EFFECT OF EDM WIRE CUT WASTE IN LONG FIBER FORM ON MECHANICAL PROPERTIES OF LAMINATED GLASS COMPOSITE

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A thesis submitted
in fulfillment of the requirements for the degree of
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2024

DECLARATION

I declare that this Choose an item. entitled “EFFECT OF EDM WIRE CUT WASTE IN LONG FIBER FORM ON MECHANICAL PROPERTIES OF LAMINATED GLASS COMPOSITE” is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology with Honours.

Signature : ....

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Date : 31/1/2024

DEDICATION

I wanted to thank everyone who helped this study succeed and who helped to make it an unforgettable experience for me. To the All-Powerful Allah, who is always there for me when I need you Allah. Thank you for leading me and empowering me in my everyday affairs. I appreciate you always being there for me and watching out for me. Thank you for ensuring that everything happened and came to a successful conclusion. Oh Allah, I adore you.

To my beloved parents, Mohamad Ropidi Bin Majid and Kamariah Binti Husin I appreciate your help in helping me pursue my dreams. If I succeed, I hope it will make you as proud of me as I am to have you as my parents. Dear Mak and abah, I love you.

ABSTRACT

In modern manufacturing industries, Electrical Discharge Machining (EDM) wire cut waste is a widely utilized method. The objective of this study is to investigate how the presence of long fiber WEDM wire cut waste affects the mechanical properties of laminated glass composites. Through a comprehensive experimental examination, we aim to understand the impact of incorporating WEDM wire cut waste in its long fiber form into laminated composites. Common tests such as tensile, flexural and impact tests will be conducted to assess their mechanical characteristics. The outcomes of this research endeavor will enhance our understanding of the potential benefits and limitations associated with using WEDM brass wire waste in this long fiber form. In the initial phase, the results reveal that incorporating 10% brass wire waste into fiberglass yields optimal performance. Moving on to the second phase, the investigation identifies that utilizing 6 layers of fiberglass with a 10% reinforcement of brass wire waste leads to notable improvements in strength force, ultimate strength,impact absorption and bending moment.

ABSTRAK

Dalam industri pembuatan moden, sisa pemotongan wayar Electrical Discharge Machining (EDM) adalah kaedah yang digunakan secara meluas. Objektif kajian ini adalah untuk menyiasat bagaimana kehadiran sisa potong dawai WEDM gentian panjang mempengaruhi sifat mekanikal komposit kaca berlamina. Melalui peperiksaan percubaan yang komprehensif, kami menyasarkan untuk memahami kesan menggabungkan sisa potong dawai WEDM dalam bentuk gentian panjangnya ke dalam komposit berlamina. Ujian biasa seperti ujian tegangan, lenturan dan hentaman akan dijalankan untuk menilai ciri mekanikalnya. Hasil daripada usaha penyelidikan ini akan meningkatkan pemahaman kita tentang potensi manfaat dan batasan yang berkaitan dengan penggunaan sisa wayar loyang WEDM dalam bentuk gentian panjang ini. Pada fasa awal, keputusan mendedahkan bahawa memasukkan 10% sisa wayar loyang ke dalam gentian kaca menghasilkan prestasi optimum. Beralih ke fasa kedua, penyiasatan mengenal pasti bahawa menggunakan 6 lapisan gentian kaca dengan tetulang 10% sisa wayar loyang membawa kepada peningkatan ketara dalam daya kekuatan, kekuatan muktamad, penyerapan hentaman dan momen lentur.

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In the Name of Allah, the Most Gracious, the Most Merciful

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LIST OF SYMBOLS AND ABBREVIATIONS

ASTM	-	American Standard Testing Method
CM	-	Carbon Fibres
C	-	Celsius
CM	-	Centimetre
CM^3	-	Cubic Centimetre
CMC	-	Ceramic Matrix Composite
CNC	-	Computerized Numerical Control
Cu	-	Cooper
D	-	Diametre
EDM	-	Electrical Discharge Machining
EOF	-	End Of Life
F	-	Fahrenheit
G	-	Gram
GFRP	-	Glass Fibre Reinforced Poplymer
GF^S	-	Glass Fibres
Gpa	-	Giga Pascal
J	-	Joule
KG	-	Kilogram
Kn	-	Kilo Newton
LCA	-	Life Cycle Asessment
MMC	-	Metal Matrix Composites
MM	-	Milimetre
Mpa	-	Mega Pascal
NF^S	-	Natural Fibres
NIJ	-	National Instutide Of Justice
PMC	-	Polymer Matrix Composites
PSI	-	Pounds Per Square Inch
SDG	-	Sustainable Development Goals
SF^S	-	Synthetic Fibers

UTM	-	Universal Testing Machine
V	-	Volt
WEDM	-	Wire Electrical Discharge Machining
Zinc	-	Zn

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Due to its accuracy and adaptability, electrical discharge machining (EDM) wire cutting is a frequently used method in contemporary manufacturing industries(Sathiyaraj *et al.*, 2020a). However, a substantial number of fine brass wire scraps are produced as waste by this method. Both environmental and financial issues are raised by the disposal of this garbage. There is a growing interest in investigating alternate strategies that can successfully reuse and utilize this waste material to address these problems. Combining reinforcing fibres with a matrix material to create composite materials, which have superior mechanical and ballistic qualities, makes them appropriate for a variety of high-performance applications. It has become popular to add waste materials to composites in order to improve their qualities and lessen the environmental impact of trash disposal. This study is to determine how adding long fibres made from EDM wire cut waste affects the mechanical and ballistic characteristics of laminated materials. Laminated composites are frequently used in sectors like automotive, aerospace, and defence where high strength, durability, and impact resistance are essential(Sathishkumar *et al.*, 2014). They are composed of layers of reinforcing fibres bonded with a matrix material. It is envisaged that the materials produced by reusing the EDM wire cut waste in long fibre form and incorporating it into the laminated composite structure will display better mechanical and ballistic qualities. In order to maximise the reinforcement effect and improve the load-bearing capacities of the composite structure, waste material is incorporated in the form of long fibres. There are various possible benefits of using long fibres made from EDM wire cut debris. First of all, it offers a chance to lessen waste production and the environmental impact of disposal techniques. Second, it makes it possible to create composite materials that are affordable by using trash that would otherwise be thrown away. Last but not least, the addition of EDM wire cut waste in the form of long fibres may improve the mechanical and ballistic performance of laminated composites, opening up a way to produce high-performance materials at a lower cost. A thorough experimental investigation will be carried out to examine the impact of adding EDM wire cut waste in the form of long fibre on laminated composites. The garbage will be gathered, prepared, and transformed into long fibre. With varied amounts of the EDM wire cut waste, laminated composite samples will be created, and their mechanical characteristics will be evaluated using common tests like tensile, flexural, drop tower test and impact tests. Additionally, the composites' ballistic performance will be assessed utilizing the right testing methods. The results of this study will further knowledge and comprehension of the possible advantages and restrictions of using EDM wire cut waste in the form of long fibre in laminated composites. The findings will support the creation of composite materials with enhanced mechanical and ballistic qualities that are both affordable and sustainable. Furthermore, by reusing waste products produced during manufacturing operations, this research will encourage the idea of recycling and the adoption of circular economy ideas.

1.2 Problem Statement

Wire Electrical Discharge Machining (WEDM) is employed for cutting plates up to a thickness of 300 mm and fabricating punches, tools, and dies from hard metals that are challenging to machine using alternative methods. In the case of brass wire, financial resources are required for proper disposal processing. Hence, opting to reuse brass wire can help circumvent the need to spend money on appropriate disposal methods. Utilizing discarded materials like brass wire through recycling contributes to environmental sustainability, ensuring a healthier planet for generations to come and save money from being sent to disposal the materials. To reused it, the brass material will be used to be part of the material that will be used to produce panel of composites.

The next is wire electrical discharge machining WEDM in wire cut. The brass material used for cutting the workpieces when edm wire cut is utilized will be used as long as the cutting. process is taking place and will be used until the workpiece cutting process is complete. The brass material will be wasted after its single use. To avoid wasting brass, the brass material will be used to be part of the material that will be used to produce panel of composites.

1.3 The Objective of This Project Are

a) To fabricates waste of long brass wire in electrical discharge machining (EDM) into composite specimen.
b) To conduct the specimen testing of long brass wire waste on electrical discharge machining (EDM) wire cut.
c) To analysis of the utilisation of the long fibre form of EDM wire cut waste in laminated glass composites.

1.4 Scope of Research

The scope of this research are as follows:

a) Woven roving E-Glass fiber and brass wire waste as a reinforcement.
b) Epoxy resin as the matrix material.
c) Nine type of different ratio to fabricate specimen in phase 1.
d) Eight type of differents layers to fabricate specimen in phase 2.
e) Using tradisional method by hand-layup techniques and follow via cold press compression to enhance the properties of composites.

f) To conduct mechanical testing of waste brass wire /woven roving E-glass fiber reinforced composites that included tensile test, flexural test and impact test.

1.5 Report organization

The purpose of this study is to research and develop low impact on mechanical properties from waste brass wire in WEDM and woven roving E-glass fiber as the reinforcement and epoxy resin with hardener as a matrix. This report includes an introduction, literature review, methodology and expected result. This Final Year Project 2 will cover Chapter 1, Chapter 2, Chapter 3, Chapter 4 and Chapter 5. In chapter 1 will begin introduction our research background, problem statement, objective, and scope of research. Besides, in chapter 2 are story about literature review as an overview of the theory and about previous research based on glass fiber composites, mechanical properties of fiber glass, application of fiber glass, brass wire in WEDM, mechanical properties of brass wire, recycling of brass wire technologies and effect of glass fiber in ballistic properties. After that, chapter 3 is about the methodology used in this research which is to describe the proper of process flow that can be applied to produce brass wire waste in WEDM/woven roving E-glass fiber hybrid composites. This methodology is included of overview of methodology, raw material, preparation of Hand-layup, mechanical testing is included tensile test, flexural test and impact test followed ASTM standard procedure. Beside in Chapter 4 outlines the outcomes derived from conducting tensile tests, flexural tests, and impact tests on each sample during both Phase 1 and Phase 2 of the research. This chapter elaborates on the levels of strength and impact absorption observed in the materials throughout the testing phases. Additionally, it discusses the findings obtained from these tests, presenting a comprehensive analysis of the mechanical properties such as tensile strength, flexural strength, and impact resistance for each sample. The comparison of these properties between Phase 1 and Phase

2 is thoroughly examined, shedding light on any improvements or distinctions. The results are typically illustrated through charts or tables, providing a visual representation of the material's performance. The discussion within the chapter also emphasizes the significance of these findings in alignment with the research objectives and the potential applications of the tested materials. in Chapter 5, the study wraps up its investigation into optimizing brass wire waste composite materials through two crucial phases. The first phase, exploring brass wire waste ratios from L10% to L90%, establishes a clear connection between varying ratios and enhanced strength and durability. Identified optimal ratios provide practical guidance for formulating composite materials with superior mechanical properties.

The second phase delves into the impact of layer thickness (L3 to L10) on material performance. Findings illuminate the intricate relationship between layer dimensions and strength/durability, enabling the identification of an optimal layer thickness. These insights contribute to a comprehensive understanding of how structural elements influence the composite material, further informing manufacturing processes for improved outcomes.

As a forward-looking recommendation, the study suggests refining the method of fabrication. Enhancing fabrication techniques, adopting innovative methods, or leveraging advanced manufacturing technologies could bolster result accuracy and reproducibility. Such improvements in fabrication methods not only strengthen the reliability of the current study but also lay the groundwork for future research endeavors seeking to advance composite material technology. In conclusion, the research outcomes provide actionable insights into optimal ratios and layer thicknesses, while the recommendation underscores the importance of continuous refinement in fabrication for the ongoing progress in the field.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will give a detailed description about what has been published on some topics by scholars, science directs and researchers. The main purpose of writing this literature review is to get knowledge and ideas that have been established about the effect of edm wire cut waste in long fiber form on mechanical and properties of laminated glass composited. Moreover, there are resources on the topic of effect of edm wire cut waste in long fiber form on mechanical and properties of laminated glass composited that have been widely published. The information has been collected from different resources such as published documentation, white paper, and journals on the web site. The function of EDM wire cut (Electrical Discharge Machining wire cutting) is used in machining wire cutting to precisely cut metal components. The brass or tungsten wire electrode is gently passed into the workpiece while being continuously electrically charged. An electrical discharge happens as the wire contacts the metal, melting a small amount of the metal and leaving a small crater.

2.2 Composites

When two or more materials are combined to form a new type of material, it is referred to as a composite material. These new materials have unique properties not found in the original materials. make up. A composite material with two phase structures is produced when two or more materials are physically and chemically mixed. The two crucial stages of composite materials are the matrix and reinforcement. The most crucial one is the matrix phase. Its main duty is to encircle the reinforcing element, hold it together, and keep it in the right shape. In composite constructions, the load-bearing reinforcing components operate best when the primary material, or matrix, has the right mechanical properties. This type of material not only performs better than any individual component in the composition, but also possesses special qualities that the component of one does not. In order to integrate the greatest properties of two or more different materials into a single material, it is a unique material created by mixing two or more different elements at the macro-level. In other words, it can be defined as a substance made up of many types of materials or phases that are combined to overcome the shortcomings of one another and reach greater attributes. The metal matrix must be compatible with the reinforcement elements, especially in terms of their chemical compatibility. It is guaranteed that neither the physical nor chemical properties of the reinforcing material will be altered by a chemical reaction with the matrix. (Kumar Sharma et al., 2022).

2.2.1 Classification Of Fiber Reinforcement

Composite materials are classified into two main categories: base material and filler material. The filler material can take the form of sheets, pieces, particles, fibers, or whiskers made from either natural or synthetic materials. On the other hand, the base material, which acts as a binding or holding component for the filler material within structures, is referred to as either a matrix or a binder material. Based on their structure, composites are divided into three primary groups, as shown in Figure 2.1.

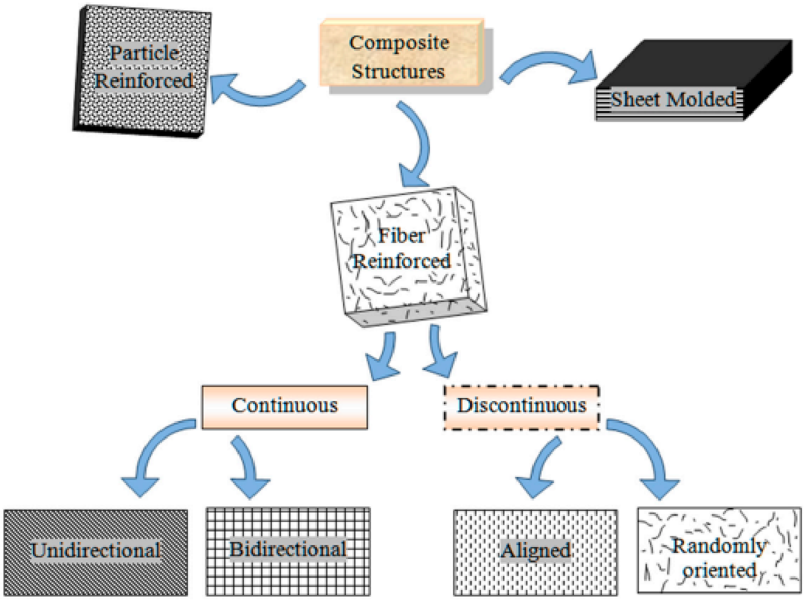

Figure 2.1 Classification of fiber reinforced(Rajak et al., 2019)

Based on the length of the fibers that make up the structure of the matrix, composites can be classified. Continuous fiber reinforcement composites consist of composites that have long fiber reinforcements, while discontinuous fiber reinforcement composites consist of composites with short fiber reinforcements. Hybrid fiber-reinforced composites are formed by reinforcing a single matrix structure with two or more types of fibers. In continuous fiber composites, the fibers in the matrix structure can be positioned either in a unidirectional or bidirectional manner, allowing for efficient and direct transfer of loads from the matrix to the fiber. In order to effectively transfer loads and prevent material failure in brittle matrices, discontinuous fibers must be of sufficient length. The arrangement and orientation of the fibers determine the characteristics and structural behavior of composite materials. (Akhshik et al., 2017)

2.2.2 Types of composites

Figure 2.2 illustrates three distinct types of composite materials based on the matrix: metal matrix composites, polymer matrix composite materials, and ceramic matrix composite materials. These composite materials have gained significant attention from researchers in the automotive industry due to reduced production costs and the development of new techniques, making them a viable alternative to other materials. Originally utilized in industries such as aviation, space, and military, composite materials have found their way into the automotive sector. Extensive studies have been conducted on composite materials, serving as a foundation for more recent research. Among the various types, fiber- and particle-reinforced polymer matrix composites have emerged as key players in the composite materials market. While their primary use is to reduce weight, they also started to contribute to improved visual aesthetics and crash performance in the automotive industry. (Arun Kumar Sharma, et al.,2020)

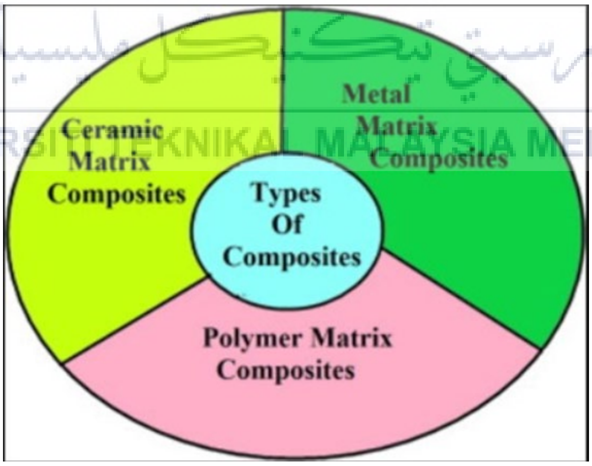

Figure 2.2 Types of composites (Kumar Sharma *et al.*, 2022)

2.2.3 Metal Matrix Composites

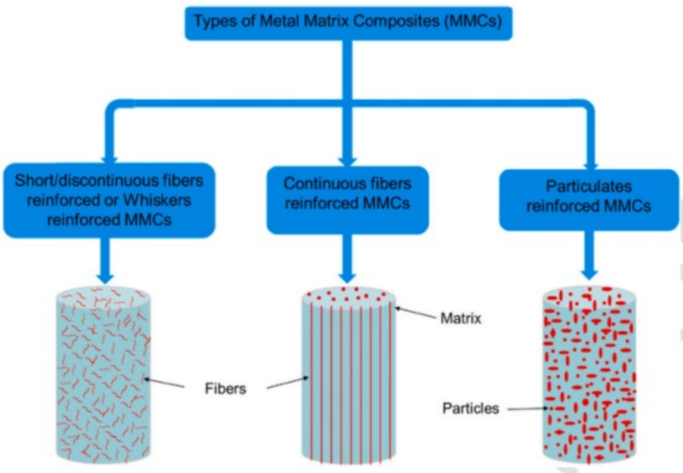

Figure 2.3 Metal matrix composites (Oladijo *et al.*, 2021)

Metal matrix composites are widely used due to the extensive application of metals and their alloys. In the industrial market, there is a growing preference for intelligent and purpose-driven materials. Smart composites, which offer innovative properties, are gaining popularity for emerging and expanding industrial applications. Metal alloys act as the matrix material in metal matrix composites, while the reinforcement can be made of metals, ceramics, polymers, or a combination of these materials in the form of particles, whiskers, or threads. Fiber-reinforced metal matrix composites, which utilize fibrous forms of materials that are inherently stiffer and stronger, are increasingly employed. These composites exhibit exceptional directional properties, and measurements of tensile strength in the direction of fiber reinforcement demonstrate remarkably high mechanical attributes. Shape memory alloys are a unique type of material that can remember and return to their previous shape. Nitinol, the most popular shape memory alloy, possesses excellent mechanical and thermo-mechanical properties. Reinforcing a shape memory alloy within the matrix significantly enhances the functionality without causing significant alterations to the matrix's structure and microstructure features. (Mishra *et al.*, 2023)

2.2.4 Polymer Matrix Composites

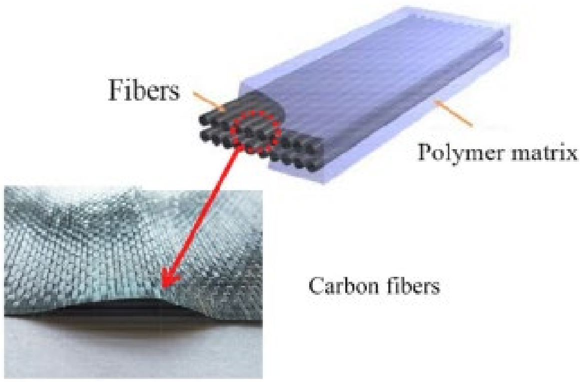

Figure 2.4 Polymer matrix composites (Rajak *et al.*, 2019)

Although polymer-based composite materials have advanced significantly in the last several years, there are still a number of technical challenges and issues that need to be looked into. Figure 2.4 illustrated of polymer matrix composite. In addition to being manufactured, matrix materials have an impact on the cost and manufacturing of composite materials. The interphase structure, reinforcements, and matrix of the PMC all affect its properties. As a result, a PMC's design must consider several variables. Several elements need to be accurately controlled in order to produce structural materials that are best suited to the conditions in which they will be used. The mechanical properties of PMCs must be isotropic, which requires continuous-fiber reinforcing. To put it another way, PMCs are weakest when stretched parallel to the fibres and are most stable when extended perpendicular to the fibres. Contrary to ceramic matrix composites, reinforcement in polymer matrix composites is used to increase the matrix's strength and stiffness as well as its fracture toughness. Reinforcement in a reinforced composite is able to withstand the mechanical loads that a structure encounters while in use. On the other hand, a variety of reinforcements typically employed in PMCs, such as particles, whiskers, fibres, and textiles, may result in lower manufacturing and maintenance costs. In polymer composite materials, it is feasible to combine the advantages of polymers with the high strength of the reinforced phase. A performance booster is a reinforcement material. PMCs are the most widely used, largest, and fastest-expanding type of composite materials. A polymer matrix composite material has a polymer matrix and is strengthened by extra components, to put it simply.

In polymer-based composite materials, thermosets or thermoplastics are used as matrix materials. Exceptional electromagnetic properties can be found in composite materials. Polymer matrix composite materials are the consequence of continuous improvements in the mechanical, physical, and chemical properties of composite materials. (Kumar Sharma *et al.*, 2022)

2.2.5 Ceramic Matrix Composites

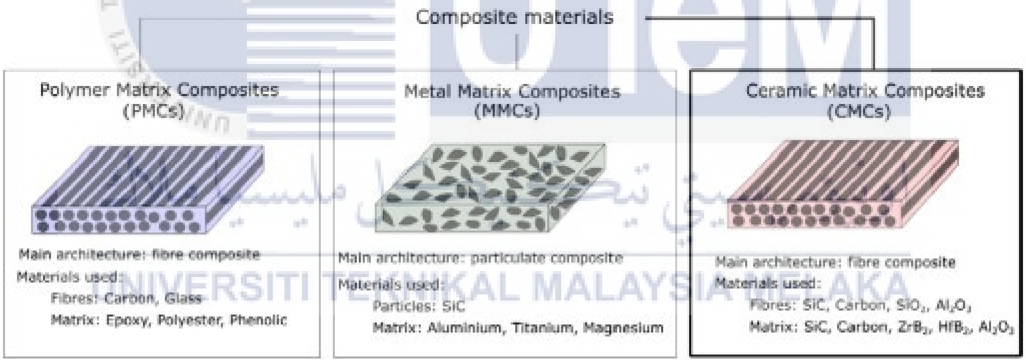

Figure 2.5 Ceramic matrix composites (Gavalda Diaz *et al.*, 2019)

Ligh weight materials with high specific strength, high temperature resistance, and high resilience to corrosive conditions are known as Ceramic Matrix Composites (CMC). Figure 2.5 shows the ceramic matrix composite by overcoming the drawbacks of traditional technical ceramics and enabling uses not achievable with metals, ceramic fibres embedded in a ceramic matrix. Brakes based on CMC, which have very low wear rates and enable brakes to last the entire service life of various applications, are just one example of how the superior properties can be seen in action. With the right remanufacturing (refurbishment), even a second or third life becomes feasible (rebrake). However, there is a significant energy requirement for the production of CMC applications, and depending on the CMC type, large quantities of pricey, high-grade silicon and ceramic or carbon fibres are needed. The CMC production has high environmental implications during its production phase, according to preliminary life cycle assessment (LCA) studies. Clearly, processing of CMC needs to be assessed in the future in order to determine a reasonable trade-off between characteristics and diminished environmental impact. Additionally, this highlights the necessity of using CMCs as effectively as possible and of closing loops during the various life-cycle stages. The ability to partially mitigate the significant environmental impacts of the production phase is provided by the circular usage of products and resources. Compared to other material classes, the production quantities of ceramic matrix composites are still relatively modest, but they have been rapidly rising in recent years. The issue of circularity becomes more significant as production quantities increase since, with some delay, increasing material volumes will eventually approach the end of their useful lives. (Wietschel *et al.*, 2023)

2.2.6 Types of Reinforcement Fiber

Recently, the usage of fiber composite materials and the effective exploitation of their features are tied to the creation of contemporary technology and technologies. The expansion of composite material production as well as the quick advancement of science and research in this area clearly demonstrate the advantages of composites over conventional materials like steel, glass, and plastics. A new generation of construction materials will replace existing ones, such as steel, concrete, bronze, and alloys, in 75% of all new construction projects by 2020, according to predictions and trends in the global industry.

