites were studied Cheung H.Y. et al. (2008) through different experimental approaches. Optimal values, in terms of fiber length and weight content of 5 mm and 5 wt. %, respectively, to achieve the maximum microhardness of the bio composites were obtained. The tensile property test revealed that the modulus of elasticity and ductility of the bio composite were substantially increased to 53% and 39%, respectively, as compared with pure PLA. Besides, the glass transition temperature of the bio composite increased approximately by 10%. SEM image also showed that good interfacial bonding between the silk fibers and PLA matrix was achieved, which reflected a good wettability of the resin during injection and extrusion process was resulted. This bio composite, made by biodegradable silk fibers and PLA together, to produce its strength and thermal stability is better than the host polymeric material for tissue engineering applications.

And also the teams of researcher, Tasdemir et al. (2013) reported on the composite structure obtained by mixing silk and cotton waste and recycled PA6 polymer was mixed. Silk and cotton wastes were in fiber lengths of 1 mm, 2.5 mm, and 5 mm. The recycled PA6/silk and cotton wastes were mixed in the rates of 97/3, respectively. There was an increase in the elasticity modulus of the composite made up of PA6 polymer/waste silk fibers. The amount of the increase for the composite made up with the addition of 1 mm length waste silk fibers especially can be explained in terms of attachment achieved by the dimensional volume increase. When tensile strength values were evaluated, there was no strength increase in either fiber added to PA6 polymer. As silk fiber is stronger than cotton fiber, tensile values were protected as before. It was known that tensile strength of a composition mainly depends on the intermediate structure. When hardness and izod impact strength values are considered; SEM pictures taken from breaking surfaces showed interestingly big gap. When mechanical, thermal and morphological characteristics are considered, with the addition of waste cotton fibers to the PA6 polymer and elasticity modulus values of composite formed with silk fibers increase and the composite formed in both fibers meet the demanded characteristics in themselves.

2.3. Chemical treatment

Natural fibers are chemically treated to remove lignin, pectin, waxy substances, and natural oils covering the external surface of the fiber cell well. This reveals the fibrils, and gives a rough surface topography to the fiber. Sodium hydroxide (NaOH) is the most commonly used chemical for bleaching and/or cleaning the surface of the plant fibers. The primary objective of surface treatments for natural fibers is to maximize the bonding strength so as to enhance the stress transferability in the composite. According to this, Mwaikambo L Y. and Ansell M. P. (2001) studied the fiber surface and fine structure due to chemical treatment by alkalization. Therefore, the fine structure of the native cellulose I to cellulose II changed by a process of alkalization. The reaction of sodium hydroxide with cellulose is shown in eq. (2.1).

$$\text{Cell} - OH + NaOH \rightarrow \text{Cell} - O^{-}Na^{+} + H_2O + [\text{surface impurities}] \quad (2.1)$$

Antoinette C. O'sullivan, (1997) studied a cellulose structure. Their result showed that cellulose I is known to be meta-stable since it is thermodynamically less stable than the cellulose II polymorph. If the polymers were formed separately, and separately, it is likely that cellulose II would be formed, instead, due to this difference in stability. After disbanding and renewal, or swelling by NaOH, cellulose I is transformed to Cellulose II. Thus, the crystalline part of the cellulose in all renewed cellulosic fibers, such as viscose and lyocell is composed of cellulose II.

Figure 2.4 shows a schematic structure of a natural fiber and Figure 2.5 presents the model of the structural organization of the three major structural constituents of the fiber cell wall (Madsen, (2004).

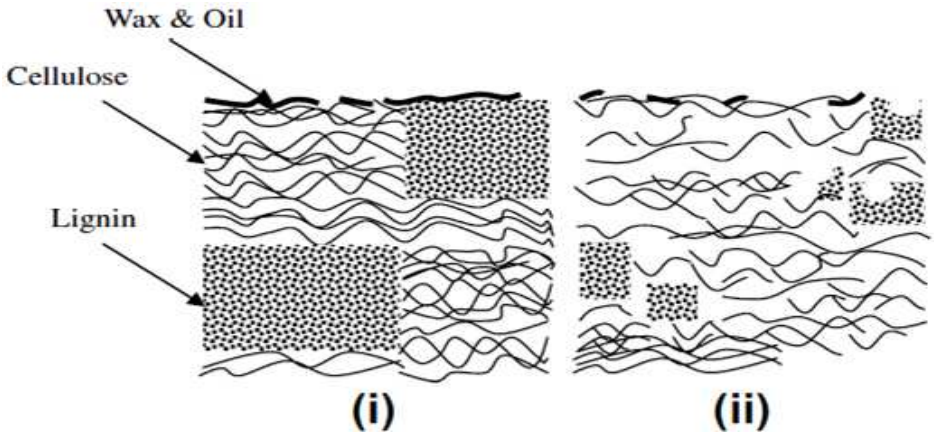


Figure 2.3. Typical structure (i) untreated and (ii) alkalized cellulose fiber, (Leonardo Y. M and martin P. A, 2001).

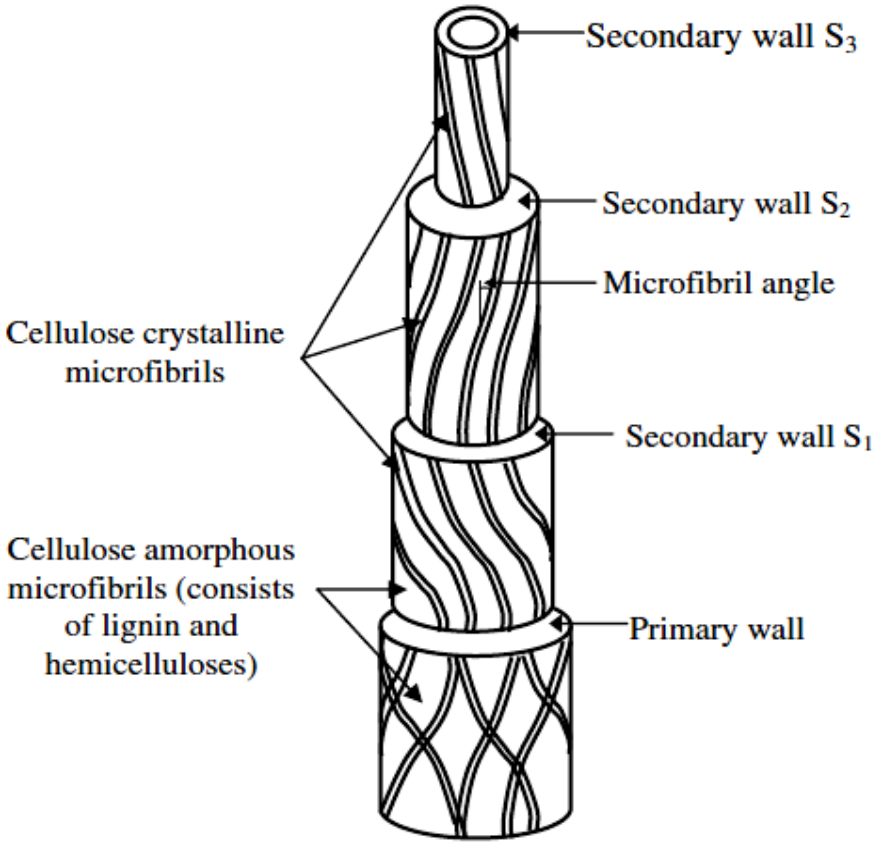


Figure 2.4. Structure of natural fiber (Kabir M.M. et al. 2012)

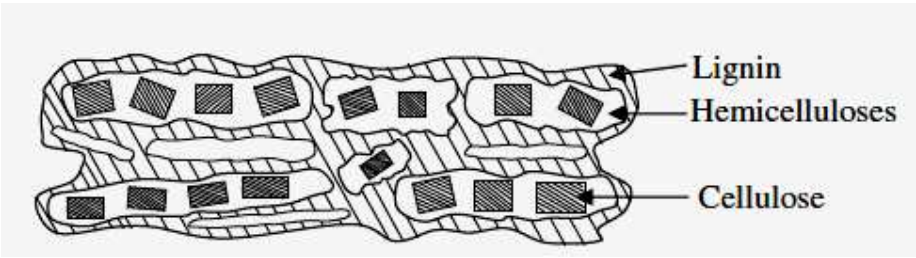


Figure 2.5. Structure organizations of the three major constituents in the fiber sell well (Kabir M.M. 2012)

Compositions of natural fibers are cellulose, hemicelluloses, and lignin shown in figure 2.5 and their properties were also shown in Figure 2.6.

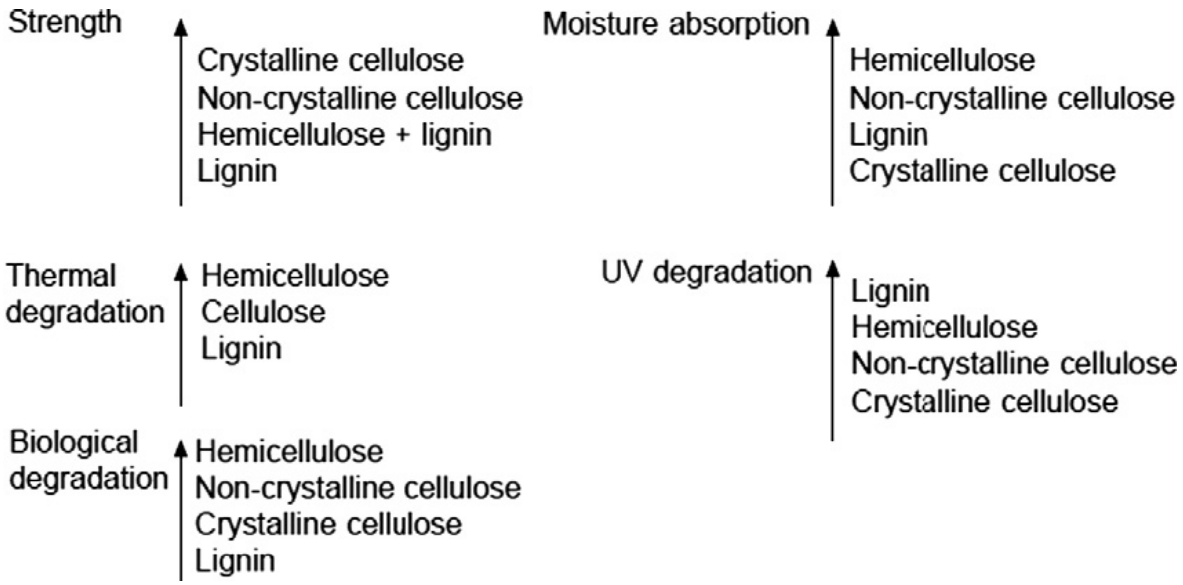


Figure 2.6. Properties of cellulose fibers and their dependence on chemical constituents (Mei-Po Ho et al. 2012)

Torres F.G. and Cubillas M.L., (2005) studied the interfacial properties of sisal reinforced polyethylene composite by means of the single fragmentation test. The specimens were prepared by compression molding. In this work, pre-treated fiber improved by 23% τ compared from untreated fibers in 130^{o}C/15 min. Qualitative improvements in interfacial shear strength for the treated specimens with respect to the untreated ones were confirmed from SEM fractographs observations.

Mwaikambo L. Y. et al, (2007) studied mechanical properties such as tensile, impact and shear properties of hemp-fiber-reinforced euphorbia composite through alkali treatment. Consequently, the untreated composite low hydroxyl groups exhibited highest impact strength followed by alkalized high hydroxyl group composite.

Li X., et al. (2007) discussed different chemical modifications such as alkali, silene, acetyletion, benzoylation, acrylation, maleated coupling agents, isocyanates, permanganate and others on natural fibers composites. In this review paper, chemical treatments can increase the interface adhesion between the fiber and matrix. Therefore, chemical treatments can be considered in modifying the properties of natural fibers.

The team of researchers, Liu L. et al. (2009) discussed the jute/PBS (poly (butylenes succinate)) biocomposites and the effects of surface modification of jute fiber treated by 2% NaOH, 2 + 5% NaOH or coupling agent on mechanical properties. According to this study,

surface modification by alkali or coupling agent both can improve the mechanical properties of biocomposites because of that surface modification can improve the compatibility between jute and PBS, leading to less microvoid and fiber-PBS deboning in the interface region.

Kabir M.M. et al. (2012) discussed the influence on the mechanical properties of natural fiber composites through different chemical treatment and to review recent research works related to different aspects of natural fibers and their composites. This team of researchers, to concluded chemical treatment is an essential processing parameter to reduce hydrophilic nature of the fibers and thus improves adhesion with the matrix. Pre-treatments of fiber change its structure and surface morphology. Table 2.3 summaries the recent results of the effect of alkali treatments for the mechanical and thermal properties of composites.

Table 2.3. Summarized the recent results on the effect of alkali treatment on the mechanical and thermal properties of composite (Kabir M.M. et al. 2012)

Fiber matrix composites	Applied treatment methods	Results on mechanical and thermal properties	References
Flex/epoxy	Alkali treatment	30% increase in tensile strength and modulus with the removal of pectin	Li X., et al. 2007
Sisal/polyester	0.5%, 1%, 2%, 4%, 10% NaOH treatment at room temperature	4% alkali treatment reported maximum tensile strength properties	Li X, et al. 2007
Hemp non-woven mat with euphorbia resin	0.16%, NaOH for 48h	Tensile strength was increased by 30% and doubled the shear strength properties was found compared in elastic modulus to the untreated fiber composites	Mwaikambo L.Y. et al. 2007
Jute/vinylester	5% NaOH for 4, 6 and 8h	4 h alkali treated composite accounted 20% and 19% increased with reaction time	Ray D. et al. 2001

Sisal/polycaprolactone	10% NaOH for 1,3,24 and 48%	Increased in elastic modulus with the increased with reaction time	Cyras VP et al. 2004
Hemp fiber	8% NaOH treatment	Thermal stability increased by 4%	Ouajai S. and Shanks Ra. 2005
Coir/polyester	5% NaOH treatment for 72h	Flexural and impact strength was increased by 40% with respect to the untreated fiber composites	Prasad SV., et al. 1983

2.4. Factor affecting mechanical performance of natural fiber composites

The major factor affecting mechanical performance of natural fiber composite products are selection of fibers and matrix, orientation of fibers, dispersion of fibers, interfacial strength, manufacturing process of composites, and porosity were reported by Pickering K. L. et al. (2016).

2.4.1. Selection of fibers

Fiber types are commonly classified based on its sources animal, plant or mineral. Cellulose is the major structural components of all plant fibers; animal also consists of protein. Although in minerals exists of asbestos group. Asbestos is the only in nature placing long mineral fiber. Six mineral have been classified as asbestos including chrystotile of the serpentine class and those belonging to the amphibole class: amosite, etc. Generally, Shan DU et al. (2014) presented much higher stiffness and strengths are obtained with the higher performance plant fibers than animal fibers. An exception of silk, which can have very high strength, but is comparatively expensive, has lower stiffness and is less readily available and annual production and much higher moisture absorption.

Table 2.1 shows some natural fibers and a glass fiber types. It can be seen that ramie, aramid fiber are having highest strength and modulus amongst the natural fibers although it should be confirmed that much variability is seen in the literature. Commonly, Abdollah M.. et al. (2015) presented the fiber selection is based on reasonably priced and availability rather than systematic approach. For example, flex fiber commonly used in Europe, whereas jute, hemp, sisal and kenaf have been much interest in Asia. Harakeke fiber is also mostly used in New

Zealand for structural application due to good mechanical properties and availability were presented by Pickering K.L. et al. (2016).

2.4.2. Selection of matrix

Matrix is very crucial part of fiber-reinforced composite products. It provides a barricade against bad environments, save the surface of the fibers from harmful mechanical abrasion and it transfers load to fibers. The most common matrices presently used in NFCs are polymeric as they are light weight and can be practiced at low temperature. Holbery J. et al. (2006) reported both thermoplastic and thermoset polymers have been used for as matrices for bonded a natural fibers.

Summerscales J. et al. (2010) presented most of the natural fibers used for reinforcement in natural fiber composite are thermally less than 200 ^{0}C, although under some situation it is effective for them to be processed at higher temperature for a while time. Resin and fiber are selected in accordingly with typical properties, requirement of application, availability and cost. However, it should be distinguished that the thermoplastics named constitute the mainly thermoplastics used by the plastics industry and extreme outweigh the use of any other thermoplastic matrices commonly used. Certainly, PP and PE are the two frequently adopted thermoplastic matrices for NFCs. The foremost thermosets used are unsaturated polyester (UP), phenol formaldehyde, epoxy resin, and VE resins. Thermoplastics are capable of being frequently softened by the application of heat and hardened by cooling and have the potential to be the most easily recycled, which has seen them most favored in recent commercial uptake, whereas better realization of the fiber properties are completely using thermosets.

2.4.3. Orientation of fibers

Herrera-Franco PJ and Valadez-Gonzalez A. (2005) studied the mechanical behaviors of short henequen fibers as reinforcement and a polyethylene as a matrix composite. Their study reveals that the greatest mechanical properties in a composite depend primarily on fiber orientation, but the adhesion between the fiber and the matrix is also important.

Joseph PV. et al. (1999) prepared sisal fiber reinforced with polypropylene composite by melt-mixing and solution-mixing methods followed by extrusion. Their result showed that fiber orientation was essentially plays an important role in the composites. Shown in Figure 2.7 and 2.8 are effect of fiber orientation on tensile strength and Young's modulus of PP/sisal composites, respectively.

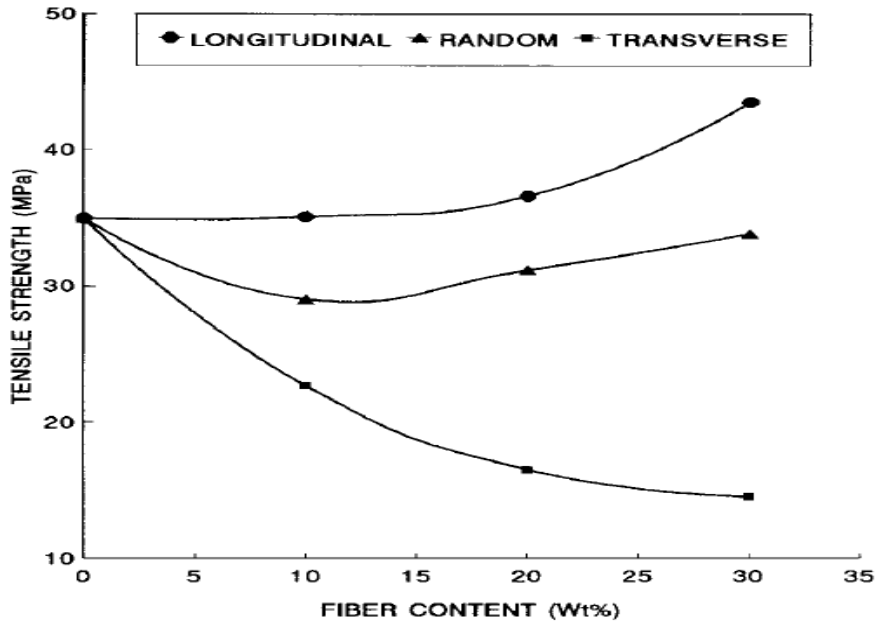


Figure 2.7. Effect of fiber orientation on tensile strength of PP/sisal composite (Joseph PV. et al. 1999)

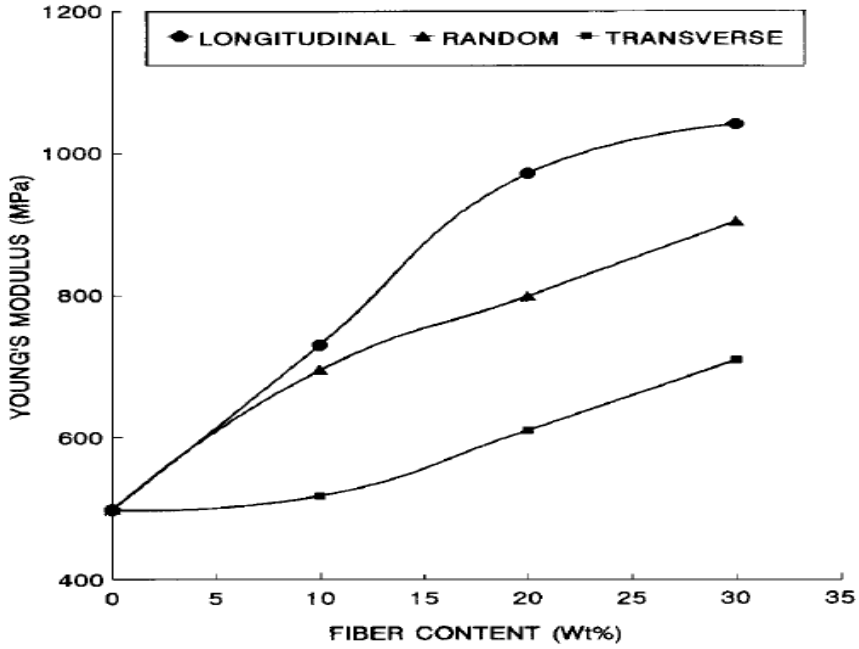


Figure 2.8. Effect of fiber orientation on Young's modulus of PP/sisal composite (Joseph PV. et al. 1999)

Alternatively, conventional textile technique of fibers can be engaged including spinning make possible a continuous yarn to be formed. However, as the name recommend, this does involve a degree of fiber twist. Aligned fiber yarns can also be produced by wrap spinning, a

technique used since the 1970s in the textile industry; here short fiber can be changed to a continuous form through the use of a continuous strand wrapped around discontinuous fiber with sufficient frequency to provide the required integrity for consequent processing. The continuous fabric can be from the similar type of fiber as the short fiber or can be thermoplastic and form the matrix material through compression molding (CM). Thermoplastic fiber to be transformed to the matrix can also be used associated in the yarn direction to act as support for the natural fiber.

Carpenter JEP. et al. (2007) studied deformation behavior of composites reinforced with four different linen flax yarn structures. Therefore, research comparing aligned fiber yarn with conventional twisted yarns for flax epoxy composites has confirmed improved tensile and flexural strength and stiffness with unidirectional yarn.

2.4.4. Dispersion of fibers

Pickering K.L. et al. (2016) reported fiber dispersion was identified as a major factor influencing the characteristics of short fiber composites and a particular challenge for NFCs, which commonly have hydrophilic fiber and hydrophobic matrices. Use of longer fibers can more increase their tendency to agglomerate. Good fiber dispersion promotes good interfacial bonding, reducing voids by ensuring that fibers are completely surrounded by the matrix.

2.4.5. Interfacial strength

Pickering K.L. et al. (2016) reported interfacial bonding between fiber and matrix plays a critical role in determining the mechanical properties of composites. Since stress is transmitted between matrix and fibers across the interface, good interfacial bonding is necessary to achieve optimum reinforcement, although, it is possible to have an interface that is very strong, permitting crack propagation which can decrease toughness and strength. However, for plant based fiber composites there is regularly limited interaction between the hydrophilic fibers and matrices which are commonly hydrophobic leading to weak interfacial bonding reducing mechanical performance as well as low moisture resistance affecting long term properties. For bonding to happen, fiber and matrix must be carried into close contact; wettability can be considered as an essential precursor to bonding.

Chen P. et al. (2006) studied the influence of fiber wettability on the interfacial adhesion of continuous fiber-reinforced PPESK composite. Their study reveals that insufficient fiber wetting results in interfacial defects which can act as stress concentrators.

