Abstract

Due to their low weight, improved mechanical properties, and cost-effective fabrication techniques, natural fiber-reinforced polymer matrix composites are highly utilized for different engineering applications in different industries. The current work is focused on investigating the effect of glass powder filler on the mechanical properties of sisal fiber-reinforced polyester matrix composites for power station applications. The characterization was performed based on the effect of the weight percentage of reinforcing glass particles, sisal fiber, and polyester matrix on the percentage water absorption, hardness, impact strength, tensile strength, and compressive strength of the newly developed polymer matrix composite. The composite was fabricated by compression molding, varying the weight percentage of glass filler particles at 10, 15, and 20 percent, sisal fiber at 20, 30, and 40 percent, and polyester matrix at 40, 45, 50, 55, 60, 65, and 70 percent. Furthermore, the microstructural investigation was performed by using a scanning electron microscope in order to identify the distribution of the reinforcing sisal fiber and the glass filler, as well as to examine the distribution of porosity and voids in the microstructure of the composite. The mechanical properties of the composite, such as compressive strength, hardness, and impact energy absorption, improve as the glass filler particle size increases. Only for the impact energy absorption property of the composite, the addition of the filler has no significant effect in improving the toughness of the composite because the addition of ceramic fillers transforms the ductile matrix phase into a brittle phase, resulting in a reduction in the material's toughness. Further, the water absorption property of the composite shows an increasing trend with the addition of the glass filler in the presence of a lower amount of matrix. From the result of the test, it can be concluded that the addition of sisal fiber and glass filler in the presence of a larger amount of polyester matrix resulted in improving the mechanical properties of the composite. The comparison of the current material with past research materials that are conducted for the same application reveals that the current composite material has better mechanical as well as physical properties than most of them and the developed polyester/sisal fiber/glass filler composite can be used as an alternative material for power station housing application.

Key Words: polyester matrix composite, sisal fiber, glass filler, compression molding, power station house.

BACKGROUND

A composite is a material structure that consists of at least two macroscopically identifiable materials that work together to achieve a better result[1]. Composite materials are commonly classified at the following two distinct levels: The first level of classification is usually done with respect to the matrix constituent. The major composite classes include Organic Matrix Composites (OMCs), Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs)[2]. The term "organic matrix composite" is generally assumed to include two classes of composites, namely polymer matrix composites (PMCs) and carbon matrix composites, commonly referred to as carbon-carbon composites[3]. The second level of classification refers to the reinforcement form: fiber reinforced composites, laminar composites, and particulate composites[4]. Fiber reinforced composites (FRP) can be further divided into those containing discontinuous or continuous fibers. The two main kinds of polymers are thermo-sets and thermoplastics.

Thermo-sets have qualities such as a well-bonded three-dimensional molecular structure after curing. They decompose instead of melting on hardening[5]. Thermo-set materials are epoxy, polyester, and phenolic polyamide resin. Thermoplastics have one-or two-dimensional molecular structures, and they tend to be at an elevated temperature and show an exaggerated melting point. Due to rapid growth in the manufacturing industry, there is a need for materials that have better properties in terms of strength, stiffness, density, and lower cost with improved sustainability[6].

Thermoplastic materials are polyethylene, polyamide, nylon, polypropylene, and polystyrene. The most important among them are the ease of processing, lightweight, higher productivity, and cost reduction[7]. For many of these applications, the properties of polymers are modified using fillers and fibers to suit the high strength modulus requirements. Natural fibers are extracted from various plant and animal sources. A few examples of natural fibers extracted from plants that are cellulose-based include cotton, flax, jute, and sisal. The animal fibers that are protein-based include wool, mohair, and silk[8]. The use of plant-based natural fibers as reinforcement agents in polymer composites has been one of the focus areas. Natural fiber reinforced polymer matrix composites could be cheaper, tougher, and more environmentally friendly. However, the potential of such fibers for polymer composites has not been developed fully[9].