Depending on the manner of textile creation and subsequent processing, the fibres that make up composite materials can take on a variety of shapes. They might be given to the receiver in the shape of mats, roving, woven fabrics with different weaves, powders (short fibres), or bundles of strands. The diameter of each fibre is quite similar to the size of crystals. The ratio determining the length to diameter ratio in fibres is often high. In the polymer matrix composite (PMC), materials like fibre glass, carbon, aramid, or natural materials are employed. Its major goal is to make the matrix more stiff and powerful. Ceramic fibres made of boron, aluminium, silicon aluminide, and silicon carbide are used as reinforcement in metallic matrix composites (MMC) and ceramic matrix composites (CMC) due to their high strength and stiffness. The main purpose of ceramic materials is to strengthen resistance to cracking or extremely high temperatures. Figure 2.6 shows the illustrated of various types of reinforcement in composites.

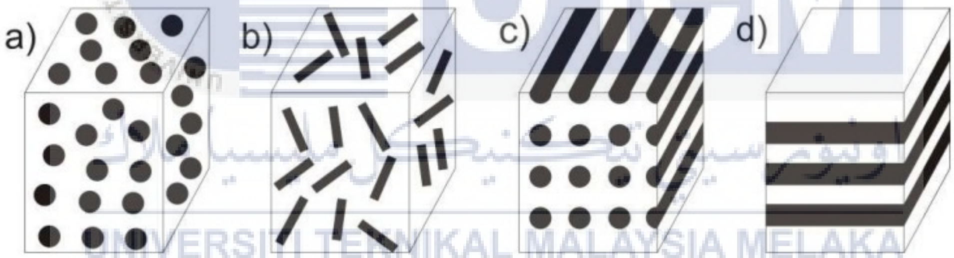

Figure 2.6 Various type of reinforcement in composites. a)particles b) short fibers c) continuos fibers d)plates (Pastuszak and Muc, 2013)

2.3 Synthetic Fiber

Synthetic fibres (SFs) are becoming increasingly necessary on a global scale since they are an important type of material for fiber-reinforced composite structures. Due to their exceptional qualities, SFs are more necessary than ever given the rising demand for lightweight and distinctive composite materials (Ahmad et al., 2022; Olszewski et al., 2020).

Natural Fibres (NFs) and Synthetic Fibres are in intense competition with one another (Camargo et al., 2020). However, SFs such ceramic textiles, carbon fibres, glass fibres, basalt fibres, and polymeric fibres have drawn particular attention over the last 20 years (Bhudolia et al., 2020). SFs are frequently employed in the creation of innovative composite materials in the aerospace and automotive industries because they offer high strength and inertia (Kirmasha et al., 2020). On the other hand, NFs are used as a backup for SFs because they are environmentally sustainable (Kampa et al., 2022). The flexibility and elastic qualities of SFs make them stronger than NFs, and they can typically withstand more water strain, chemicals, and heat than NFs (Baji et al., 2011). Since there is a global shortage of NFs, SFs are used to make up the difference. The SF industry has experienced rapid growth in recent years as a result of the rising demand for several applications. In comparison to traditional high-density metals, the usage of SFs in fiber-reinforced composites offers unique properties (Manteghi et al., 2019). Excellent tensile strength, electrical conductivity, a remarkable strength-to-weight ratio, and fatigue stability are a few characteristics There is a big market for composites made of glass, carbon, and aramid fibres in the aerospace, defence, automotive, wind energy, and pipes manufacturing industries (Di Maida et al., 2018).

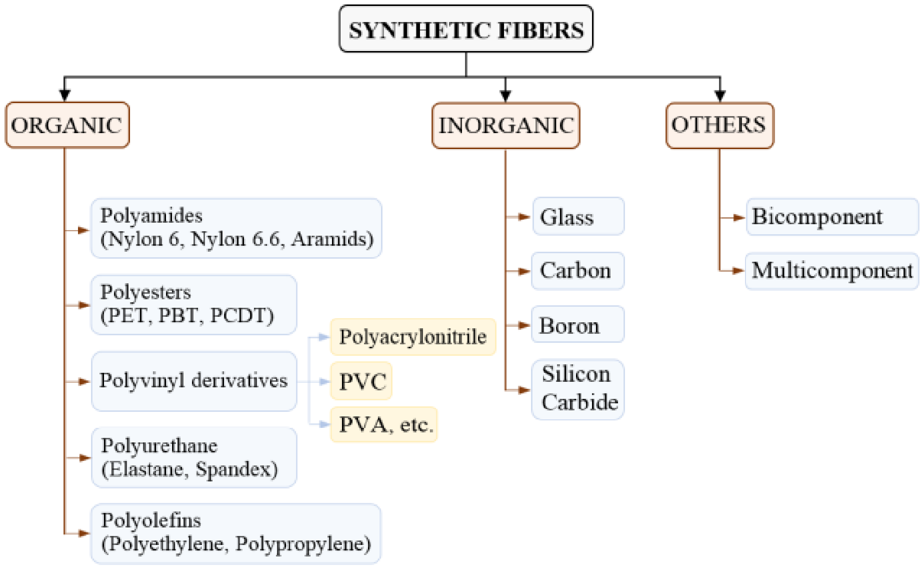

Figure 2.7 Classification of synthetic fiber based on organic, inorganic and others fiber (Rajak et al., 2022).

2.3.1 Inorganic Fiber

Inorganic fibres are becoming more common in modern society. Figure 2.7 show inorganic materials are Glass, carbon, boron, silica carbide, alumina, potassium titanate, and ceramics are the most often used inorganic materials to make fibres (Wang et al., 2019). Amorphous, polycrystalline, and monocrystalline fibres are the three primary divisions of inorganic fibres. Amorphous fibres have a high strength and a low elasticity modulus because they lack a grain boundary (Silva et al., 2021). Small crystals give polycrystalline fibres their outstanding thermal stability. The strength of monocrystalline fibres, which resemble very fine fibres, is extraordinarily great (Cooke, 1991).

2.3.2 Glass Fiber

Silica sand, limestone, boric acid, and other materials are melted at a very high temperature of approximately 1200 C higher to create glass fibres (GFs) (Shahari et al., 2021). Additionally, a number of metal oxides are added to the mixture that has been formed.

Glass fibre is a material that is incredibly thin, light, strong, and long-lasting (Rani et al., 2021). GFs are less expensive yet have lower strength when compared to carbon fibre (CF). Glass fibre is easily made using casting techniques, and because of how strong and light it is compared to metals, GFs are very profitable. The chemical composition of GF, a non-crystalline substance having a short-range network structure, is depicted in Figure 2.8 As comparable, it lacks a distinct microstructure, therefore the mechanical properties, which are greatly influenced by composition and surface quality, are the same (Mujumdar, 2006).

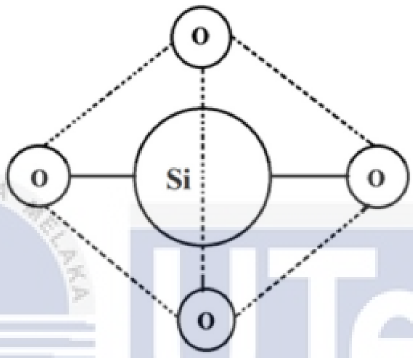

Figure 2.8 Chemical structure of glass fiber (Mujumdar, 2006).

The GF reinforced epoxy composite sites are often utilised in high voltage insulation applications because of their great efficiency over a wide temperature range. The dynamic mechanical properties of GF reinforced epoxy composites are improved by the addition of nano and micro fillers to epoxy (Manjunath et al., 2015). Additionally, an eco-friendly polymer composite can be employed to lighten the weight of the automotive parts and increase their strength and hardness. In this instance, the glass and palm fibres enhanced reinforcement and epoxy resin serve as the composite's matrix and matrix, respectively (Jiang et al., 2018). The tensile strength of the composite has reportedly been greatly increased by raising the phase ratio of the fibre particles (Raju & Balakrishnan, 2020). The inter-laminar shear strength of composites, which is crucial for the application of laminated composites, is also one of the more significant features in composite design. As a result, between the glass fibre and epoxy matrix, certain oxides, such as graphene converted short GFs, have been added to increase the interlaminar shear strength of composites (Dang et al., 2019).

2.4 Wire Electrical Discharge Machining (WEDM)

Electrical discharge machining (EDM) stands out as a widely employed method for removing materials, which deviates from conventional approaches. Its remarkable aspect lies in its ability to utilize thermal energy for shaping electrically conductive parts, disregarding their hardness. This exceptional advantage has established EDM as a preferred choice in the production of diverse components, including molds, dies, automotive, aerospace, and surgical parts. Additionally, EDM's characteristic of avoiding direct contact between the electrode and the workpiece eliminates concerns such as mechanical stresses, chatter, and vibrations that typically arise during the machining process. Notably, modern advancements allow the utilization of ultra-small electrodes, as tiny as 0.1 mm, to effectively create holes in curved surfaces at steep angles, without experiencing any drill deviation or wandering (Singh et al., 2008).

The roots of electrical discharge machining (EDM) can be traced back to as early as 1770 when Joseph Priestly, an English chemist, discovered the erosive effect of electrical sparks ("Surrey Satellite Technology Ltd Scores UK First," 2001). However, it was not until 1943, at Moscow University, that Lazarenko and Lazarenko (Bhattacharyya & Kettle, 1972) harnessed the destructive properties of electrical discharges for constructive purposes. They developed a controlled process for machining challenging metals by vaporizing material from the metal surface. The Lazarenko EDM system utilized a resistance-capacitance power supply, which became widely adopted in EDM machines during the 1950s and served as a model for subsequent EDM developments ("A Review of 'Electro-erosion Machining of

Metals.' by a. L. Livshits. Translated Hy E. Bishop. (London: Butterworths, 1960.) Price 305.," 1961). Around the same time, three American employees conceptualized the use of electrical charges to remove broken taps and drills from hydraulic valves. Their work formed the basis for the vacuum tube EDM machine and an electronic-circuit servo system that automatically maintained the appropriate electrode-to-workpiece spacing (spark gap) for sparking, without direct contact between the electrode and workpiece (YANAGIDA et al., 2021). Figure 2.9 shows the Machine of WEDM.

Figure 2.9 Machine of WEDM (Sathiyaraj *et al.*, 2020b)

2.4.1 The Main Part For Electrical Discharge Machining (WEDM).

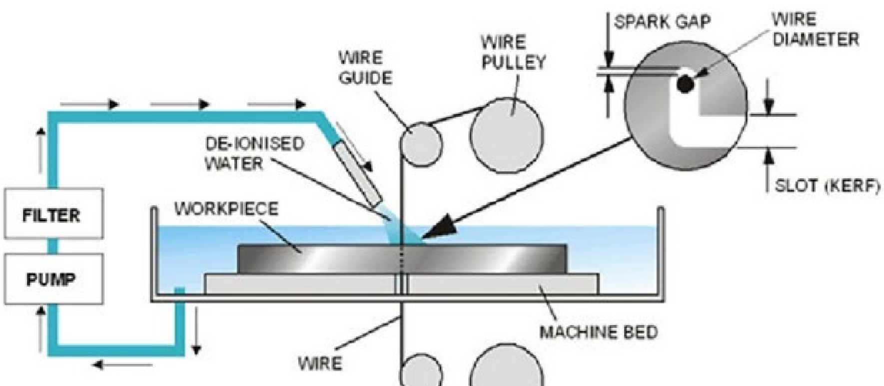

Figure 2.10 Schematic diagram of wire cut WEDM.(D. Vijay Praveen et al, 2020)

I. CNC Tools

CNC tools control the entire Wire EDM machining procedure. Being able to manage the cutting process automatically and sequence the wire path are necessary for controlling the complete procedure.

II. Power Supply

The part that sends pulses (ranging in voltage from 100V to 300V) to the wire electrode and the workpiece is the power supply unit. It also regulates the quantity and intensity of electrical charges that travel through the wire electrode and encounter the workpiece. For Wire EDM machining, a highly developed power supply equipment is required to produce the required quality and type of charges.

III. Wire

To produce the electrical discharge, the wire acts as the electrode. The workpiece's thickness and form have a direct impact on the wire's diameter. Typically, wires with sizes between 0.05 and 0.25 mm can be used.

IV. Dielectric Medium

During the wire cut EDM process, it is essential to have a dielectric fluid present in the tank. This fluid serves multiple purposes, including preventing minute particles from adhering to the wire electrode. The most commonly used medium for this purpose is deionized water. Deionized water not only helps in cooling the process but also contributes to achieving a smooth surface on the workpiece.

V. Electrodes

The workpiece (anode) and the wire (cathode) serve as the machine's electrodes. The wire electrode is controlled by the servo motor, ensuring that it never contacts the workpiece while cutting with wire EDM.

2.4.2 The Process of Electrical Discharge Machining (WEDM)

WEDM (Wire Electrical Discharge Machining) is a widely employed non-traditional method for material removal, as shown in Figure 2.11. The material removal process employed in WEDM is similar to that in electrical discharge machining (EDM). It is widely accepted that the primary mechanism for metal removal in EDM is thermal in nature. The fundamental concept of the EDM process involves a series of electric sparks occurring between the workpiece and wire electrode. The heat generated during the electrical discharge process leads to the melting or evaporation of the surface layers on both the wire electrode and workpiece. The heat also causes the evaporation of the dielectric fluid, resulting in the formation of high-pressure waves that flush away the molten or vaporized metal from the workpiece, creating fragments. The dielectric fluid is continuously supplied and carries away the metal droplets. WEDM is considered a specialized variant of the traditional EDM process. However, WEDM utilizes a continuously moving wire electrode, allowing for the achievement of very small corner radii. This wire electrode is typically made of thin copper, brass, or tungsten material. For optimal performance, it is important that both the workpiece and wire electrode are electrically conductive. (Jatinder Kumar on 01 February 2015)

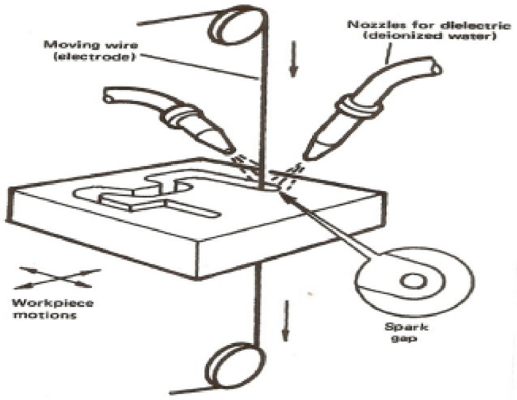

Figure 2.11 Mechanism of wire in WEDM process(Jatinder Kumar, et., al 2015).

2.4.3 Type of Wire For WEDM

The choice of wire electrode material is one of the first choices the WEDM user must make. Depending on the nature of the work piece and its intended use, EDM wires are often produced from a range of materials. There are numerous types of wire materials that are frequently used, including copper, tungsten, brass, and brass with a zinc coating. Typically, the flexibility of wires which is necessary for taper machining and the traction resistance which promotes accuracy are what set them apart. Three key requirements must be met for the perfect wire electrode material: high electrical conductivity, adequate mechanical strength, and good spark and flush properties. There is no perfect wire that excels in every category, according to the information gathered from readings, thus some sacrifices may be necessary. based on the application and the intended results. The most popular wires and their general fields of application are listed below.(Kumar *et al.*, n.d.)

Figure 2.12 Brass Wire (Utem Laboratory)

- *Brass Wire*

  Brass is the most often used material for EDM wire due to its excellent conducting properties. The wire cuts more swiftly the more zinc there is in the copper and zinc alloy, which is a copper and zinc alloy. However, since the rate of corrosion of brass wire is reduced when the zinc concentration exceeds 40%, there needs to be a balance. Figure 2.12 are show brass Wire (Yan-bin Jiang, et, al.2020)

Figure 2.13 Zinc coated wire(M.M. Ali and A.F. Ibrahim,2022)

- Zinc Coated Wire

  As the name implies, obtain it by applying pure zinc or zinc oxide to the wire's surface. Manufacturers employ zinc-coated wires because they speed up machining. (Wayken et al., 2022)

Figure 2.14 Diffusion Annealed Wire (Wayken et al., 2022)

- Diffusion Annealed Wire

The diffusion annealing method is utilized to produce wires with a higher zinc content, typically exceeding 40%. This process involves applying layers of pure zinc coating to the wires. Wires produced through this method have the capability to process a wide range of materials and are particularly well-suited for mass production purposes.

Figure 2.15 Cooper wire

- Coopers Wire

Copper wire was the original wire used in wire EDM. At the time, copper was a sensible choice for an EDM electrode due to its accessibility and high conductivity (100% IACS), but as generators got more powerful, copper's slow cutting speed and low tensile strength (34,000–60,000psi) quickly became apparent. This wire is rarely advised, apart from older equipment that call for the usage of copper wire. There is no other option, hence this wire must be used in these machines to wire-cut all materials.

Figure 2.16 Molybdenum Wire

- Molybdenum Wire

Molybdenum (moly) wire, despite its high tensile strength exceeding 275,000 psi, is considered a suboptimal electrode material due to its high melting and vaporization temperatures of 4,757°F (2,625°C) and 10,040°F (5,560°C), respectively. The high operating temperatures result in smaller EDM craters on the wire's surface compared to brass-based wire, leading to less effective flushing.

However, moly wire is frequently employed in wire EDM when blueprint requirements demand tight kerfs and nearly sharp inside corner radii. It is particularly used in small dimensions ranging from 0.006 to 0.004 inches and fine dimensions of 0.004 inches. Moly wire helps maintain excellent wall straightness and reduces wire breakage frequency, which is common with small and fine brass wires, owing to its high tensile strength.

In certain exceptional cases, such as in medical and military applications, the wire cut surface must not be contaminated with copper or zinc. This requirement prohibits the use of any wires from the copper family and necessitates the utilization of molybdenum or tungsten wire. (Qi *et al.*, 2023)

Figure 2.17 Steel Core-Wire

- Steel-Cores Wire

This wire contains a carbon steel core for high strength and fracture resistance, and it is covered in a thick layer of zinc-rich, diffusion-annealed brass for good cutting properties. This wire might be a solution for challenging applications because of its break-resistance and 50/50 brass performance. Steel-core fine wires (.001"-.004") have a tensile strength of 290,000 psi, which is higher than moly but has far superior cutting properties. Tensile strengths for larger diameters (.006"-.012") are between 116,000 and 145,000 psi. When attempting extremely tall parts, parts that demand good straightness, and parts where poor flushing conditions exist, steel core wire is an option.

Figure 2.18 Tungsten Wire

- Tungsten Wires

When searching for a solution to a difficult application, tungsten wire is frequently one of the final options. Sometimes this wire is the only option for an EDM problem, despite being prohibitively expensive, poorly suited for cutting, and difficult to manipulate. It is the least effective wire electrode for cutting because its melting and vaporisation temperatures are significantly higher than those of moly, 6170°F

(3410°C) and 10,706 (5986°C), respectively. EDM wires with the highest tensile strength include tungsten wire, which is readily available in small diameters (.001"-.002"). This allows it to precisely carve extremely small, straight-walled details. Tungsten wire, like moly wire, is used in applications where cut surfaces must be free of copper and zinc.

2.5 Brass Wire

Figure 2.19 Brass Wire (UTeM Laboratory)

The most common material for EDM wire is brass, Figure 2.19 shows the Brass wire. It is an alloy of copper and zinc, and the wire is more easily cut the more zinc is present in the alloy. However, there must be a balance, as the corrosion rate of brass wire decreases when the zinc concentration exceeds 40 percent. (Yan-bin JIANG, et, al.2020)

Brass is a term used to describe a variety of copper-zinc alloys with varying combinations of properties such as strength, machinability, ductility, wear resistance, electric and thermal conductivity, and many others. Brass is typically the primary decision material for many of the components for equipment made in the general, electrical, and precision engineering industries. Brasses are available in a wide range of products and sizes to enable machines to complete dimensions and are also accepted as the industry standard for the machinability of other materials. Brass exhibits an odd behavior because, unlike other materials, it retains its ductility characteristics when the temperature is lowered. Due to its excellent heat conductivity, brass is also the material of choice for thermal applications. Brass is a very versatile alloy that is often combined with various substances to enhance its general characteristics and distinctive colour. A variety of appealing colours, including red, gold, brown, bronze, and silver, are available in brass. A particular form of brass that has been alloyed with nickel finds extensive use in the sector. These alloys have an additional resistance to stress corrosion cracking because of the 10–20 % of nickel they contain. One of the most popular alloys in use today is brass. There is always a risk associated with using materials like brass on a large scale. Brass, on the other hand, is a very environmentally friendly alloy that can be recycled numerous times and reduces the alloy's manufacturing cost. The environment is owing to the enormous volume of waste. According to a statistic, British manufacturers create the new alloy, which can be utilised in a variety of applications, using 100 percent scrap brass. Unfortunately, its qualities at below-freezing temperatures are given very little attention. In the current work, we are examining the mechanical characteristics of brass at low temperatures and how they change with strain rate and orientation. This study aids in our understanding of brass's low-temperature non-brittle properties. One benefit of copper and its alloys is that as the temperature decreases, they grow stronger and more ductile while maintaining exceptional impact resistance to 20K. Additionally, they can be continuously recycled at temperatures below zero without suffering any performance or quality losses. Additionally, they can be continuously recycled at temperatures below zero without suffering any performance or quality losses. A wide range of applications, including those in the automotive industry, transportation, telecommunications, architecture, industrial machinery, maritime industry, heat exchangers, and renewable energy, can be made with copper and its alloys thanks to the combination of these qualities.(Sandeep *et al.*, 2019)

2.5.1 Mechanical Properties of Brass Wire

Late in the 1970s, brass wire usage in WEDM machining started. After being programmed with the desired shape, these conductive metal wires (diameter 0.05mm to 0.35mm) are utilised in three-dimensional machining. The following characteristics should be prioritized: heat resistance, low clarification, heat release, and electric discharge performance. (Aniza Alias et al,.2012). Brass wire with a diameter of 0.25 mm is used in the current work as a tool. Brass, which has a composition of 63% copper (Cu) and 37% zinc (Zn), is inexpensive, moderately conductive, highly tensile, flushable, and widely available.

Brass wire can be die-cast or extruded for specialized applications and is commonly used in WEDM processes due to its excellent machining properties. Some researchers [13, 14] used brass wire as the WEDM electrode due to its high tensile strength, high electrical conductivity, and good wire durability to close tolerances. The optimal wire electrode material for this process satisfies three essential criteria: high electrical conductivity, adequate mechanical strength, and optimal sparks and flushes characteristics.

2.5.2 Recycling Technologies

Recycling is commonly understood as the process of reusing waste materials, which may involve various processes to recover or transform them into new products, materials, or ingredients. The concept of the circular economy, also referred to as zero-waste manufacturing, is an industrial system that promotes the remanufacturing, reuse, and recycling of products at the end of their life cycle (EOL) (Berger et al., 2020; Karuppannan

Goparaj & Karki, 2020). Embracing closed-loop recycling is a crucial strategy for industries in the modern world to advance the principles of a circular economy. This approach focuses on designing systems that allow materials to be recycled and reintegrated into the production cycle, minimizing waste, and promoting sustainability. In addition, recycling composite materials is particularly effective due to their physical properties that facilitate transformation. In conclusion, a circular economy not only aids in the elimination of toxic materials and waste, but also results in the production of mechanically sound products (Demets et al., 2021). Recycling is beneficial not only for solid waste management but also for circular economy and sustainable technologies. The United Nations established the sustainable development goals (SDG) in 2015, which are the most important societal goals (Saha et al., 2021). Recycling technologies have the potential to contribute to the attainment of several Sustainable Development Goals. Recycling technologies, for instance, facilitate the reuse of waste materials, thereby reducing overall waste, fostering a cleaner environment, and improving the quality of life for all species (Khalid et al., 2021). As depicted in Fig. 2.20, these benefits ultimately contribute to the achievement of Sustainable Development Goals such as (Goal 6: Clean water and sanitation), (Goal 13: Climate action), and (Goal 17: Quality education) (Goal 15: Life on land).