2.4.6. Manufacturing process of composites

Adrian P. P. and Gheorghe B. M. (2010) reported in function of composite constructions, those can be divided in two categories, which are laminates (which have layers bonded together) and sandwiches (which are multiple-layer structural materials containing). Composites creation have numerous forms, some of the most imperative forms are hand and automated tape lay-up, extrusion, injection, compression molding, and fiber winding. Factors determining properties incorporate temperature, weight and speed of processing. It is conceivable for fiber degradation to happen in case the temperature utilized is too high, which limits the thermoplastic matrices utilized to those with melting points lower than the temperature at which degradation will happen.

In hand lay-up, Resins are impregnated by hand into fibers which are in the form of woven, knitted, stitched or bonded fabrics. This is usually accomplished by rollers or brushes, with an increasing use of nip-roller type impregnators for forcing resin into the fabrics by means of rotating rollers and a bath of resin. Laminates are left to cure under standard atmospheric conditions.

2.4.7. Porosity

Porosity is one of the most common defects found in composite parts. The porosity is caused by inadequate tooling, incorrect lay-up and cure procedure. The presence of porosity can degrade structural strength depending on the extent and location of the porosity in the composite component. Bo Madsen et al. (2009) studied porosity and stiffness on plant fiber composite. They reported that porosity is a common defect and manifest part of all composite materials due to the combination and consolidation of two unlike materials phases which are fibers and matrix. It is well documented that the main causes of influencing the mechanical performance of composites. Placing of air during processing, incomplete wettability of fibers, lumens and other vacant space within fibers/fiber bundles (which may become closed during processing at high pressure) are low ability of fibers to condense.

2.5. Summary of reviewed of literature

Generally, many researchers have addressed in recent decades in the mechanical performance of NFCs. Therefore, natural fiber-based composite are closely linked to their tensile, flexural and impact properties. The majority of researchers had focused their studies on three properties of the natural fibers as well as the performance of the composites system. Natural fibers were chemically treated to remove covering of external surface. This paper explored the

technical properties of a new product produced from the textile waste to change twisted strand for manufacturing 3D woven preforms in order to determine its usefulness as a new composite materials and analyze their mechanical characteristics to convenient production of eco-design methodology, based on recycling the textile waste which are extremely abundant in Ethiopia. In addition, this work is aiming to contribute for the scarcity of literature. Textile waste cotton is used in blanket factory for blanket and carpet mat production in Ethiopia, but the application of this study will add the value of textile waste materials by hybridizing with fiber glass.

CHAPTER THREE

3. MATERIAL AND METHODOLOGY

3.1. Materials

Material selection is the key and significant steps in the structural or mechanical design process. If the material selection is not done properly, the design may show poor performance; may require repeated maintenance, repair or replacement; and in the extreme cases, may fail, causing damage, injures or losses. The material selection process has need of the understanding of the performance requirements of the structure or component under consideration.

3.1.1. Matrix materials

Many materials when they are in fibrous form reveal very good strength properties but to attain these properties the fiber must be bonded by a suitable matrix. The matrix separates out the fibers from one another in order to avert abrasion and formation of new surface flaws and acts as a connection to grip the fibers in place. A good matrix should possess competency to deform facilely under applied load, transfer the load on to the fibers and evenly distribute stresses concentration. A study of the nature of bonding forces in laminates indicates that upon initial loading there is a tendency towards the adhesive bond between them account for the high strength properties of the of the laminates.

The polymer matrix joined the fibers together so as to transfer the load to and among them and defend them from environments and handling. Resin method used to engender advanced polymer matrix composites (PMCs) are two rudimentary types, thermosets and thermoplastics. Polyester is one type of thermoset polymer used as a matrix.

3.1.1.1. Unsaturated polyester resin

The resin GP (TOPAZ-1110 Phthalic Anhydride) are extremely versatile in properties and application and has been popular thermoset used as the polymer matrix in composite; it's also called 'resin GP' supplied by World Fiber Glass and Water Proofing Engineering. It has high mechanical properties due their low shrinkage and relatively unstressed structures. The chemical nature of epoxides viz., polar hydroxyl and ether groups present causes outstanding adhesion to a variety of materials. Low shrinkage further assists in formation of a strong and relatively unstrained adhesive bond. Resin systems exhibit prodigiously high resistance to alkali and good resistance to acids and solvent. It has excellent electrical properties in excess

of a range of frequencies and temperature. They are admirable insulating materials having high dielectric strength, arc and tracking resistance. The cured resin frameworks for the most part display great dimensional soundness, warm soundness, and resistance to most organisms. They are self-incredible dampness hindrances demonstrated low water ingestion and dampness transmission.

Table 3.1. Physical properties of resin (at 25^0C) (*Source: (Industrial chemicals and Resin Co. Ltd (Technical data sheet)*)

Properties	Values	Unit
Glass type	E	
Appearance	Pinkish viscous liquid	
Coupling agent	Silane	
Viscosity	575	Cps
Specific gravity	1.13	g/cc
Filament diameter	11	Microns
Add value	23-28	Mg/koh/gm
Styrene content	38±3	% weight
Flash point	340	Centigrade
Storage stability	4	Months
Peak Exotherm	150-165	Centigrade

Table 3.2. Mechanical and physical properties data in cured state (*Source: Industrial chemicals and Resin Co. Ltd (Technical data sheet*)

Properties	Pure resin	Reinforced	Unit
Glass content		33%	% weight
Specific gravity	1.2	1.45	g/cc
Tensile strength	50	80	N/mm^2
Tensile modulus	3000	6000	N/mm^2
Elongation (Mn)	2.5	2	%
Flexural strength	80	120	N/mm^2
Flexural modulus	3000	6000	N/mm^2
Volume shrinkage	7		%
Heat Distortion Tem.	75±5		Centigrade
Barcol hardness	40	45	

3.1.1.2. Hardener

Hardeners (TOPAZ-1110 TP; Thixotropic hardener) are almost always necessary to make an epoxy resin useful for its intended purpose. Without hardener, resins don't accomplish

anyplace close the noteworthy mechanical and chemical properties that they would with the hardener. It is used as strengthener and moisture absorber in the composite by mixed with ratio of resin. It is supplied by World Fiber Glass and Water Proofing Engineering.

3.1.2. Reinforcing fibers

Mechanical properties of the manufactured composites are represented by reinforcement and matrix properties, as well as the interfacial grip between them. Fiber reinforced polymer receives considerable demands in structural application, automotive, recreation, and sport tool, as well as furniture and aerospace. In this work textile waste fabric and glass fiber materials were utilized in composite fabrication.

3.1.2.1. E-Glass fiber

Composite materials are a critical lesson of materials which are presently accessible to mankind in huge amount. In recent years, numerous glass fiber-reinforced composite materials are broadly utilized within the aviation and car businesses (Mathapati, et al. 2014)

Glass fibers are among the most versatile industrial materials known today. They are readily produced as row materials, which are available in virtually unlimited supply. They display valuable bulk properties such as hardness, transparency, resistance to chemical assault, stability, and dormancy, as well as desirable fiber properties such as strength, flexibility, and stiffness. Chopped E-glass type was used for sample preparation as showed Figure 3.2 and chemical compositions are showed in Table 3.3, its manufactured by Binani Industries Limited and supplied by World Fiber Glass and Water Proofing Engineering.

Figure 3.2. Chopped E-glass fiber

Table 3.3. Composition of E-glass fiber (*Source: Industrial chemicals and Resin Co. Ltd (Technical data sheet*))

SiO_2	52-62%
Alkaline oxides (Na_2O_2, K_2O)	<2%
Alkaline terrous oxides (CaO, MgO, …)	16-30%
B_2O_3	0-10%
Al_2O_3	11-16%
TiO_2	0-3%
Fe_2O_3	0-1%
F_2	0-2%

Binani Chopped Strand Mat is made of randomly, yet evenly distributed strands, chopped from continuous Boron free "E" - glass fibers into 50mm length, bonded with "emulsion binder," possesses excellent surface bonding efficiency, mechanical properties are shown in Table 3.4, and features are:

- Easy air removal and rapid resin impregnation.
- Drapes well to suit the surface of intricate moulds
- Fasts wet-through and wet-out due to excellent Styrene solubility of binder.
- Easy taking care of and way better appearance of the composite parts.
- Good surfaces holding and high strand integrity. Congruous with Unsaturated Polyester resins

Table 3.4. Mechanical properties of glass fiber (*Source: Industrial chemicals and Resin Co. Ltd (Technical data sheet*))

Property	Value	Unite
Single Filament Tensile Strength	3,100 - 3,800	MPa
Young's Modulus of Elasticity	80 – 81	GPa
Fiber Density	2.62	g/cc
Moisture content (%)	0.20 max	
Softening Point	916	°C
Annealing Point	736	°C
Refractive Index	1.560 - 1.562	Oil Immersion
Dielectric Strength	100 – 106	kV/cm

3.1.2.2. Textile waste fabrics

In recent years, expanded emphasis has been placed on developing reusing strategies for industrial waste products, with the objectives of protecting the environment. However, relatively little investigation has been conducted regarding such a recycling system and most of these waste products are destroyed by fixing or burning underground.

Textile waste is a material that is deemed unusable for its original purpose by the owner. Textile waste can incorporate textile industry waste, created during fiber; textile and clothing production, and consumer waste, created during consumer utilize and transfer. This wastes textile collected and removed any dust particles then recycled to form a spin, this spin changed to weave as shown in Figure 3.3. Debre Berhan Blanket factory in Ethiopia is producing this form of textile waste material. Figure 3.4 as shown, the fiber for equal distribution in the matrix was prepared plain weave orientations.

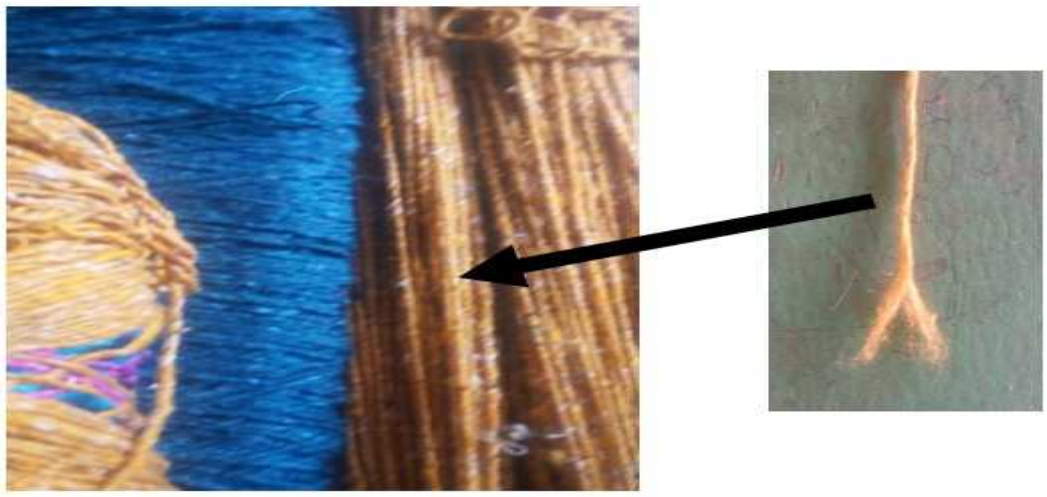


Figure 3.3. Recycled textile waste fabrics

Textile refers to materials that are made from fibers, thin threads which are natural or made or a combination. The fibers are spun into yarn and then made into fabric by diverse strategies like weaving, knitting, and felting.

There are different types of fiber are found within advertise (Mallick P.K. 1946) but all have not same characteristics. The characteristics of the fiber vary depending on the source from where it is delivered. Generally textile fibers are classified into two main types, natural fiber and synthetic fiber (Figure 2.1).

Cotton fiber is one of natural fiber. It has worldwide popularity for its variety of use. Cotton fiber is most used fibers for producing various types of fabric through all over the world because cheep and available and also easily recyclable.

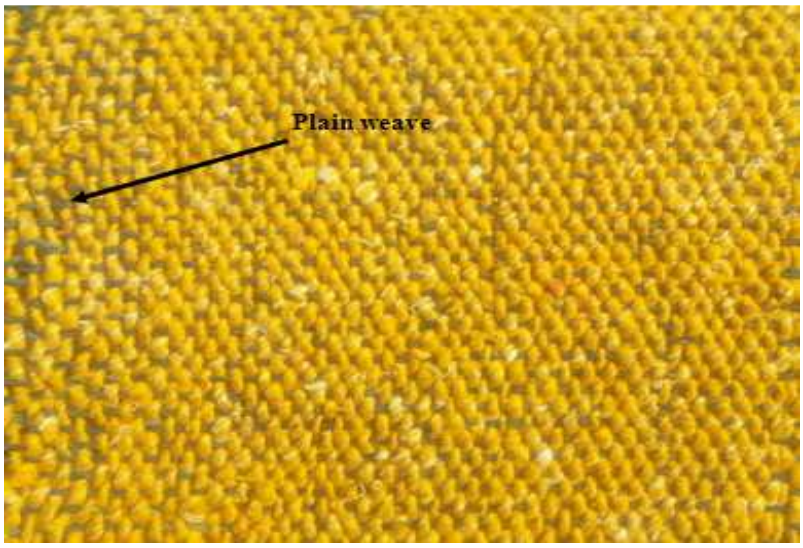


Figure 3.4. Woven textile waste fabrics

3.2. Surface treatment of textile waste fabrics

Hydrophilic nature of fiber and hydrophobic nature of matrix are the major problems of natural fiber composite. The characteristic inconsistency between these two phases comes about debilitating bonding with the interface. Chemical treatments for reinforcing fiber can reduce its hydrophobic tendency and hence make strides compatibility with the framework.

Several studies have been conducted to move forward fiber adhesion properties with the matrix through chemical treatments. The treatment for natural filaments by sodium hydroxide (NaOH) is broadly being utilized to alter the cellulosic molecular structure. Goda K et al. (2006) was detailed that plant base treatment of a high concentration promotes a distortion of individual microfibrils by breakage of interlocking hydrogen bonds and evacuation of hemicelluloses from the fiber. The absence of hemicelluloses causes slippage of cellulose microfibrils, thereby importing a loosely bound structure. In addition, the breakage of hydrogen bonds to make numerous dynamic hydroxyl bunches that increment the fiber's hydrophilicity and this truth hypothetically leads to advancement on water assimilation that can cause increment in fracture strain of exceedingly concentrated alkali-treated fiber composites. Besides, the young's modulus of alkali-treated fiber composite diminished compared to that of untreated fiber composites. Therefore, for this study NaOH chemical is

used for bleaching and/or cleaning dust particle, oil and grease the surface of plant fibers. This reveals the fibrils, and gives a harsh surface structure to the filaments.

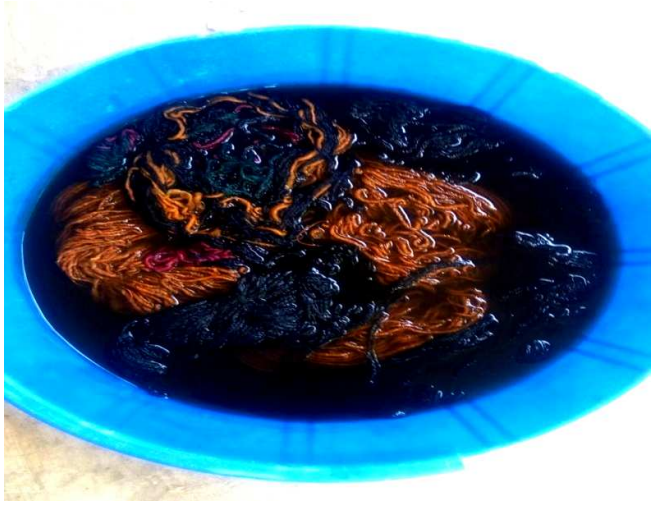


Figure 3.5. Fiber soaked with NaOH solution

Recycle textile waste were soaked in beakers containing NaOH concentrations as shown Figure 3.5 and placed for 24h. The fibers were then removed, washed with distilled water for three times to neutralize excess sodium hydroxide as shown Figure 3.6. The strands were at that point dried by daylight for 3 days to evacuate free water. This treatment is used to reduce the surface tension of a liquid in contact with fiber surface (wettability). Previous work on this related analysis the chemical concentration seems to be enough in order to achieve a considerable fiber treatment during standard processing operations (Li X., et al. (2007), Mwaikambo L.Y. et al. (2007), Ray D. et al. (2001), Prasad SV., et al. (1983)).

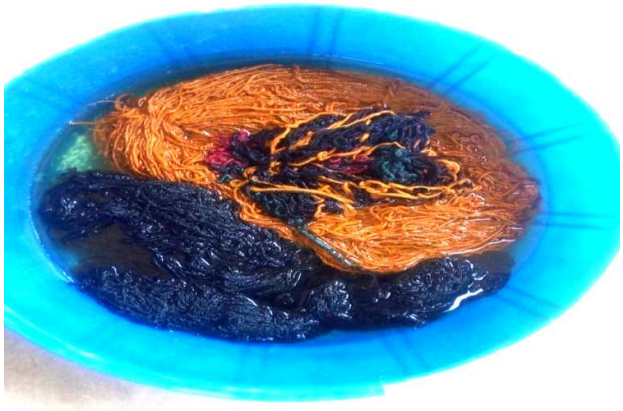


Figure 3.6. Treated fiber (Clean site)

3.3. Mold

The mold is used for shaped the product. In order to have a smooth or appearance on the surface of the created goods, the mold surface moreover should have the respective wrap up. The outer surface of the product to be smooth, the die mold likewise, and also the inner side of product has to be smooth the mold is done over a punch mold. The mold should be free from defects, since the imprint of any defect will be composed on the product.

Generally, a mold should be utilized for making components utilizing the lay-up process to place the layer in or on in order to get the desired shape.

3.3.1. Mold preparation

Metal plate is used as a mold. The size of flat plate is as follows: 400 mm in length, 300 mm in width and 4mm depth are shown in the photograph of figure 3.1.

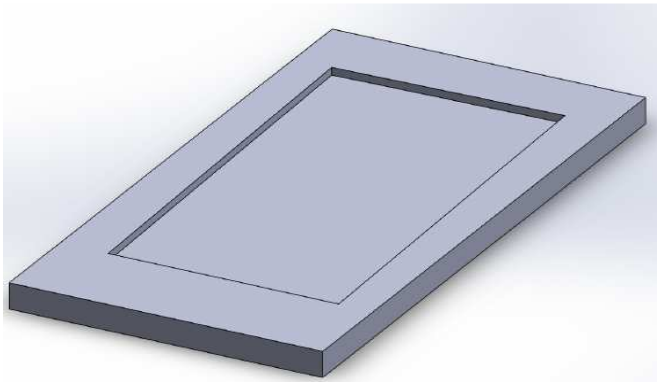


Figure 3.1. Mold for making composite plates

3.4. Release agent

Release agent is used preventing a matrix sticking on the mold such as wax. But some other release agents used in industry are:

- Plastic sheet
- Spray releases
- Release films and
- Internal mold releases (added to gel coat or resin system)

Release agents are usually used to prevent other materials from bonding to surface of molds or tool in a separate designated area as they can act as contaminate if accidentally incorporated into the composite lay-up.

3.5. Preparation of composite specimen

Within the display examination composite materials are created by hand lay-up. The composite laminate consist of number of layers in which glass fibers and textile waste fiber layers are placed alternatively until we obtain required thickness. The realizing agent placed on the mold which is wax to avoid the adherence of laminate on mold. Resin GP and hardener are blended within the weight ratio 10:1 and kept for a minute. Then a layer of matrix is applied to the wax in a particular direction. Later alternative layers of textile waste and glass fiber are placed. Then, layer is squeezed by using roller brush for escaping air bubble ('hand lay-up method').

The composites were arranged four distinctive compositions of weight proportion of glass fiber and textile waste fabrics. The distinctive compositions of fibers weight are measured as shown in Table 3.5.

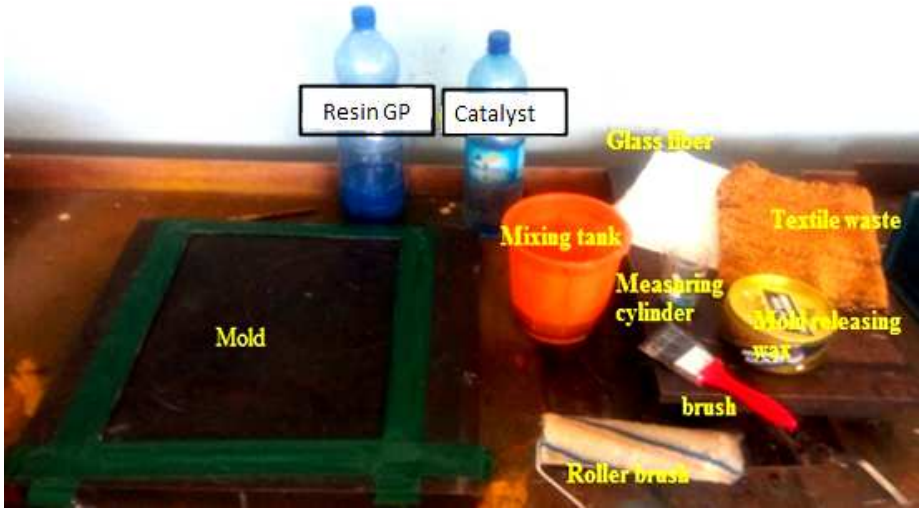


Figure 3.7. Materials used for preparing composite

Figure 3.8. After cured the resin rolled for releasing bubble and for equal distributions of resin

In this study, developed hybrid composite consist of three components which are matrix, glass fiber and textile squander fabric. Geetanjali Das and Sandhayarani Biswas, (2016) detailed the real density (ρ_m) of the composite is determined experimentally by simple water submersion method. However, hypothetical density of composite materials in terms of weight fraction is calculated utilizing the following equation:

$$\rho_{ct} = \frac{1}{W_f/\rho_f + W_p/\rho_p + W_m/\rho_m} \quad (2.1)$$

Where, W and ρ represent the weight fraction and density respectively. The suffix f, m, p and ct stand for the fiber, matrix, particulate filler and the composite materials respectively.