Sheet molding compound composites (SMC) are increasingly being used as load-structure materials in automotive components, and are thus frequently exposed to mild impacts. Automobile safety regulations, particularly those concerning passengers, have become critical. Furthermore, requirements in automotive structural design demand that energy be dissipated as effectively as possible to minimize the decelerations experienced by vehicle passengers during intense shocks (crashworthiness)[10]. SMC represents a mixture of the subsequent components: polymer resin, fiber reinforcement, inert fillers, pigments, catalysts, release agents, stabilizers, and thickeners exactly as other thermosets[11].

SMC is a composite material that is being used in several industrial applications; thanks to its aesthetic and mechanical properties it can be employed in the manufacturing of many components in a wide range of industrial fields: building constructions, electrical/electronics, transportation, aerospace, chemical engineering, and the marine industry[12]. The chopped fibers, that compose SMC, have a length ranging from 25 to 50 mm put in a thermosetting resin polyester matrix system. SMC is normally manufactured in a conveyor belt where it is processed to form a compression molding by mixing containing the chopped fibers, resin or polyesters matrix, and functional glass fillers, composite. Then a shape, at a temperature of 140-170 °C, is used to press the SMC for 1-10 minutes depending on the thickness and sizes of the panels[13].

In this paper the author is going to analyze the mechanical properties of SMC plates used as low cost structural components in the power station housing purpose using a natural fiber reinforcing and glass powder filler to a polyester matrix. One a type of natural fiber is Sisal fiber (SF). It is strong, durable, stable and versatile material and it has been recognized as an important source of fiber for composites[14, 15]. It has generally accepted that the mechanical properties of fiber reinforced polymer composites are controlled by factors such as type of matrix, fiber-matrix interface, fiber volume or fraction, fiber aspect ratio, fiber orientation...etc. Composites reinforced with natural fibers have received increasing interest from industries in a wide field of application such as automobile, construction, aerospace and packing[15].

The aim of this research was to fabricate composite material using sisal fiber as a reinforcement, powder glass filler/matrix ratio and mechanical property characterization of sisal fiber reinforced polyester composite to have the alternative materials for power substation housing purpose or application industry.

1.1 Scope and limitation of the Research

1.4.1 Scope of the research

This study experimentally discovers the feasibility of using sisal fiber reinforced polyester composite in power house station industry for development of lightweight, strong and ecofriendly materials. The study was focused in some processing variables like fiber weight fraction, filler weight fraction and concentration of alkali used in fiber modifications. For this study, chopped random fiber orientation used in three variable weight fractions 20%, 30% and 40% of the composite and 10%, 15% and 20% weight fraction of glass filler and evaluate the mechanical properties of the alternate composite materials.

1.1.1 Limitation of the research

- The main limitation of this research work is that, the thermal degradation property of the developed composite material was investigated by exposing the composite material for direct sun light, but to obtain better result of thermal degradation it is better to use some electronic measuring standard devices for the thermal degradation property of the developed composite material. It is left for future work by the current researcher.
- And it was difficult to find full information about SMC in Ethio-plastic industries

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter of the thesis presents the literature review section of the study. The section includes reviews of different articles, which are classified under different subsections. Section 2.2 provides an overview of polymer matrix composites with various reinforcing, matrix, and filler materials, as well as natural fiber treatment techniques; Section 2.3 provides a review of some of the different processing or fabrication techniques of natural fiber-reinforced polymer matrix composites, including their advantages and limitations, as well as their effect on the mechanical performance of the final product; Section 2.4 provides a review of some of the different processing or fabrication techniques of natural fiber-reinforced polymer matrix composites Section 2.5; reviews articles focusing on sheet-molded sisal fiber reinforced polyester matrix composites from past research works; Section 2.6 illustrates the summary of the literature review; and finally, Section 2.7 presents the identification of the research gap from the papers reviewed in Section 2.5.

The major point of literature is to give special meaning of previous work, present study and to provide overview of work done till date towards mechanical description of ordinary fiber composites and its properties. Figure 2.1 illustrates the flow chart of the literature review section of the study in a short detail.