In addition, recycling is particularly effective for composite materials due to their physical characteristics that facilitate transformation. In conclusion, a circular economy not only aids in the elimination of toxic materials and waste, but also results in the creation of products with the proper mechanical properties (Demets et al., 2021). Recycling is valuable not only for solid waste management, but also for the concepts of circular economy and sustainable technologies. The sustainable development goals (SDG) established by the United Nations in 2015 are the most important societal objectives (Saha et al., 2021). Recycling technologies have the potential to help achieve some of the Sustainable

Development Goals. For instance, recycling technologies aid in the reuse of waste materials, thereby reducing overall waste, fostering a cleaner environment, and enhancing the quality of life for all species (Khalid et al., 2021). As depicted in Figure 2.20, these benefits ultimately contribute to the achievement of SDGs such as (Goal 6: Clean water and sanitation), (Goal 13: Climate action), and (Goal 15: Life on land). (Khalid et al., 2021)

Figure 2.20 The schematic diagram show the SDG goals for recycling and reusing of materials. (Khalid et al., 2021)

2.6 Fiber glass

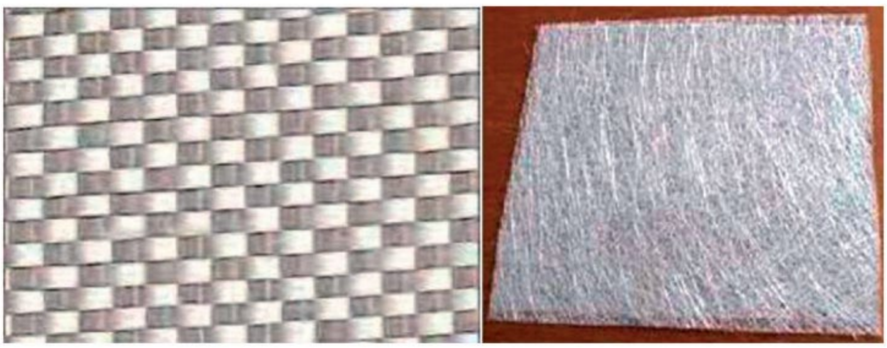

Figure 2.21 Fiber glass (Sathishkumar *et al.*, 2014)

Composite materials are composed of two or more materials combined to achieve properties that cannot be achieved by either the fiber or matrix alone. Optical fiber reinforced polymer composites, specifically Glass Fiber Reinforced Polymers (GFRP), find extensive use in various engineering applications. The mechanical behavior of reinforced composites depends on the stability of the fibers, strength of the matrix, and Young's modulus. By carefully selecting the orientation and composition of glass fibers, GFRP composites can exhibit desirable characteristics and functional attributes comparable to steel, with higher stiffness than aluminum and lower relative density than steel. These superior properties make GFRP composites an attractive alternative to steel in certain applications. Optical fiber reinforced composites, with their cost-effectiveness and exceptional strength, are widely employed in polymer matrix composites. Staple or continuous glass fibers can be augmented with SiO2. S-type glass contains higher amounts of silicon and aluminum compared to E-type glass, each offering distinct properties suitable for different applications. The matrix materials bind the fibers together and transfer loads and stresses between them. The maximum operating temperature of the composite is determined by the matrix material, which can be classified into two main categories: thermoplastics and thermosets, based on their glass transition temperatures. The high cost of polymers initially limited their commercial applications. However, the addition of fillers has improved the characteristics of composites while reducing the cost of the base materials and the final products. Laminated GFRP composite materials find applications in the marine and piping industries due to their excellent environmental resistance, damage tolerance against impact loading, high specific strength, and stiffness. Figure 2.21 illustrates fiber glass.

In the aviation industry, polymeric composites are widely used for components such as rudders, landing gear, doors, and for aesthetic purposes. These composites offer low weight and high resistance to fatigue, making them advantageous for aviation applications. (Morampudi et al., 2020)

2.6.1 Mechanical Properties of Fiber Glass

Atas et al.18 studied the impact response of GF-reinforced woven mat composites with orthogonal and non-orthogonal fabric at weaving angles of 20, 30, 45, 60, 75, and 90 degrees from the vertical (warp direction), respectively. With a reduction in the weaving angle between the interlacing threads, more energy was absorbed. The peak force, contact time, deflection, and absorbed energy of woven composites with smaller weaving angles of 20 and 30 between interlacing yarns are higher than those with larger weaving angles of 60, 75, and 90. In comparison to [0/90] woven composite, [0/20] woven composite absorbed more energy.

Alam et al.6 looked at the effects of different fibre orientations, such as 0, 45, and 90, on chopped strand and roving GFRP composites. Neither the density of the composites nor their hardness had an impact on the fibre orientation. The maximum tensile strength was attained with a fibre orientation of 90. The impact strength was shown to be decreased by the short fibre.

Unidirectional glass fibre reinforced composites' behaviour and material characteristics under static and low temperature circumstances have been examined. In low temperatures, he studied the behaviour of G11 woven glass composite laminates with temperature-dependent material properties. In his study, he employed epoxy resin as the selection and peer-review material and unidirectional glass fibres as the reinforcing material.

Both were done under the supervision of the scientific committee of the first international conference on energy, material sciences, and mechanical engineering. substance for the matrix. The unidirectional laminates can be created by hand-laying processes.

They were chopped after being cured for seven days at room temperature. These unidirectional laminates are put through tensile, compressive, and shear testing at both room temperature and below. It is discovered that as the temperature drops, laminates' tensile strength and young's modulus increase till fracture. In addition, brittleness increases quickly at cryogenic temperatures. The relationship between shear stress and strain is slightly nonlinear, and catastrophic failure always happens at the final stage. The interaction between the fibres and matrix is to blame for this. Compressive stress at low temperatures causes unidirectional laminates to cure imperfectly, and this behaviour was linked to the plastic deformation of polymeric matrix. At all temperatures, measurements for in-plane shear stress have displayed significantly nonlinear behaviour. (Torabizadeh, Mohammad A et al.,2013)

2.6.2 Application of Fiber Glass

Electronics: The fabrication of circuit boards (PCBs), TVs, radios, computers, cell phones, electrical motor covers, etc. has seen extensive use of GRP Figure 2.22 is illustrated of application fiber of various factor. Property and furnishings: exhibit racks, book racks, tea tables, sunshades, roof sheets, bathroom furniture, etc. GRP has been widely employed in the aviation and aerospace industries, although it is not frequently used for the primary airframe construction because there are other materials that are more appropriate for the purposes. Engine cowlings, luggage racks, instrument enclosures, bulkheads, ducting, storage bins, and antenna enclosures are examples of common GRP applications. Additionally, it is commonly utilised in ground-handling machinery. Marine and boats: Its qualities make it the perfect material for making boats. Despite issues with water absorption, contemporary resins are utilized to create the basic type of boats since they are more durable. In actuality, GRP is a lighter material than materials like wood and metal. Medical: The low porosity, stain-resistance, and durable finish of GRP make it a popular choice for medical applications. GRP is used to construct everything from instrument enclosures to X-ray beds (where X-ray transparency is crucial). Automobiles: GRP has been widely utilized for automotive components such engine covers, bumpers, door panels, seat cover plates, and body panels. Although tooling costs are relatively modest as compared to metal assemblies, GRP has been widely employed to replace the current metal and non-metal parts in many applications.(Organization, Structure and Properties of Materials, n.d.; Sathishkumar et al., 2014)

Figure 2.22 Application of Fiber in various factor

2.7 Matrix

In such materials, the matrix just acts as a binder for the fibres, keeping them in the desired shape and guarding against mechanical or chemical harm. Polymers, metals, and ceramics are the three categories of matrix materials (Fig. 2.23). These sorts of features vary greatly from one another and have a significant impact on the characteristics of the composites they are used in.

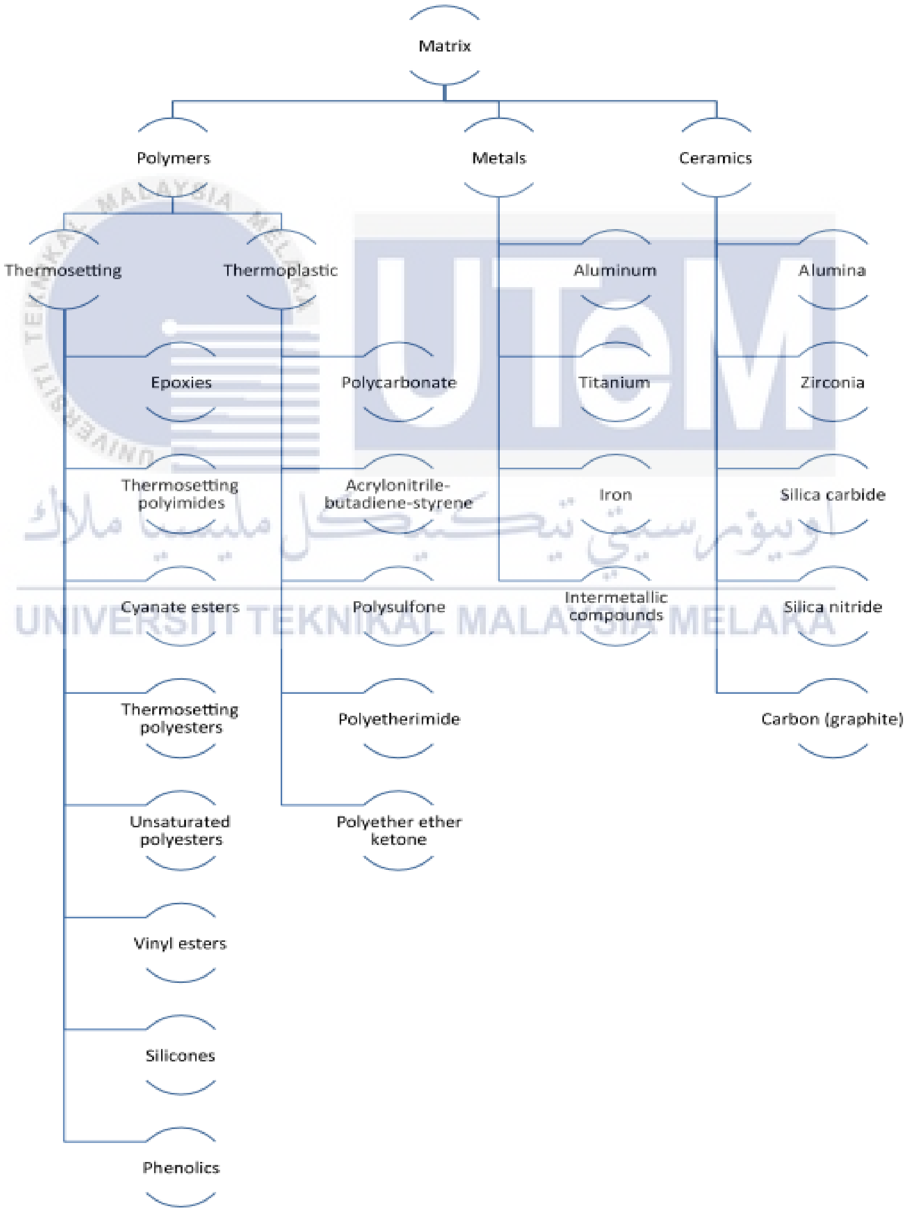

Figure 2.23 Type of matrix (Anon, n.d.)

In general, polymer matrices are viscoelastic, low-stiffness materials that are quite weak; in reality, the main source of mechanical strength and stiffness is the reinforcing fibres or particles. Thermosets and thermoplastics are the two main categories of polymers utilised as matrix materials. Thermosets are currently the most commonly utilised matrix resins for structural applications in industrial settings, though thermosets are steadily gaining ground. resins that set in the heat. Epoxies, thermosetting polyimides, cyanate esters, thermosetting polyesters, unsaturated polyesters, vinyl esters, silicones, and phenolics are the main types of thermosetting resins used in composites; it should be noted that this list is constantly growing.

2.7.1 Epoxy Resin

In 1909, Prileschajew made the discovery of epoxy resins Figure 2.24 are shows structure of epoxy resin. These resins are characterized by their low-molecular-weight pre-polymers, which contain multiple epoxide groups (C. A may., et.al 1998). Epoxy resins belong to the category of thermosetting resins and undergo curing reactions with various curing agents. The properties of epoxy resins are determined by the specific ratio of curing agents to epoxy resins employed. Due to their outstanding mechanical properties, strong adhesion to various substrates, and excellent resistance to heat and chemicals, epoxy resins are widely utilized in diverse fields. They find extensive applications such as fiber-reinforced materials, general-purpose adhesives, high-performance coatings, and encapsulating materials. Their versatility makes them highly sought after in different industries.

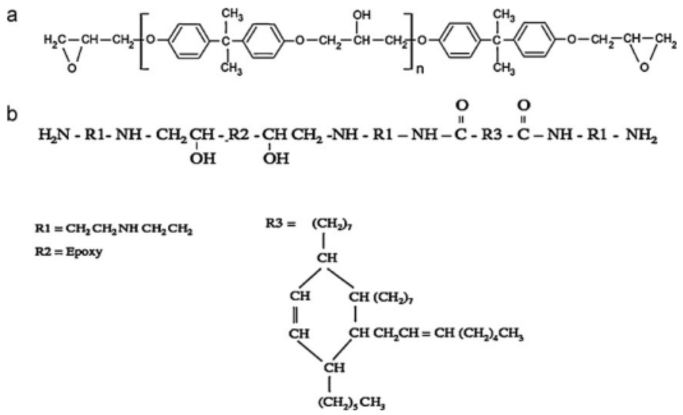

Figure 2.24 Structure epoxy resin(parves.,et al 2014)

Epoxies are utilised to create composites with superior structural qualities, such as those used in aerospace applications like airframe structures. Although epoxies are more expensive than other thermosetting polymeric matrices, they are the material of choice for carbon- and aramid-fiber reinforced composites because of their advantages over other, more brittle materials. Due to their low cost, simplicity of processing, and resistance to corrosion, polyester resins are the most popular resins in commercial applications. In boat hulls, construction panels, and structural panels for the automotive and aerospace industries, unsaturated polyesters are frequently utilized as matrix for fiber-reinforced composites (parves., et al 2014)

Table 2.1 Material properties of matrix

Material	Properties	Notes
Epoxy	Good chemical resistance Moderate thermal resistance	Maximum temperature < 100 °C
Phenolic	Good chemical resistance Moderate thermal resistance Good fire resistance	

2.8 Effect of Fiber Orientation and Thickness Using Glass Fiber Reinforcement to Impact Conditions

examine the impact of fibre orientation and thickness while using glass fibre reinforced polymers. Composite materials are susceptible to impact conditions. The ability to absorb energy and have a ballistic limit were claimed for laminates. They employed an air cannon and a sturdy 9.5 mm diameter conical bullet weighing 7.5 g as their test subject. Fibre-woven glass cloth and epoxy resin were used to create the composite laminates. The projectile was fired in experiments using a gas piston that was powered by compressed air. To determine the projectile's ballistic limit, it was stimulated at various angles and velocities. When moving slowly, it made an indentation in the plate but did not break through. The energy and ballistic constraints that were present at that examined and tabulated based on location. The velocity of 170 m/s is fixed, and projectiles were shot at various thicknesses and fibre directions to review the causes of thickness on the glass/epoxy laminates. When the modulus of elasticity at greater strain rates are considered, the experimental analysis and mathematical analysis demonstrate that the glass/epoxy composites have better agreement with impact loading. Increases in projectile speed result in a reduction in the damage area at velocities that were above the ballistic range. As the modulus and failure strain of the dynamic young grow, so do the laminates' capacity to absorb energy and their ballistic limit. (Sikarwar, Rahul S et al.,2014)

2.8.1 Effect of Fiber Loading, Tensile Orientation, And Impact Strength Of Composites Polymer Materials

Research was done on how impact strength, tensile orientation, and fibre loading affected composite polymeric materials. This research paper's fundamental argument is that fibre loading, and fibre direction define the properties of composite materials. They claim that fibre loading affects the mechanical and corrosion resistance properties of reinforced composites as well as the strength of polymer composites. The percentage of fibre volume in GFRP composites also increases the qualities of strength and stiffness. In addition to mechanical characteristics, the composite material's thermal conductivity is improved. 10% more fibre volume will increase this proportion. In this experiment, manual lay-up was used to create fibre reinforced composites. The reinforcement material for epoxy resin ampreg-21 is woven E glass. They created five distinct Composite sheets with various levels of fibre augmentation, and the output parameters were based on various ratios of the loads and orientations of the fibres. Despite their orientation, it is discovered that fibre volume increases impact strength. Increase in impact energy is a reasonable indicator of the direction effect. (Adekomaya, O et al,2017)

2.9 Testing Of Composites

2.9.1 Tensile Test

Tensile testing is a mechanical testing method that involves subjecting a material to uniaxial stress until it reaches its point of failure. To conduct tensile testing, carefully machined specimens of defined dimensions and gripping ends are prepared according to the specified standards. Machinists employ various techniques such as manual machining, automated CNC solutions, wire EDM, or water jet machining. Once the test specimens are fabricated, they are placed into a Universal Testing Machine, ensuring proper alignment. During the testing process, strain gauges are employed to measure the rate of strain as required. Tensile testing results include parameters such as ultimate tensile strength, maximum elongation, and area reduction. Additionally, these measurements enable the determination of other material properties including Young's modulus, Poisson's ratio, yield strength, and strain hardening characteristics. Tensile testing is a destructive procedure, but it provides valuable insights into the mechanical properties of materials, aiding in their characterization and performance evaluation.(R. *et al.*, 2022)

The Universal Testing Machine (UTM) used for the tensile test is depicted in Figure 2.25 and was manufactured by Fine Instrument Engineering Limited in Poona, 1979. The specific model is Al-UTE 600kN. The tension test was performed on specimens according to ASTM D3039 standards. The dimensions of the specimens were 210 mm x 20 mm x 6 mm, with a gauge length of 150 mm. The test was conducted at a strain rate of 2 mm/minute. Three specimens were tested for each variation, and the results were recorded (Krishnakumar et al., 2013).

The tensile properties of the glass fiber were found to increase with a higher content of glass fiber. This enhancement in strength can be attributed to the presence of high-strength glass fibers combined with the polymer matrix. For composites with a glass fiber content of 70% by weight.(Kumar and Ravikiran, 2018)

Figure 2.25 Universal testing Machine(Kumar and Ravikiran, 2018)

2.9.2 Impact Test

Impact testing is a destructive mechanical method used to assess the ability of a material to withstand high-rate loading or absorb energy from dynamic collisions. It involves conducting impact tests such as the Charpy and Izod tests to measure the amount of energy a material can absorb during a specific impact event. During the impact test, a test apparatus consisting of a pendulum-like arm with an attached impact hammer is utilized. The pendulum is dropped from a known height and strikes the test specimen. The energy absorbed by the pendulum upon impact is accurately measured using specialized technology. The energy absorption characteristics of a material are crucial as they indicate its ability to withstand plastic deformation before experiencing catastrophic failure. The amount of energy absorbed is also indicative of the material's brittleness. Brittle materials like ceramics or glass tend to absorb less energy compared to ductile materials like copper or aluminum. Impact testing provides valuable information about a material's resistance to sudden impact or dynamic loading, making it an essential tool for assessing its performance and suitability for specific applications.(R. *et al.*, 2022)

The impact test specimens, as illustrated in Figure 2.26, were prepared in accordance with the ASTM D256 standard. The test was conducted using a pendulum impact tester, specifically the IT-30 model, which has a maximum energy capacity range of 300J/170J. The notched Izod impact test specimen has dimensions of 63.5 mm x 12.7 mm, with a thickness of 4 ±0.2 mm. The specimen features a V-notch with an angle of 45 degrees and a depth of 2 mm, which was created using a milling machine. To calculate the cross-sectional area of the specimen, the width and breadth of the specimen need to be determined.

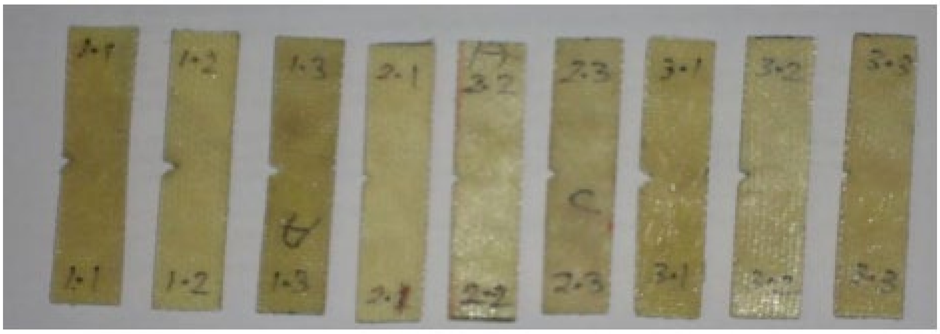

Figure 2.26 Impact Test (Kumar and Ravikiran, 2018)

The "V" notch is a crucial element in conducting the Impact test. To carry out the Impact test, the testing specimens should be properly positioned on the Pendulum impact tester using fixtures as specified in the standard. The test results are obtained by directly reading the scale on the machine, indicated by a pointer. This reading represents the energy absorbed by the specimen during the impact.

In your case, the tests were performed on E glass woven fabric reinforced polymer matrix composites with volume fractions of 60%, 65%, and 70%.(Kumar and Ravikiran, 2018)

2.9.3 Flexural Test

Flexural testing is commonly used to evaluate the bending or flexural properties of materials. In this test, a specimen is placed on a support span and subjected to a predetermined load until it fractures. The maximum force recorded during the test represents the flexural strength of the material under examination. The flexural strength and flexural modulus are commonly determined through the flexure test. Flexural strength refers to the maximum stress experienced by the outermost fiber on either the compression or tension side of the specimen. It provides insights into the material's ability to resist bending or flexing without fracturing. By conducting flexural testing, engineers and researchers can gain valuable information about a material's structural integrity, stiffness, and ability to withstand bending forces. This information is crucial for designing and evaluating materials for various applications, such as beams, columns, and other structural components subjected to bending loads.(R. *et al.*, 2022)

The test specimens for the flexural bending test were prepared following the ASTM D790 standard. The test was conducted using the three-point flexural bending method. A universal testing machine, equipped with flexural test fixtures, was used to perform the test with a displacement velocity of 1.5 mm/min. The specimens used in the test had a rectangular cross-section with dimensions of 127 mm x 12.7 mm x 3 mm. The test was carried out under room temperature conditions. During the test, a load was applied to the top of the specimen, causing bending in the center portion, while the lower part of the specimen experienced tension, as shown in Figure 2.27. Readings were recorded for the corresponding load and deflection measurements. The tests were conducted on E glass woven fabric reinforced polymer matrix composites with volume fractions of 60%, 65%, and 70%.(Kumar and Ravikiran, 2018)

Figure 2.27 Flexural Testing Machine (Kumar and Ravikiran, 2018)

2.10 Fiber Material Used in Body Amour System

Extensive research is being conducted to enhance body armor and protect BAS-based synthetic fibers against high-velocity impacts, such as projectiles. These impacts pose significant risks in various ballistic and civilian applications, including helmets and military vehicles. Synthetic fibers are chosen for their desirable properties, including high modulus, high specific toughness, and low density. These characteristics enable synthetic fibers to effectively absorb and dissipate impact energy, providing enhanced protection to the wearer. The development of body armor using synthetic fibers aims to improve the overall safety and performance of individuals in high-risk situations. Table 2.2: General bulletproof material properties for military and defence applications. (Dharani Kumar et al., 2023)

Table 2.2 Material properties of general bulletproof material used in military and defence application (Abtew et al., 2019)

Fibre type	Tensile strength (MPa)	Tensile modulus (GPa)	Elongation at rupture (%)	Density kg/m3)
E-glass	3100–4800	75–89	4.65–2.71	2478–2619
S-glass	4438	91.0	5.7	2482
Carbon	3400–6100	231–545	0.6–2.0	1728–1919
Dyneema	2850–3690	87	3.4	953–1010
Nylon 6–6	1140	9	16–19.5	1140
Kevlar 29	2900	73	11.3–29.8	1440
Kevlar 49	2800	104	2.48	–
Kevlar 129	3300	94	3.46	–
Kevlar – KM2	3428	63	4.28	–
Twaron	2300–3500	61–119	2.12–3.96	1139–1451
Technora	3300	3.8	4.58	1388
Silcom carbide	4000	418	0.58	2814
Boron carbide	3448–4192	418–448	3.8	2642
Spectra	2100–3290	65–119	2.85–3.74	970
Alumina	1698	151.5	2.0	2448
PIPD (M5)	3950–9450	272–449	1.62–2.78	1700
PBO	5750	182–269	2.49–3.69	1538–1559
PBZT	4095	324	1.1–2.4	1579

2.11 Ballistic Performance of Glass Fiber

Glass fibres have lower stiffness and strength than carbon fibres, but greater strain-to-failure characteristics. Carbon fibres are more expensive than glass fibres. Glass fibres are a diverse group of materials composed of silica and minerals. They were categorised according to their functions, composition, and final uses. S-glass fibre and C-glass fibre are chemically resistant and possess high strength. Mglass fibre has high rigidity. E-glass fibre and S-glass are electrically insulating. E-glass fibre is commonly used in ballistic composites reinforced with glass. Due to its tensile strength, elasticity, heat resistance, and chemical resistance, it provides tremendous power deposition and protection against impacts, fire, hazardous chemicals, and gas. High-velocity impact was used by Rahman et al. to investigate E-glass/epoxy containing MWCNT. According to them, adding MWCNT to the composite increased its ballistic limit by approximately 5 percent. Bernasconi et al. fabricated a glass/polyamide thermoplastic composite using injection moulding. For example, E and glass are being studied for ballistic armour. According to the aforementioned review article, the addition of E-glass reinforcement to carbon fiber-based composites improves their impact resistance. According to Sabouri et al., the thickness of the glass/epoxy layers remains constant when different aluminium thicknesses are used at different locations, thereby enhancing ballistic resistance. Naik et al. evaluated the ballistic properties of E-glass/epoxy hybrid composites against flat projectiles using analytical and empirical methods. The research examined the ballistic limit velocities of various objects based on the amount of energy they absorb. Shaktivesh et al. compared E-glass and steel in terms of target plate thickness as determined by the ballistic limit. Ganesh et al. conducted research on the energy absorption of E-glass laminate. They found that woven fibre rugs outperformed continuous fibre composites in terms of energy retention and ballistic resistance. (Babu et al., 2008).