According to designation of ASTM-D2734 – 09 void content of a reinforced composite was significantly affected some of its mechanical properties. Higher void contents usually greater susceptibility to water penetration and weathering, and increased variation or scatter in strength properties. The knowledge of void content is desirable for estimation of quality of composites. Measuring density was found by using in water immersed the sample specimen to read increased level of volume.

$$V = \frac{\rho_{ct} - \rho_m}{\rho_{ct}} \times 100 \quad (2.2)$$

Where, V void content, volume %, and ρ_m measuring density

Table 3.5. Weight percentage, density and void content of composite

Composition	Textile waste fabric %Wt	Glass fiber %Wt	Matrix %Wt	Composite density (ρ_{ct}=g/cm^3)	Measured density (ρ_m=g/cm^3)	Void content (%)
Pure resin	--	--	100%	--	1.2	
T/T/T	15%	--	85%	1.15	1.13	1.74
T/G/T	10%	10%	80%	1.21	1.17	3.31
G/T/G	8%	23%	69%	1.31	1.23	6.11
G/G/G	--	44%	56%	1.49	1.48	0.67

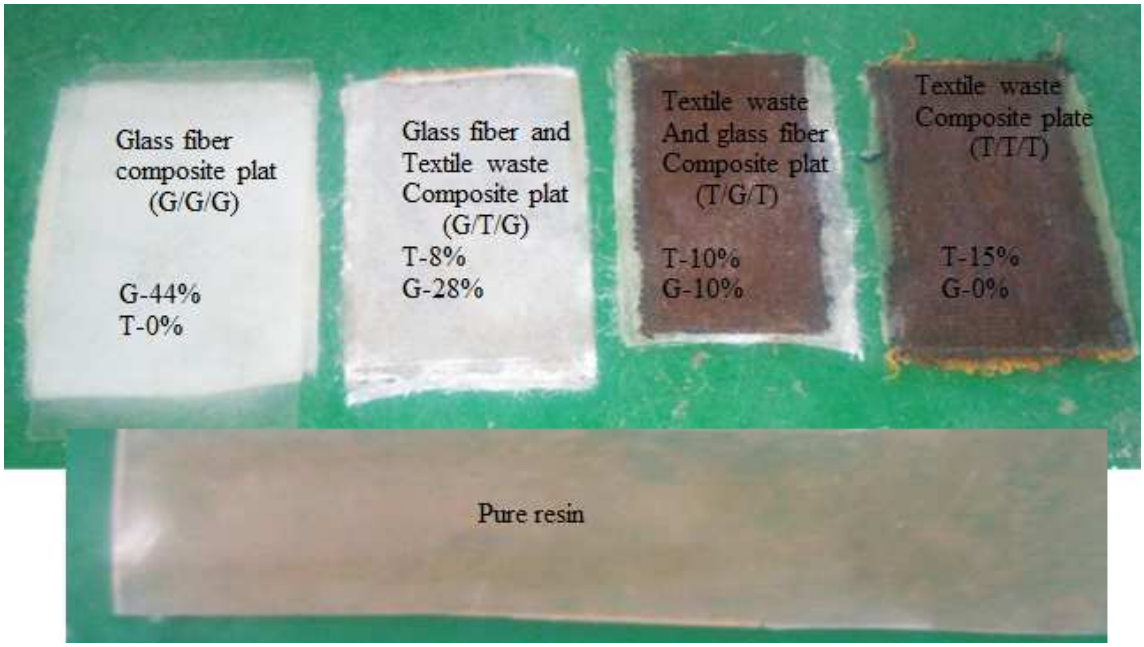


Figure 3.2. Prepared composite plates (G-glass fiber, T-textile waste)

3.6. Mechanical tests

Mechanical properties of natural fiber-reinforced polymer composites are commonly characterized tensile, flexural, impact strength and hardness tests. It was presented by Rahman M. A. et al. (2015).

3.6.1. Tensile test

Tensile testing is one of the more fundamental tests to decide stress-strain relationships. A basic uniaxial test comprises of gradually pulling a test of fabric in tension until it breaks. Test specimens for tensile testing are for the most part either circular or rectangular with bigger closes to encourage holding the test. Tensile test was performed in order to determine tensile strength and young's modulus according to ISO 6892-1.

The normal testing strategy is to deform or extend the fabric at a steady speed. The specified load that must be connected to realize this displacement will shift as the test proceeds. Amid testing, the stress within the test can be calculated at any time by dividing the load over the cross-sectional zone.

$$\sigma = {}^{P}/_{A} \tag{2.3}$$

The displacement within the test can be measured at any area where the cross-sectional zone is consistent and the strain calculated by taking this alters in length and dividing it by the initial or introductory length.

$$\varepsilon = {}^{\Delta L}/_{L_o} \tag{2.4}$$

Engineering material properties that can be found from easy tensile testing incorporate the elastic modulus. These values are regularly calculated in tension experimentation and compared to published values. The tensile test machine is appeared in figure 3.11.

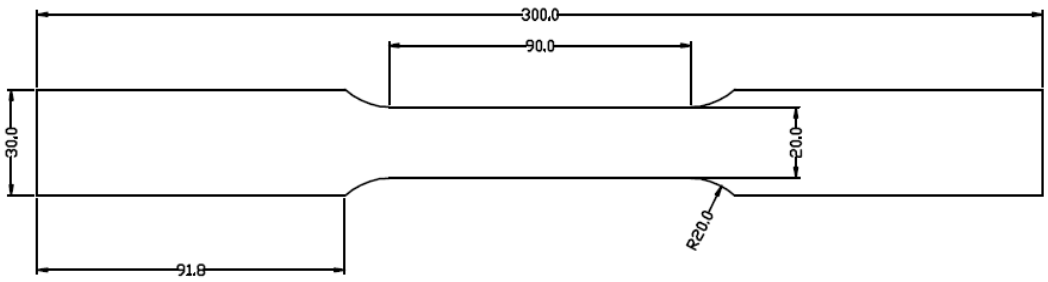


Figure 3.3. Tensile specimen

Figure 3.4. Universal tensile testing machine

Specimens for tension test were carefully cut from the laminate using optimum quality wood cutting band saw machine and finished to the accurate size using angle grinding machine; 12,000 rpm. The geometry of the test specimen is as shown in Figure 3.12.

Figure 3.5. Tensile testing specimens

3.6.2. Flexural test

The test method determined the flexural property of glass fiber/textile waste hybrid composites was performed using three-point set-up accordance with ASTM-D790: Standard Test Methods for Flexural Properties on Unreinforced and Reinforced Plastics and Electrical Insulating Materials. Flexural tests were performed using Hydraulic Universal Amsler Testing Machine a load cell of 25 KN at a constant rate of 0.6 mm/min.

Figure 3.6. Universal bending test machine set up (Amsler product)

Thirteen testing specimens were cut to 191 mm length; 160 mm span length and 13 mm width as shown Figure 3.18. The specimen were loaded in three point bending with the suggested span to dept ratio of 40:1 as shown figure 3.15. Flexural strength and flexural modulus were calculated using equation (2.5) and (2.6), respectively (ASTM-D790).

$$\text{Flexural strength} = \frac{3PL}{2bh^2}\text{MPa} \tag{2.5}$$

$$\text{Flexural modulus} = \frac{mL^3}{4bh^3}\text{MPa} \tag{2.6}$$

Where P is the maximum load applied on test specimen (N), L the support span (mm), b the width of specimen tested (mm), h the thickness of specimen tested (mm), and m the slope of tangent to the initial straight line portion of load deflection curve (N/mm).

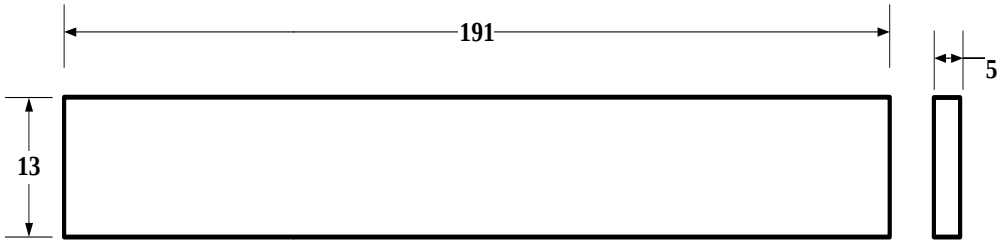


Figure 3.7. Dimension of flexural test specimen

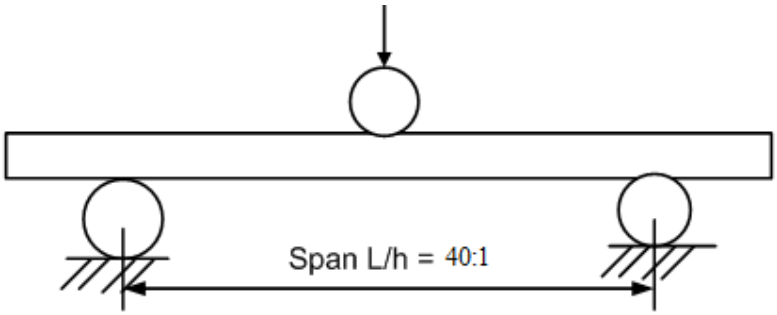


Figure 3.8. Flexural test configurations

Figure 3.9. Flexural testing specimen

3.6.3. Impact Test

Pendulum-type hammers testing machine model; EKE MAT 20 was used in the Izod impact test exerted of full scale 30J, striking velocity of pendulum is 3.8m/s, angle of fall of pendulum is 120^{o} and maximum permissible loss of friction is 0.5%.

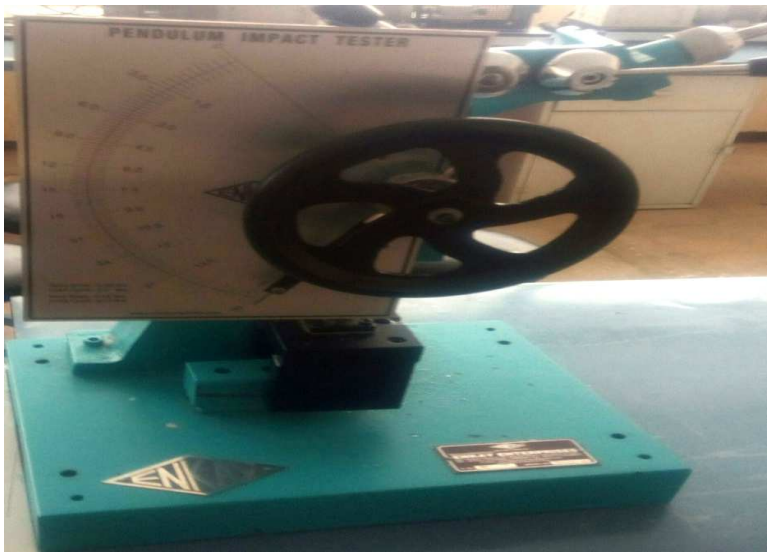


Figure 3.10. Izod impact test machine (ISO 9001:2000)

The specimen was located in the testing machine precisely. The specimen is held inflexibly in a vice type fixture with the notched side in front of the path of impact. The centerline of the notch must be within the plane of the vice top inside 25 mm. Once the specimen was in placed the hammer is released from a specific height and allowed to strike the specimen thus rupturing it at the vee notch. The impact test specimens are prepared according to the required dimension following the ASTM-A370 standard; length 55mm, width 10mm, depth 4mm and 45^0 V-notch of 3 × 5mm in shown Figure 3.18.

$$\text{Izod Impact strength (KJ/m}^2\text{)} = \frac{\text{Energy Absorbed in joules}}{\text{Width of notched face} \times \text{Length below the notched}} \quad (2.7)$$

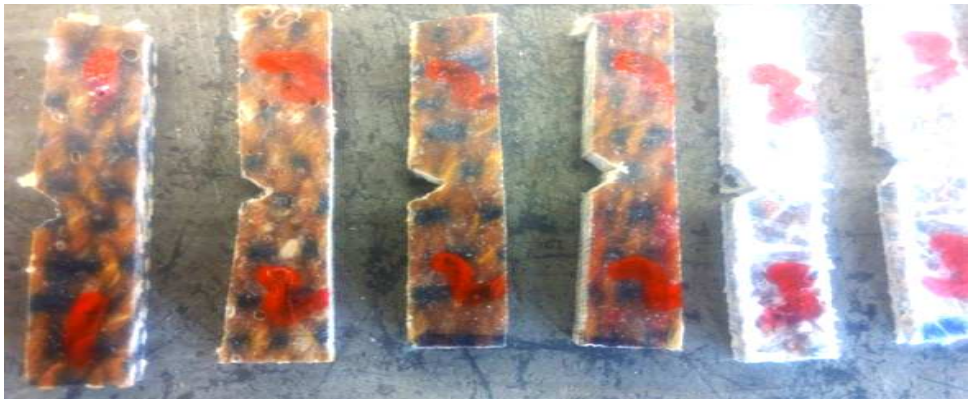


Figure 3.11. Impact specimens (ASTM-A370)

3.6.4. Micro hardness test

In micro hardness testing, a space is made on the tested by a square-based pyramid diamond indenter through the application of a load *P* (Figure 3.19-a). The measure *d* of the resultant space is measured with the assistance of a calibrated optical magnifying instrument, and the hardness is assessed as the cruel stretch connected under the indenter measure used Vickers hardness test. Minimum scale value the optical micro meter is 0.5µm (source: machine's manual).

HV= constant × test force/surface area of indenter

$$\text{HV}= 0.102\times 2\text{P } (\sin\frac{136^0}{2})/d^2 \quad (2.8)$$

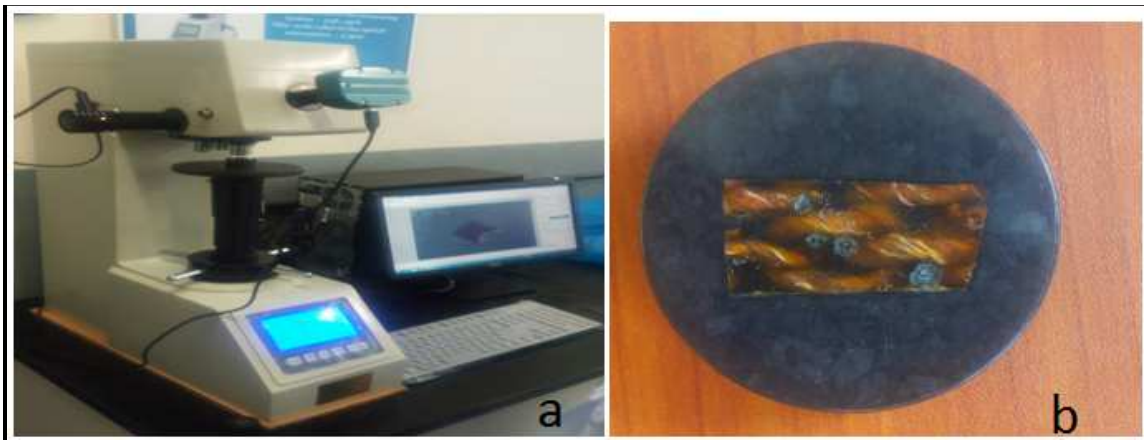


Figure 3.12. Micro hardness test: a-instrument set-up, b-specimen

3.7. Water absorption

The water absorption tests of textile waste/glass fiber reinforced polyester composites were done as per ASTM 570 by immersion in tap water, salty water and distilled water at room temperature; having measurements of 20mm × 20mm × 4mm. The specimens were dried in room temperature and measured the weight and thickness before immersed in water tank. The composites are submerged for 230h in tank but by 24h interval are measured by used analytical precision balance (Figure 3.13). Composite samples were immersed in a water bath during a time period until the saturation was reached. This process was repeated, to weigh the specimens regularly over 10 days of water immersion. The rising value was calculated by using equation (2.9).

$$\text{Water absorption (\%)} = \frac{\text{Final weight} - \text{Original weight}}{\text{Orginal weight}} \times 100 \qquad (2.9)$$

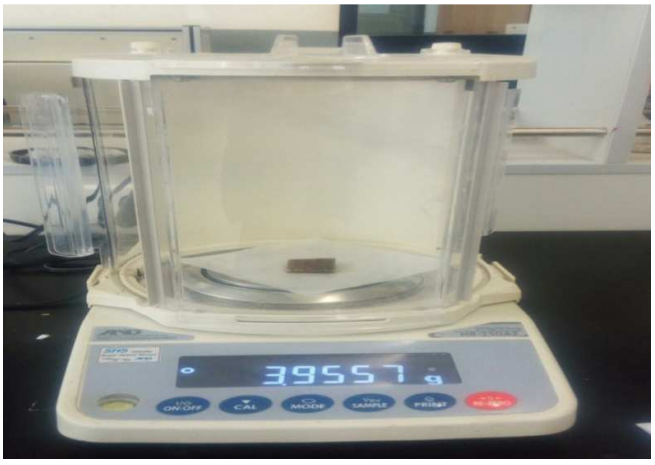


Figure 3.13. Analytical precision balance

Four distinctive test types of composites product arranged for testing of thickness walling. It is calculated agreeing to ASTM-D570 by utilizing equation (2.10) in three conditions such as in tap water, in salt solution and in distilled water. The rate of thickness swelling was evaluated by:

$$T_{re}(\mathrm{t}) = 100 \times \left[\frac{T_t - T_0}{T_0}\right] \tag{2.10}$$

Ware T_{re} is the percentage of thickness swelling, T_t is the thickness at a time *t*, and T_0 is the initial thickness at $t = 0$.

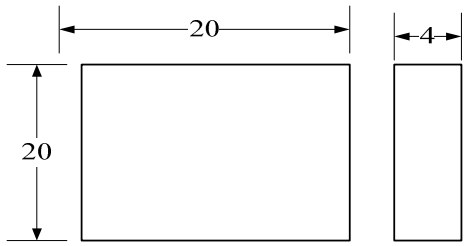


Figure 3.14. Water absorption specimen dimension (ASTM-D570)

Figure 3.15. Water absorption specimen

3.8. Optical microscopy

Optical inspections were performed using Huviz HR-300 series Magnification shown in Figure 3.23. It is used to magnify flat polished section by reflected light mode the results are shown in Figure section 4.4, where the reinforcing fibers can be clearly distinguished from the matrix and some small defects (voids) were observed.

Figure 3.16. Optical microscopy

3.8.1. Sample preparation for optical testing

I. Specimen mounting

Preparation for optical testing was mount the samples in a thermoplastic hot-pressed resin (Figure 3.24-a). This provides a hard, easily-polished surround to the specimen**.**

II. Grinding the mounting surface

The obverse side is then prepared by hand under running water on a series of abrasive papers from grade 280, 400, 600-1200 until the surface is free of major defects and the fibers are clearly visible under a low-power microscope. From this stage onwards extreme cleanliness is necessary and the specimen should be ultrasonically cleaned at each stage.

III. Polishing

Next, the grinding and polishing of the specimens was performed via standard metallographic techniques to achieve a fine smooth surface for etching. For uniform polishing, the grinder consisted of a rotating wheel in shown Figure 3.24-C.

IV. Etching

After polishing, samples ware etched for 10min by ethanol (CH_3CH_2OH) with HCl (50:1). It is ready for viewing in microscopy.

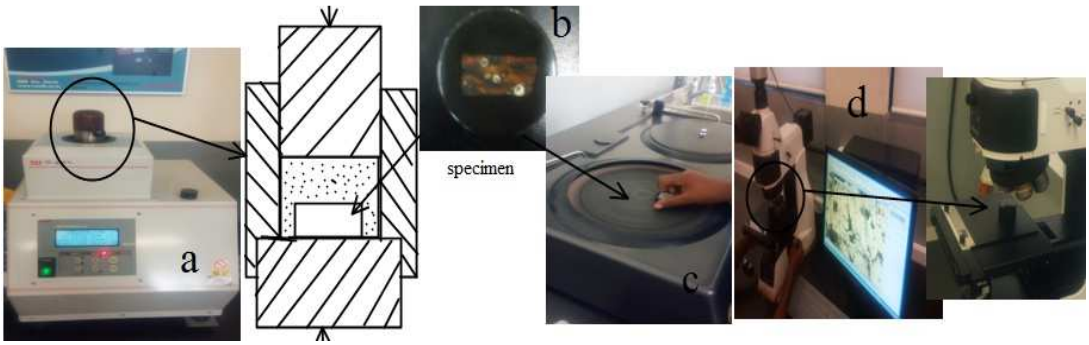


Figure 3.24. Specimen preparation process for optical testing: a-mounting (high temperature mold), b-mounted specimen, c-polishing, d-optical microscopy

CHAPTER FOUR

4. Result and discussion

4.1. Mechanical test analysis

Mechanical properties of composites such as flexural strength, tensile strength, and impact strength have been investigated and also discussed. The mechanical properties of the composite are primarily depending on fiber content.

4.1.1. Tensile test analysis

The tensile test is one of the most commonly used assessing strength of materials for illustrations metal, polymer etc. Amid this test, a specimen is pulled, or put in tension in a gradually increasing load until it breaks. The tensile strength is calculated from the load in Newton (N) required to break the test bar divided by its cross sectional range in square mm. Coming about estimation is expressed in N/mm^2. The tensile strength is the most extreme load a part can withstand before breaking.

The tested results of tensile strength and modulus are depicted in Table 4.1 and graphical representation of tensile strength and Young's modulus of textile waste/glass fiber resin-based hybrid composites are shown in Figures 4.2 and 4.4, respectively. Results showed the hybridized, the tensile modulus properties of neat resin-based composite have been improved.

Table 4.1. Experimental Results for tensile testing of composite

Samples	Sample 1	Sample 2	Sample 3	Load(KN)	Av. Tensile strength (MPa)	Young's modulus (MPa)	Elongation (%)
Pr	--	--	26.7	2.1	26.7	420	6.36
T/T/T	31	37	36	3.24	35	581	6.2
T/G/T	62	56	74	8.1	64	1011.1	6.33
G/T/G	49	37	71	5.75	52.33	929.5	5.63
G/G/G	163	156	172	10.18	164	476	34.9

According to the tensile stress results, the effect of glass fiber on the tensile strength T/G/T to G/T/G samples was decreased because of sample G/T/G had more number of porosity.

Similar trend, textile waste fabric composite (T/T/T) is greater than 31.1% found from pure resin composite. Sample G/T/G shown the smallest elongation value is 5.63% and not easily permitted glass fiber layers emitted the matrix like T/G/T composite. In this experimental test, chopped glass fiber laminate outer layer to be piles and the inner layer of textile wastes was broken shown in Figure 4.3. Due to this, the result of tensile strength of G/T/G was 18% decreased than sample of T/G/T. Within the tensile test, the most noteworthy value is glass fiber as it were composite, the strength 164MPa was measured.

Figure 4.1. Ruptured specimens of hybrid composites due to tensile test load

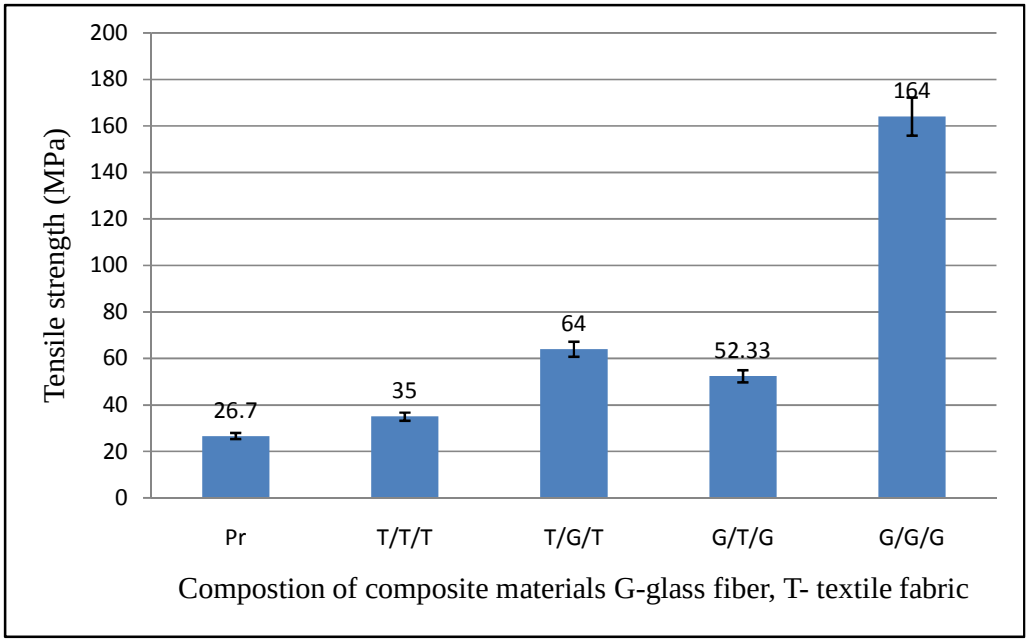


Figure 4.2. Tensile strength properties of hybrid composites

Figure 4.3. Rapture due to tensile load

Young modulus for T/T/T and G/G/G composite are recorded 581MPa and 476MPa, respectively in shown figure 4.4. Glass fiber only composite is found the smallest young modulus result this means glass fiber composite more flexible and less stiffness than textile waste fiber can decrease the modulus of composite but increase elongation at break. In according to hybrid composite, the same properties can be shown for a change in young modulus with consequences of glass fiber content evaluating tensile strength results. However, the content of glass fiber is increased by 10%, but textile waste is decreased by 5% to produced T/G/T composite then the young modulus increased by 74%.