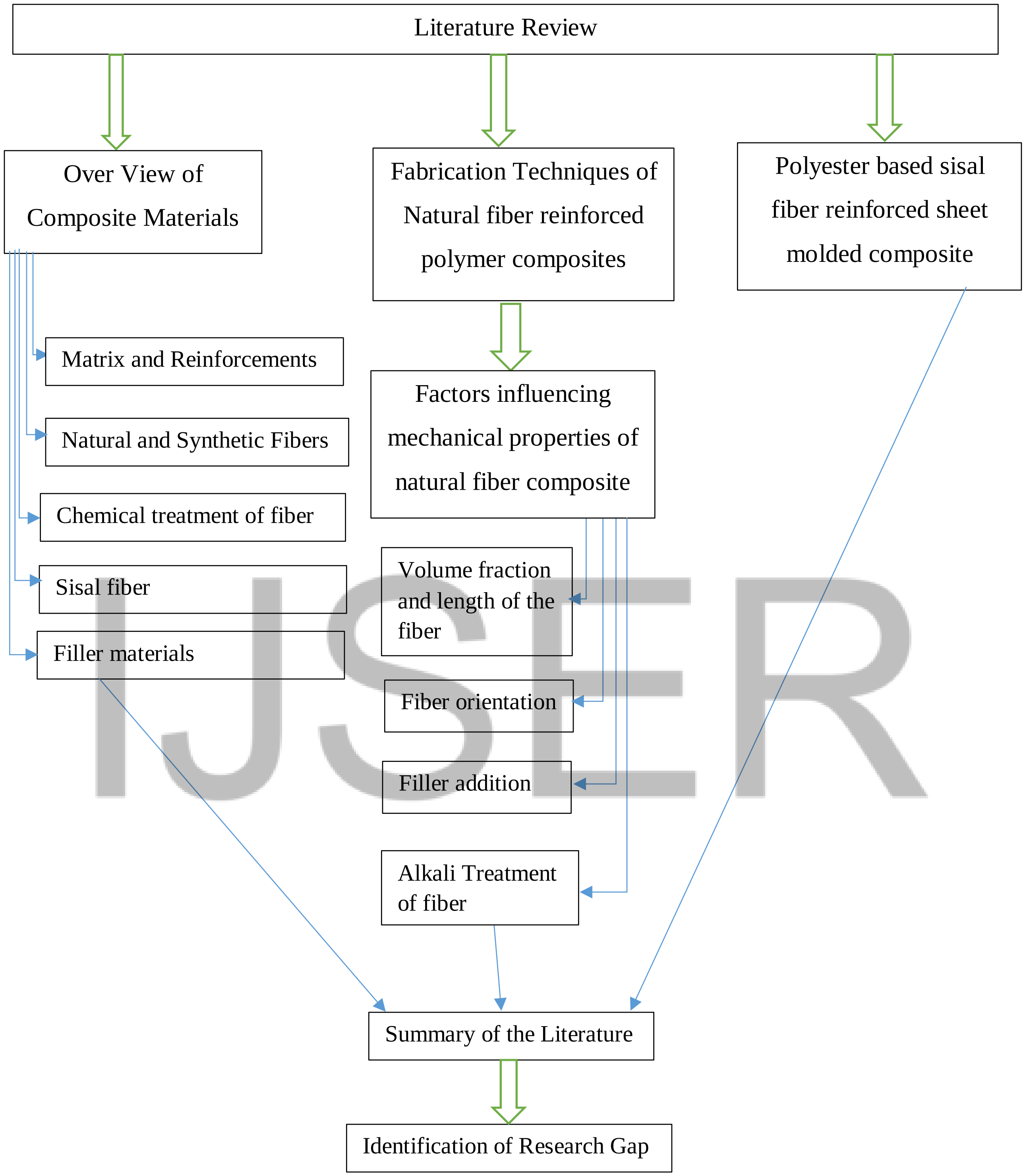

Figure 2. 1 Flow diagram of the literature review

CHAPTER 3

MATERALS AND METHODS

3.1 Introduction

This chapter presents the testing program and the experimental procedures used in the study including materials used, mix design proportions, compressive strength measurement, tensile test measurement, impact strength measurement, hardness measurement, water absorption measurement, density measurement and microstructural study properties of materials which are used in the study such as polyester resin, glass particulate and sisal fibers are presented in section 3.2. The detail of laboratory testing program was presented in section 3.3. In order to fulfill the stated objectives, the study was carried out in few steps. At the beginning stage the required properties of material for electrical warehouse application are studied and the significant properties of material for the application were listed based on their priority then based on that materials are selected for preparation of the polymer composite. Nine (9) the specimens were prepared according to the pri designed mixture proportion. After the preparation of the specimen standard tests are performed on different testing machines. Finally, the results obtained were analyzed to draw out conclusion. Flow diagram available for experimental study were shown in the figure 3.1