2.12 Summary

The primary focus of this literature review is to explore the impact of EDM wire cut waste in long fiber form on the mechanical properties of laminated glass composites. There is a wealth of published resources available on this subject. EDM wire cutting, a precise method used in cutting metal components, plays a significant role in this process. Composite materials, which result from combining multiple materials to create a new material with unique properties, consist of a matrix and reinforcement. The reinforcement is responsible for providing strength to the composites. Classifying composites is based on the length of the fibers used. Polymer matrix composites, metal matrix composites, and ceramic matrix composites are commonly employed in various industries. Different types of reinforcement fibers, including glass fibers, carbon fibers, and synthetic fibers, are utilized to enhance the properties of composites.

The choice of matrix material has a significant impact on the cost and manufacturing of composite materials. In polymer matrix composites, reinforcement is used to enhance strength, stiffness, and fracture toughness. These composites offer a combination of polymer advantages and reinforced phase strength. Thermosets and thermoplastics are commonly used as matrix materials in polymer composites. Ceramic matrix composites (CMC) have gained attention due to their lightweight nature, high specific strength, temperature resistance, and corrosion resistance. CMCs utilize ceramic fibers embedded in a ceramic matrix to achieve exceptional properties. Various types of reinforcement fibers, such as glass fibers, carbon fibers, and aramid fibers, are employed in composites. Synthetic fibers (SFs) are increasingly important in fiber-reinforced composite structures due to their high strength and inertia. Glass fibers (GFs) offer numerous advantages in composite materials, including high strength, low density, and resistance to environmental factors. Non-traditional methods like Electrical Discharge Machining (EDM) and Wire Electrical Discharge Machining (WEDM) are utilized for material removal. The choice of wire electrode material is critical in WEDM and includes options like copper, tungsten, brass, and zinc-coated brass. Recycling technologies play a significant role in transforming and reusing composite materials. Glass fiber-reinforced polymers (GFRP) find extensive applications in engineering, thanks to their excellent mechanical behavior, environmental resistance, and high specific strength. The orientation, composition, and thickness of fibers within composites influence their properties. Tensile testing, impact testing, and flexural testing are commonly employed to evaluate the mechanical properties of composites. Ongoing research aims to enhance ballistic panel using fiber materials such as glass fibers brass wire waste.

CHAPTER 3

METHODOLOGY

3.1 Overview of methodology

Chapter 3 talks about the detailed plan and method used to produce specimens for low impact ballistic impact testing to guarantee that all the listed objectives can be achieved. Chapter 3 will examine and describe all the materials used, the design of low impact ballistic testing on mechanical properties, and the fabrication method. Next, this chapter shows the analysis of this research in detail. Furthermore, this research is following the standard operating procedure (SOP) of the American Society for Testing Materials (ASTM), which includes standard testing methodology, instruments, and techniques. The raw material is begun with material preparation and the processing of sample specimens. Figure 3.1 is a description of the procedure required for this research. last but not least, the materials used are woven roving glass fibre and long wire brass as a reinforcement and epoxy resin and hardener as a matrix. The fabrication used for making specimen samples is hand-layup techniques to combine the two-materials reinforcement combined with matrix will produce composites.

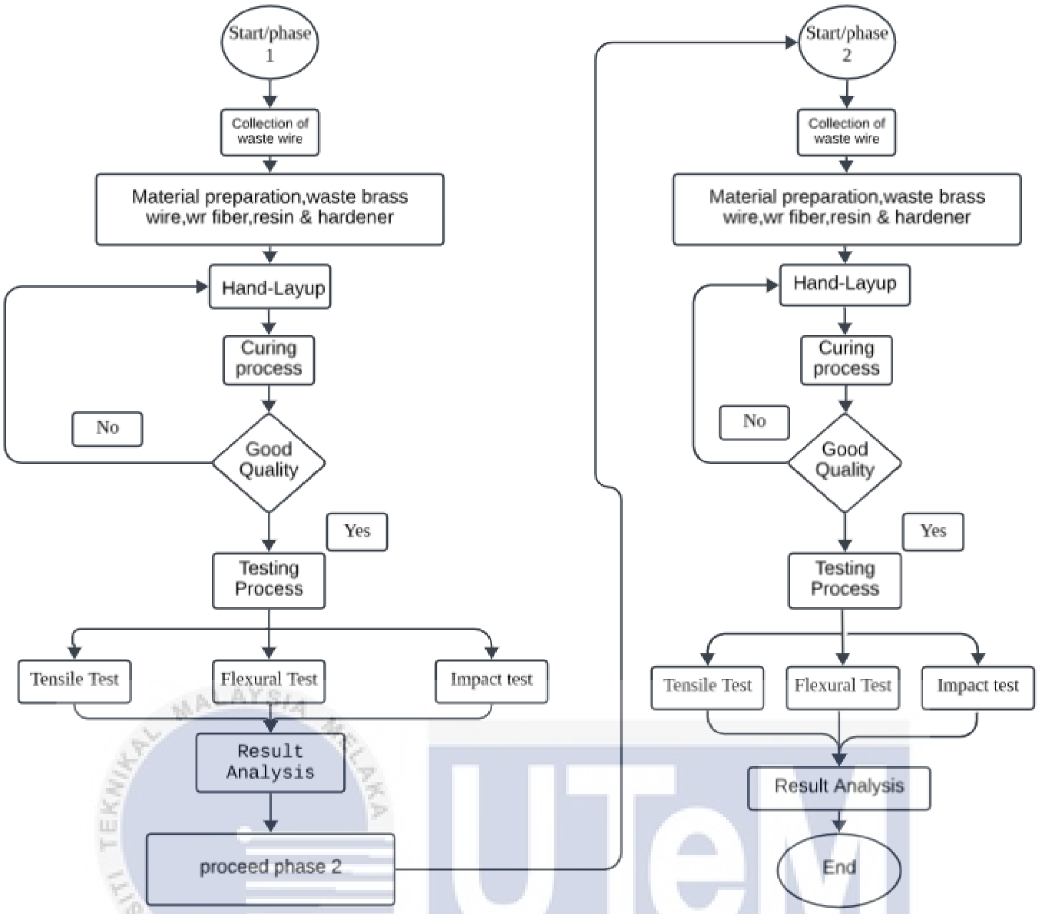

Figure 3.1Flow Chart Of Research Study.

3.2 Raw material preparation Phase 1 and Phase 2

For this experiment, some materials need to be prepared to be used in the hand-layup process. The materials that need to be prepared are woven roving E-glass fibre and long brass wire as reinforcement, as well as epoxy resin and hardener as a matrix to make it a composite material. Picture 3.2 shows the materials needed: a) woven roving fibre glass; b) long brass wire waste; c) epoxy resin + hardener. According to the market price of all the materials, woven roving fibre glass is Rm 18.00 per metre, long brass wire is taken from the lab in Utem, which is waste from the WEDM machine, and epoxy resin + hardener is Rm 250.00 per kilogram.

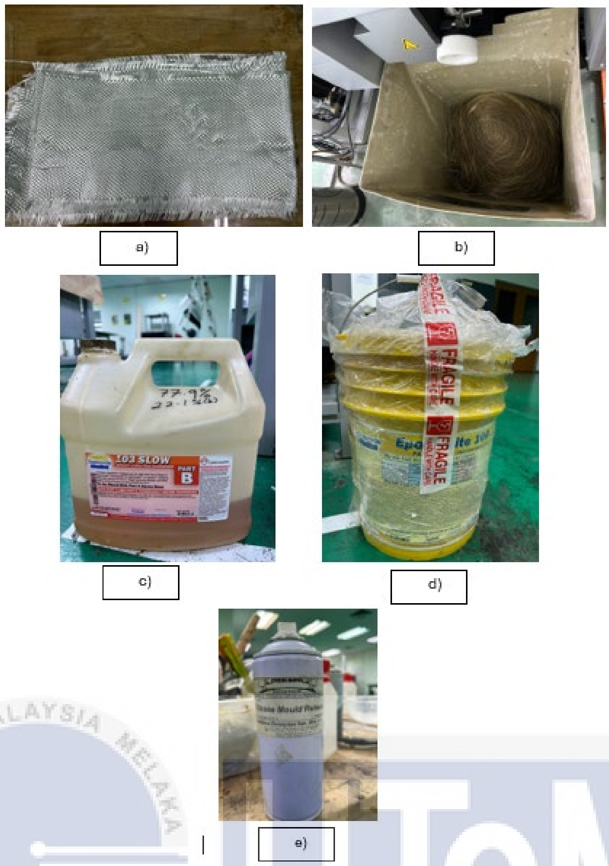

Figure 3.2 Raw material for Hand-layup process (a) woven roving fiber E-glass; (b) Brass Wire Waste; (c) Hardener; (d) Epoxy; (e) Mould Release.

3.2.1 Collection Of Brass Wire Waste Phase 1 and Phase 2.

To prepare brass wire waste, will be collected at Utem laboratory at Factory 2 in wire electrical discharge machining (WEDM) machine. In the lab there are two machines of WEDM with different diameter which is 0.20mm and 0.25mm for both machine WEDM, so it will be decided whether to use both wire or just used only one brass wire waste to prepared as reinforcement. Figure 3.3 shows the wire electrical discharge machining (WEDM) and Figure 3.4 shows brass waste wire.

Figure 3.3 Wire Electrical Discharge Machining(Utem Laboratory)

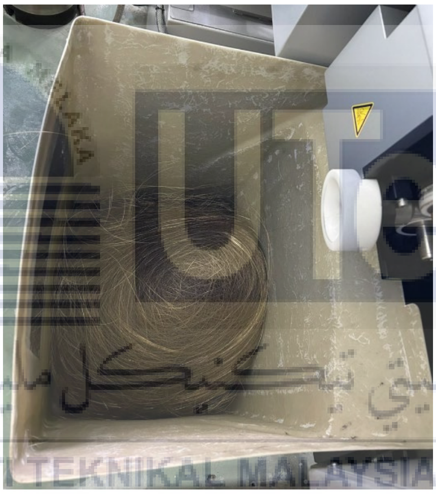

Figure 3.4 Brass Waste Wire (Utem Laboratory)

3.2.2 Calculation of The material and matrix used in Theoretical

To know resin used quantities of woven roving E-glass fiber, brass wire waste and epoxy resin used in this research, based on the theoretical the density for two materials and matrix should determine the value of density and thickness to calculate the volume of three materials which brass wire waste density is 8.6 g/cm^3,woven roving E-glass is 2.2 g/cm^3 and density of epoxy is 1.2 g/cm^3.the thickness of all laminated will be planned for 9 mm.

To calculate the volume of waste brass wire and epoxy for tensile test, flexural test, impact test, drop tower test and impact test. The total full thickness of all composites laminated should be terminated by the thickness of woven roving E-glass fibre, as the information of research the thickness of woven roving E-glass fiber is 0.43mm. After that, the volume of brass wire waste mixed with epoxy resin for all mechanical testing can be calculated following the formula in equation (2). After the volume obtained, the mass for brass wire waste and epoxy resin can be calculated by using the formula in equation (3) and (4).

$$volume = Length \times Width \times thickness \tag{2}$$

$$Ratio\ Volume = Ratio\ Percentage \times Volume \tag{3}$$

$$Density, \rho = \frac{mass, m}{volume, v} \tag{4}$$

In equation (4), the density represents the density of either epoxy resin or brass wire waste materials. Based on the research, the density range for epoxy resin is 1.2 - 1.3 g/cm³, while for brass wire waste, it is 8.4 – 8.73 g/cm³. To calculate the mass, the average density of epoxy resin (1.25 g/cm³) and brass waste wire (8.6g/cm³) is used.

Next, the mass of both materials is calculated. The calculation for the impact test follows the same procedure as the tensile test, drop tower test, flexural tests, and ballistic test. The thickness of the woven roving fiber needs to be subtracted from the full composite thickness of 9 mm. Once the volume is determined, the mass of the materials can be calculated using the formulas in equations (3) and (4).

3.3 Preparation of Hand-layup Phase 1.

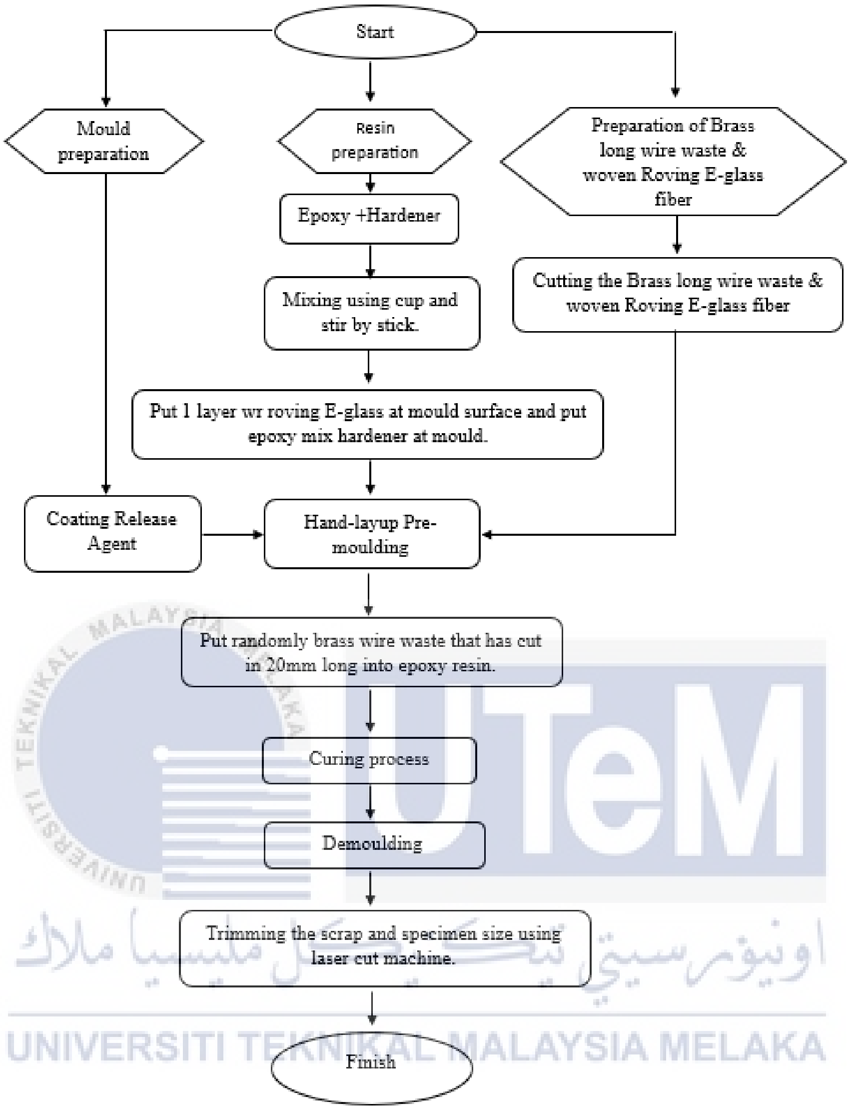

Figure 3.5 Flow/process Chart in phase 1

For hand-layup preparation in phase 1, it have several steps to setup, which include preparing the mould will be on the size length 300mm x width 240mm x thickness 20mm and cutting the material, such as woven roving glass fibre in size 270 mm length x 240 mm and brass wire waste in long fiber form size 10 mm to 50 mm. Do the preparation of the mould to be used; for example, clean first the surface of the mould before proceeding with hand-layup laminated. In order to facilitate easy extraction, fiber preforms are first placed in a mould with a thin antiadhesive coating.

In Figure 3.5 show the flow chart of Hand-Layup process and 3.6 show the woven roving E-glass fiber already cut, and Figure 3.7 for hand-layup technique.

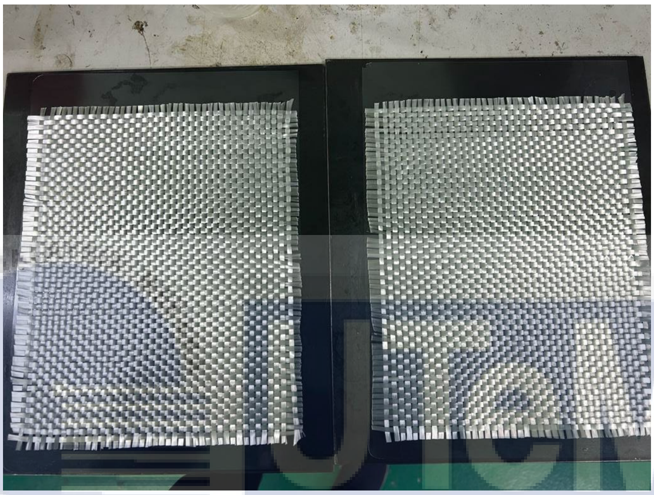

Figure 3.6Woven Roving E-glass Fiber Fabric Geometry for cutting.

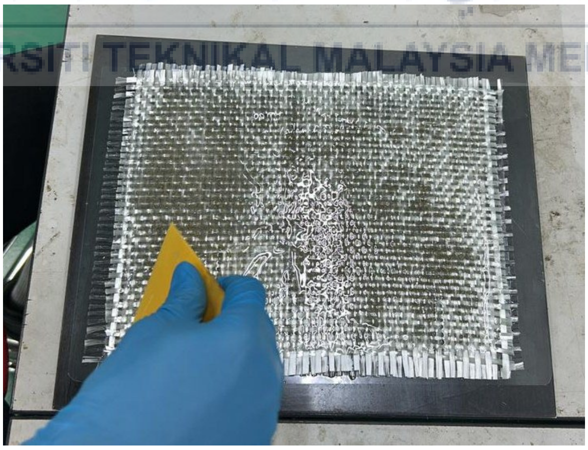

Figure 3.7Hand-layup process open mould.

Table 3.1 Classified specimen layered by layered in phase 1.

Ratio (%)	Fiber glass (f2)	Ratio (%)	Fiber glass (f2)
10	Brass wire waste (w1)	20	Brass wire waste (w1)
	Fiber glass (f1)		Fiber glass (f1)
Ratio (%)	Fiber glass (f2)	Ratio (%)	Fiber glass (f2)
30	Brass wire waste (w1)	40	Brass wire waste (w1)
	Fiber glass (f1)		Fiber glass (f1)
Ratio (%)	Fiber glass (f2)	Ratio (%)	Fiber glass (f2)
50	Brass wire waste (w1)	60	Brass wire waste (w1)
	Fiber glass (f1)		Fiber glass (f1)
Ratio (%)	Fiber glass (f2)	Ratio (%)	Fiber glass (f2)
70	Brass wire waste (w1)	80	Brass wire waste (w1)
	Fiber glass (f1)		Fiber glass (f1)
Ratio (%)	Fiber glass (f2)		
90	Brass wire waste (w1)		
	Fiber glass (f1)		

Figure 3.8Open mould plate.

For the laminating process, all materials, including long brass wire and woven roving glass fibre, will be merged with epoxy resin and hardener. This matrix's ratio and the fibre ratio for reinforcing are as follows. The laminating procedure will be carried out layer by layer. For the laminating process, epoxy resin and hardener will be blended with all materials, including woven roving glass fibre and long brass wire will be put into the epoxy resin randomly Figure 3.8 show method of laminating process using open mould. The fibre ratios for reinforcing are employed in this matrix at a ratio followed table 3.1, and the laminating process will be carried out layer by layer. Next, the orientation for the laminating procedure is the 0/90 direction.

3.3.1 Preparation of Hand-layup Phase 2.

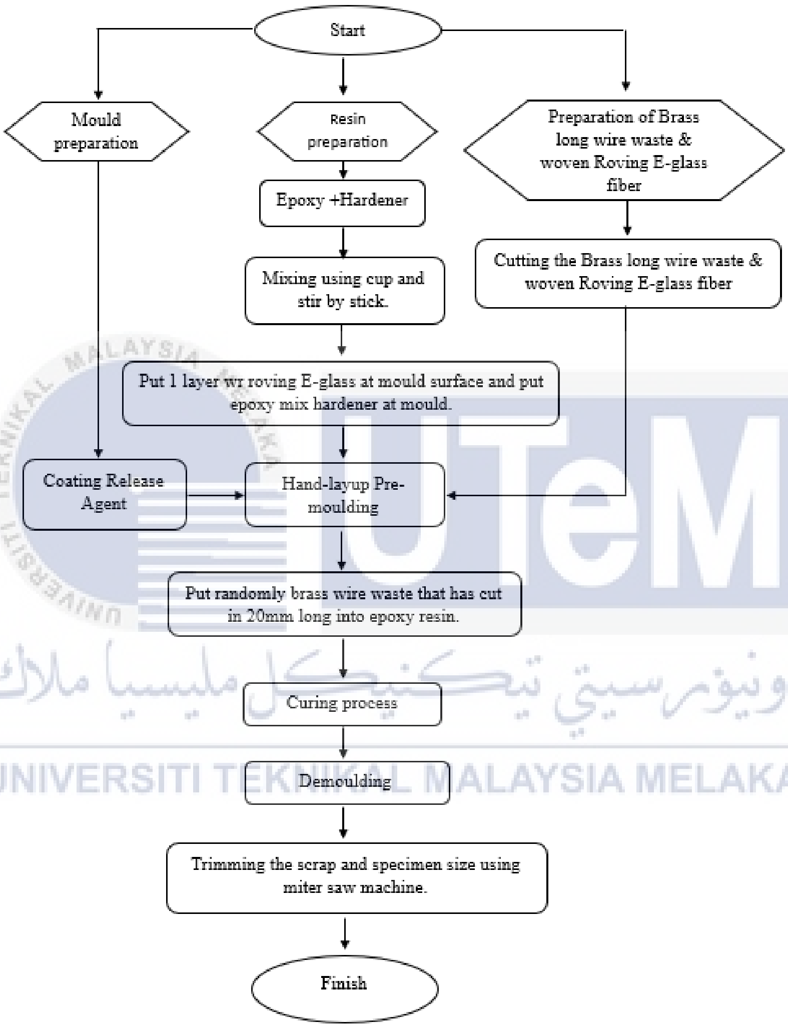

Figure 3.9 Flow/process in phase 2

After finishing Phase 1, we move on to what is call fiber loading. This is where we figure out the best ratio, ranging from 10% to 90%, of using brass wire waste as reinforcement on the fiberglass surface for Phase 2. In Phase 2 such as depict 3.9 , our goal is to find the right number of layers for making a product, using materials like woven roving fiberglass and having brass wire waste as reinforcement. We start with 2 layers of woven roving and go up to 10 layers.

Now, for the lamination process in Phase 2, we're using the hand-layup technique with an open mold made of iron. This mold has two parts – one on top and one on the bottom. After we finish the hand-layup on the top mold, we place a box-shaped weight over it. This weight is 30 centimeters long and 8 centimeters wide, and each one weighs 6.7 kilograms. To make sure the surface of the open mold stays stable, we need three of these weights for each mold. Figure 3.10 is the material used it call woven roving .