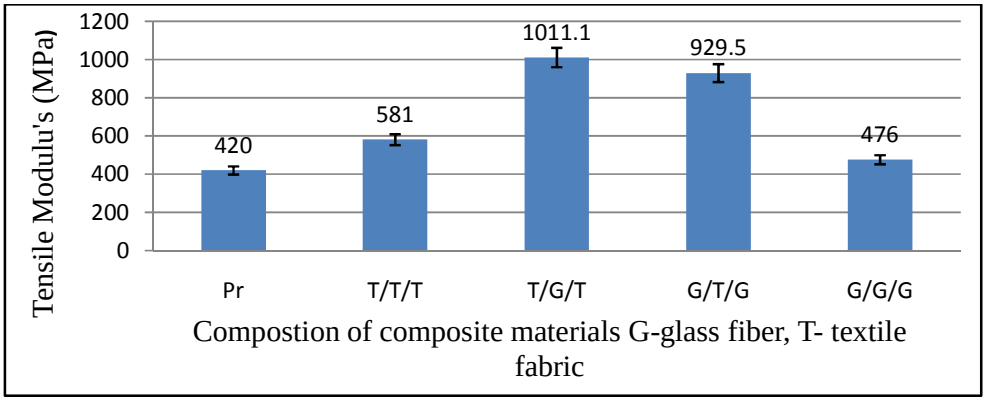


Figure 4.4. Effect of stacking sequence on tensile modulus of composite

4.1.2. Flexural test analysis

The flexural strength speaks to the most elevated stress experienced inside the material at its moment of burst. It is considered as stress and agreed the symbol. At the border of the object of the interior of the bend (concave) the stress will be at its most extreme compressive stress value. At the exterior of the bend (convex) the stress will be at its most extreme ductile value. These internal and external edges of the beam or bar are known as the 'extreme fibers'. Most materials come up short under tensile stress some time recently they fail under compressive stress, so the most extreme tensile stress value that can be maintained before the pillar or bar fails is its flexural quality.

Table 4.2. Experimental Results for flexural testing of composite

samples	Trial 1	Trial 2	Trial 3	Load (N)	Deflection (mm)	Av. flexural strength (MPa)	Flexural modulus (GPa)
Pure resin	57.69	--	--	50	37	57.69	45.54
T/T/T	80.77	80.77	75	68.33	36	78.85	44.31
T/G/T	118.85	138.46	138.46	114.33	39.3	131.91	48.37
G/T/G	184.62	178.85	155.77	150	27.3	173.1	32.63
G/G/G	188.38	195.92	165.78	121.67	33.7	183.36	61.85

The numerical analysis pointed out important differences between composites both for the flexural strength and modulus of elasticity in shown Table 4.2. Hybrid composites are very important to achieve the requirement of materials and its mechanical properties shown in Figure 4.5. The glass fiber content increase from 10% to 23% the flexural strength is increased from 131.91MPa to 173.1MPa but sample T/G/T less void content than sample G/T/G because sample T/G/T is outer surface covered by textile waste fiber; it is more brittle than glass fiber and initiated fracture propagation. Woven textile waste fabric of 15% weight fraction composite (T/T/T) is found 78.85MPa flexural strength, 36.7% increased from pure resin.

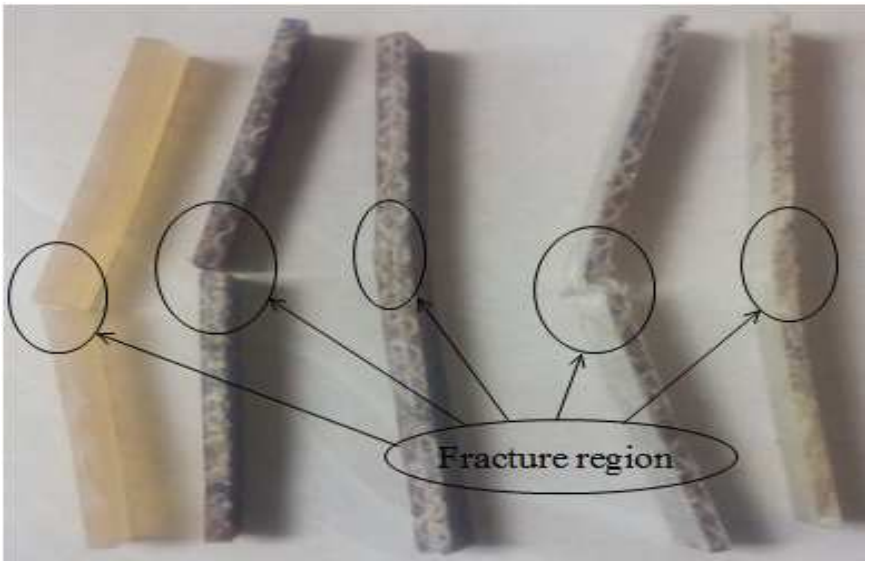


Figure 4.5. Ruptured specimens of hybrid composites due to flexural test force

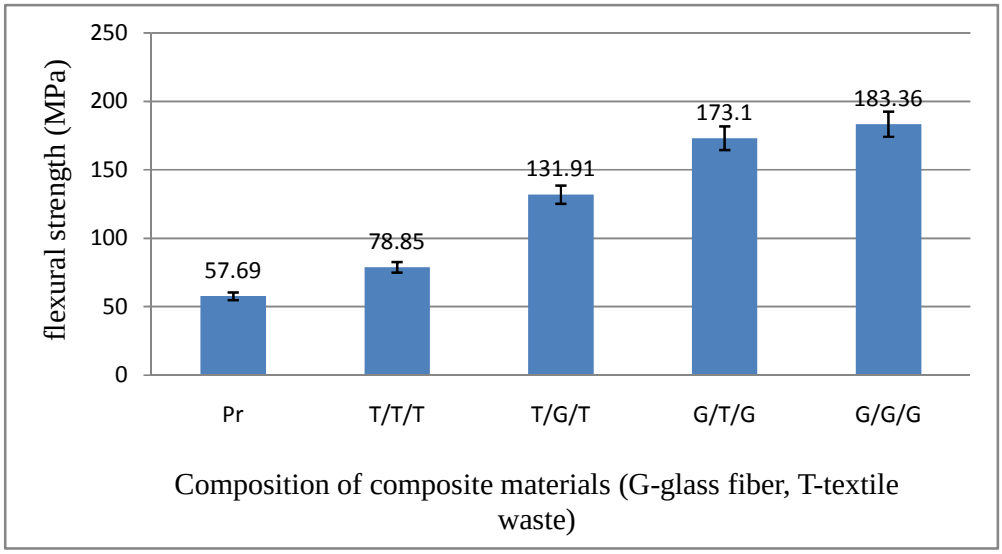


Figure 4.6. Flexural strength properties of developed composite

In flexural test, tensile and compressive stress is evaluated at the moment of burst and glass fiber is the highest tensile strength. Due to this a flexural strength increased with increase a content of glass fiber in composite.

Analyzing the flexural modulus of resin with textile waste/glass fiber hybrid composite, as shown in Figure 4.7, G/T/G sample is reduced by 15.74 GPa flexural strength with the reduction of 2% textile waste and addition of 13% glass fiber. Otherwise, there was an increased flexural elastic modulus, besides on increased deflection as shown in Table 4.2. The

flexural modulus of the pure resin is calculated as 45.54 GPa. The flexural modulus of G/T/G is shown 32.63GPa, it is smallest value because of having porosity, and this defect is initiating of crack propagation.

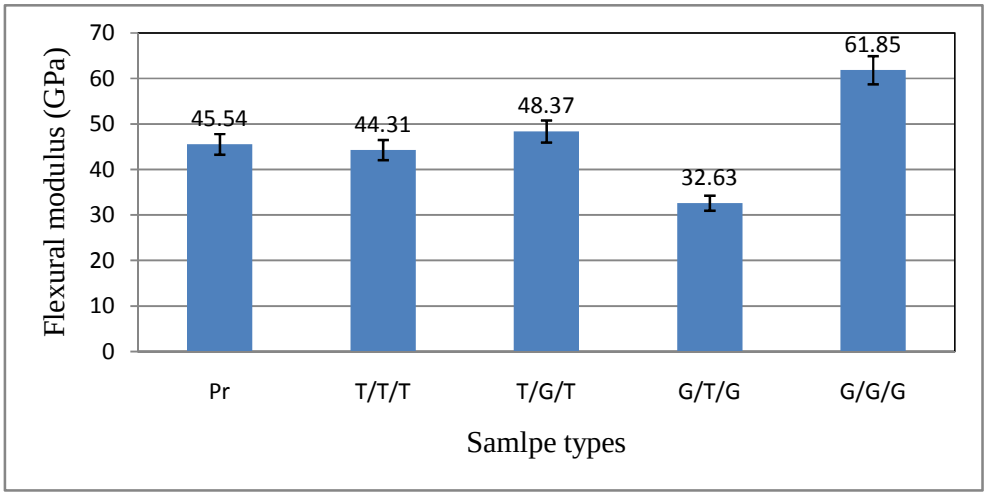


Figure 4.7. Effect of stacking sequence on flexural modulus of composite

4.1.3. Impact test analysis

Izod and Charpy impact tests are common types of tests utilized to measure impact strength or toughness; as a central both are comparative. The impact testing includes sharp blow to the test specimen. A pendulum swings from a starting distance against the test portion that's held unbending in a clamp. Sharma P. et al. (2017) presented the impact data cannot be utilized for plan criteria and is only great for comparing the relative toughness of distinctive materials. The impact recorded information is accommodating in comparing the toughness of a material at distinctive temperatures and under diverse heat treat conditions.

Strength of the made composite materials, the izod impact test has been carried out. The impact strength may be characterized as toughness or capacity of material to absorb energy amid plastic distortion. In this test, Table 4.3 depicted izod impact tested results of resin GP matrix composites reinforcement with different volume divisions of textile wastes and glass fiber hybrid composites. Pure resin composite is less impact strength resistance than fiber contents composite shown in figure 4.9. Textile only wasted woven fabric composite was found 11.91KJ/m^2.

Table 4.3. Experimental results for impact testing of composite

Samples	Trial 1	Trial 2	Trial 3	Energy absorbed	Average impact strength (KJ/m^2)
Pure resin	--	--	73.2	2.05	73.2
T/T/T	98.2	108.93	128.6	3.13	111.91
T/G/T	92.9	114.3	92.9	2.8	100
G/T/G	76.8	92.9	103.6	2.55	91.1
G/G/G	83.7	87.8	93.9	2.17	88.5

Figure 4.8. Ruptured specimens of hybrid composites due to impact load

To analyze the impact capability of the hybrid composites, izod impact tests were carried out and results are displayed in Figure 4.9. In according to this composite, the highest and lowest impact strength of T/T/T and G/G/G are found 111.91KJ\$m^2$ and 88.5 KJ\$m^2$, respectively. However, the strengthened textile wastes fabric decreased with increasing glass fiber content, while stiffness at the same time decreased. The textile wastes dedicate 5wt.% and addition 10wt.% glass fiber is found $100KJ/m^2$ when strength is decreased by 10.64% compared to T/T/T composite. Moreover, the hybrid showed a fiber weight of textile waste decreased while glass fiber increased, impact strength was explored $91.1KJ/m^2$ which is lower than 8.9% of T/G/T sample. Therefore, textile wastes composite T/T/T is higher energy absorbed than glass fiber G/G/G composite as shown in the figure 4.3 explored the strength $111.91KJ/m^2$ to $88.5KJ/m^2$, respectively.

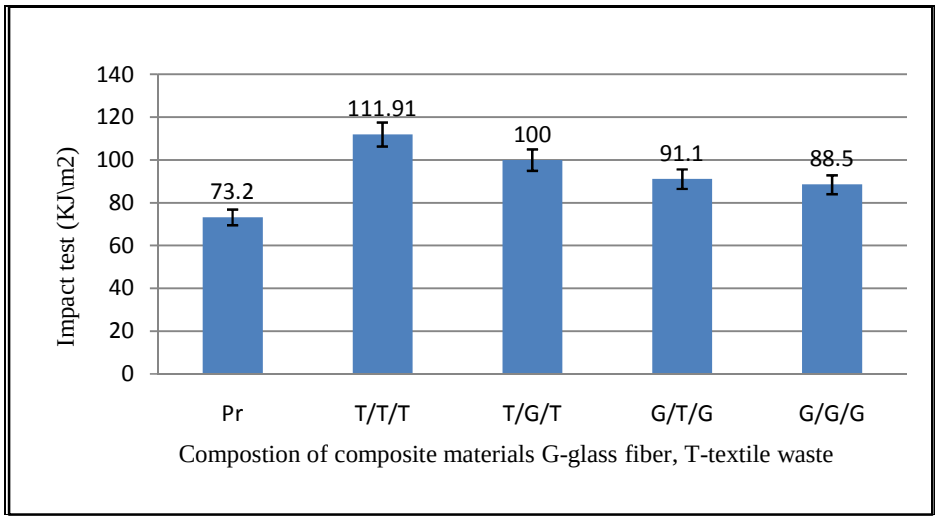


Figure 4.9. Impact strength of textile waste/glass fiber-reinforced hybrid composites

4.1.4. Micro hardness analysis

Figure 4.10 is showed the effect of fiber content on the micro-hardness test of composites. It is showed weight rate of fiber within the hybrid composite increments, the hardness of composite increased. The composite of T/T/T is greater than 141.9%from pure resin composite. Similar trend of G/T/G hybrid composites is greater than 99.3% from T/T/T composite and 70% from G/G/G composite in hardness test result. As shown in the figure much affected glass fiber in hybrid sample between T/G/T and G/T/G which is 2wt.% textile waste fiber decrease and 13wt.% glass fiber increase, hardness tested result is increased 167.2Kgf/mm^2 to 304.2Kgf/mm^2, respectively.

Table 4.4. Experimental Results for micro hardness testing of composite

Samples	Trial 1	Trial 2	Trial 3	Average HV= (kgf/mm²)
Pure resin	61	63.5	65.9	63.5
T/T/T	172.8	147.4	140.5	153.6
T/G/T	137	140	136.7	137.9
G/T/G	345.5	347.2	220	304.2
G/G/G	95.6	283.4	178.9	186

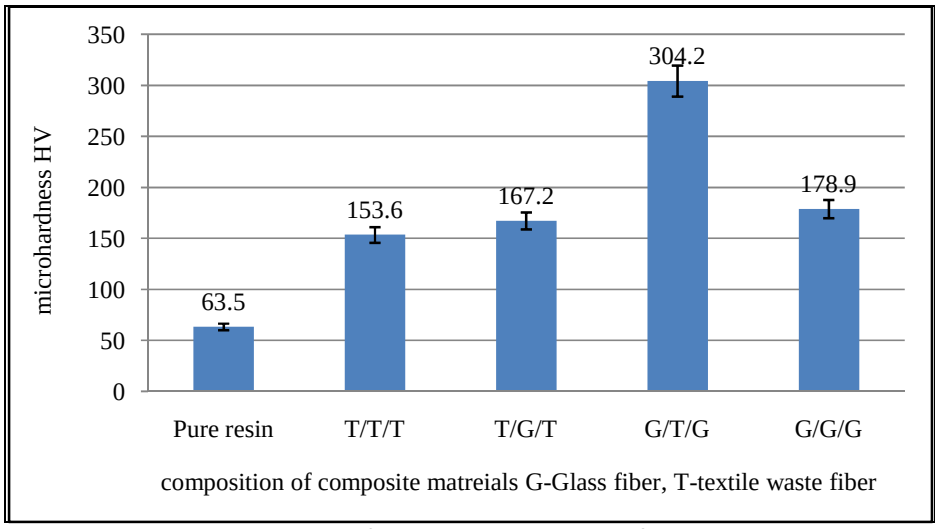


Figure 4.10. Properties of micro hardness test of hybrid composites

A graphical overview of the major mechanical properties of composite materials is showed in Figure 4.11. The difference in densities indicates the void content. A good composite have less void, while a poorly made composite have a much higher void content. Therefore, the highest water absorbed composite is G/T/G sample because of have much void contents.

Table 4.5. Mechanical properties of developed composite

	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (KJ/m^2)
Samples types	ISO 6892-1	ASTM-D790	ASTM-A370
Pure resin	26.7	57.69	167.8333
T/T/T	35	78.85	276.2
T/G/T	64	131.91	228.6
G/T/G	65.7	173.1	226.8
G/G/G	164	183.36	195.7667

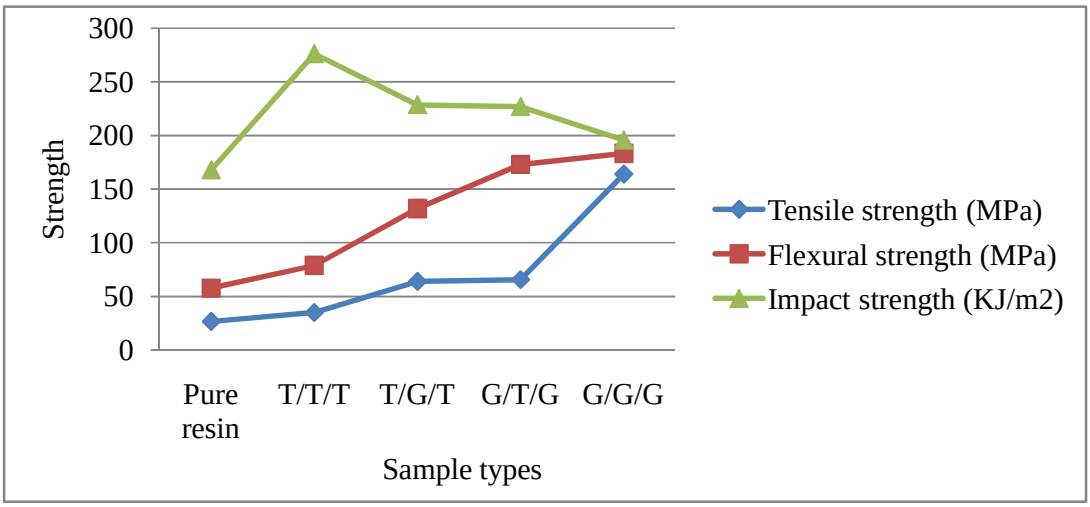


Figure 4.11. Average tensile and bending strength

In table 4.6 is presented a closed relate previews papers to compared with developed composite materials of textile waste/resin GP sample (T/T/T).

Table 4.6. Comparison of mechanical properties of close related with developed composite

mechanical properties	close related				developed composite
	Cotton/Isophthallic Polyester	Glass fiber/cotton	Cotton/PP	Sisal/PP	
TS (MPa)	26	10.92	31.9	23.8	35
TM (MPa)		470.3	1960	2.11GPa	581
FS (MPa)	48	11.15		60.9	78.85
FM (MPa)		284.88		3.91GPa	44.31 GPa
Reference	Sabinesh S. et al, (2014)	Bodur M.S. et al,(2016)	Petrucci R. et ai, (1015)	Jarukumjorn K & Suppakarn N. (2009)	

Note: TS-tensile strength; TM-Tensile modulus; FS-flexural strength; FM-flexural modulus

4.2. Water absorption test analysis

Figure 4.13-4.15 is appeared the effect of fiber parameters on the water retention of composites with increment in immersion time. It is observed from the figure that the water absorption handle is sharp at the beginning and leveled off for a number of lengths of time where it approaches to equilibriums in these three conditions. Water assimilation in a natural fiber strengthened composite is depending on temperature, fiber loading, orientation of strands, penetrability of fibers, surface assurance, region of the uncovered surfaces, diffusivity, void content, hydrophilicity of the individual components, etc were clarified by Jawaid et al. (2012). Fiber reinforced composites are increased water absorption than pure epoxy resin plate. In this study, the highest water absorbed composite is G/T/G hybrid composite while the smallest water absorption is G/G/G composite in the salt solution. This will be due to more prominent number voids inside the composite. It is consistent with the truth that water molecules are able to construct up within the voids, leading to an increment in the water absorption of composite. Furthermore, increasing water absorption of the hybrid composites at prepared of G/T/G composite the textile wastes fiber covered by glass fibers can be attributed to poor compatibility between fibers shown in Figure 4.3 since of this more water assimilation properties is appeared in hybrid composite (Figure 4.17). T/G/T hybrid composite in distilled water media is the highest water absorbed. In tap water media less factor on composite water absorption than salty and distilled water media.