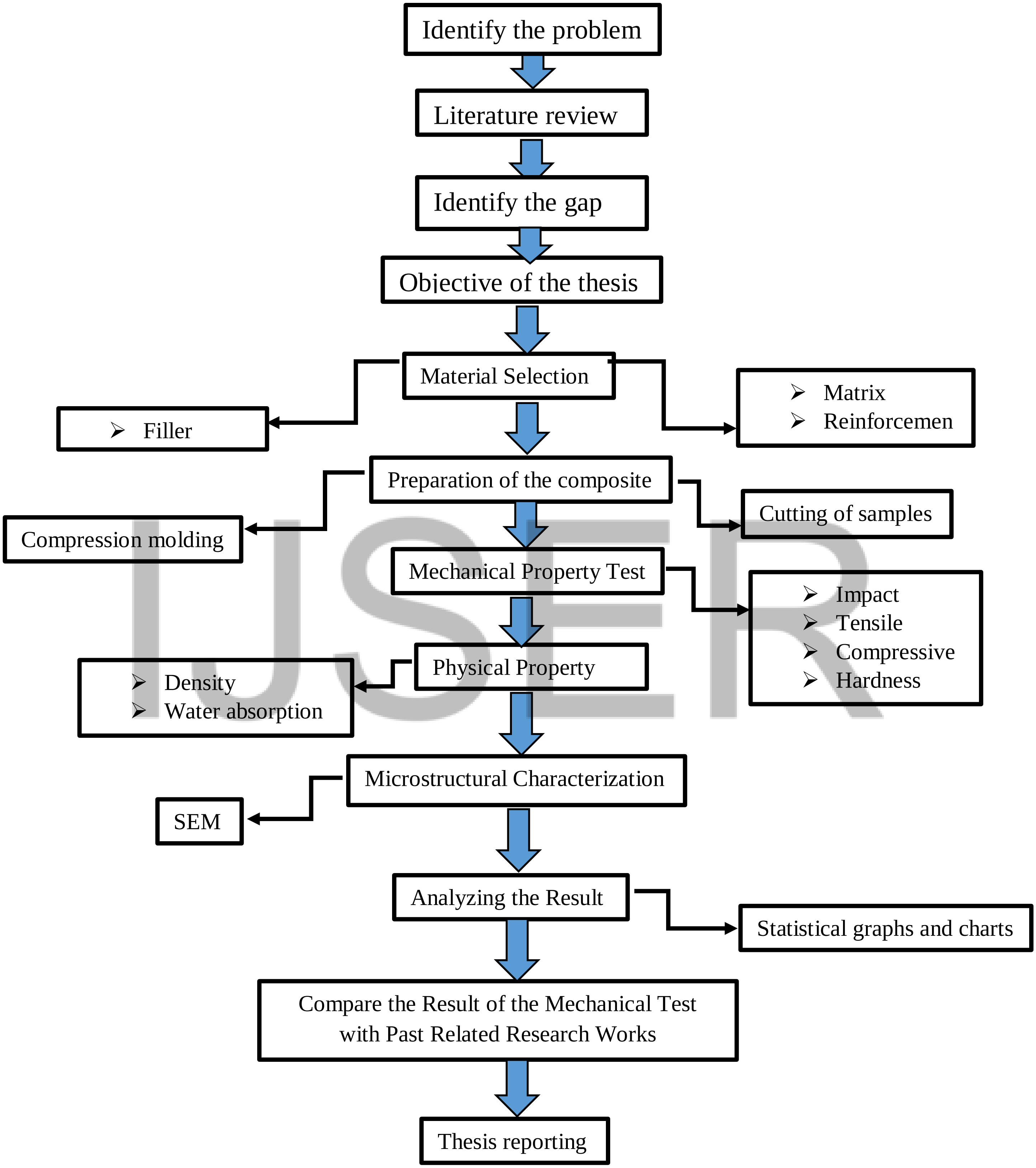

Figure 3. 1 Work Flow of the Research

3.1.1 Fabrication of the Composite

The current composite material is developed by using a compression molding machine, which is found in the Ethio-plastic industry. The machine can be automatically set at different working pressures and temperatures, and the finished composite product is taken out of the machine. But before loading the composite mix into the machine, the individual composite materials, that is, the sisal fiber, glass fiber, and polyester matrix, can be mixed outside the machine by stirring the mix using manual stirring mechanisms for a few minutes, as shown in Figure 3.12 below. Then, after mixing the individual composite phases, the mix is loaded on a special compression molding machine that is used to produce power stations housing composite materials. For the current composite fabrication, a ready-made mold of the machine was used without making another mold.

a) Mixing b) collecting together c) lading the mix on the machine

Figure 3. 2 Fabrication process of the polyester/sisal fiber/ glass filler composite

After curing inside the compression machine, the composite sample is taken out and cut in to different sizes as per the ASTM standard for different mechanical as well as water absorption property tests.

3.1.1.1 Cutting of the composite to prepare taste specimens

The specimen prepared in this thesis was according to American Society for Testing Materials specification. The specimens were prepared for Tensile, Compression, Impact, hardness, SEM analysis and Water Absorption. Vertical cut jig saw machine was used to cut fabricated composites according to ASTM standards. The Machine has cutting speed of 500 – 1000 m/min.

Figure 3. 3 cutting sample for each test

Tensile Test Specimen: The tensile test standard used is ASTM D3039. This standard has a rectangular shape with dimension of 235 mm x 30mm x 4mm.

Compression Test Specimen: The compression test standard used is ASTM D3410. This standard has a rectangular shape with dimension of 25mm x 25mm x 4mm.

Impact Test Specimen: The impact test standard used is ASTM D256. This standard has a rectangular shape with dimension of 64mm x 13mm x 4mm.

Water absorption Test Specimen: The water absorption test standard used is ASTMD570. This standard has a rectangular shape with dimension of 30mm x 28mm x 4mm.