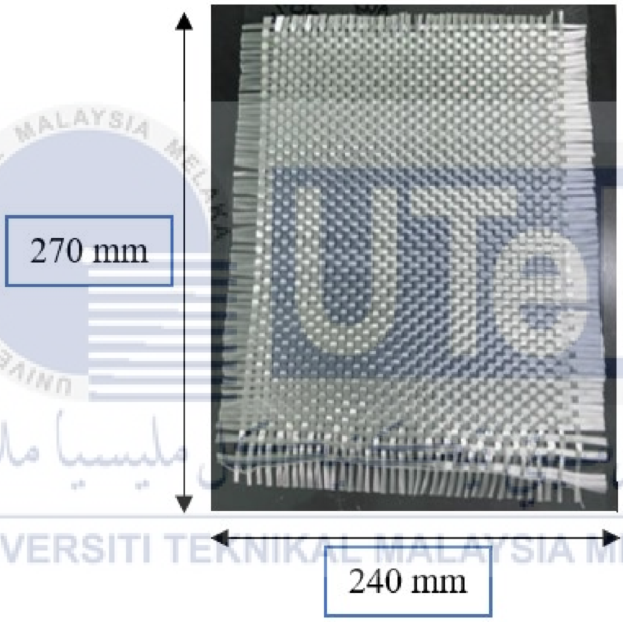

Figure 3.10   Woven Roving Fiber Glass

In phase 2, we applied the same approach as in phase 1, with the only variation being the incorporation of woven roving fiberglass, ranging from three layers to 10 layers. Additionally, the epoxy ratio was maintained at 1:1. The hand layup technique, as illustrated in figure 3.10 , was computed, followed by cold pressing using three weights of solid iron in figure 3.11 . This was done to guarantee that there was no blending during the curing process.

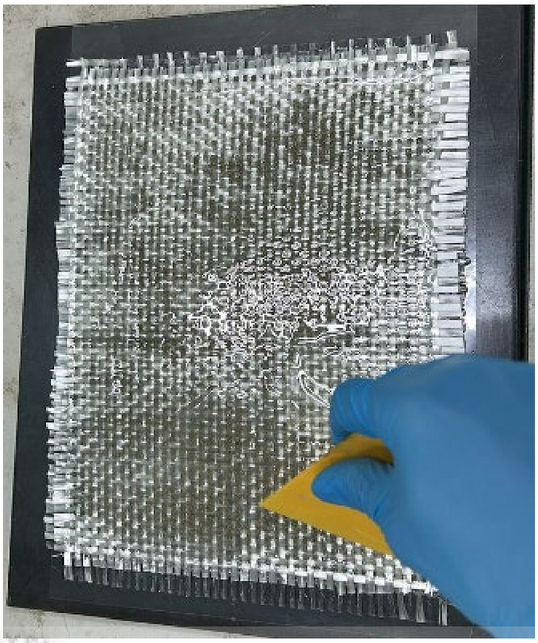

Figure 3.11 Hand-Layup Process.

Figure 3.12 Cold press using solid iron.

The cold press method serves two main purposes: first, it prevents the produced panel from developing defects like curvature; second, it allows for the even distribution of epoxy across the entire surface. Each cold press weighs 6.70 kilograms, and three of these weights are needed for a single mold, effectively covering all upper surfaces when placed on the open mold. Refer to Figure 3.12 for a visual guide on using the cold press on the mold surface.

Table 3.2 illustrates the sequential arrangement of the layup process, progressing from 3 layers to 10 layers. Additionally, it details the alternating order of reinforcements during the layup, comprising brass wire waste, fiberglass, and again, brass wire waste.

Table 3.2 Classified specimen layered by layered phase 2

Layers	Fiber glass / brass wire waste	Layers	Fiber glass / brass wire waste
3	F3 W F2 W F1	4	F4 W F3 W F2 W F1
5	F5 W F4 W F3 W F2 W F1	6	F6 W F5 W F4 W F3 W F2 W F1
7	F7 W F6 W F5 W F4 W F3 W F2 W F1	8	F8 W F7 W F6 W F5 W F4 W F3 W F2 W F1
9	F9 W F8 W F7 W F6 W F5 W F4 W F3 W F2 W F1	10	F10 W F9 W F8 W F7 W F6 W F5 W F4 W F3 W F2 W F1

3.4 Development of Hybrid Laminate Phase 1 and Phase 2.

Materials are used for the laminated hybrid composites in phase 1 and phase 2 is woven roving E-glass fiber with brass wire waste as a reinforcement and epoxy resin and hardener as a matrix. Before proceeding to hand lay-up, the material should be cut based on the required size, 300 mm length, 240 mm width. The next, the epoxy resin should be placed into a container in a desire quantity and the hardener should be added to the same container to mixed for brass wire waste will put randomly. Finally, can proceed with the hand layup process. Moreover, the specimen is laminated layer by layer into a 1 layer in fiber loading. Table 3.3 Show the ratio are using in the process it also happens to phase to in the table 3.4.

Table 3.3 Ratio of brass wire waste and epoxy resin for fibre loading phase 1.

No	Brass waste wire (%)	Brass waste wire weight(g)	Woven Roving Fibre Glass(gram)	Epoxy Resin ratio (77.9: 22.1)	Type of properties
1	0	-	2 plies = 60g		• Tensile test • Flexural test • Impact test (Charpy)
2	10	60 x 0.1 = 6		Epoxy resin weight $\frac{77.9}{100} x\ 60g = 46.74\ g$ Hardener $\frac{22.1}{100} x\ 60g = 13.26\ g$	
3	20	60 x 0.2 =12			
4	30	60 x 0.3 =18			
5	40	60 x 0.4 =24			
6	50	60 x 0.5 = 30			
6	60	60 x 0.6 =36			
7	70	60 x 0.7 =42			
8	80	60 x 0.8 =48			
9	90	60 x 0.9 =54			
10	100 (brass waste wire)	60 x 1.0= 60	-		
11	100(fibre)	-	2 plies = 60g		

Table 3.4 Ratio of brass wire waste and epoxy resin for fibre loading phase 2.

No	No of Fiber layers	Brass waste wire (10%)	Woven Roving Fibre Glass(gram)	Epoxy Resin ratio (77.9: 22.1)	Type of properties
1	3	90 x 0.1 = 9g	90 g	Epoxy 70.1 gram + Hardener 20 gram.	Tensile test Flexural test Impact test (Charpy)
2	4	120 x 0.1 = 12g	120 g	Epoxy 93.48 gram + Hardener 26.52 gram.	
3	5	150 x 0.1 = 15g	150 g	Epoxy 116.85 gram + Hardener 33.15 gram.	
4	6	180 x 0.1 = 18g	180 g	Epoxy 140.22 gram + Hardener 39.78 gram.	
5	7	210 x 0.1 = 21g	210 g	Epoxy 163.59 gram + Hardener 46.41 gram.	
6	8	240 x 0.1 = 24g	240 g	Epoxy 186.96 gram + Hardener 53.04 gram.	
7	9	270 x 0.1 = 27g	270 g	Epoxy 210.33 gram + Hardener 59.67 gram.	
8	10	300 x 0.1 = 30g	300 g	Epoxy 233.7 gram + Hardener 66.3 gram.	

3.4.1 Specimen cutting preparation in phase 1 and phase 2.

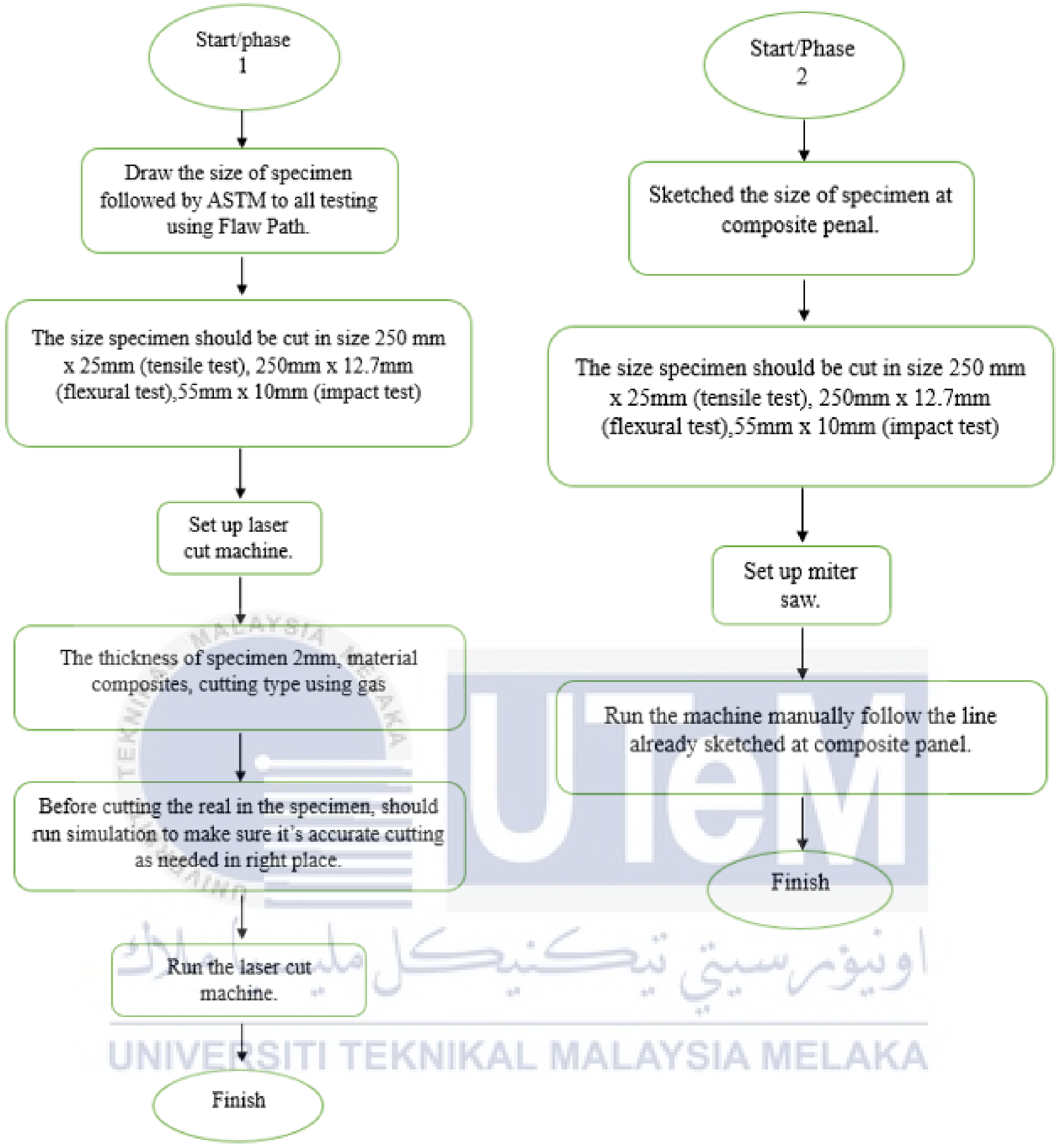

Figure 3.13 Cutting Specimen Using Laser Cut Machine for Phase 1 and machine miter saw for phase 2.

Figure 3.14 Machine Laser cut Phase 1.

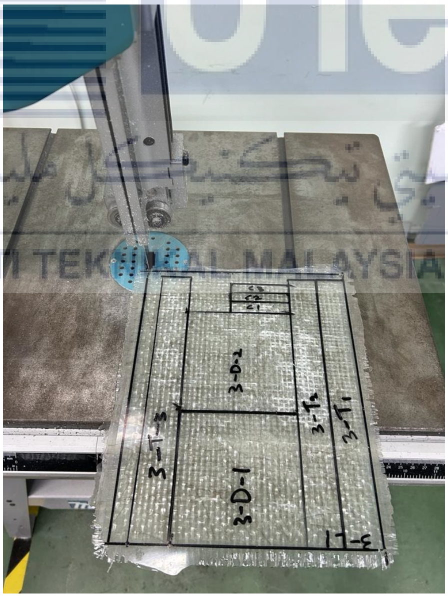

Figure 3.15 Machine Miter Saw Phase 2.

After demolding the specimen, the next step is prepared for cutting specimen followed by ASTM size to all testing. For cutting specimen, it will be used laser cut machine to cut the specimen based on requirements size to all testing specimens Figure 3.13 shows the flow chart for phase 1 and phase 2 cutting specimen using laser cut machine and miter saw also Figure 3.14 and Figure 3.15 are showing the machine are using.

3.5 Mechanical Testing

To assess the performance and physical characteristics of materials and components, mechanical testing is used. To evaluate the material's strength, durability, and other mechanical properties, various mechanical forces or stresses must be applied to the woven roving fibre glass and long waste brass wire used in this experiment. A well-known organization that creates and disseminates standards for testing techniques and methodologies is ASTM International, originally known as the American Society for Testing and Materials. ASTM specifications offer instructions and requirements for performing mechanical testing in a standardized and reproducible manner. These regulations include a variety of substances, such as metals, polymers, composites, ceramics, and others. Table 3.5 are guidelines that follow the ASTM standard for testing.

Table 3.5 ASTM Standard For Testing.

No.	Testing	ASTM Standard	Size Of Specimen(L × W × T)
1	Tensile test	ASTM D3039	250mm x 25mm x 9mm
2	Flexural test	ASTM D790	250mm x 12.7mm x 9mm
3	Impact test	ASTM D256	55mm x 10mm x 10mm

3.5.1 Tensile Test

The goal of tensile testing specimens is to assess the mechanical characteristics and behavior of materials under tension, such as woven roving laminated with long brass wire. Tensile testing examines a material's strength, ductility, and other crucial properties as well as how it reacts to applied forces. In this research, it will prepare around 72 specimens for testing with various layers and ratio, followed by guidelines of the ASTM (D3039) standard test for tensile test specimens is 3 for each testing. Also, the sizing for the specimen is 250 mm in length ,25 mm in width and the thickness is 9mm; Figure 3.16 shows the sizing of the specimen.

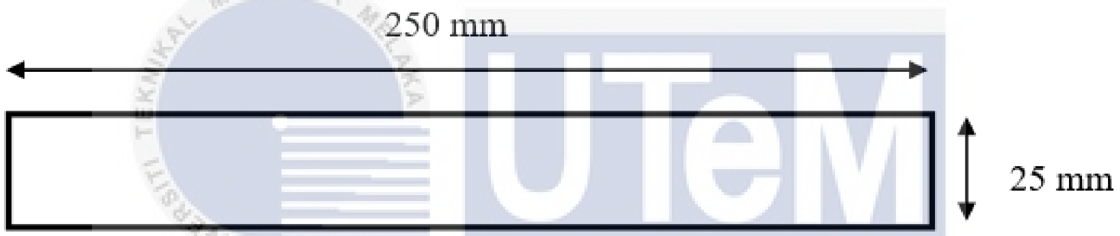

Figure 3.16 Dimensions of the specimen followed by the ASTM (D3039)

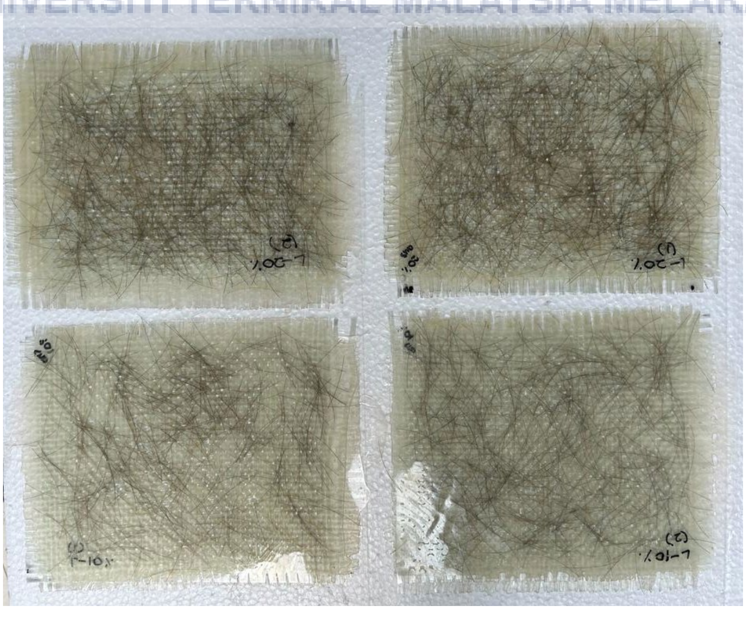

Figure 3.17 Panel Long Fiber Brass Wire Waste Before Cut.

A sample specimen is prepared beforehand in accordance with particular criteria and measurements. The specimen typically has a standardized cross-section and is cylindrical or rectangular in shape. The tensile testing machine's clamps are tightly clamped around the specimen. The grips guarantee accurate alignment and stop the specimen from slipping while being tested. To provide an initial load or stress to the specimen, the machine places the grips. While doing this, any gap in the system has been eliminated and the specimen is ensured to be properly seated. Figure 3.18 below shows the machine for tensile test and figure 3.17 are show panel before cutting.

Figure 3.18 Tensile Test Machine at Lab Utem

A constant tensile load is applied to the specimen by the machine. The strain rate, which is the normal rate at which the load is applied, remains constant. The device gauges and logs the applied load and the specimen's associated deformation or extension. The test is carried out until the specimen breaks or deforms to a predetermined level. Once the endpoint requirements have been satisfied, the machine automatically stops applying the load. The data analysis will be recorded in chapter 4.

3.5.2 Flexural Test

Flexural testing is frequently used to evaluate the performance of materials, including metals, polymers, and composites, in sectors including construction, aircraft, and automotive. The test results aid in the evaluation and design of structural components, the selection of materials for applications, and the assurance of regulatory and industry standards observance. The flexural testing will be followed by ASTM D790 standard test method as shown in the machine in Figure 3.19.

Figure 3.19 Universal Testing Machine at Lab in Utem

Besides, in this flexural testing 72 specimens for testing will be prepared to be tested with various layers and ratio. The sizing for the specimen is 250 mm in length ,25 mm in width and the thickness is based on each ratio of wire when laminated will follow ASTM D790 standard method testing shown in Figure 3.20 and figure 3.21 shown the panel before cutting.

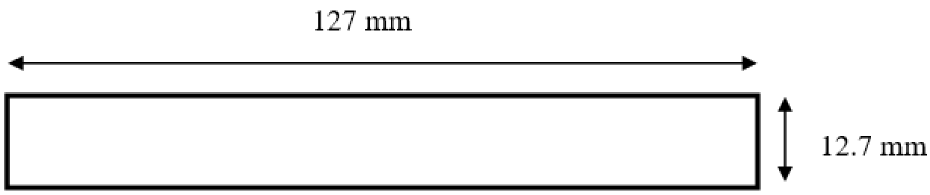

Figure 3.20 Dimension of flexural test specimen based on ASTM (D790)

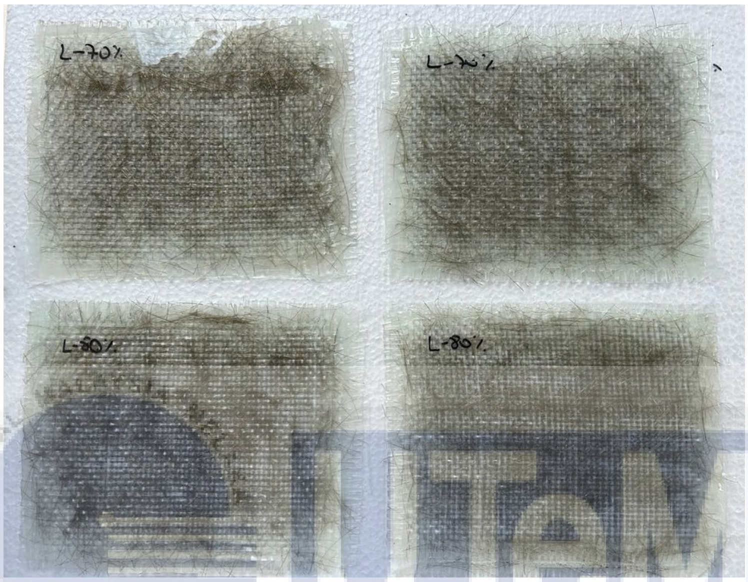

Figure 3.21 Fiber Brass Wire Waste Before Cut.

3.5.3 Impact Test

Impact testing is a mechanical procedure that assesses a material's resilience to transient, high-energy loads as well as its capacity to withstand force before breaking. A standardised specimen is tested by being struck at a predetermined speed by a pendulum or falling weight. A pendulum is hoisted to a predetermined height while the specimen is clamped in place horizontally for a normal pendulum impact test. After being released, the pendulum swings down and strikes the specimen. The specimen deforms and finally fractures as a result of the impact force. Numerous factors are measured during the impact, including the energy received by the specimen, the highest force applied, and the degree of deformation. These measurements reveal information about how robust, resilient, and shock-resistant the material is. The difference between the pendulum's beginning and final heights can be used to calculate the amount of energy that the specimen has absorbed. This material's capacity to withstand impact loads can be determined in large part by its energy absorption value. Figure 3.22 is the illustration of Pendulum impact test for testing.

Figure 3.22 Pendulum Impact Test in Lab Utem

Besides The sample specimen of impact test are follow ASTM D256 method testing. In this testing 72 specimens are prepared for impact test with various layers to analyze the result which are effective for this experiment. Figure 3.23 shows the dimensions of specimen followed by ASTM D256 method testing which is for the specimen is 55 mm in length ,10 mm in width and the thickness is 10mm.

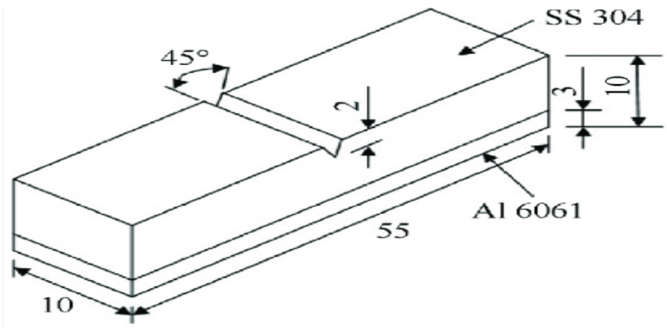

Figure 3.23 Dimension of specimen based on ASTM (D256)

3.6 Summary

Chapter 3 generally explains how to prepare the raw of material such as brass waste wire, for brass waste wire will be collected at Utem laboratory at Factory 2 WEDM, woven roving E-glass Fibre will be collected at Utem laboratory composites and fabricate the specimen and all the testing procedures that will be used to demonstrate this experiment. In order to obtain the results and data of all the testing that will be done, including the tensile test, flexural test and impact test in accordance with standard operating procedure of the American Society for Testing Materials (ASTM).

CHAPTER 4

RESULT AND DISCUSSION

4.1 Fabrication And Characteristics of Laminated Composite in phase 1 and phase 2.

In this research, significant emphasis is placed on the meticulous fabrication of panels using the hand lamination process for composites. The study unfolds in two distinct phases, phase 1 and phase 2. Phase 1 is dedicated to a comprehensive exploration of the impact of different ratios, ranging from L10% to L90%, on enhancing the strength of fiberglass. This investigation delves into the synergistic effects achieved by incorporating long brass wire waste as reinforcement. In phase 2, the focus shifts to the intricate details of layering, where the study assesses the influence of adding layers of fiberglass across eight distinct panel types. These panels are meticulously crafted with variations in the number of layers, spanning from L3 to L10 layers of fiberglass. While the reinforcement pattern, featuring the alternating arrangement with fiberglass, remains consistent across all panel types, the pivotal factor distinguishing them lies in the specific number of layers integrated during the fabrication process. This two-phased approach allows for a nuanced understanding of the interplay between ratio variations and layering configurations, shedding light on optimal combinations for achieving heightened strength in composite panels. The code for each specimen is coded in table 4.1.

Table 4.1 Code from each specimen

PHASE 1			PHASE 2	
No.	Code	Name	Code	Name
1.	EP	Epoxy		
2.	WW	Wire waste		
3.	FG	Fiber glass		
4.	L10	Long 10 % brass wire	L2	Long 2 layers fiber glass
5.	L20	Long 20 % brass wire	L3	Long 3 layers fiber glass
6.	L30	Long 30 % brass wire	L4	Long 4 layers fiber glass
7.	L40	Long 40 % brass wire	L5	Long 5 layers fiber glass
8.	L50	Long 50 % brass wire	L6	Long 6 layers fiber glass
9.	L60	Long 60 % brass wire	L7	Long 7 layers fiber glass
10.	L70	Long 70 % brass wire	L8	Long 8 layers fiber glass
11.	L80	Long 80 % brass wire	L9	Long 9 layers fiber glass
12.	L90	Long 90 % brass wire	L10	Long 10 layers fiber glass

4.1.1 Ratio of Brass waste wire and Matrix phase 1 and Phase 2.

Table 4.2 Ratio Of Brass Waste Wire and Epoxy Resin Phase 1.