Figure 4.12. Water absorption test (a-tap water, b-salt solution water and c-distilled water)

Table 4.7. Water absorption testing in tape water

Time(h)	Measured	Composites				
		Pure resin (Pr)	T/T/T	T/G/T	G/T/G	G/G/G
0	Thickness (mm)	5.3	5	6.5	5	3.2
	Weight (g)	3.018	2.7595	3.9052	2.9901	2.3537
24	Thickness (mm)	5.3	5.1	6.5	5	3.2
	Weight (g)	3.0193	2.7795	3.9353	3.0028	2.359
72	Thickness (mm)	5.3	5.1	6.5	5.3	3.2
	W eight (g)	3.0197	2.7893	3.9411	3.0191	2.3673
96	Thickness (mm)	5.3	5.2	6.5	5.3	3.3
	Weight (g)	3.0203	2.796	3.9557	3.0266	2.3853
168	Thickness (mm)	5.3	5.2	6.8	5	3.4
	W eight (g)	3.0216	2.8001	3.9594	3.0406	2.3858
182	Thickness (mm)	5.3	5.2	6.8	5.3	3.4
	Weight (g)	3.0217	2.8016	3.9602	3.0439	2.386
206	Thickness (mm)	5.3	5.2	6.8	5.3	3.4
	Weight (g)	3.022	2.8115	3.9728	3.0458	2.3868
130	Thickness (mm)	5.3	5.2	6.8	5.3	3.4
	Weight (g)	3.0222	2.8145	3.9785	3.0485	2.3879
Thickness swelling (T_{rt}%)		0	4	6.6	6	6.25
Water absorption (%)		0.1392	1.9931	1.877	1.9531	1.453

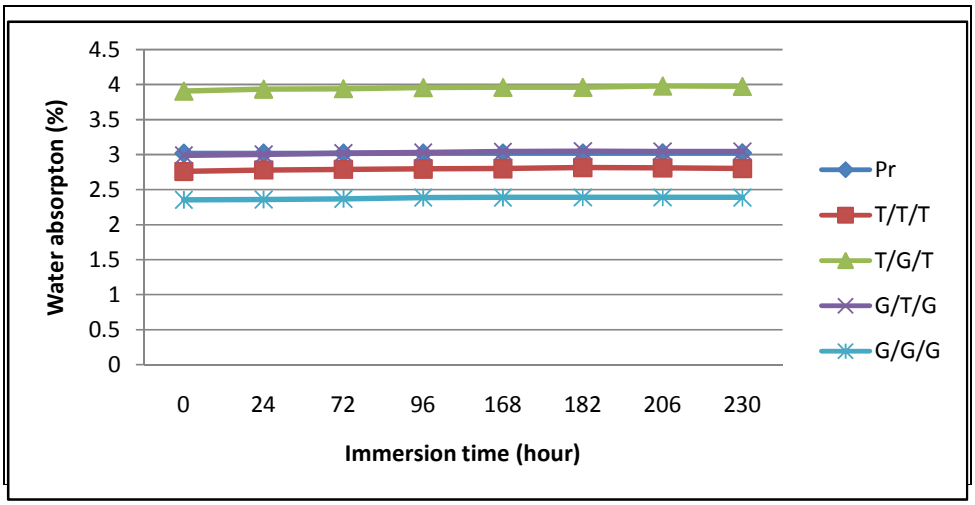


Figure 4.13. Water absorption in tap water

Table 4.8. Water absorption test in salt solution water

Time(h)	Measured	Composites				
		Pure resin (Pr)	T/T/T	T/G/T	G/T/G	G/G/G
0	Thickness (mm)	5.3	4.5	5.8	5.1	3.2
	Weight (g)	3.0145	2.6491	3.5483	2.8365	2.5132
24	Thickness (mm)	5.3	4.5	5.8	5.1	3.2
	Weight (g)	3.0162	2.6693	3.5784	2.8638	2.5257
72	Thickness (mm)	5.3	4.7	6	5.1	3.2
	W eight (g)	3.0168	2.6832	3.5951	2.8949	2.5389
96	Thickness (mm)	5.3	4.7	6	5.2	3.5
	Weight (g)	3.0173	2.6855	3.5971	2.9082	2.5404
168	Thickness (mm)	5.3	4.8	6	5.2	3.5
	W eight (g)	3.0175	2.6927	3.599	2.9288	2.5465
182	Thickness (mm)	5.3	4.8	6	5.3	3.5
	Weight (g)	3.0177	2.6951	3.6102	2.9395	2.5421
206	Thickness (mm)	5.3	4.8	6	5.3	3.5
	Weight (g)	3.0178	2.6956	3.6202	2.9412	2.5477
130	Thickness (mm)	5.3	4.8	6	5.3	3.5
	Weight (g)	3.0179	2.6973	3.6235	2.9427	2.5479
Thickness swelling (T_{rt}%)		0	6.67	3.33	3.92	9.38
Water absorption (%)		0.1128	1.8195	2.1193	3.7441	1.3807

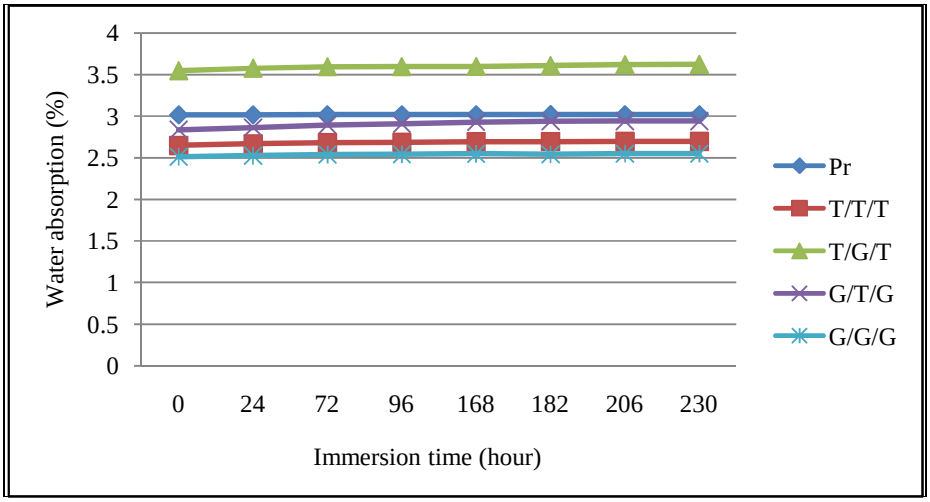


Figure 4.14. Water absorption in salt solution media

Table 4.9. Water absorption test in distilled water

Time(h)	Measured	Composites				
		Pure resin (Pr)	T/T/T	T/G/T	G/T/G	G/G/G
0	Thickness (mm)	5.3	4.5	6.6	5.2	3.4
	Weight (g)	3.0158	2.5831	3.9625	3.0654	2.2471
24	Thickness (mm)	5.3	4.5	6.6	5.2	3.2
	Weight (g)	3.0161	2.6123	3.991	3.087	2.2658
72	Thickness (mm)	5.3	4.5	6.7	5.2	3.2
	W eight (g)	3.0184	2.6232	4.017	3.1081	2.2701
96	Thickness (mm)	5.3	4.6	6.8	5.2	3.3
	Weight (g)	3.0189	2.6271	4.0322	3.1107	2.2797
168	Thickness (mm)	53	4.8	6.8	5.2	3.5
	W eight (g)	3.0191	2.63	4.0401	3.1126	2.2782
182	Thickness (mm)	5.3	4.8	6.9	5.2	3.5
	Weight (g)	3.0193	2.637	4.0421	3.1132	2.2852
206	Thickness (mm)	5.3	4.8	6.9	5.3	3.5
	Weight (g)	3.0193	2.6377	4.0518	3.1175	2.2931
130	Thickness (mm)	5.3	4.8	7	5.3	3.5
	Weight (g)	3.0194	2.6378	4.0593	3.1249	2.2945
Thickness swelling (T_{rt}%)		0	6.67	6.06	1.92	9.38
Water absorption (%)		0.1194	2.1176	2.4429	1.941	2.1094

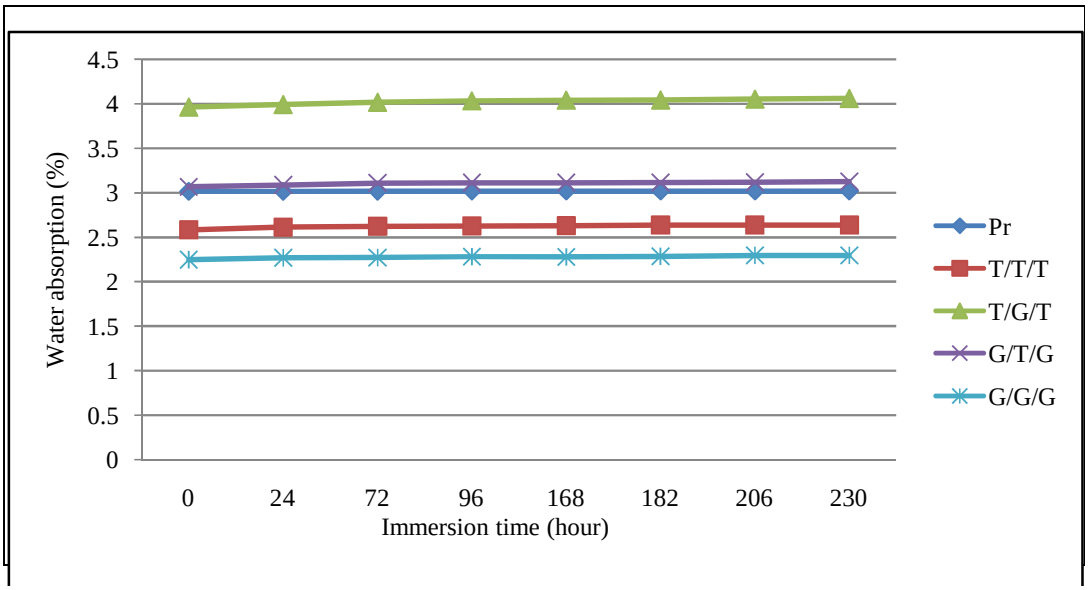
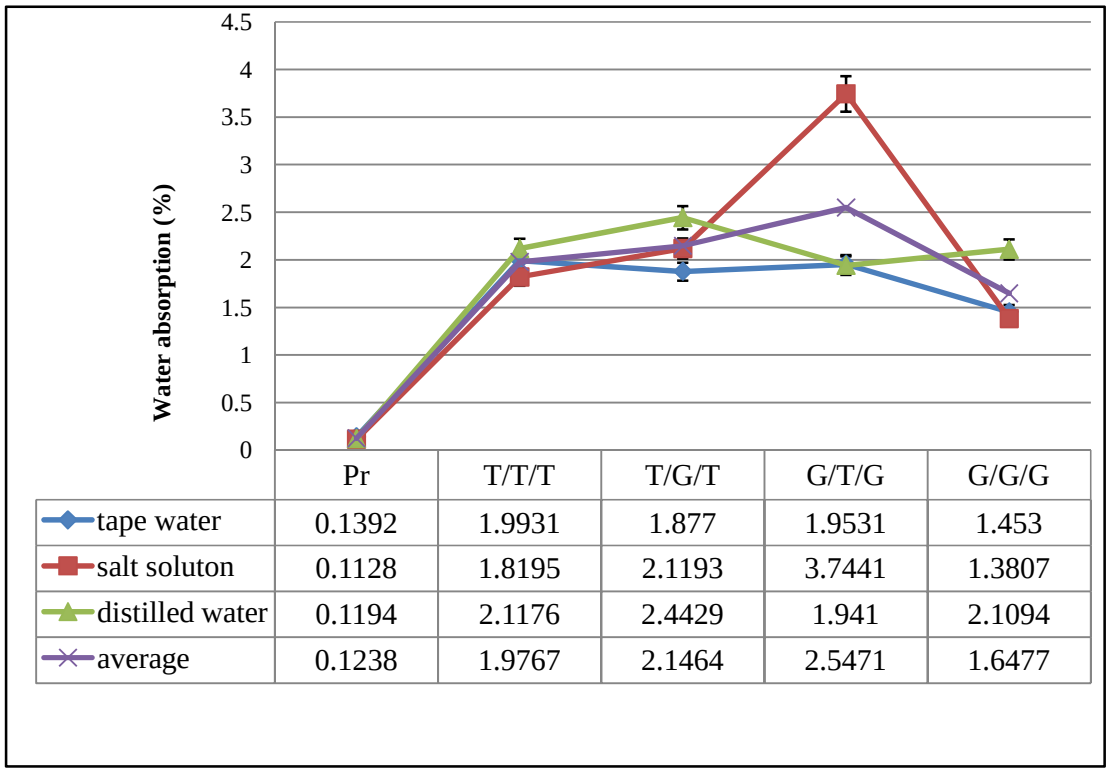


Figure 4.15. Water absorption in distilled water



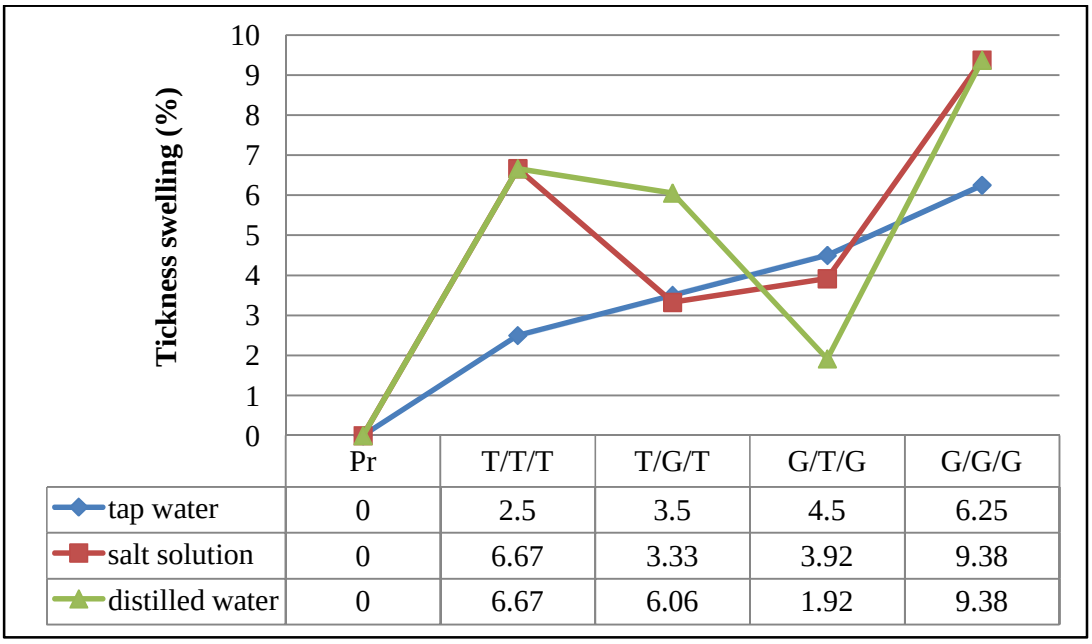
	Pr	T/T/T	T/G/T	G/T/G	G/G/G
tape water	0.1392	1.9931	1.877	1.9531	1.453
salt soluton	0.1128	1.8195	2.1193	3.7441	1.3807
distilled water	0.1194	2.1176	2.4429	1.941	2.1094
average	0.1238	1.9767	2.1464	2.5471	1.6477

Figure 4.16. Comparison of water absorption in three media

4.3. Thickness swelling

Figure 4.17 shows the thickness swelling behaviors of hybrid composites after being immersed in tap, salt and distilled water media for several hours. Thickness swelling of hybrid composite essentially decreased with decrease in textile wastes content, whereas a reverse

trend was observed increased with as the glass fiber content increase in salt solution of 41.23% and 181.7% and distilled water media of 71.2% and 54.79%, respectively. In this pondered, appeared clearly the thickness swelling expanded with submersion time and come to a certain value where no more thickness swells happened. When the submersion time of composites is expanded, a noteworthy amount of water is absorbed; coming about within the swelling of the fiber until the cell walls is saturated with water. Beyond that, water exits as free water in the voids, this leads to composite delaminating or void formation had been reported by Jawaid et al.(2012). Glass fiber only composite showed the highest percentage in thickness swelling compared to other hybrid and textile only composites.



	Pr	T/T/T	T/G/T	G/T/G	G/G/G
tap water	0	2.5	3.5	4.5	6.25
salt solution	0	6.67	3.33	3.92	9.38
distilled water	0	6.67	6.06	1.92	9.38

Figure 4.17. Comparison of thickness swelling in three media

4.4. Optical microscopy analysis

Optical microscope is used to study the microstructure; optical illumination systems are its basic elements. For materials that are opaque to visible light, only the surface is subject to observation, and the light microscope used in a reflective mode. Contrasts in the image produced result from differences in reflectivity of the various regions of the microstructure. The specimen surface is first mounted and polished to a smooth and mirror like finish and grind by used successively finer abrasive papers finally etched the surface this is explained in appendix D.

Optical microscopy estimation is a success characterized the micro structural details of the different cross-sections composite shown in Figure 4.18-4.20. Delimitations, these are planar

defects of porosity usually at ply boundaries and may be produced by contamination during lay-up. It is initiated due to service loads at stress concentrators such as holes, piles at bonded two fibers, etc. Porosity (voids) due to volatile resin components, or air not properly controlled during cure. Bonding defects: During manufacture, components may be bonded together and it is possible for defects to occur in the bond line due to incorrect cure conditions for the adhesive or contamination of the surfaces to be bonded.

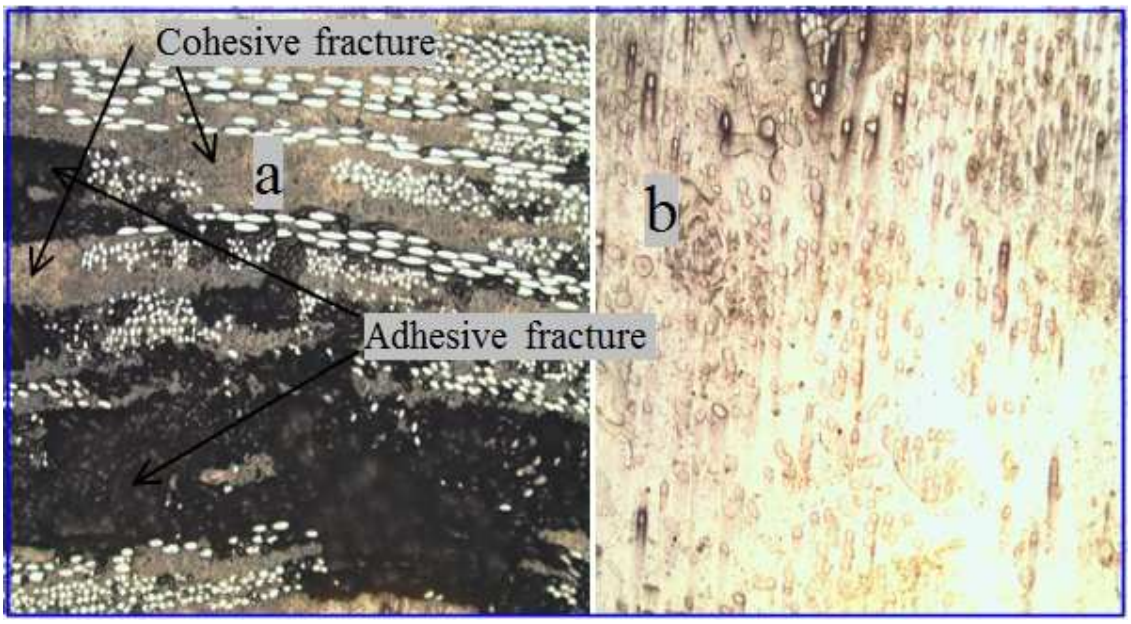


Figure 4.18. Fiber distribution (a-glass fiber and b-textile wastes fabric)

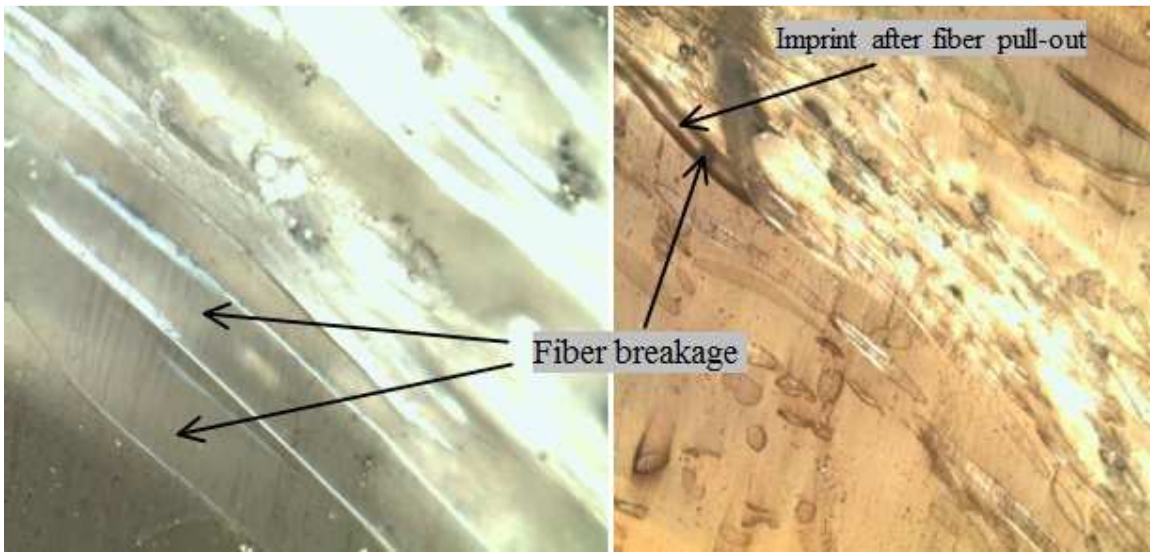


Figure 4.19. Fracture surface

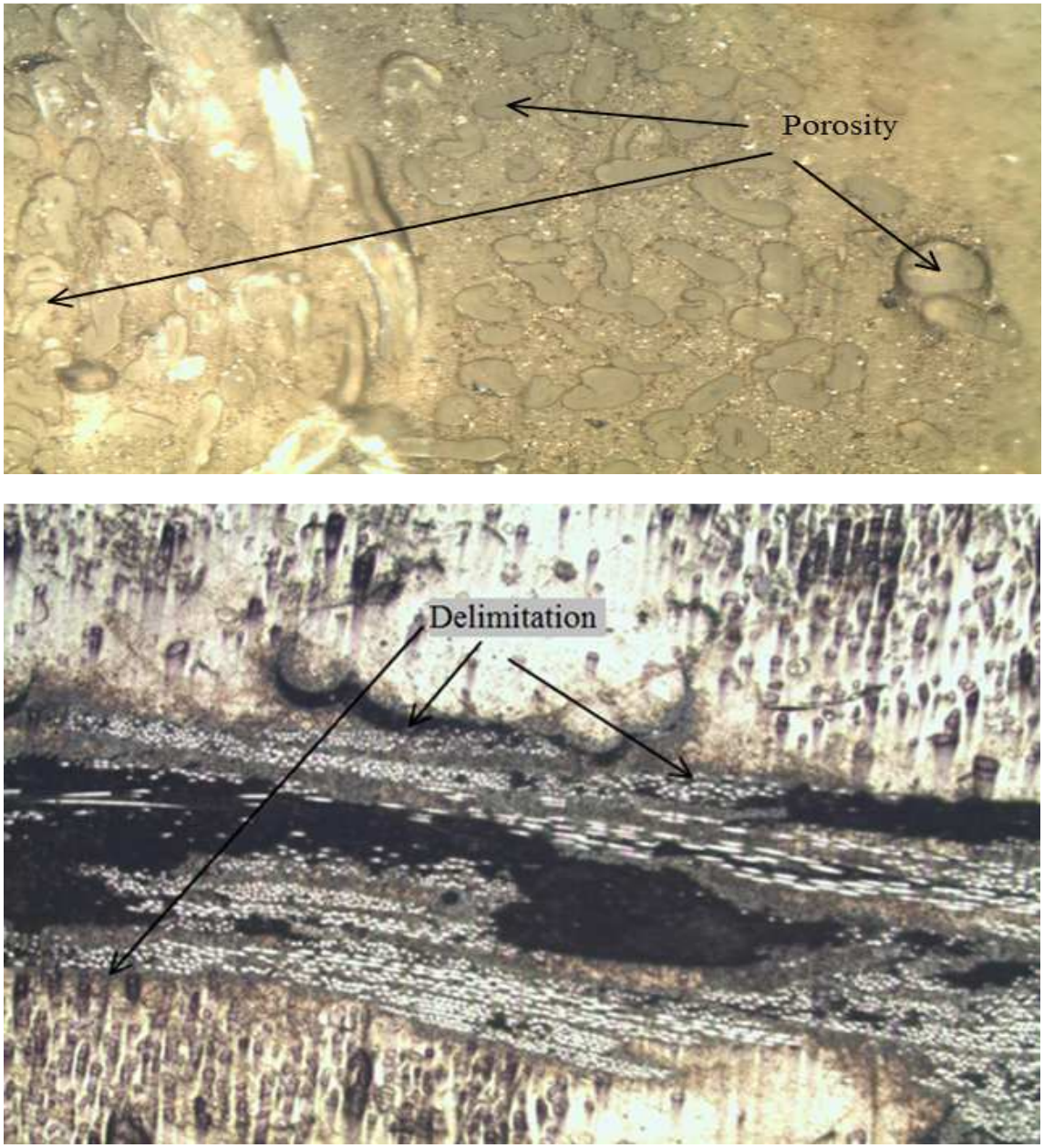


Figure 4.20. Examined surface of samples

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

In this study, multilayered of textile waste fabric and glass fiber reinforced hybrid polymer composite samples have been fabricated successfully by low cost, low weight, and the hand lay-up technique. The tensile strength, flexural strength and impact strength of the made-up composite material have been evaluated satisfactorily. The combination of the useful properties of two different materials, make them as a versatile material in the field of engineering and technology.