Table 3. 1: experimental test standards

Test	Standard	Specimen dimension
Tensile test	ASTM D3039	227mm x 30mm x 4mm
Compression test	ASTM D3410	25mm x 25mm x 4mm
Impact test	ASTM D256	64mm x 13mm x 4mm
Hardness	ASTM D 384	20mm x 20mm x 3mm

SEM analysis	ASTM D3105	10mm x 10mm x 4mm
Water absorption test	ASTM D570	30mm x 28mm x 4mm

After cutting fabricated composite materials in to standard specimen sizes, they were tested using six different testing procedures. The four experiments (Tensile, Compression, Impact, and water absorption test) were conducted at Addis Ababa science and Technology University. Universal testing machine having maximum 50KN capacity was used for Tensile, Compression and impact testing. Hardness test at Ethio-china institute technical university by Rockwell hardness test machine and SEM analysis at Adama science and Technology University.

For the six experimental tests, at least three specimen samples were tested for all the nine composite compositions. Therefore, a minimum of 162 specimen samples were tested to show repeatability and minimize errors as much as possible. All was executed under room temperature.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the result and detail discussion of the manufactured composite materials based on the result of the different tests that was performed on the composite. These results include the result of the physical test (water absorption test), Mechanical test (Compressive strength, impact strength, tensile strength, hardness), and microstructural analysis using SEM. The experimental results were elaborated by using graphs, stress – strain curve diagram for each designed composition of the reinforcement, filler and the matrix of the polymer composite. Finally, the result of this research work was compared with previously published works considering both mechanical and water absorption properties.

As mentioned in the previous section, there were nine composite specimens that were tested according to ASTM standards. The test results express properties of the Sisal fiber reinforced and glass powder as a filler polyesters matrix composites are manufactured. All fabricated composites have sisal fiber reinforcement that were chopped into 10mm length. All composites were treated with NaOH and have different fiber loading. From each composition, a minimum of three specimen samples were prepared and tested.