No	Brass waste wire (%)	Brass waste wire weight(g)	Woven Roving Fibre Glass(gram)	Epoxy Resin ratio (77.9: 22.1)	Type of properties
1	0	-	2 plies = 60g		• Tensile test • Flexural test • Impact test (Charpy)
2	10	60 x 0.1 = 6		Epoxy resin weight $\frac{77.9}{100} x\ 60g = 46.74$ g Hardener $\frac{22.1}{100} x\ 60g = 13.26\ g$	
3	20	60 x 0.2 =12			
4	30	60 x 0.3 =18			
5	40	60 x 0.4 =24			
6	50	60 x 0.5 = 30			
6	60	60 x 0.6 =36			
7	70	60 x 0.7 =42			
8	80	60 x 0.8 =48			
9	90	60 x 0.9 =54			
10	100 (brass waste wire)	60 x 1.0= 60	-		
11	100(fibre)	-	2 plies = 60g		

Table 4.2 outlines the utilization of fiberglass and epoxy in the fabrication process, maintaining a consistent ratio of 1:1. The table provides a comprehensive guide on calculating the weights of epoxy and hardener for each panel. The ratios for brass wire waste and fiberglass are constant at 10% and 90%, respectively, across all nine different ratios. Additionally, this consistency extends to the application of two layers of fiberglass in each panel fabrication.

Table 4.3 Ratio Of Brass Waste Wire and Epoxy Resin Phase 2.

No	No of Fiber layers	Brass waste wire (10%)	Woven Roving Fibre Glass(gram)	Epoxy Resin ratio (77.9: 22.1)	Type of properties
1	3	90 x 0.1 = 9g	90 g	Epoxy 70.1 gram + Hardener 20 gram.	Tensile test Flexural test Impact test (Charpy)
2	4	120 x 0.1 = 12g	120 g	Epoxy 93.48 gram + Hardener 26.52 gram.	
3	5	150 x 0.1 = 15g	150 g	Epoxy 116.85 gram + Hardener 33.15 gram.	
4	6	180 x 0.1 = 18g	180 g	Epoxy 140.22 gram + Hardener 39.78 gram.	
5	7	210 x 0.1 = 21g	210 g	Epoxy 163.59 gram + Hardener 46.41 gram.	
6	8	240 x 0.1 = 24g	240 g	Epoxy 186.96 gram + Hardener 53.04 gram.	
7	9	270 x 0.1 = 27g	270 g	Epoxy 210.33 gram + Hardener 59.67 gram.	
8	10	300 x 0.1 = 30g	300 g	Epoxy 233.7 gram + Hardener 66.3 gram.	

Table 4.3 details the computation of epoxy usage and the incorporation of brass wire waste as reinforcement. The matrix consumption is determined based on the weight (in grams) of each fabric layer. The fabrication method adheres to a 1:1 ratio for the matrix. As for the reinforcement during phase 2, a consistent 10% ratio is applied to all layers across the eight types, ranging from L3 to L10 layers. The objective of phase 2 is to assess and identify the optimal layer configuration, determining the most suitable combination for product development.

4.2 Fiber loading in phase 1.

In phase 1, the focus of fiber loading is to determine the optimal ratio for combining long brass wire waste with fiberglass, assessing the effectiveness of this combination. The appropriate ratio is sought to achieve the highest level of effectiveness in reinforcing the fiberglass material.

Moving on to phase 2, nine different ratios ranging from 10% to 90% are examined. The goal is to evaluate the strength and effectiveness of long brass wire waste when combined with fiberglass. Testing is conducted on panels for each of the nine ratios, utilizing tensile, flexural, and impact tests. These tests serve to establish the comparative performance across the different ratios. The outcomes of these tests will aid in identifying the most effective ratio that can be employed in the subsequent phase, phase 2, for further development and application.

4.2.1 Mechanical Properties Of Laminated Composite in Phase 1.

The applied research and experiments are assessed to ascertain the mechanical properties of the laminated composite specimens through various tests, including the tensile test, flexural test, and impact test, following ASTM standards. The evaluations are conducted across different ratios, specifically L10%, L20%, L30%, L40%, L50%, L60%, L70%, L80%, and L90%. The aim is to determine the optimal performance among these ratios, justifying the selection of the most effective ratio for the laminated composite material. This comprehensive testing approach aligns with ASTM standards to ensure a rigorous and reliable evaluation of the mechanical characteristics of the specimens.

4.2.2 Sample Properties in phase 1.

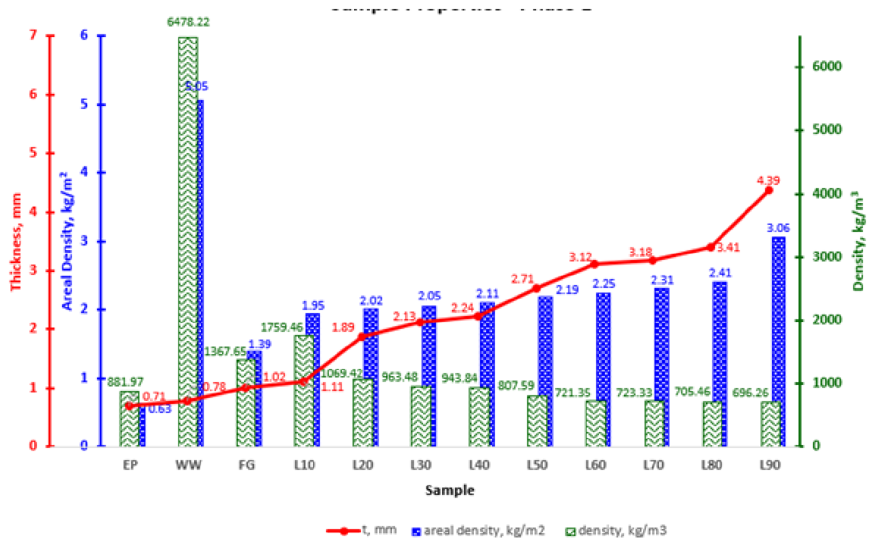

Figure 4.1 Sample Properties phase 1

Phase 1 is fiber loading figure 4.1 shown the graph sample properties in phase 1 to identify the strength level of each material that wants to be combined into one material. It is called composite, the purpose of the sample for these three materials is to see the results of testing data in the form of mechanical strength where to see the dependence and the combination of these three materials to become one material. Based on the trend graph result show from Epoxy (EP), Wire Waste (WW), and Fiber Glass (FG). The thickness of these three materials shows the difference where epoxy is 0.71mm, wire waste 0.78mm and fiber glass 1.02mm, based on the graph plot showing the increase of each material. the factor that causes the thickness to increase because epoxy is in liquid form, wire waste in the form of fiber and also fiber in the form of a mat, when each material is laminated, it will affect the thickness of the three materials.

L10 to L90 are showing the thickness are increasing start from 1.11 mm to 4.39 mm because of the increasing of the using brass waste wire followed by percentage 10% to 90% of brass wire waste and the composites material such as woven roving fiber glass and epoxy resin, hardener are consistent which is weight of using epoxy, hardener based on weight woven roving fiber glass such as woven roving fiber glass is two layers the weight both of the material is 60 gram, so the epoxy and hardener will follow the ratio 77.9 : 22.1, to calculate the usage of this material are using the ratio epoxy and hardener 60 x 0.79 is equal to 47.4 gram epoxy and hardener 60 gram x 0.21 is equal to 12.6 gram in phase 1 the weight of epoxy and hardener is consistent but for reinforcement are increasing because of the different ratio from 10% to 90%. For waste brass wire are calculated based on the percentage start from 10% to 90%, the calculation also followed weight of woven roving fiber glass, which is 60 gram x 0.1 is equal to 6 gram and the weight are increasing until 90% the using of waste fiber glass as reinforcement.

The result shows, area density is increasing from L10, 1.95 kg/m2 to L90, 3.09 kg/m2, but if compared to density from L10 to L90 are show decreasing from 1759.46 kg/m3 to 696.26 kg/m3. Based on the graph L10 area density is 1.95 km/m2 and density is 1759.46 kg/m3, L20 area density 2.02 km/m2 and density is 1069.42 kg/m3, L30 area density 2.05 km/m2 and L30 density 963.48 km/m2, L40 area density 2.11 km/m2 and L40 density is 943.84 kg/m3, L50 area density 2.19 km/m2 and L50 density is 807.59 kg/m3, L60 area density is 2.25 km/m2 and density 721.35 kg/m3, L70 area density is 2.31 km/m2 and density is 723.33 kg/m3, L80 area density is 2.41 km/m2 and density is 705.46 kg/m3, and lastly is L90 area density is 696.26 km/m2 and density is 3.06 kg/m3. From the sample properties in phase 1, the result show from L10 to L90 the best result show area density and density is at L10 which is Both areal density and density are factors that can influence the strength of a material, although their impact.

This because L10 are fabricated with 10% of weight of fiber which is 6 gram of brass wire waste and two layers of fiber glass, when fabricated the specimen, the reinforcement placed in the middle between the first layer and the second layer it’s called sandwich, the distribution of brass wire waste is random throughout the woven roving fiber glass area compare to the other ration which is L20 until L90 shows the ratio for reinforcement which is brass wire waste is not suitable because the waste wire is too thick and causes the epoxy laminating process to not stick well because the brass wire waste used for L20% 12grams, L30% 18grams, L40% 24grams, L50% 30 grams, L60% 36 grams, L70% 42 grams, L80% 48 grams and L90% 54 grams. The cause of the inappropriate reinforcement ratio causes the strength of the specimen to become weak and unable to adhere perfectly according to the amount of epoxy used to laminate the specimen. The relationship between area density and density is, Density, which represents the mass of a material per unit volume, often exhibits a direct relationship with strength. In many cases, higher density materials are associated with greater mass and depending on the material composition, this can contribute to increased strength. Areal density, on the other hand, provides insight into how mass is distributed across a surface area. The distribution of mass, as characterized by areal density, can impact the strength-to-weight ratio of a material. Achieving high strength with lower areal density is often desirable, particularly in applications where weight considerations are critical.

The purpose of fiber loading in phase one is to obtain results from testing done between L10 until L90 which reinforcement ratio is brass wire waste which is the best to combine two materials to become a composite. Meaning that woven roving fiber glass and reinforcement brass wire waste, epoxy and hardener are binding materials for both materials for laminated purposes.

4.2.3 Tensile Performance of laminated composite in phase 1.

The tensile test was employed to assess the mechanical properties of the hybrid laminated reinforced composite samples. These samples were prepared in accordance with ASTM D3039, featuring dimensions of 250 mm x 25 mm, and the resulting averages were documented. Utilizing the Shimadzu 100 kN Universal Testing Machine, the samples underwent tensile testing to analyze their tensile strength. The test was conducted at a standard speed of 2 mm/min for typical test specimens. Tensile strain was precisely measured through strain gauges strategically attached along the longitudinal axis of the specimen.

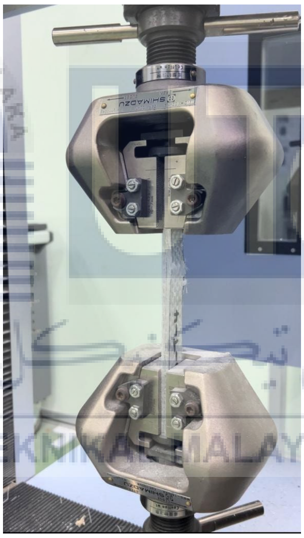

Figure 4.2 Tensile Test Machine

The primary objective of the tensile test was to evaluate the interaction between the fiber and matrix within the composite material. Figure 4.2 illustrates the setup of the tensile test machine, showcasing the apparatus utilized in the experimentation. This rigorous testing methodology conforms to established standards, ensuring a comprehensive understanding of the mechanical behavior of the hybrid laminated reinforced composite.

Table 4.4 Tensile Properties

Samples	Force, kN	Ultimate Tensile Strength, MPa
EP	0.35	19.72
WW	0.34	17.43
FG	8.03	314.59
L10	9.23	332.61
L20	8.61	182.22
L30	7.37	138.39
L40	6.89	123.03
L50	5.68	83.84
L60	5.56	71.28
L70	5.36	67.42
L80	5.34	62.64
L90	5.31	48.38

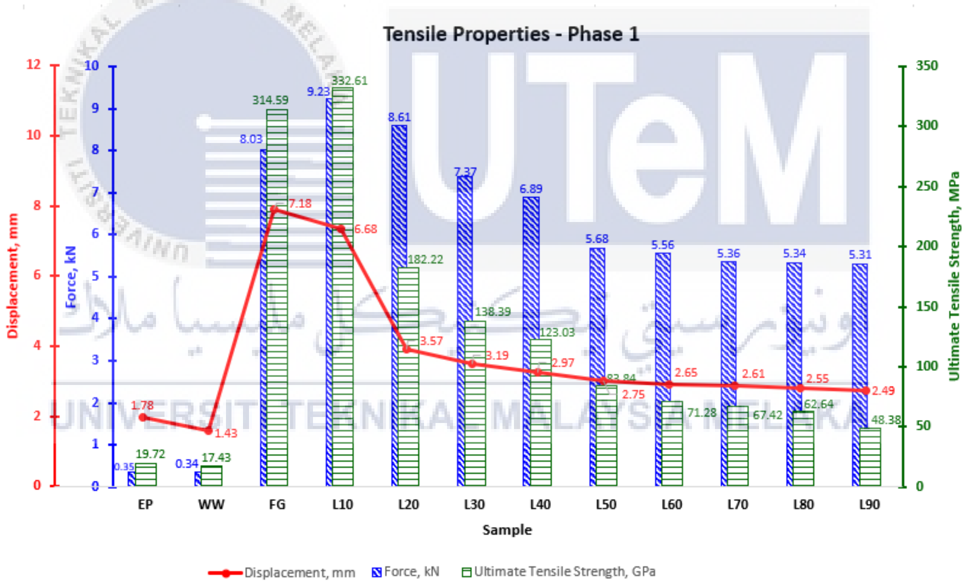

Figure 4.3 Graph Tensile Testing

Figure 4.4 Interfacial bonding of flber glass with brass wire waste

In this research, nine distinct ratios of brass wire waste were utilized, namely L10%, L20%, L30%, L40%, L50%, L60%, L70%, L80%, and L90%. Each ratio represents a variation in the weight of brass wire waste in the form of long fibers. Figure 4.3 visually illustrates the maximum force values for tensile strength obtained from the laminated combination of fiberglass and brass wire waste in its long fiber form and the table 4.4 is shown the value. This figure serves as a graphical representation of the tensile strength performance across the different ratios, providing a clear insight into the influence of varying amounts of brass wire waste on the composite material's mechanical properties.

The analysis of the graph indicates that among the different ratios of brass wire waste used as reinforcement, L10 exhibits the highest force value at 9.23 kN, while L90 shows the lowest force value at 5.31 kN, representing a decrease of 3.92 kN. The graphical representation further illustrates a clear trend: as the proportion of long brass wire waste used as reinforcement increases, there is a noticeable decrease in the force values on the graph. Specifically, the force values decrease from 9.23 kN at L10 to 5.31 kN at L90, indicating a systematic decline in tensile strength as the amount of brass wire waste reinforcement increases.

The analysis of the ultimate strength graph reveals that L10 exhibits the highest value at 332.61 MPa, while L90 shows the lowest value at 48.38 MPa. The decrease in ultimate strength from L10 to L90 is significant, amounting to 284.23 MPa. Similarly, examining the values from L20 to L80, there is a decline from 182.22 MPa to 62.64 MPa.

The graph trends indicate a sharp drop in ultimate strength with the addition of long brass wire waste combined with fiberglass to form the composite material. This observation suggests that as the ratio of brass wire waste increases, the ultimate strength of the composite material decreases substantially. This trend is valuable information for understanding the impact of different ratios on the mechanical properties of the composite.

Analyzing all the results obtained from the specimens tested with the tensile test machine, it is evident that L10 stands out with the highest force recorded at 9.23 kN. Correspondingly, when assessing ultimate strength, L10 also exhibits the highest value, reaching 332.61 MPa. This consistency in performance across both force and ultimate strength metrics indicates.

That L10 is the most robust among the ratios tested, showcasing superior mechanical properties compared to the other ratios, ranging from L20 to L90. Figure 4.4 is the sample of tensile test interfacial bonding of fiber glass with brass wire waste.

4.2.4 Flexural Performance of laminated composite in phase 1.

In this section, the flexural performance of the samples was assessed through testing using the Universal Testing Machine (UTM), specifically the Instron 100 kN model, as depicted in Figure 4.5. The samples used for testing were of dimensions 12.7 mm x 127 mm. The collected data was meticulously recorded, and graphs were generated to facilitate the analysis and comparison of the flexural performance across various compositions with different layers and stacking sequences. The testing procedure adhered to the ASTM D790 standard, with the crosshead speed set at 2 mm/min. Additionally, the lower support was positioned at a height of 60 mm. This standardized testing approach ensures consistency and reliability in assessing the flexural characteristics of the composite samples, providing valuable insights into their mechanical behavior under bending loads.

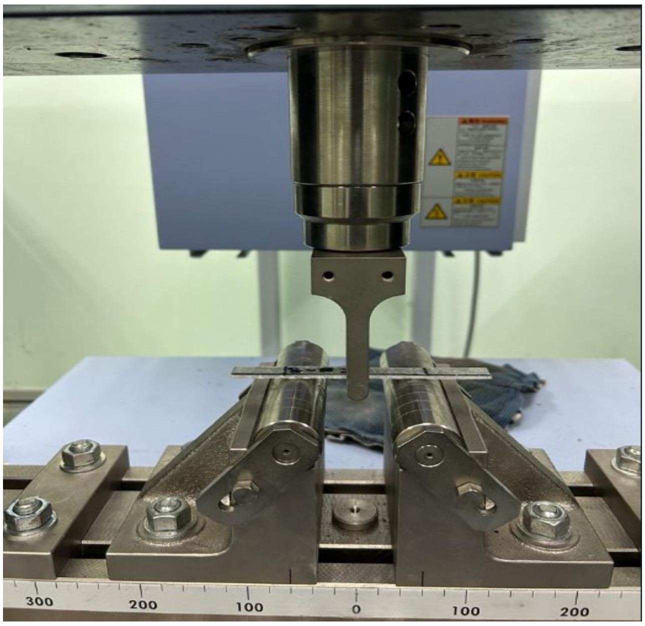

Figure 4.5 Flexural Test Machine

Table 4.5 Flexural test

Samples	Force, N	Flexural Strenght, MPa	Displacement, mm
EP	1.53	22.76	15.05
WW	12.79	157.67	11.08
FG	32.62	235.15	12.78
L10	64.34	391.65	11.52
L20	46.45	97.53	11.49
L30	38.47	63.59	11.41
L40	37.11	55.47	11.04
L50	32.33	33.02	10.33
L60	27.54	21.22	9.67
L70	22.13	16.41	9.12
L80	20.85	13.45	8.85
L90	20.84	8.11	8.84

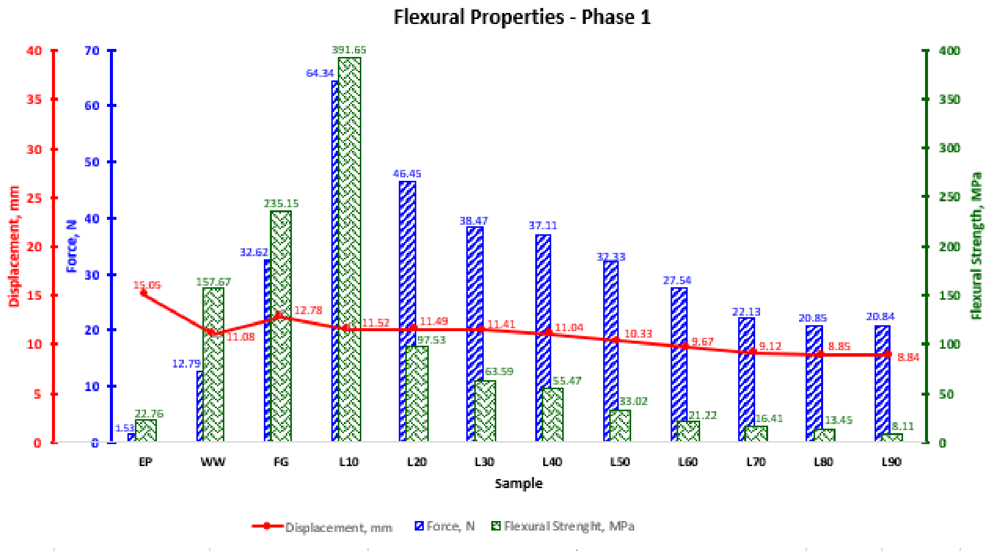

Figure 4.6 Flexural Test

Figure 4.7 Interfacial bonding of fiber glass with brass wire waste

The data reveals in table 4.5 and figure 4.6 a detailed look at how different materials and ratios perform under flexural testing. When we look at EP (epoxy), WW (brass wire waste), and FG (fiber glass), they generally show higher force, flexural strength, and displacement compared to samples with varying percentages of long brass wire waste (L ratios). Notably, L10 stands out with the highest force (64.34 N) and flexural strength (391.65 MPa), indicating it's particularly sturdy. On the other hand, L90 has the lowest force (20.84 N) and flexural strength (8.11 MPa), suggesting it's less resilient. The displacement data adds another layer, showing how the materials deform during testing. Overall, the results highlight the intricate connection between material composition, flexural strength, and displacement. L10 seems to be the top performer, emphasizing the importance of getting the composition ratio right the picture 4.7 shown the interfacial bonding of fiberglass.

Analyzing the trends in the data, it's clear that the ratio of long brass wire waste to fiber glass plays a crucial role in shaping the material's mechanical properties. As the ratio increases from L10 to L90, there's a consistent drop in force, flexural strength, and displacement. This suggests that a higher percentage of brass wire waste negatively impacts the material's ability to handle bending stresses. These insights are essential for material engineering, emphasizing the need for careful consideration when selecting composition ratios. While L10 seems to be the sweet spot for optimal performance, the variations in other samples underscore how sensitive these materials are to changes in composition.

4.2.5 Impact Charpy Performance of laminated composite in phase 1

In adherence to ASTM D256 standards, the Pendulum Charpy test was conducted on fiberglass-reinforced composite samples. Each sample, measuring 10 mm x 55 mm the actual thickness without a notch, was meticulously prepared for testing. The Charpy test, performed using the EUROTECH Charpy-Izod impact tester as illustrated in Figure 4.6, involved applying an impact load of 8.8 kg. The samples, cut precisely with a laser-cut machine in phase 1 as depicted in Figure 4.13, aimed to ensure accuracy in dimensions.

The primary objective of the Charpy Impact test was twofold. Firstly, it sought to quantify the amount of energy absorbed by the sample upon the application of force. This measurement provides valuable insights into the material's resilience and ability to absorb impact energy. Secondly, the test aimed to identify the failure modes of the composite material. Understanding how the material responds to impact loads is crucial in assessing its overall performance and durability. The combination of precise sample preparation, adherence to testing standards, and the use of specialized equipment contributes to a comprehensive evaluation of the fiberglass-reinforced composite's impact resistance characteristics.

Table 4.6 Impact test

Samples	**Joule, J**	Energy, kJ/m^2
EP	3.02	425.35
WW	4.12	528.19
FG	3.78	370.59
L10	5.69	512.61
L20	5.46	288.89
L30	4.53	212.68
L40	4.11	183.48
L50	4.12	152.03
L60	4.17	133.65
L70	4.18	131.45
L80	4.27	125.22
L90	4.26	97.04

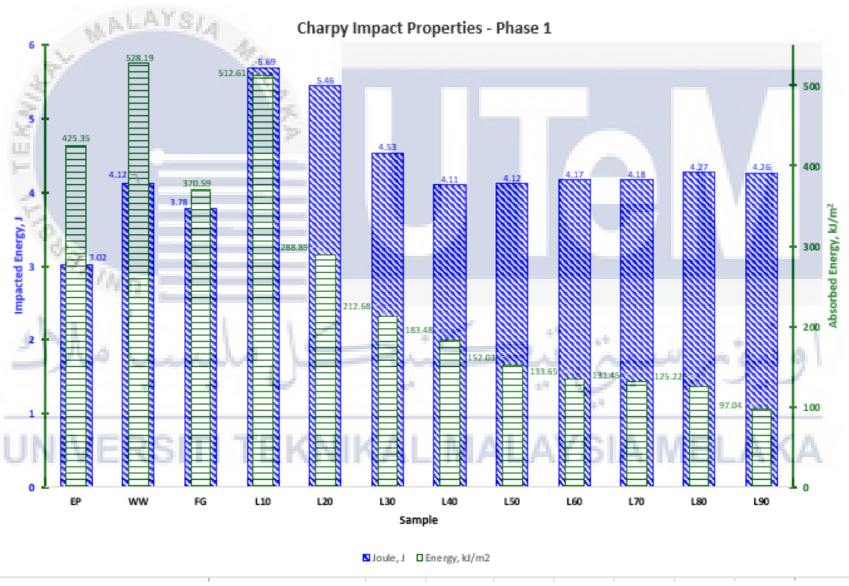

Figure 4.8 Energy absorb of laminated glass fiber reinforced composite

Figure 4.9 Interfacial bonding of fiber glass with brass wire waste

The Charpy Impact test results provide a detailed understanding of how different composite samples respond to impact forces table 4.6 shown the value of impact and figure 4.8 shown the graph, shedding light on their resilience and fracture resistance. Starting with individual materials, the epoxy (EP) sample displays moderate impact resistance with a Joule value of 3.02 and an Energy value of 425.35 kJ/m2. Brass wire waste (WW) surpasses this with a higher Joule value of 4.12 and an Energy value of 528.19 kJ/m2, indicating superior energy absorption and impact resistance. Fiber glass (FG) shows respectable impact resistance with a Joule value of 3.78 and an Energy value of 370.59 kJ/m2.