- Natural fibers are gaining interest to be used as reinforcement in polymer composites due to its potential mechanical properties.
- From the results, it can be concluded that hybrid composites performing better for tensile modulus.
- The presence of porosity can degrade structural strength depending on the extent and location of the porosity in the composite component.
- According to impact tested the reinforcement textile wastes fabric decreased with increasing glass fiber content, while stiffness at the same time decreased. Textile wastes fabric is more entanglement than glass fiber, as confirmed by cutting condition.
- Thickness swelling of hybrid composite essentially decreased with decrease in textile wastes loading, whereas a reverse trend was observed increased, as the glass fiber content increased in salt solution and distilled water media.
- The highest water absorbed composite is G/T/G hybrid composite while the smallest water absorption is G/G/G composite in the salt solution. This will be due to more prominent number voids inside the composite. It is consistent with the truth that water molecules are able to construct up within the voids, leading to an increment in the water absorption of composite. Void contents is indicated the quality of composite materials. However, higher void content composite is low quality while less content of void is indicated good quality composite product.
- Based on the present investigation on the developed textile waste/glass fiber hybrid composite it can be finally concluded hybrid composite this material suitable for structural applications.

5.2. Recommendation for further research

- The present investigation of new class hybrid composite by hand lay-up technique was used to fabricate the composite. However, other manufacturing process for polymers matrix composite are exists. They could be tried and analyzed, so that a final conclusion can be drawn there from. However the results provided in this thesis can act as a base for the utilization of textile waste and glass fiber.
- The current study is limited to the ratio of resin and hardener constant (10:1). So, by varying this ratio further study can be done to analyses the mechanical properties of textile waste/glass fiber hybrid composite.
- For this work the fiber treatment is used of alkali. Other chemical modification methods such as acetone, silane, acetylation, Permanganate, Maleated coupling agents treatment can be applied for further extension this work for analysis mechanical properties.
- In present investigation fiber and resin for prepared composites, where used. The same work can be extended by adding filler materials like metal powder, ash, calcium carbonate.

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APPENDIX

Appendix A: Plain weaves textile waste fiber preparation

Recycled textile waste fabric is twisted in layer changed yarn form shown in figure (A.I-a). Then, prepared plain weaves of weft and warp in figure (A.I-b) and finally, to make ready for composite preparation figure (A.I-c,d).

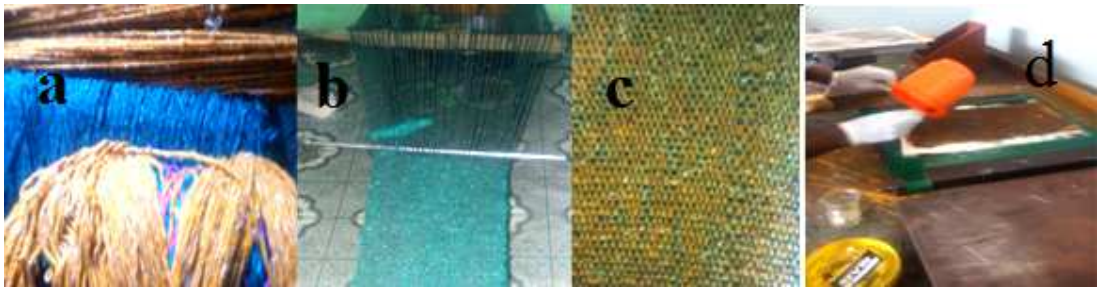


Figure A.1. Preparation of textile waste for composite

Appendix B: Steps of hand layup process

Mold cleaning: Dust and dirt are removed from mold with soft cloth.

Smearing resin: Generally with the brush, resin is smeared on mold similar to painting a wall.

Fiber layup: Chopped fibers or fiber mats are laid out or laminated over the resin layer on the mold.

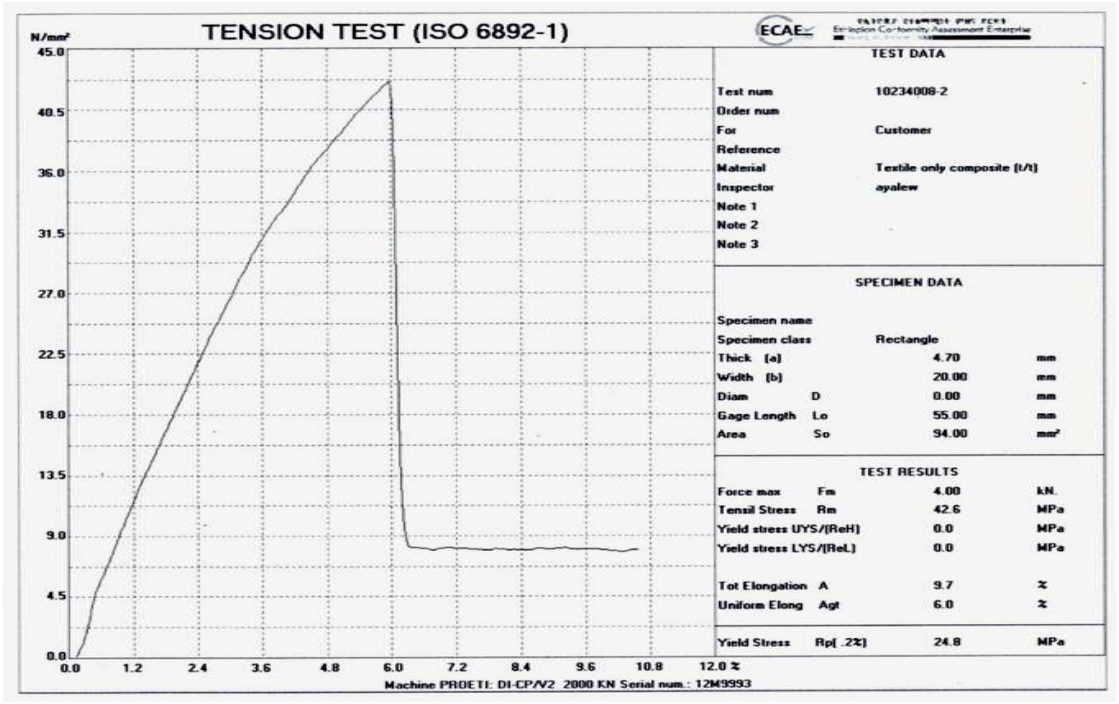
Smearing resin: Reapply resin by brushing over the strand of fiber layer.

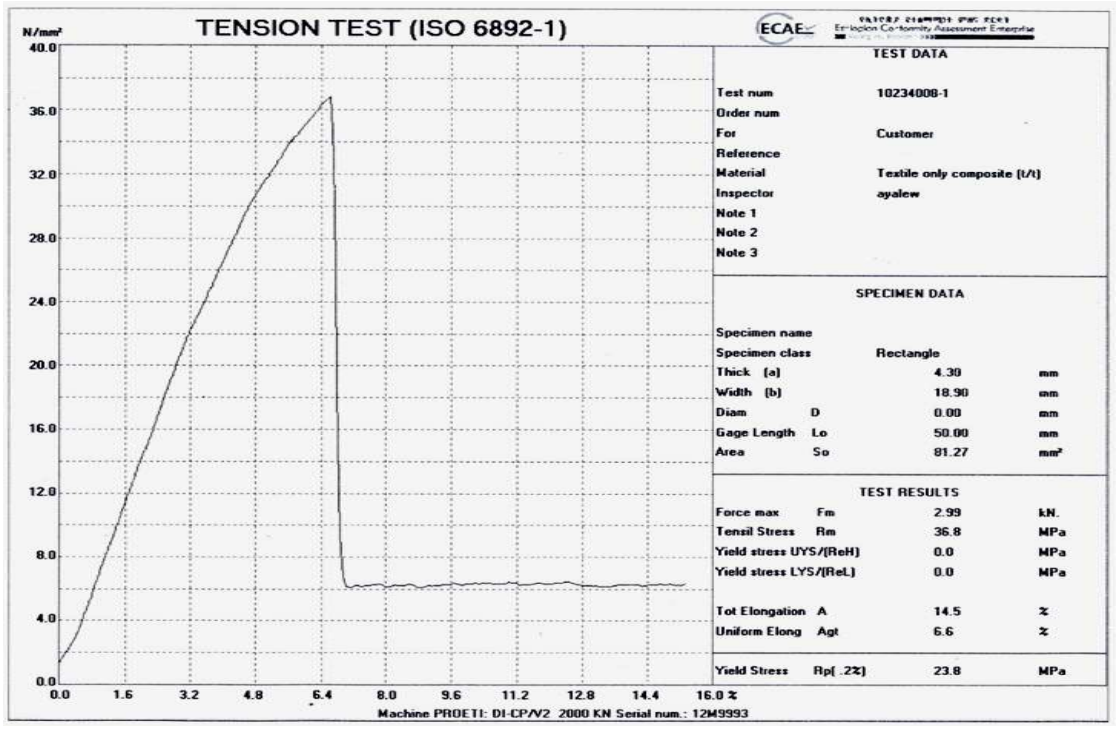
Squeeze action: Roller applied to move over the resin–fiber–resin layers to eliminate air sandwiched between layers, called squeeze action, which is usually used to compact the fabricated products.

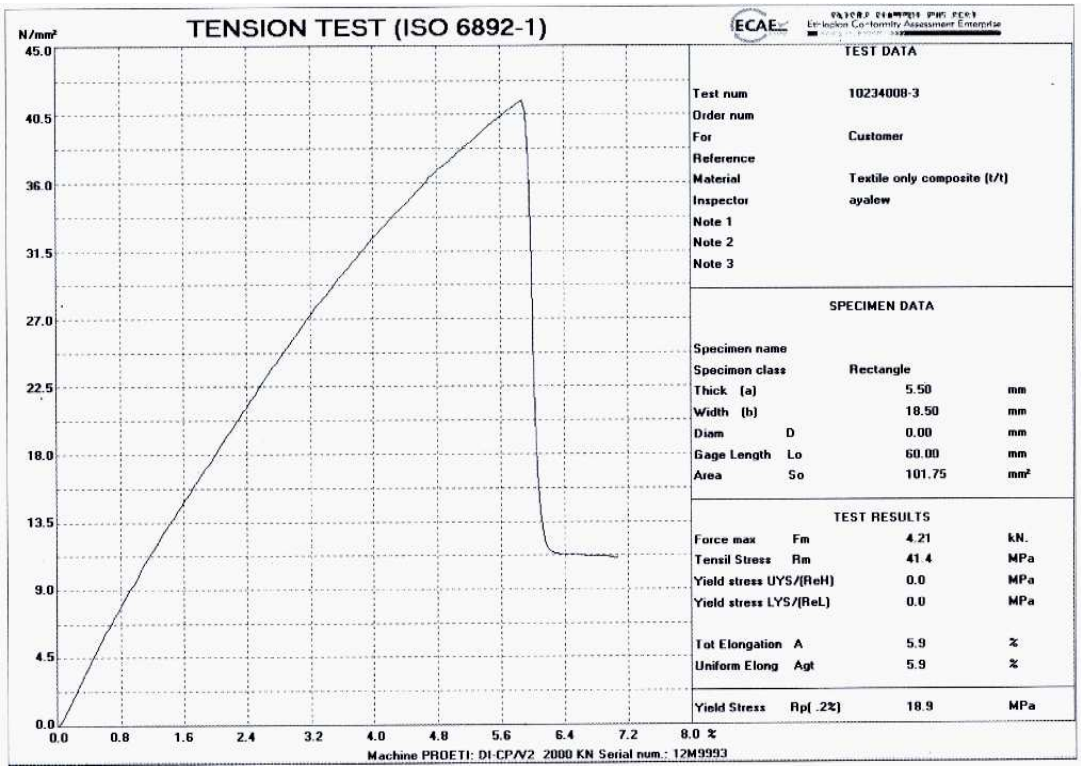
Remold: The last step, remolding is done after curing at room temperature to remove the sheet from mold.

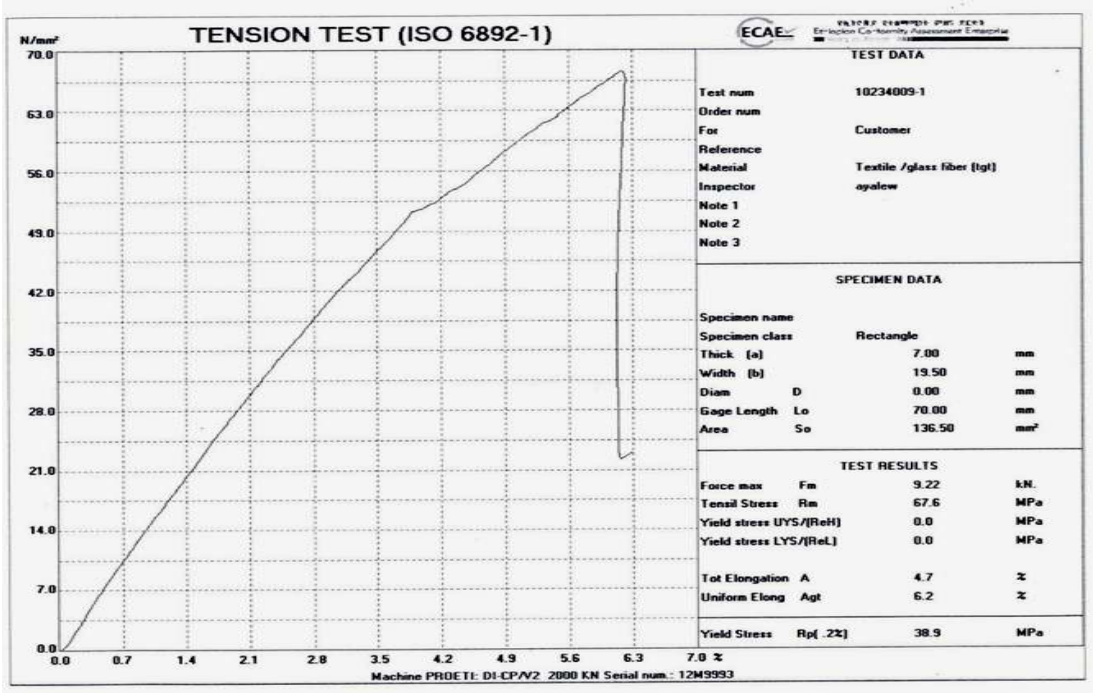
Appendix C. Tensile test diagrams

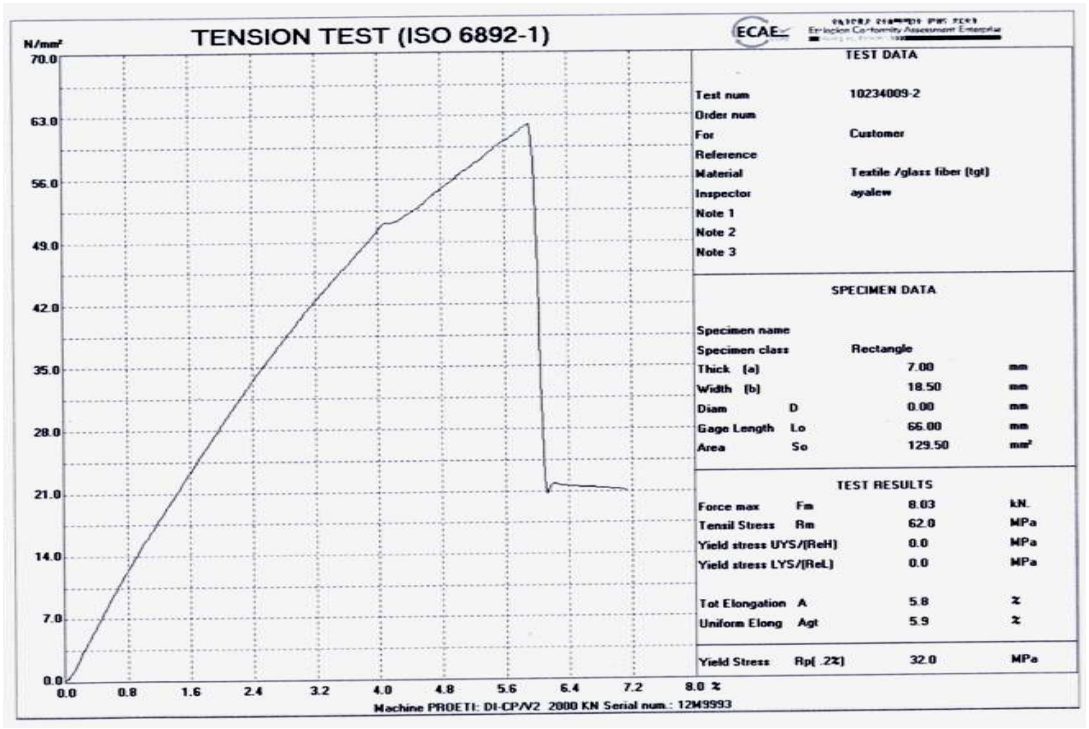
C.I. Stress-elongation diagram

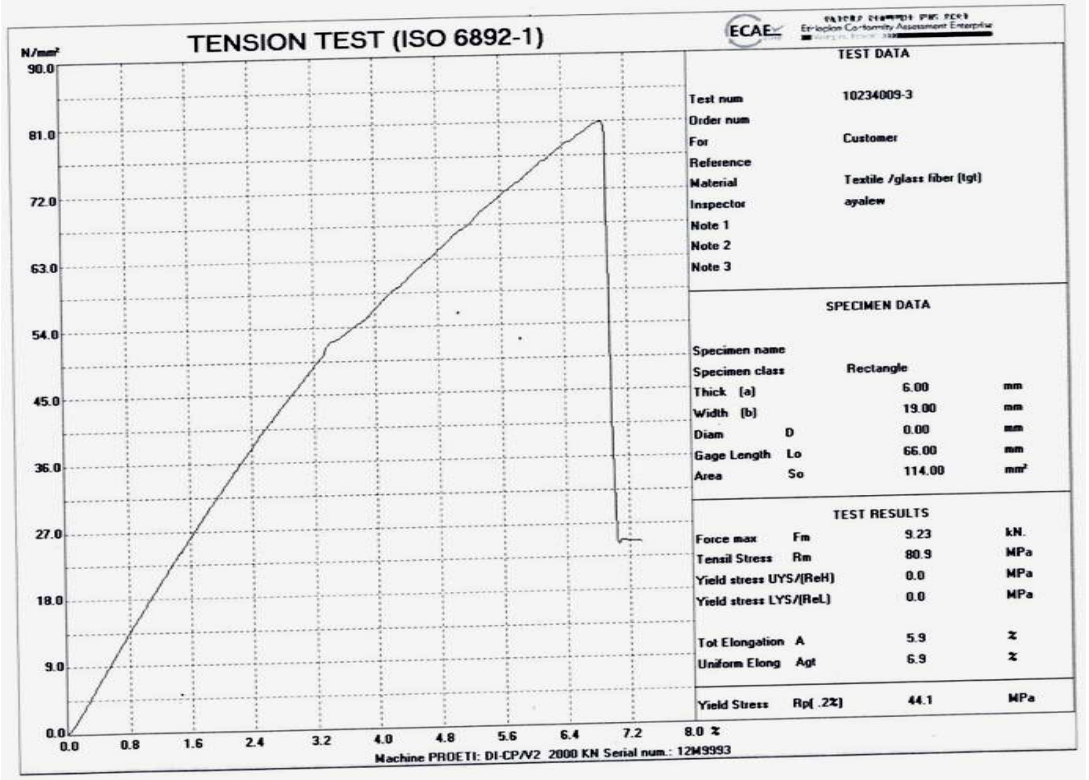


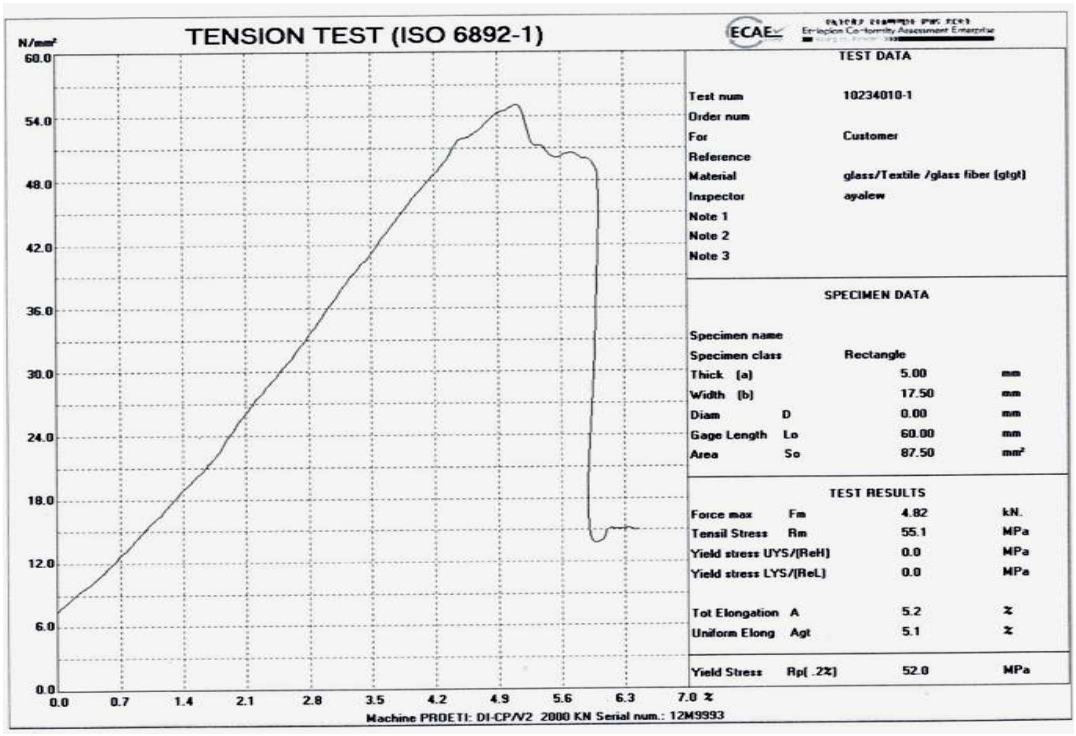


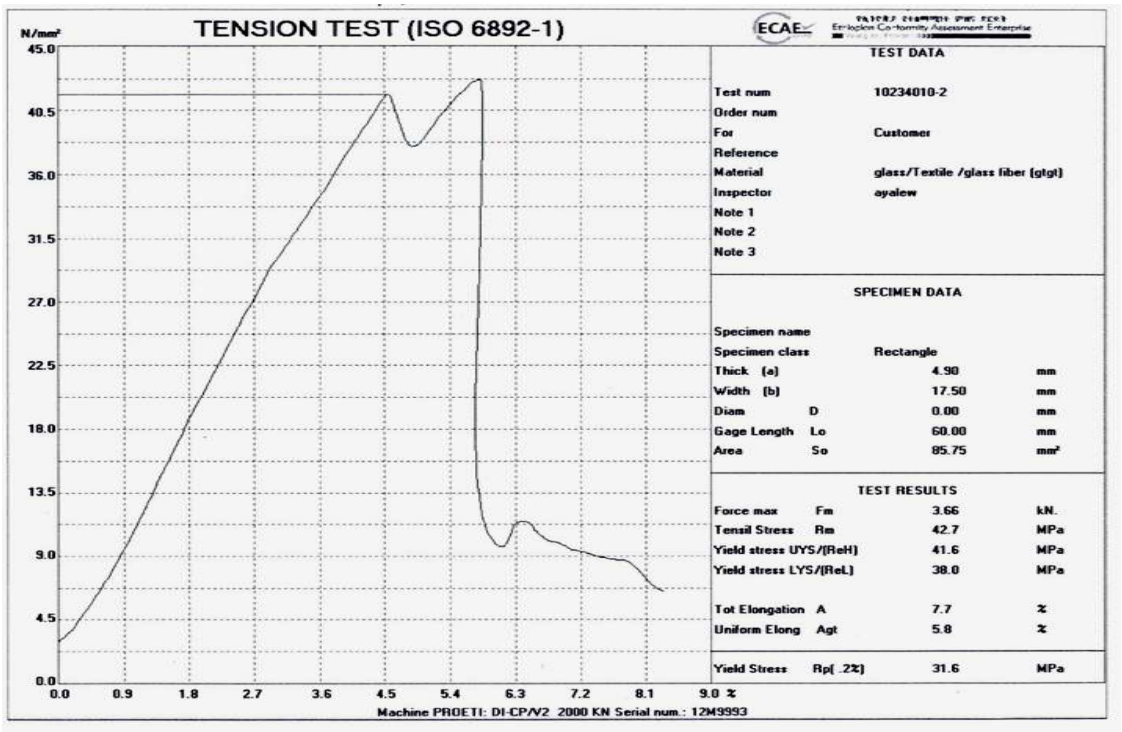

TENSION TEST (ISO 6892-1)
ECAE
N/mm²
45.0
40.5
36.0
31.5
27.0
22.5
18.0
13.5
9.0
4.5
0.0
0.0 0.8 1.6 2.4 3.2 4.0 4.8 5.6 6.4 7.2 8.0 %
Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993
TEST DATA
Test num 10234008-3
Order num
For Customer
Reference
Material Textile only composite (t/t)
Inspector ayalew
Note 1
Note 2
Note 3
SPECIMEN DATA
Specimen name
Specimen class Rectangle
Thick (a) 5.50 mm
Width (b) 18.50 mm
Diam D 0.00 mm
Gage Length Lo 60.00 mm
Area So 101.75 mm²
TEST RESULTS
Force max Fm 4.21 kN.
Tensil Stress Rm 41.4 MPa
Yield stress UYS/(ReH) 0.0 MPa
Yield stress LYS/(ReL) 0.0 MPa
Tot Elongation A 5.9 %
Uniform Elong Agt 5.9 %
Yield Stress Rp(.2%) 18.9 MPa

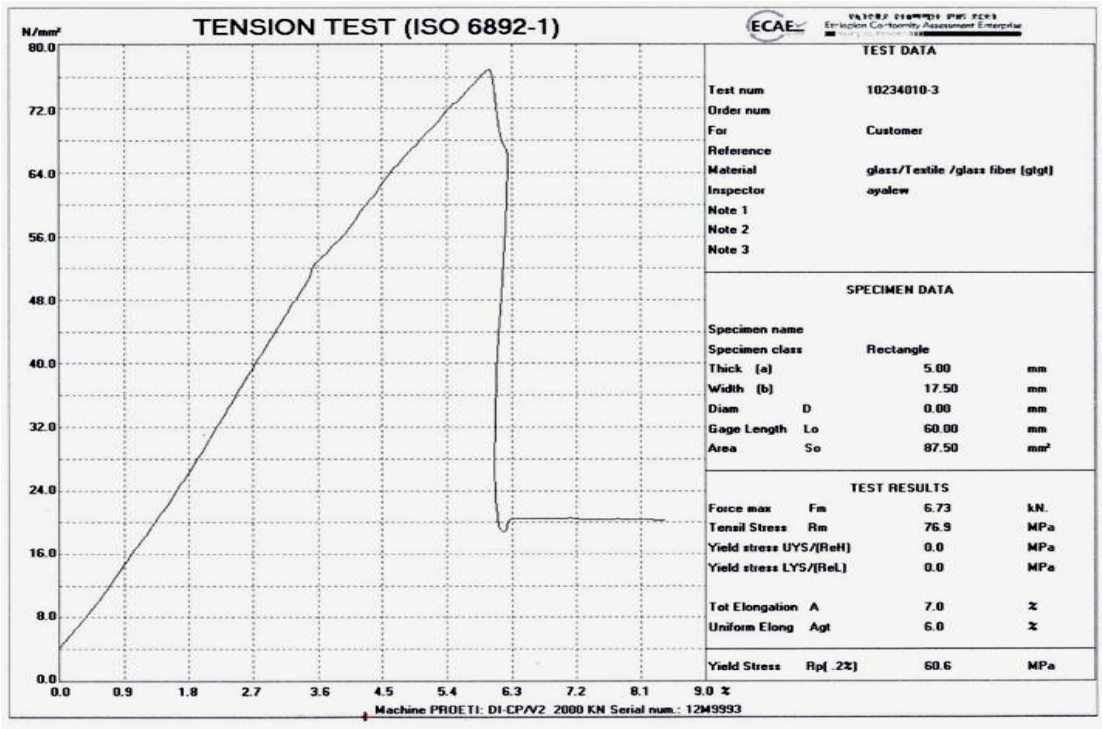

TENSION TEST (ISO 6892-1)
ECAE
N/mm²
70.0
63.0
56.0
49.0
42.0
35.0
28.0
21.0
14.0
7.0
0.0
0.0 0.7 1.4 2.1 2.8 3.5 4.2 4.9 5.6 6.3 7.0 %
Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993
TEST DATA
Test num 10234009-1
Order num
For Customer
Reference
Material Textile /glass fiber (tgf)
Inspector ayalew
Note 1
Note 2
Note 3
SPECIMEN DATA
Specimen name
Specimen class Rectangle
Thick (a) 7.00 mm
Width (b) 19.50 mm
Diam D 0.00 mm
Gage Length Lo 70.00 mm
Area So 136.50 mm²
TEST RESULTS
Force max Fm 9.22 kN.
Tensil Stress Rm 67.6 MPa
Yield stress UYS/(ReH) 0.0 MPa
Yield stress LYS/(ReL) 0.0 MPa
Tot Elongation A 4.7 %
Uniform Elong Agt 6.2 %
Yield Stress Rp(.2%) 38.9 MPa

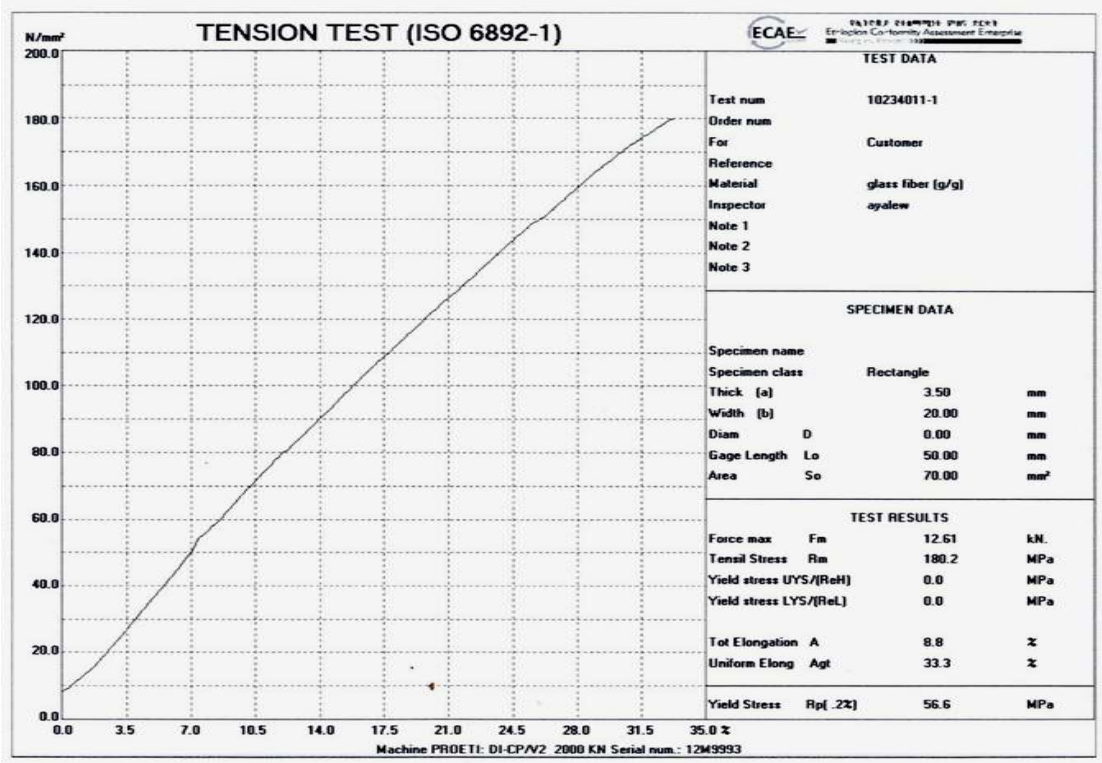

TENSION TEST (ISO 6892-1)
ECAE
N/mm²
70.0
63.0
56.0
49.0
42.0
35.0
28.0
21.0
14.0
7.0
0.0
0.0 0.8 1.6 2.4 3.2 4.0 4.8 5.6 6.4 7.2 8.0 %
Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993
TEST DATA
Test num 10234009-2
Order num
For Customer
Reference
Material Textile /glass fiber (tgt)
Inspector ayalew
Note 1
Note 2
Note 3
SPECIMEN DATA
Specimen name
Specimen class Rectangle
Thick (a) 7.00 mm
Width (b) 18.50 mm
Diam D 0.00 mm
Gage Length Lo 66.00 mm
Area So 129.50 mm²
TEST RESULTS
Force max Fm 8.03 kN
Tensil Stress Rm 62.0 MPa
Yield stress UYS/(ReH) 0.0 MPa
Yield stress LYS/(ReL) 0.0 MPa
Tot Elongation A 5.8 %
Uniform Elong Agt 5.9 %
Yield Stress Rp(.2%) 32.0 MPa

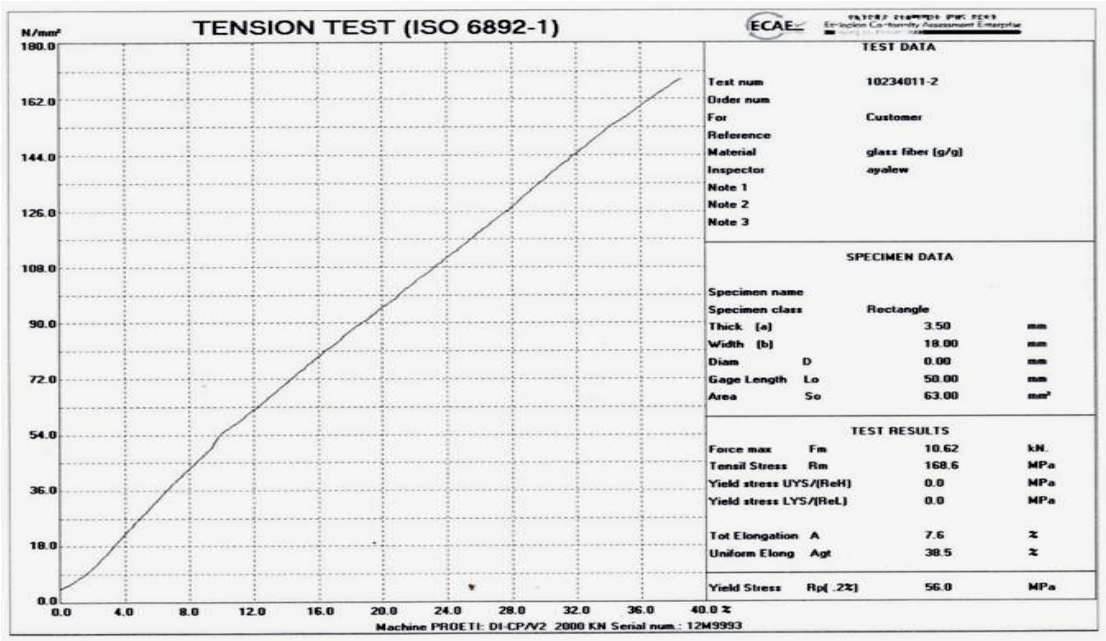

TENSION TEST (ISO 6892-1)
ECAE
N/mm²
90.0
81.0
72.0
63.0
54.0
45.0
36.0
27.0
18.0
9.0
0.0
0.0 0.8 1.6 2.4 3.2 4.0 4.8 5.6 6.4 7.2 8.0 %
Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993
TEST DATA
Test num 10234009-3
Order num
For Customer
Reference
Material Textile /glass fiber (tgt)
Inspector ayalew
Note 1
Note 2
Note 3
SPECIMEN DATA
Specimen name
Specimen class Rectangle
Thick (a) 6.00 mm
Width (b) 19.00 mm
Diam D 0.00 mm
Gage Length Lo 66.00 mm
Area So 114.00 mm²
TEST RESULTS
Force max Fm 9.23 kN
Tensil Stress Rm 80.9 MPa
Yield stress UYS/(ReH) 0.0 MPa
Yield stress LYS/(ReL) 0.0 MPa
Tot Elongation A 5.9 %
Uniform Elong Agt 6.9 %
Yield Stress Rp(.2%) 44.1 MPa

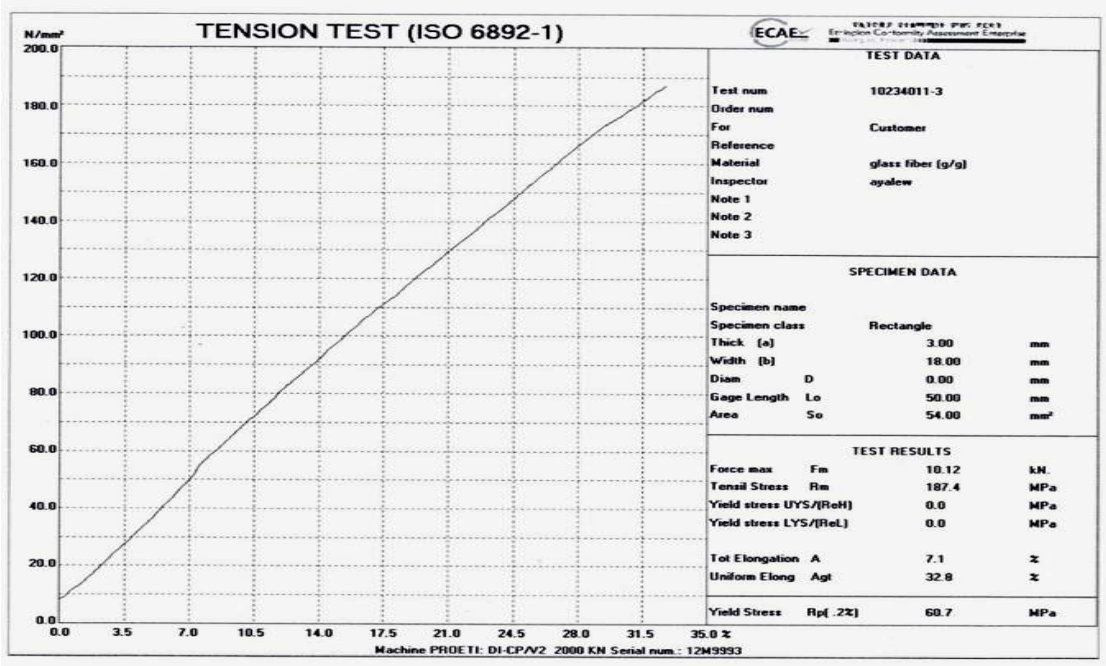

TENSION TEST (ISO 6892-1)
ECAE
Ethiopian Conformity Assessment Enterprise
N/mm²
60.0
54.0
48.0
42.0
36.0
30.0
24.0
18.0
12.0
6.0
0.0
0.0 0.7 1.4 2.1 2.8 3.5 4.2 4.9 5.6 6.3 7.0 %
Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993
TEST DATA
Test num 10234010-1
Order num
For Customer
Reference
Material glass/Textile /glass fiber (gtgt)
Inspector ayalew
Note 1
Note 2
Note 3
SPECIMEN DATA
Specimen name
Specimen class Rectangle
Thick (a) 5.00 mm
Width (b) 17.50 mm
Diam D 0.00 mm
Gage Length Lo 60.00 mm
Area So 87.50 mm²
TEST RESULTS
Force max Fm 4.82 kN.
Tensil Stress Rm 55.1 MPa
Yield stress UYS/(ReH) 0.0 MPa
Yield stress LYS/(ReL) 0.0 MPa
Tot Elongation A 5.2 %
Uniform Elong Agt 5.1 %
Yield Stress Rp(.2%) 52.0 MPa


TENSION TEST (ISO 6892-1)
ECAE
Ethiopian Conformity Assessment Enterprise
N/mm²
45.0
40.5
36.0
31.5
27.0
22.5
18.0
13.5
9.0
4.5
0.0
0.0 0.9 1.8 2.7 3.6 4.5 5.4 6.3 7.2 8.1 9.0 %
Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993
TEST DATA
Test num 10234010-2
Order num
For Customer
Reference
Material glass/Textile /glass fiber (gtgt)
Inspector ayalew
Note 1
Note 2
Note 3
SPECIMEN DATA
Specimen name
Specimen class Rectangle
Thick (a) 4.90 mm
Width (b) 17.50 mm
Diam D 0.00 mm
Gage Length Lo 60.00 mm
Area So 85.75 mm²
TEST RESULTS
Force max Fm 3.66 kN.
Tensil Stress Rm 42.7 MPa
Yield stress UYS/(ReH) 41.6 MPa
Yield stress LYS/(ReL) 38.0 MPa
Tot Elongation A 7.7 %
Uniform Elong Agt 5.8 %
Yield Stress Rp(.2%) 31.6 MPa

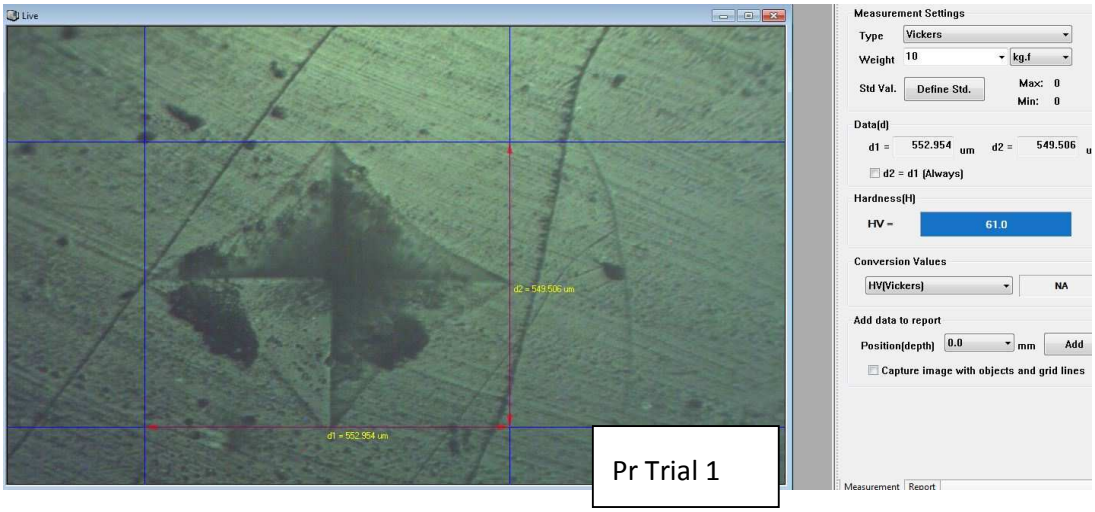

TENSION TEST (ISO 6892-1)
N/mm²
80.0
72.0
64.0
56.0
48.0
40.0
32.0
24.0
16.0
8.0
0.0
0.0 0.9 1.8 2.7 3.6 4.5 5.4 6.3 7.2 8.1 9.0 %
Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993
ECAE
TEST DATA
Test num 10234010-3
Order num
For Customer
Reference
Material glass/Textile /glass fiber (gtgt)
Inspector ayalew
Note 1
Note 2
Note 3
SPECIMEN DATA
Specimen name
Specimen class Rectangle
Thick (a) 5.00 mm
Width (b) 17.50 mm
Diam D 0.00 mm
Gage Length Lo 60.00 mm
Area So 87.50 mm²
TEST RESULTS
Force max Fm 6.73 kN
Tensil Stress Rm 76.9 MPa
Yield stress UYS/(ReH) 0.0 MPa
Yield stress LYS/(ReL) 0.0 MPa
Tot Elongation A 7.0 %
Uniform Elong Agt 6.0 %
Yield Stress Rp(.2%) 60.6 MPa

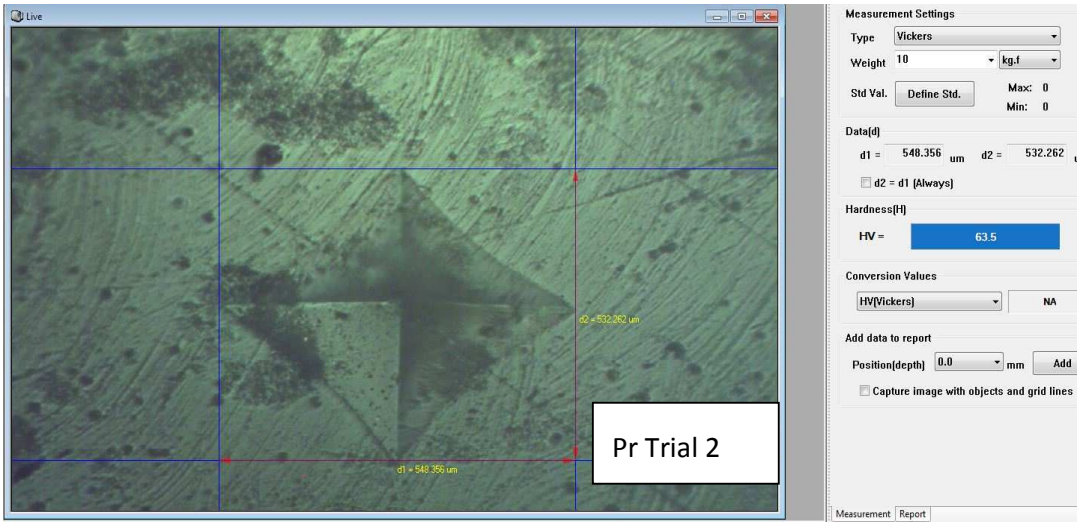

TENSION TEST (ISO 6892-1)
N/mm²
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0.0 3.5 7.0 10.5 14.0 17.5 21.0 24.5 28.0 31.5 35.0 %
Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993
ECAE
TEST DATA
Test num 10234011-1
Order num
For Customer
Reference
Material glass fiber (g/g)
Inspector ayalew
Note 1
Note 2
Note 3
SPECIMEN DATA
Specimen name
Specimen class Rectangle
Thick (a) 3.50 mm
Width (b) 20.00 mm
Diam D 0.00 mm
Gage Length Lo 50.00 mm
Area So 70.00 mm²
TEST RESULTS
Force max Fm 12.61 kN
Tensil Stress Rm 180.2 MPa
Yield stress UYS/(ReH) 0.0 MPa
Yield stress LYS/(ReL) 0.0 MPa
Tot Elongation A 8.8 %
Uniform Elong Agt 33.3 %
Yield Stress Rp(.2%) 56.6 MPa