The data becomes more intriguing when considering different ratios of long brass wire waste with fiber glass (L10 to L90). Here, there's a discernible trend. Initially, impact resistance increases from L10 to L30, reaching its peak at L10 with the highest values of 5.69 Joules and 512.61 kJ/m2. However, beyond L30, the impact resistance gradually decreases. L90, at the end of the spectrum, exhibits lower impact resistance with values of 4.26 Joules and 97.04 kJ/m2. This trend suggests that while certain ratios enhance impact resistance, there's a diminishing return beyond a certain point.

The impact test results reveal a positive outcome for the L10 specimen figure 4.9 shown the interfacial of the impact test, particularly in the combination of reinforcement, where brass wire waste is added at ratios of 10%, 20%, and 30% to fiber glass. Interestingly, the highest impact resistance is observed in the L10 sample with a 10% long brass wire waste ratio. This implies that, among the tested ratios, the composition featuring 10% brass wire waste is particularly effective in enhancing the material's ability to absorb energy and resist fractures under impact. The results suggest that this specific ratio may offer an optimal balance between the reinforcing properties of brass wire waste and the structural integrity provided by fiber glass, showcasing the significance of the composition in determining impact resistance.

4.3 Enhancements introduced by incorporating brass wire waste 10 % into a fiberglass panel in phase 1.

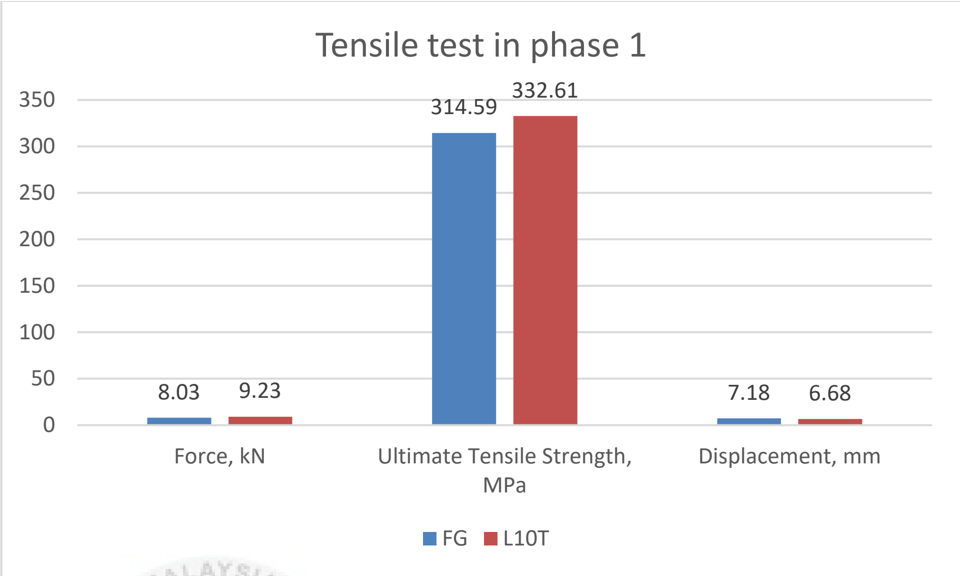

Figure 4.10 Comparison strength of fiber glass only and with reinforcement

based on this study shows the figure 4.10 the change in the strength of fiber glass when combined with brass wire waste in the tensile test increasing 1.2 kN in force, 18.02 MPa increasing in ultimate tensile strength this value is the test in phase 1, while in the flexural test is increasing 31.72 N in force, 156.5 MPa in flexural. The last strength is the impact test increased by 1.91 joules and 142.02 energy absorption. based on research done showing an increase in the resulting strength when fiberglass is combined with brass wire waste.

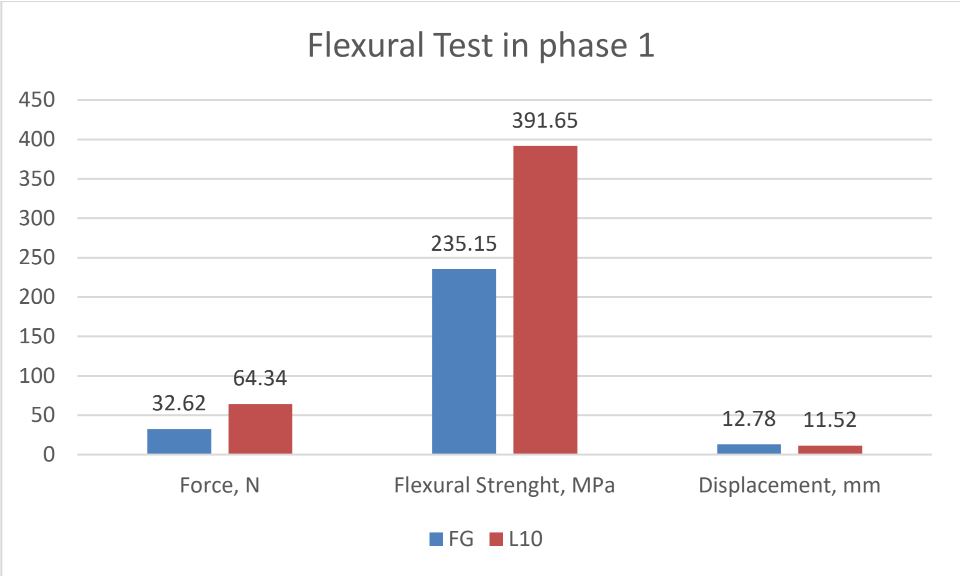

Figure 4.11 Comparison strength of fiber glass only and with reinforcement

The provided figure 4.11 presents data on the force and flexural strength of two samples, FG and L10. In terms of force, the FG sample registers at 32.62 N, while the L10 sample exhibits a noticeably higher force of 64.34 N. This discrepancy in force values suggests that the L10 sample may be subjected to a more substantial load or stress during testing. Moving on to flexural strength, the FG sample shows a value of 235.15 MPa, whereas the L10 sample demonstrates a significantly higher flexural strength at 391.65 MPa. This discrepancy indicates that the L10 sample possesses a greater resistance to bending or deformation compared to the FG sample. Overall, the data implies that the L10 sample exhibits superior mechanical properties in both force tolerance and flexural strength, making it a potentially more robust material for applications requiring strength and structural integrity. Analyzing the graph reveals that integrating reinforcement into fiberglass within a single sample contributes to an enhancement in the sample's strength.

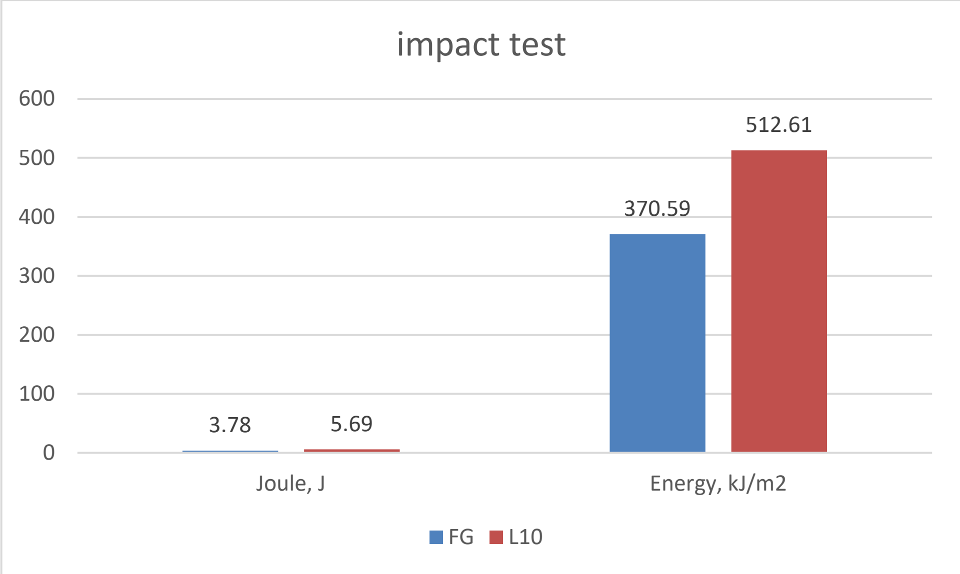

Figure 4.12 Comparison strength of fiber glass only and with reinforcement brass wire waste 10%.

The data provided illustrates 4.12 the energy characteristics of two samples, FG and L10. The FG sample shows an energy value of 3.78 Joules and 370.59 kJ/m2, while the L10 sample demonstrates a higher energy value of 5.69 Joules and 512.61 kJ/m2. This information implies that the L10 sample has a greater capacity to absorb and endure energy compared to the FG sample. In essence, the L10 sample appears to excel in properties related to energy, suggesting it might be more resilient in applications requiring effective energy absorption.

4.4 Summary of Analysis Findings in Phase 1

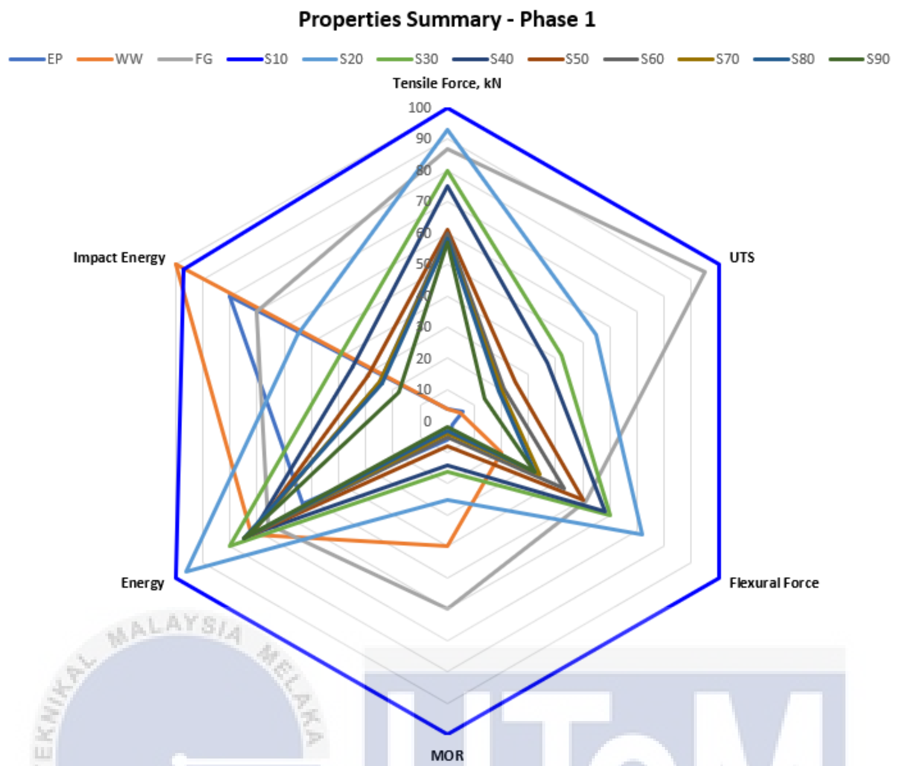

Figure 4.13 Summary

The results in figure 4.13 obtained from the three machine tests, tensile test, impact test, and flexural test, provide a comprehensive evaluation of the strength, impact absorption, and durability of the tested samples. These samples, featuring different ratios (L10 - L90) in combination with fiber glass, exhibit varying levels of effectiveness in enhancing material properties. Notably, the analysis of the tensile test highlights the positive performance of the L10 sample, showcasing a force of 9.23 kN, ultimate strength of 332.61 MPa, and a displacement of 6.68 mm. In the flexural test, L10 again stands out with the highest values, recording a force of 64.34 kN, flexural strength of 391.65 MPa, and displacement of 11.52 mm. The impact test further emphasizes the superior performance of the L10 specimen, with the highest impact absorption (5.69 J) and energy absorption (512.61 kJ/m2).

Combining the results from these three tests, it is evident that L10 consistently outperforms other ratios (L20 - L90) across all aspects studied. The high values obtained in force, ultimate strength, flexural strength, impact absorption, and energy absorption collectively indicate that L10 is the most effective ratio among the nine tested. This conclusion underscores the critical importance of the composition ratio in determining the overall mechanical performance of composite materials. The findings provide valuable insights for material engineers seeking to optimize strength, impact resistance, and durability in composite materials, highlighting L10 as the preferred choice based on the conducted tests.

The test results unequivocally demonstrate that L10, when combined with fiber glass, leads to a notable increase in strength. Across various tests, including tensile, flexural, and impact assessments, L10 consistently outperforms other ratios (L20 - L90) in terms of strength. This upward trend in strength indicates that the specific composition of L10, blending brass wire waste with fiber glass, is particularly effective in reinforcing the material. The positive outcomes observed in force values, ultimate strength, flexural strength, and impact absorption collectively emphasize L10's superiority and highlight the successful synergy between brass wire waste and fiber glass in enhancing the material's overall strength. These findings provide valuable insights for material engineering, indicating that the L10 composition is a promising choice for applications requiring increased strength and mechanical resilience.

4.5 Sample properties in phase 2

Table 4.7 Sample properties of data value

Percentage (%)	Samples	Force, kN	Ultimate Tensile Strength, MPa	Displacement, mm
	L2	9.23	332.61	6.68
	L3	12.09	231.39	6.82
6.80%	L4	16.13	247.19	7.03
1.14%	L5	20.59	250.33	6.96
15.61%	L6	26.12	289.42	7.65
-3.30%	L7	30.22	279.81	7.97
6.26%	L8	34.34	297.32	8.29
-4.44%	L9	40.06	284.11	8.67
5.20%	L10	46.03	298.89	9.07

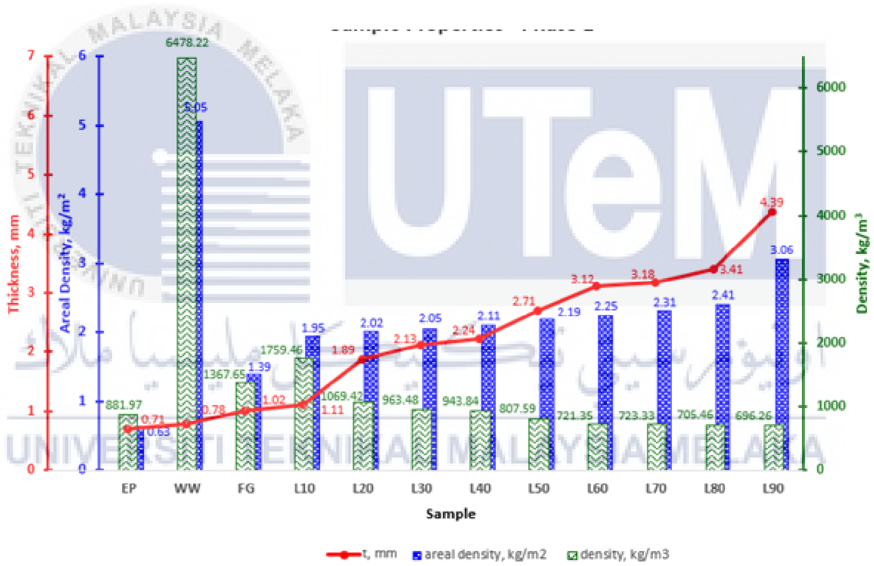

Figure 4.14 Graph sample properties phase 2

Phase 2 is aimed at identifying how many layers of woven roving glass fiber are required to achieve the maximum level of strength to be used to produce products at the same time necessary to minimize cost and composite products are also known as light products. Phase 2 has 9 types of self-fabricated samples such as table 4.7 shown starting from 2 layers to 10 layers. The picture 4.14 are shown graph in phase 2 to study the strength between L2 to L10 which is the best to choose to produce the product is to perform tests such as tensile test, flexural test, and impact Charpy test. From the results of the tensile, flexural and impact tests, it shows that L4 and L6 are the best based on the graph sample properties. indeed, the more layers of woven roving glass fiber are done, the more the strength for the sample increases, however the effect that occurs is that it can increase the weight of the sample at the same time the strength does not show an aggressive increase and also the thickness will indirectly increase, as in the bar chart showing L2 is 1.11mm, L3 2.09mm, L4 2.61mm, L5 3.29mm, L6 3.61mm, L7 4.32mm, L8 4.62mm, L9 5.64mm and L10 6.16. based on the thickness according to the layer from L2 to L10 shows an increase in the thickness of the sample, the thicker the sample, the heavier the sample. turning to area density against density shows L2 area density is 1.95 kg/m2 and density 1759.46 kg/m3, L3 area density is 3.53 kg/m2 and density 1687.94, L4 area density is 4.72 kg/m2 and density is 1807.74 kg/m3, L5 area density is 5.55 kg/m2 and density is 1686.63 kg/m3, L6 area density is 6.28 kg/m2 and density 7.77 kg/m3, L8 area density is 9.41 kg/m2 and density 2037.15 kg/m3, L9 area density is 1077 kg/m2 and density is 1909.47 kg/m3 and the last is L10 area density is 11.54 kg/m2 and density is 1873.09 kg/m3.

From the result show area density, kg/m2 increased from 1.95kgm2 to 11.54kg,m2 while for density, kg/m3 from the graph does not show consistent according to the quantity of added layers of woven roving from L2 to L10. when comparing L2 and L3 there is a decrease from 1759.46 to 1687.94, L2 to L4 increased from 1759.46 to 1807.74, L2 to L5 decreased from 1759.46 to 1686.63, L2 to L6 also decreased from 1759.46 to 1739.78, L2 to L7 increased from 1759.46 to 17 98.29, L2 to L8 also increased from 1759.46 to 2037.15, L2 to L9 increased from 1759.46 to 1909.47 and lastly L2 to L10 increased from 1759.46 to 1873.09.

Based on the inconsistent values shown on the density graph, kg/m3 can be concluded that the trend of increase is not very significant even though from L2 to L10 there is an addition of layers, but the graph shows that the increase and decrease is due to many factors, the first factor is resin saturation The fiberglass layers need to be adequately saturated with resin for proper bonding and strength. If resin saturation is uneven across the layers, it can lead to variations in density, second is application technique, The technique used to apply the fiberglass layers plays a crucial role. If the application is uneven, it can result in variations in thickness and density and the last is air bubbles, Air bubbles trapped between the layers or within the resin can affect the overall density.

Based on the result show bar chart L4 is the best result which is in laminating L4 it just used woven roving fiber glass as many as 4 layers interspersed with reinforcement which is brass wire waste, however it shows a positive increase when compared from L2 to L4 it increases by 48.28 kg/m3 compared to others there is also an increase in density but due to the increase factor to the layer of woven roving fiber glass, for heavy composites play an important role to be taken into account, because want to produce products that have maximum strength and are also light weight.

4.5.1 Tensile performance of laminated fiber glass reinforced composite in phase 2

Table 4.8 Tensile test

Percentage (%)	Samples	Force, kN	Ultimate Tensile Strength, MPa	Displacement, mm
	L2	9.23	332.61	6.68
	L3	12.09	231.39	6.82
6.80%	L4	16.13	247.19	7.03
1.14%	L5	20.59	250.33	6.96
15.61%	L6	26.12	289.42	7.65
-3.30%	L7	30.22	279.81	7.97
6.26%	L8	34.34	297.32	8.29
-4.44%	L9	40.06	284.11	8.67
5.20%	L10	46.03	298.89	9.07

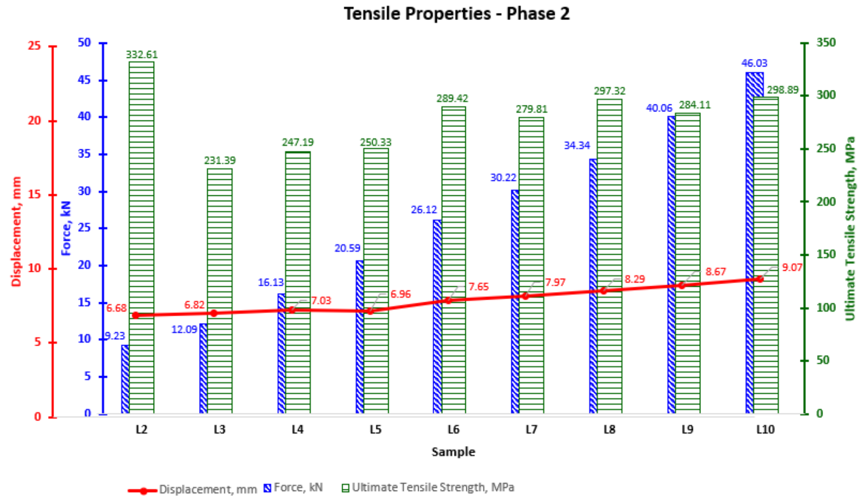

Figure 4.15 Tensile test graph

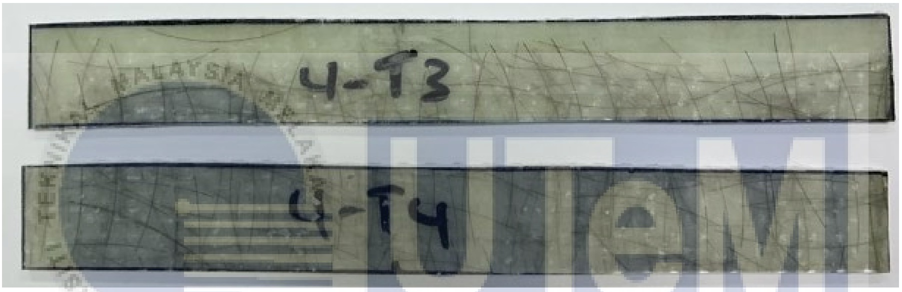

Figure 4.16 Interfacial bonding of fiber glass with brass wire waste

based on table 4.8 shows the value of each different layer from L2 to L10, according to the graph in 4.15 shows L3, the force increases to 12.09 kN, but there is a considerable decrease in UTS to 231.39 MPa, accompanied by a slight increase in displacement to 6.82 mm the figure 4.16 are shown sample after cutting. This decrease in UTS may be attributed to various factors, such as material defects or variations. The increase in force, however, indicates a higher stress applied to the sample, leading to increased deformation as reflected in the displacement. While Sample L4 exhibits a force of 16.13 kN, a UTS of 247.19 MPa, and a displacement of 7.03 mm. Compared to L3, there is a further increase in force and UTS, suggesting that the material may be responding positively to the applied stress. The displacement continues to rise, indicating enhanced material deformation. The next, L5 shows a force of 20.59 kN, a UTS of 250.33 MPa, and a displacement of 6.96 mm. The force and UTS exhibit incremental growth, signifying a continuous application of stress. The displacement, however, experiences a slight decrease, which could be attributed to the intricate interplay between material properties and external forces. However Sample L6 stands out with a force of 26.12 kN, the highest UTS of 289.42 MPa, and a displacement of 7.65 mm. This suggests that L6 is a critical point in the experiment, showcasing both a peak in force and UTS. The material seems to endure higher stress levels, resulting in substantial deformation and The subsequent samples, L7 to L10, demonstrate varying patterns. L7 exhibits a force of 30.22 kN, a UTS of 279.81 MPa, and a displacement of 7.97 mm. L8 shows a force of 34.34 kN, a UTS of 297.32 MPa, and a displacement of 8.29 mm. L9 displays a force of 40.06 kN, a UTS of 284.11 MPa, and a displacement of 8.67 mm. Lastly, L10 reveals a force of 46.03 kN, a UTS of 298.89 MPa, and a displacement of 9.07 mm. These samples collectively showcase the ongoing impact of increasing force on the material, with fluctuations in UTS and displacement suggesting a dynamic response to the applied stress.