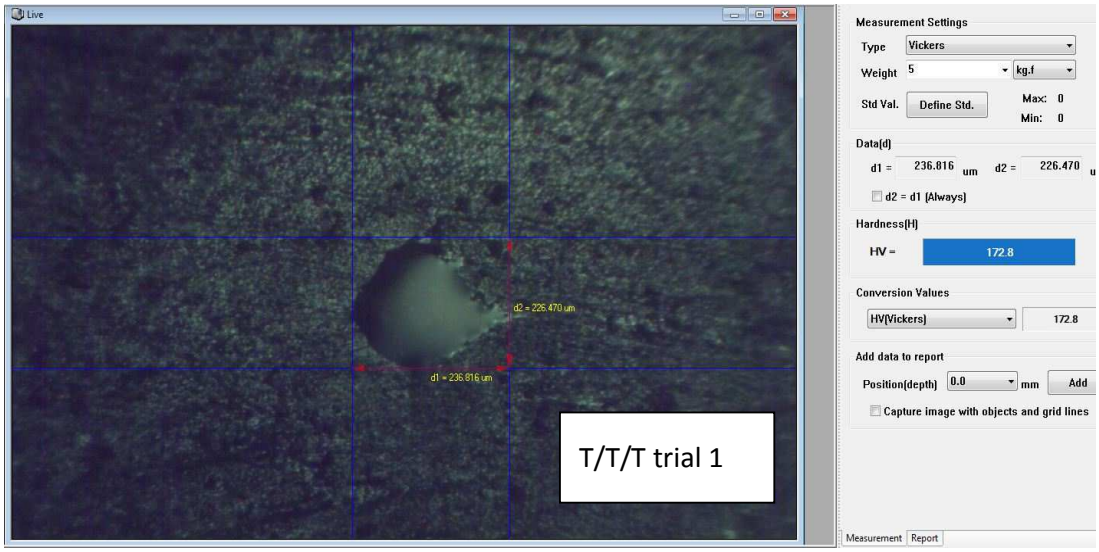

TENSION TEST (ISO 6892-1)
N/mm²
180.0
162.0
144.0
126.0
108.0
90.0
72.0
54.0
36.0
18.0
0.0
0.0 4.0 8.0 12.0 16.0 20.0 24.0 28.0 32.0 36.0 40.0 %
Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993
ECAE
TEST DATA
Test num 10234011-2
Order num
For Customer
Reference
Material glass fiber (g/g)
Inspector ayalew
Note 1
Note 2
Note 3
SPECIMEN DATA
Specimen name
Specimen class Rectangle
Thick (a) 3.50 mm
Width (b) 18.00 mm
Diam D 0.00 mm
Gage Length Lo 50.00 mm
Area So 63.00 mm²
TEST RESULTS
Force max Fm 10.62 kN
Tensil Stress Rm 168.6 MPa
Yield stress UYS/(ReH) 0.0 MPa
Yield stress LYS/(ReL) 0.0 MPa
Tot Elongation A 7.6 %
Uniform Elong Agt 38.5 %
Yield Stress Rp(.2%) 56.0 MPa

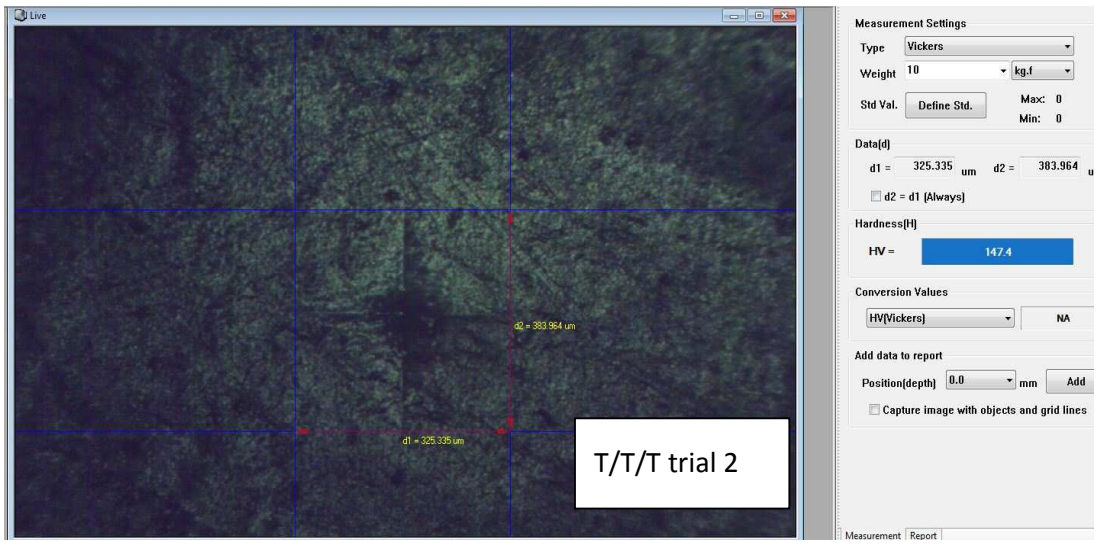

TENSION TEST (ISO 6892-1)
N/mm²
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0.0 3.5 7.0 10.5 14.0 17.5 21.0 24.5 28.0 31.5 35.0 %
Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993
ECAE
TEST DATA
Test num 10234011-3
Order num
For Customer
Reference
Material glass fiber (g/g)
Inspector ayalew
Note 1
Note 2
Note 3
SPECIMEN DATA
Specimen name
Specimen class Rectangle
Thick (a) 3.00 mm
Width (b) 18.00 mm
Diam D 0.00 mm
Gage Length Lo 50.00 mm
Area So 54.00 mm²
TEST RESULTS
Force max Fm 10.12 kN
Tensil Stress Rm 187.4 MPa
Yield stress UYS/(ReH) 0.0 MPa
Yield stress LYS/(ReL) 0.0 MPa
Tot Elongation A 7.1 %
Uniform Elong Agt 32.8 %
Yield Stress Rp(.2%) 60.7 MPa

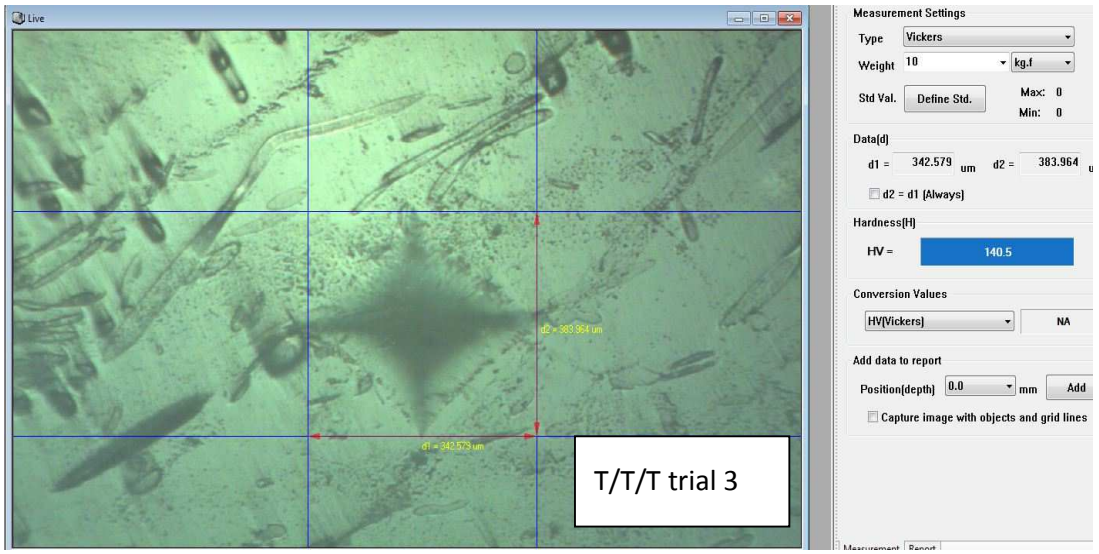
Appendix E: Micro hardness test results

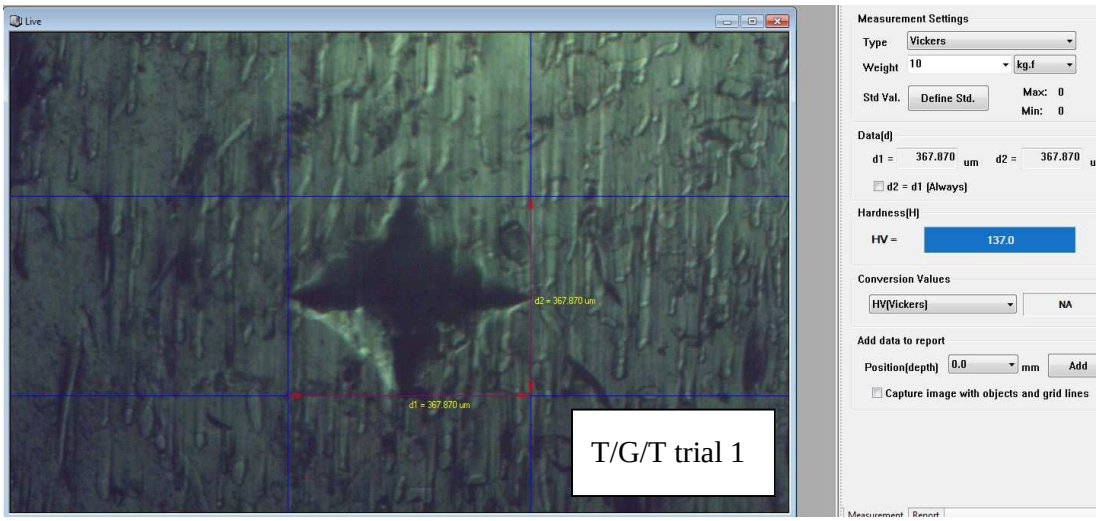


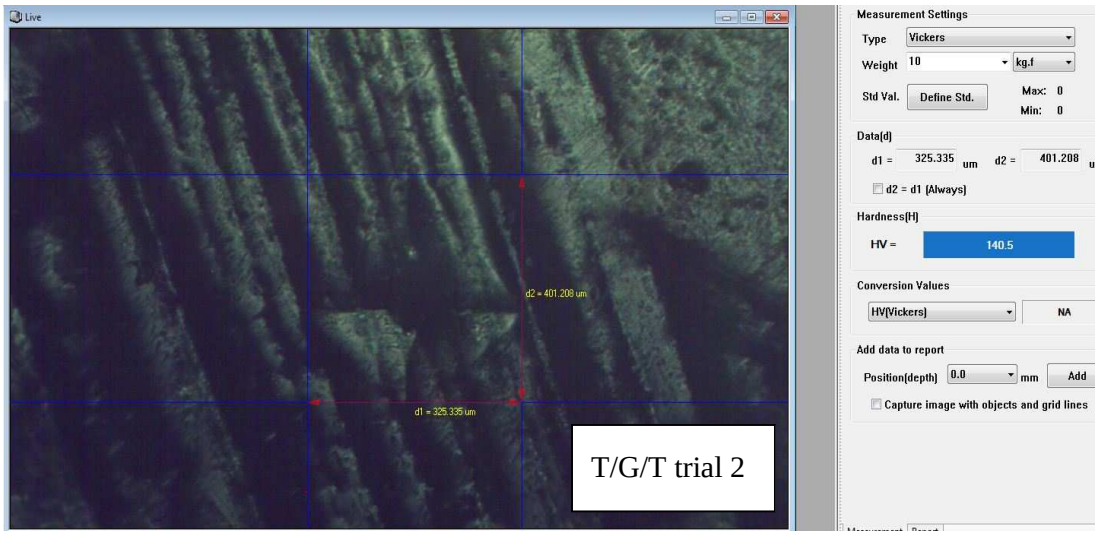


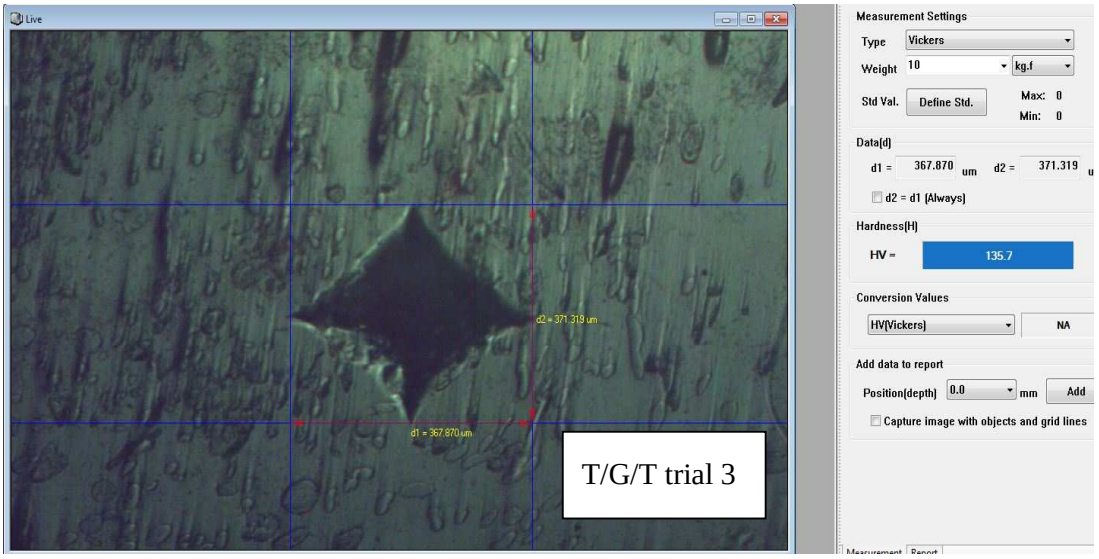

Live
d2 = 226.470 um
d1 = 236.816 um
T/T/T trial 1
Measurement Settings
Type Vickers
Weight 5 kg.f
Std Val. Define Std.
Max: 0
Min: 0
Data[d]
d1 = 236.816 um
d2 = 226.470
d2 = d1 [Always]
Hardness[H]
HV = 172.8
Conversion Values
HV[Vickers] 172.8
Add data to report
Position[depth] 0.0 mm Add
Capture image with objects and grid lines
Measurement Report

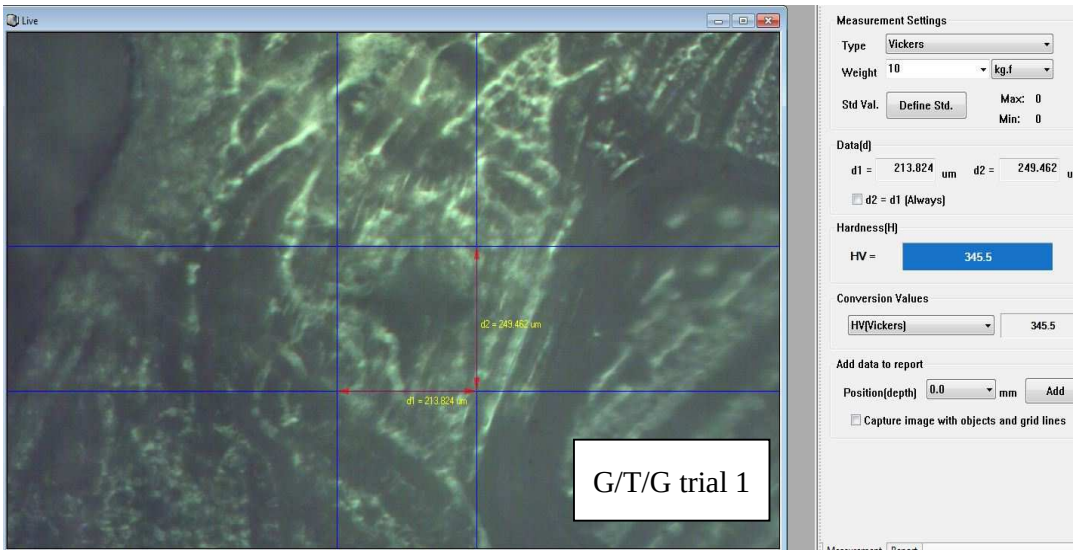

Live
d2 = 383.964 um
d1 = 325.335 um
T/T/T trial 2
Measurement Settings
Type Vickers
Weight 10 kg.f
Std Val. Define Std.
Max: 0
Min: 0
Data[d]
d1 = 325.335 um
d2 = 383.964
d2 = d1 [Always]
Hardness[H]
HV = 147.4
Conversion Values
HV[Vickers] NA
Add data to report
Position[depth] 0.0 mm Add
Capture image with objects and grid lines
Measurement Report

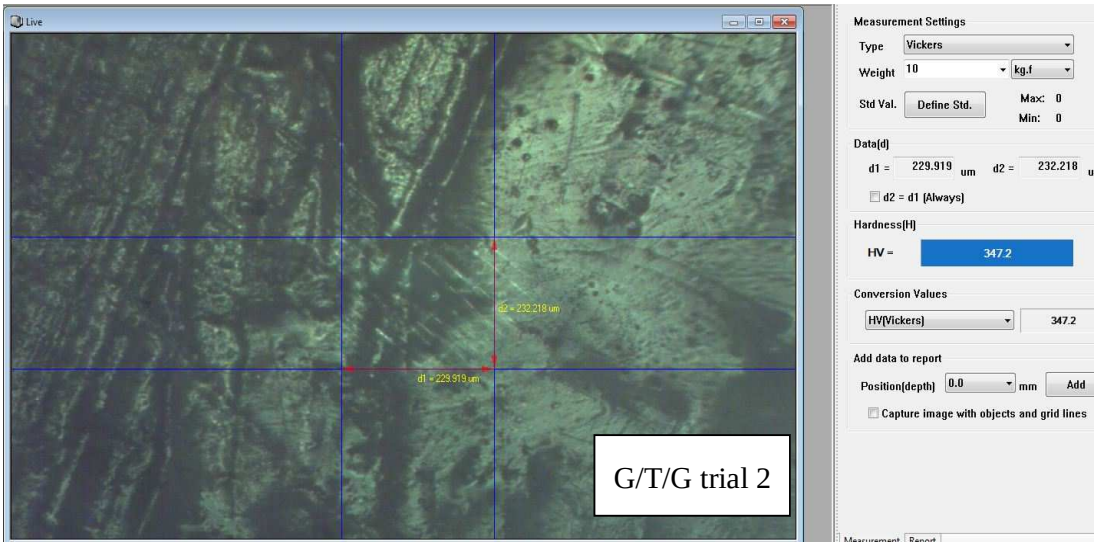

Live
d2 = 383.964 um
d1 = 342.573 um
T/T/T trial 3
Measurement Settings
Type Vickers
Weight 10 kg.f
Std Val. Define Std.
Max: 0
Min: 0
Data[d]
d1 = 342.579 um
d2 = 383.964
d2 = d1 [Always]
Hardness[H]
HV = 140.5
Conversion Values
HV[Vickers] NA
Add data to report
Position[depth] 0.0 mm Add
Capture image with objects and grid lines


Live
d2 = 367.870 um
d1 = 367.870 um
T/G/T trial 1
Measurement Settings
Type Vickers
Weight 10 kg.f
Std Val. Define Std.
Max: 0
Min: 0
Data[d]
d1 = 367.870 um
d2 = 367.870
d2 = d1 (Always)
Hardness[H]
HV = 137.0
Conversion Values
HV[Vickers] NA
Add data to report
Position[depth] 0.0 mm Add
Capture image with objects and grid lines


Live
d2 = 401.208 um
d1 = 325.335 um
T/G/T trial 2
Measurement Settings
Type Vickers
Weight 10 kg.f
Std Val. Define Std.
Max: 0
Min: 0
Data[d]
d1 = 325.335 um
d2 = 401.208
d2 = d1 (Always)
Hardness[H]
HV = 140.5
Conversion Values
HV[Vickers] NA
Add data to report
Position[depth] 0.0 mm Add
Capture image with objects and grid lines


Live
d2 = 371.319 um
d1 = 367.870 um
T/G/T trial 3
Measurement Settings
Type Vickers
Weight 10 kg.f
Std Val. Define Std.
Max: 0
Min: 0
Data[d]
d1 = 367.870 um
d2 = 371.319
d2 = d1 (Always)
Hardness[H]
HV = 135.7
Conversion Values
HV[Vickers] NA
Add data to report
Position[depth] 0.0 mm Add
Capture image with objects and grid lines


Live
d2 = 249.462 um
d1 = 213.824 um
G/T/G trial 1
Measurement Settings
Type Vickers
Weight 10 kg.f
Std Val. Define Std.
Max: 0
Min: 0
Data[d]
d1 = 213.824 um
d2 = 249.462
d2 = d1 (Always)
Hardness[H]
HV = 345.5
Conversion Values
HV(Vickers) 345.5
Add data to report
Position(depth) 0.0 mm Add
Capture image with objects and grid lines


Live
d2 = 232.218 um
d1 = 229.919 um
G/T/G trial 2
Measurement Settings
Type Vickers
Weight 10 kg.f
Std Val. Define Std.
Max: 0
Min: 0
Data[d]
d1 = 229.919 um
d2 = 232.218
d2 = d1 (Always)
Hardness[H]
HV = 347.2
Conversion Values
HV(Vickers) 347.2
Add data to report
Position(depth) 0.0 mm Add
Capture image with objects and grid lines


Live
d2 = 318.437 um
d1 = 262.107 um
G/T/G trial 3
Measurement Settings
Type Vickers
Weight 10 kg.f
Std Val. Define Std.
Max: 0
Min: 0
Data[d]
d1 = 262.107 um
d2 = 318.437
d2 = d1 (Always)
Hardness[H]
HV = 220.0
Conversion Values
HV(Vickers) 220.0
Add data to report
Position(depth) 0.0 mm Add
Capture image with objects and grid lines


Live
d2 = 408.106 um
d1 = 472.483 um
G/G/G trial 1
Measurement Settings
Type Vickers
Weight 10 kg.f
Std Val. Define Std.
Max: 0
Min: 0
Data[d]
d1 = 472.483 um
d2 = 408.106
d2 = d1 (Always)
Hardness[H]
HV = 95.6
Conversion Values
HV(Vickers) NA
Add data to report
Position(depth) 0.0 mm Add
Capture image with objects and grid lines


Live
d2 = 274.753 um
d1 = 236.816 um
G/G/G trial 2
Measurement Settings
Type Vickers
Weight 10 kg.f
Std Val. Define Std.
Max: 0
Min: 0
Data[d]
d1 = 236.816 um
d2 = 274.753
d2 = d1 (Always)
Hardness[H]
HV = 283.4
Conversion Values
HV(Vickers) 283.4
Add data to report
Position(depth) 0.0 mm Add
Capture image with objects and grid lines


Live
d2 = 313.839 um
d1 = 329.933 um
G/G/G trial 3
Measurement Settings
Type Vickers
Weight 10 kg.f
Std Val. Define Std.
Max: 0
Min: 0
Data[d]
d1 = 329.933 um
d2 = 313.839
d2 = d1 (Always)
Hardness[H]
HV = 178.9
Conversion Values
HV(Vickers) 178.9
Add data to report
Position(depth) 0.0 mm Add
Capture image with objects and grid lines