In general, there is improvement observed in the resulting graph, particularly in L4 and L6. There is a 6.8% increase from L2 to L4 and a 15.6% increase from L2 to L6. The obtained values indicate a positive trend when combining and augmenting the L4 and L6 layers in this experiment. Additionally, the reinforcement employed exhibits an upward trajectory in both force and ultimate tensile strength.

4.5.2 Flexural performance of laminated fiber glass reinforced composite in phase 2

Table 4.9 Flexural data value

Percentage (%)	Samples	Force, N	Flexural Strenght, MPa	Displacement, mm
	L2	64.34	391.65	11.52
	L3	135.82	233.19	16.88
40.45%	L4	297.47	327.51	12.78
	L5	339.42	235.18	11.58
16.62%	L6	476.58	274.27	13.78
	L7	699.96	281.29	15.45
	L8	969.42	340.64	15.54
	L9	1257.51	296.49	13.99
	L10	1564.59	309.24	12.72

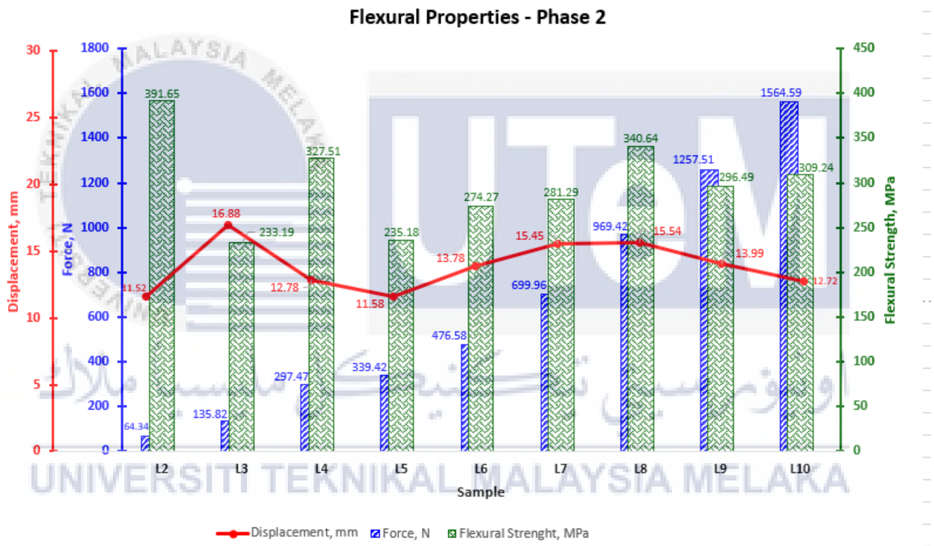

Figure 4.17 Flexural performance of fiber glass laminated composite

Figure 4.18 Interfacial bonding of fiber glass with brass wire waste

Based on the table 4.9 shown Sample L3 is characterized by a force of 135.82 N, a flexural strength of 233.19 MPa, and a displacement of 16.88 mm. The picture 4.17 shown the graph represents the second point for the experiment, with moderate force applied and a corresponding level of flexural strength . The relatively high displacement suggests a notable degree of bending or deformation in response to the applied force. Moving to L4, the force increases significantly to 297.47 N, resulting in a higher flexural strength of 327.51 MPa. Despite the increase in force, the displacement decreases to 12.78 mm, indicating a more efficient response to stress. This improvement in flexural strength suggests that L4 exhibits enhanced resistance to bending compared to L3. Sample L5 shows a force of 339.42 N, a flexural strength of 235.18 MPa, and a displacement of 11.58 mm. While the force continues to rise, the flexural strength slightly decreases, and the displacement shows a further reduction. This suggests a nuanced relationship between force, flexural strength, and displacement, requiring further investigation. L6 exhibits a higher force of 476.58 N, a flexural strength of 274.27 MPa, and a displacement of 13.78 mm. The increased force corresponds to higher flexural strength, indicating a positive response to the applied load. The displacement also increases, suggesting more pronounced bending compared to L4. The subsequent samples, L7 to L10, demonstrate a consistent trend of increasing force, with L10 reaching the highest force of 1564.59 N. Flexural strength shows variations, with L8 having the highest value of 340.64 MPa. Displacement values fluctuate, indicating differing levels of material deformation in response to the applied forces. These variations highlight the diverse behaviors of the material under different stress conditions.

The results obtained from the graph highlight a significant performance improvement in sample L4 compared to L3, L5, L6, and L7. Despite each sample having an additional layer of fiberglass, L4 stands out by recording a substantial 40.45% increase in force, reaching 297.47 N. This improvement is accompanied by a higher flexural strength of 327.51 MPa and a displacement of 12.78 mm. The enhanced performance of L4 suggests that the addition of another layer of fiberglass contributes positively to the material's strength and deformation characteristics the picture 4.18 are shown the interfacial of the sample.

In the context of product manufacturing, particularly in the production of heavy and cost-effective composites, these findings hold significant importance. The substantial increase in force, coupled with high flexural strength, implies that L4 has the potential to serve as a robust material for applications where strength and resilience are crucial. The combination of fiberglass and brass wire waste further underscores the innovative use of recycled materials, contributing to sustainability in manufacturing processes.

The observation that L4 outperforms other samples with additional layers of fiberglass suggests that the composition and layering of materials play a vital role in determining the final product's mechanical properties. This information can be valuable for industries seeking to optimize material usage, reduce costs, and enhance the overall performance of composite products.

In conclusion, the noteworthy improvement seen in L4 emphasizes the significance of material composition in composite product manufacturing. The successful combination of fiberglass and recycled brass wire waste not only contributes to strength but also aligns with sustainable practices. These findings could have implications for industries aiming to produce cost-effective, strong, and environmentally friendly composite materials for various applications.

4.5.3 Impact performance of laminated fiber glass reinforced composite in phase 2

Table 4.10 Impact test data value

*10 wt.%	Samples	Joule, J	Energy, kJ/m^2
	L2	5.69	512.61
	L3	6.95	332.54
19.90%	L4	10.41	398.85
	L5	11.98	364.13
26.00%	L6	16.57	458.99
	L7	19.22	444.91
	L8	20.67	447.39
	L9	21.33	378.19
	L10	22.33	362.49

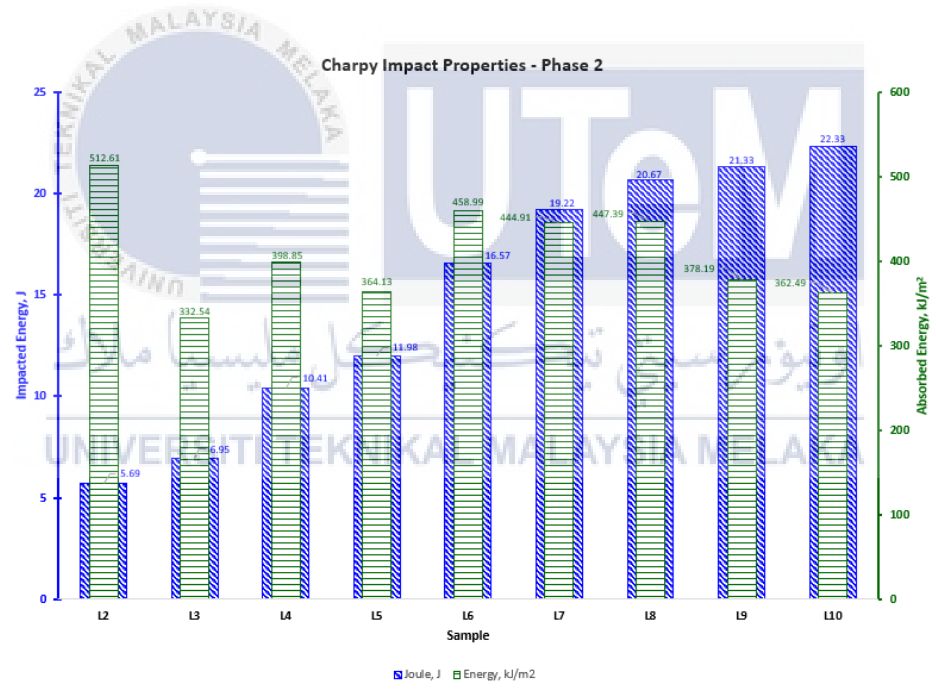

Figure 4.19 Impact performance of fiber glass laminated composite

Figure 4.20 Interfacial bonding of fiber glass with brass wire waste

The table 4.10 and figure 4.19 provides a comprehensive overview of energy-related measurements for different samples (L2 to L10) with varying weight percentages of an unspecified material. The parameters of interest include Joule values and energy values in kJ/m², offering insights into the material's performance under different conditions. Beginning with L2 and L3, we observe a moderate increase in both Joule values and energy values. L3 records a higher Joule value of 6.95 compared to L2's 5.69 Joule, indicating a more substantial amount of energy absorbed. However, this increase in energy is achieved with a lower weight percentage, implying that L3 might exhibit more efficient energy absorption characteristics. Sample L4 stands out prominently with a weight percentage increase of 19.90%, marked by a significant surge in both Joule and energy values. The Joule value jumps to 10.41, and the energy value rises to 398.85 kJ/m². This remarkable increase may suggest an optimized material composition in L4, resulting in enhanced energy absorption capacity. The substantial improvement aligns with the higher weight percentage, indicating the positive impact of material modifications on energy-related properties.

Continuing to L5, we observe another notable increase in both Joule and energy values, with a weight percentage rise of 26.00%. L6 further extends this trend, showcasing the highest Joule value of 16.57 and an energy value of 458.99 kJ/m². These findings underscore the correlation between weight percentage and energy absorption, indicating a progressive improvement in material performance with increasing weight percentages. L6, in particular, demonstrates a significant capacity for absorbing energy, suggesting it could be a promising candidate for applications requiring high energy absorption materials.

The subsequent samples, L7 to L10, continue to show variations in Joule and energy values. L7 and L8 demonstrate relatively high energy absorption, with values of 19.22, 444.91 kJ/m², and 20.67, 447.39 kJ/m², respectively. Although L9 and L10 show a slight decrease in Joule values, the energy values remain relatively high at 21.33, 378.19 kJ/m², and 22.33, 362.49 kJ/m², respectively. These variations highlight the nuanced relationship between weight percentage and energy absorption, with each sample exhibiting unique characteristics. The overall trend in the table indicates that an increase in weight percentage correlates with improved energy absorption capabilities. Samples with higher weight percentages, particularly L6, showcase enhanced performance in absorbing energy.

This finding holds significance in various engineering applications where materials with superior energy absorption properties are crucial, such as in impact-resistant structures or safety equipment.

In practical terms, the ability of these materials to absorb and dissipate energy efficiently is a critical factor for the design and development of products aimed at withstanding external forces or impacts the figure 4.20 shows the interfacial bonding of fiber glass with brass wire waste. The data presented in the table provides valuable insights into the energy absorption characteristics of these materials, paving the way for informed material selection in engineering and manufacturing processes.

4.5.4 Summary in phase 2.

Table 4.11 Summary in phase 2

Samples	Tensile Force	UTS	Flexural Force	MOR	Energy	Impact Energy
S2	20	100	4	100	25	100
S3	26	69	9	59	31	65
S4	35	74	19	84	47	78
S5	45	75	22	60	54	71
S6	57	87	30	70	74	89
S7	66	84	45	72	86	87
S8	75	89	62	87	92	87
S9	87	85	80	76	95	74
S10	100	90	100	79	100	71

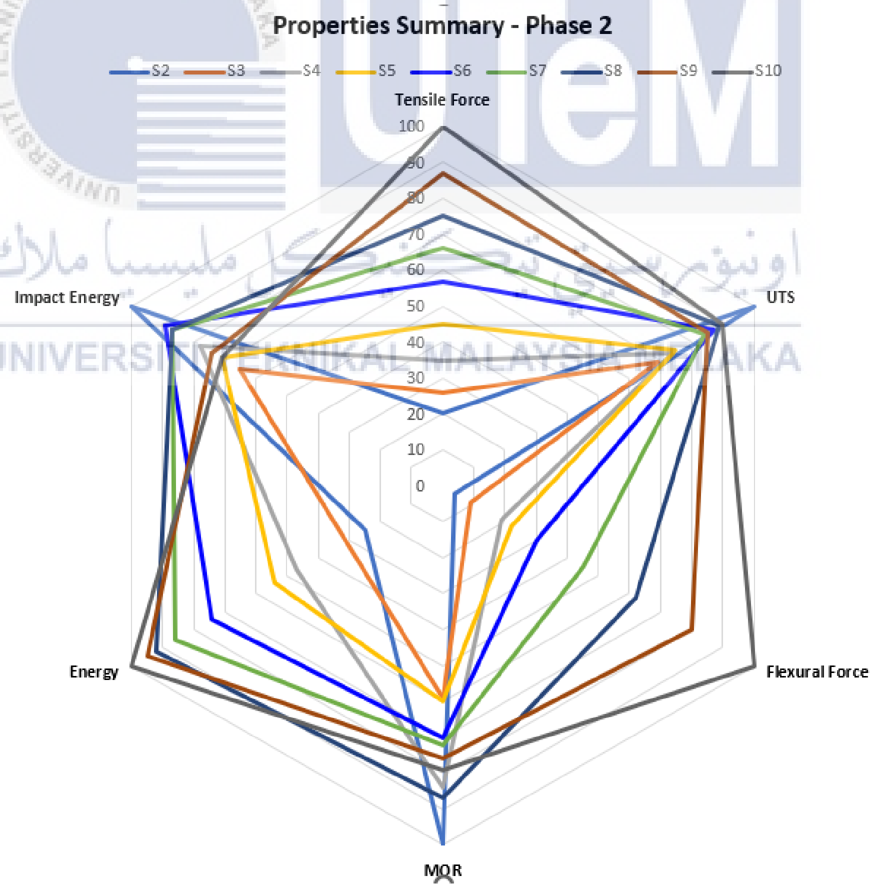

Figure 4.21 Properties summary in phase

This table 4.11 summarizes the provided data, including various mechanical properties for each sample (S2 to S10), such as tensile force, ultimate tensile strength (UTS), flexural force, modulus of rupture (MOR), energy, and impact energy. Starting with S2, the tensile force is 20, indicating a moderate force applied during the tensile test. The UTS is recorded at 100, suggesting a high level of strength in resisting tension. In the flexural test, the force is 4, and the MOR is also 100, showcasing a robust resistance to bending. The energy value is 25, reflecting the material's capacity to absorb energy efficiently. The impact energy is at 100, indicating a high level of resistance to sudden forces or impacts. As we progress to S3, S4, and S5, a trend emerges. While the tensile force steadily increases, reaching 45 in S5, the UTS shows variations, with S4 having the highest value of 74. The flexural force and MOR increase consistently, indicating improved resistance to bending forces. Energy values, however, witness a more substantial increase, with S5 reaching 54, suggesting enhanced energy absorption capacity such as the picture 4.21. Impact energy values fluctuate, emphasizing the materials' varying responses to sudden impacts.S6 to S8 continues the upward trend in tensile force, UTS, flexural force, and MOR. Notably, S8 records the highest tensile force of 75, UTS of 89, flexural force of 62, and MOR of 87. Energy values consistently increase, with S8 reaching 92, reflecting a higher capacity for energy absorption. Impact energy values exhibit some variations, underlining the materials' differing responses to dynamic forces. S9 and S10 mark the culmination of the dataset. Tensile force, UTS, flexural force, and MOR continue to rise, reaching their maximum values in S10. The energy values reflect an increasing capacity for energy absorption, with S10 reaching the maximum value of 100. The impact energy, however, shows a decrease in S10 compared to the previous samples, suggesting a nuanced relationship between impact resistance and other mechanical properties.

According to the spider web chart depicting various mechanical properties such as tensile force, ultimate tensile strength (UTS), flexural force, modulus of rupture (MOR), energy, and impact energy, it is evident that S6 stands out as the most favorable among the tested layers. This conclusion is drawn from the overall assessment of key parameters where S6 exhibits exceptional performance.

Looking at the specific values, S6 demonstrates a tensile force of 57, indicating its ability to withstand tension effectively. The UTS of 87 underscores its superior strength in resisting maximum stress during the tensile test. In the flexural test, S6 showcases a flexural force of 30, indicating its capacity to withstand bending forces. The MOR, or modulus of rupture, is notable at 70, further emphasizing the material's robustness in resisting deformation under flexural stress.

The energy values for S6 are noteworthy, with an overall score of 74. This implies that S6 has a commendable capacity to absorb and dissipate energy efficiently, making it suitable for applications where such characteristics are crucial. Additionally, the impact energy value for S6 is particularly outstanding at 89, suggesting a high resistance to sudden forces or impacts.

In essence, when considering the spider web chart, the concentric arrangement of the plotted parameters creates a visual representation of each layer's performance. The outermost points on the chart, corresponding to tensile force, UTS, flexural force, MOR, energy, and impact energy, collectively contribute to the overall evaluation. S6 stands out as the layer with the most extended reach in all these aspects, depicting a well-rounded and balanced mechanical profile.

This analysis supports the conclusion that S6 excels in multiple mechanical properties simultaneously, making it a standout layer compared to others. The spider web chart, by encapsulating various parameters in a visually accessible format, allows for a comprehensive assessment of each layer's strengths and weaknesses. Ultimately, the information derived from such charts aids in informed decision-making for material selection, particularly in applications where a combination of tensile strength, flexural resistance, energy absorption, and impact resistance is crucial for optimal performance.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study provides an exploration of the prospective utilization of fiberglass combined with discarded brass wire, aiming to enhance the strength of composite materials. The application involves a straightforward hand layup cold press technique. The motivation behind this research lies in the adoption of lightweight and economical materials, introducing a novel avenue for the development of advanced composites.

The initial goal of this study is to successfully create a laminated panel using fiber glass and discarded brass wire waste, adhering to a predetermined layer sequence for a hybrid system. This is accomplished through the application of the hand layup cold press technique, with notable highlights as outlined below:

a) To fabricates waste of long brass wire in electrical discharge machining (EDM) into composite specimen. The fabrication process comprises two distinct phases. In the initial phase, known as fiber loading, the investigation is focused on determining the optimal ratio of brass wire waste ranging from L10% to L90%. This phase aims to identify the most effective ratio that enhances strength when combined with fiber glass. The second phase involves a comprehensive study of the incorporation of fiber glass layers, specifically from L3 to L10. This investigation aims to pinpoint the combination of brass wire waste and additional fiber glass layers that results in the highest achievable strength. In essence, these two phases collectively contribute to understanding the synergistic effects of brass wire waste and fiber glass layers on the overall strength of the composite material. The matrix ratio for phase 1 and phase 2 are consistant 1:1.

b) Phase 1 involves a comprehensive exploration of nine different ratios ranging from L10% to L90%, with the incorporation of two layers of fiber glass reinforcement according to the specified ratio under investigation. The objective is to identify the most effective ratio that maximizes strength when combined with the two layers of fiber glass. Moving on to Phase 2, the study comprises the utilization of eight distinct layers on the produced panel, spanning from L3 to L10. The findings from Phase 1 indicate that L10% demonstrates superior performance, establishing it as the most promising ratio to be further examined in Phase 2. This phase involves the exploration of different layers, providing valuable insights into how the selected ratio interacts with various fiber glass layer combinations, ultimately contributing to a more comprehensive understanding of the material's strength characteristics.

The second objective of this research is to conduct the specimen testing of long brass wire waste on electrical discharge machining (EDM) wire cut. This objective also achieving by this research the testing included :

a) Tensile test.

b) Flexural test.

c) Impact test.

In addition the third objective is to Analysis of the Utilisation of the Long Fibre Form of EDM Wire Cut Waste in Laminated Glass Composites.

a) Based on a series of tests conducted using three different methods, namely tensile test, flexural test, and impact test, the results indicate that in Phase 1, the combination of fiber glass with reinforcement, specifically brass wire waste, provides additional strength. Phase 1 highlights the effectiveness of a 10% ratio of brass wire waste, as evidenced by values reaching 100% on the spider web chart for parameters such as tensile force, ultimate tensile strength, flexural force, modulus of rupture, energy, and impact energy, with the only exception being a 97% score for impact energy. The results obtained suggest that in Phase 1, the L10% ratio demonstrates overall strength according to the spider web chart, emphasizing its high effectiveness in enhancing the combination of fiberglass and brass wire waste as reinforcement.

b) In Phase 2, the investigation reveals that the optimal layer is found at L6, where six layers of fiberglass and brass wire waste are alternately placed on each layer. This specific configuration was subjected to three tests: the tensile test, flexural test, and impact test. According to the spider web chart analysis, L6 emerges as the most effective and comprehensive layer, showcasing impressive percentages in various mechanical properties. Specifically, L6 demonstrates 97% tensile force, 87% ultimate tensile strength, 30% flexural force, 70% modulus of rupture, 74% energy absorption, and 87% impact energy. These results highlight the superior performance of the L6 layer configuration across multiple testing parameters, as depicted in the spider web chart.

5.2 Recommendation

5.2.1 Fabrication method.

After creating panels through the hand layup process in phases 1 and 2, a potential enhancement lies in adopting vacuum bagging. This technique offers a method to regulate excess adhesive within the laminate, leading to elevated fiber-to-resin ratios. The outcome is an augmentation in strength-to-weight ratios and cost efficiencies for the builder. This stands in contrast to the cold press method employed during the production of panels in phases 1 and 2. By incorporating vacuum bagging, not only can the excess adhesive be better managed, but the resulting panels may exhibit superior strength relative to their weight, providing a more advantageous scenario for the builder in terms of both performance and cost-effectiveness.

5.2.2 Strategies for Scrap Cutting of Brass Wire

Prior to shaping brass wire waste into the desired dimensions, a crucial preliminary step involves rolling the wire to achieve the appropriate thickness. This initial process lays the foundation for subsequent precise scissor cutting, a method meticulously employed to align with the required size specifications. The objective is to minimize any unnecessary waste of the brass wire material by ensuring each cut is tailored accurately. This sequential approach not only enhances efficiency but also contributes to resource optimization. By integrating precision rolling and scissor cutting, this methodology not only meets size requirements but also promotes a sustainable and economical use of brass wire, aligning with best practices in material management and fabrication processes.

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **EFFECT OF EDM WIRE CUT WASTE IN LONG FIBER FORM ON MECHANICAL PROPERTIES OF LAMINATED GLASS COMPOSITE**

SESI PENGAJIAN: **2023-2024 Semester 1**

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APPENDICES

APPENDIX A Gantt Chart for PSM 1

No	TASK PROJECT	Plan/Actual	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Gantt Chart for PSM 1															
			week													
1	Approach Supervisor and registered the title	Plan														
		Actual														
2	Briefing in details about the title of project by supervisor	Plan														
		Actual														
3	Discussing problem statement,objective & scope of research	Plan														
		Actual														
4	Writing and Drafting Chapter 1	Plan														
		Actual														
5	Submission for checking in chapter 1	Plan														
		Actual														
6	correction for chapter 1	Plan														
		Actual														
7	Research on literature review and writing for Chapter 2	Plan														
		Actual														
8	Drafting Literiture Review and writing for Chapter 2	Plan														
		Actual														
9	submission for checking in Chapter 2	Plan														
		Actual														
10	Correction for Chapter 2	Plan														
		Actual														
11	presenting chapter 1 and chapter 2 front of supervisor	Plan														
		Actual														
12	Discussion with Supervisor for Chapter 3	Plan														
		Actual														
13	submission of chapter 3 for checking	Plan														
		Actual														
14	correction of chapter 3	Plan														
		Actual														
15	Drafting and writing for chapter 4	Plan														
		Actual														
16	Submission of draft PSM for full report	Plan														
		Actual														
17	Last correction of the PSM report 1	Plan														
		Actual														
18	submission of report PSM 1 to supervisor and panels	Plan														
		Actual														
19	preparation slide and presentation PSM 1	Plan														
		Actual														

APPENDIX B Gantt Chart for PSM 2

GANTT CHART for PSM 2																	
No	Task Project	Plan/Actual	Week														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Discussion planning task with supervisor and co-supervisor	Plan														
		Actual														
2	Raw material preparation and equipment	Plan														
		Actual														
3	Fabrication process in phase 1	Plan														
		Actual														
4	Cutting process all panel	Plan														
		Actual														
5	Testing all panel	Plan														
		Actual														
6	Analysis of the data in phase 1	Plan														
		Actual														
7	Fabrication in phase 2	Plan														
		Actual														
8	Cutting process all panel	Plan														
		Actual														
9	Testing all panel	Plan														
		Actual														
10	Analysis of the data in phase phase 2	Plan														
		Actual														
11	Writing of chapter 4 & 5	Plan														
		Actual														
12	Submission first draft report psm 2 to supervisor	Plan														
		Actual														
13	Submission draft report psm 2 panel 1 and supervisor	Plan														
		Actual														
14	Presentation preparation	Plan														
		Actual														