UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Mechanical Properties of Glass Fiber Polyester Hybrid Composite Filled with Wood Dust

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2024

Faculty of Industrial and Manufacturing Engineering and Engineering

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2024

MECHANICAL PROPERTIES OF GLASS FIBER POLYESTER HYBRID COMPOSITE FILLED WITH WOOD DUST

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A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours

Faculty of Industrial and Manufacturing Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **MECHANICAL PROPERTIES OF GLASS FIBER POLYESTER HYBRID COMPOSITE FILLED WITH WOOD DUST**

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

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DEDICATION

To my dear father, mother, brother, and friends, who have always been there for me spiritually and emotionally

Ts. Dr Khairum Bin Hamzah, my supervisor for monitoring ,instructing and assisting me from beginning until finish my thesis

ABSTRACT

Nowadays recycle of natural waste-based materials have been widely used in engineering and technology due to their considerable properties, and one of the waste-based material is wood dust. The mechanical properties of glass fiber polyester hybrid composite filled with wood dust are very important and interesting areas to discuss in detail. The objectives of this research are to fabricate a glass fiber polyester hybrid composite filled with wood dust, perform the fabricated materials into the testing specimen, and investigate the mechanical properties of the fabricated materials using tensile, flexural, and impact tests. This research will divide into four stages. The first stage is the fabrication of the materials by using the hand lay-up technique These composites ratios are 20% of wood dust and 80% of polyester (20WD80PR), 40% of wood dust and 60% of polyester (40WD60PR), 50% of wood dust and 50% of polyester (50WD50PR), 60% of wood dust and 40% of polyester (60WD40PR), and 80% of wood dust and 20% of polyester (80WD20PR). The second stage is cutting the fabricated material into the testing specimen using the CNC router machine. The third stage is the testing of the mechanical properties of the specimen using tensile, flexural, impact tests and water absorption test. The final stage is the analysis of the results using statistical analysis ANOVA and bar chart. Based on the analyzed results of the mechanical properties, we will be obtained the best ratio of glass fiber polyester hybrid composite filled with wood dust. The findings indicated that the composite containing 20% wood dust demonstrated better mechanical performance when compared to the other composites.

ABSTRAK

Pada masa kini kitar semula bahan berasaskan sisa semula jadi telah digunakan secara meluas dalam kejuruteraan dan teknologi kerana sifatnya yang besar, dan salah satu bahan berasaskan sisa adalah habuk kayu. Sifat mekanikal komposit hibrid poliester gentian kaca yang diisi dengan habuk kayu adalah kawasan yang sangat penting dan menarik untuk dibincangkan secara terperinci. Objektif penyelidikan ini adalah untuk menghasilkan komposit hibrid poliester gentian kaca yang diisi dengan habuk kayu, melaksanakan bahan yang difabrikasi ke dalam spesimen ujian, dan menyiasat sifat mekanikal bahan yang direka menggunakan ujian tegangan, lentur dan hentaman. Penyelidikan ini akan dibahagikan kepada empat peringkat. Peringkat pertama ialah fabrikasi bahan dengan menggunakan teknik letak tangan. Nisbah komposit ini ialah 20% daripada habuk kayu dan 80% daripada poliester (20WD80PR), 40% daripada habuk kayu dan 60% daripada poliester (40WD60PR), 50% daripada habuk kayu dan 50% daripada poliester (50WD50PR), 60% daripada kayu habuk dan 40% poliester (60WD40PR), dan 80% habuk kayu dan 20% poliester (80WD20PR). Peringkat kedua ialah memotong bahan fabrikasi ke dalam spesimen ujian menggunakan mesin penghala CNC. Peringkat ketiga ialah ujian sifat mekanikal spesimen menggunakan ujian tegangan, lentur dan hentaman. Peringkat terakhir ialah analisis keputusan menggunakan analisis statistik. Berdasarkan hasil analisis sifat mekanikal, kami akan memperoleh nisbah terbaik komposit gentian kaca poliester hibrid yang diisi dengan habuk kayu. Penemuan menunjukkan bahawa komposit yang mengandungi 20% habuk kayu menunjukkan prestasi mekanikal yang lebih baik jika dibandingkan dengan komposit lain.

ACKNOWLEDGEMENTS

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

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life. I would like to extend my appreciation to Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform.

My atmost appreciation goes to my main supervisor, Ts. Dr Khairum Bin Hamzah, Universiti Teknikal Malaysia Melaka (UTeM) for all his support, advice and inspiration. His constant patience for guiding and providing priceless insights will forever be remembered for all the help and support I received from them.

Then , I would also like to thank my beloved parents and brother for their endless support, love and prayers. Finally, thank you to all the individual who had provided me with the assistance, support and inspiration to embark on my study.

Last but not least, I wanna thank me , I wanna thank me for believing in me, I wanna thank me for doing all this hard work, I wanna thank me for having no days off, I wanna thank me for never quitting, I wanna thank me for always being a giver and tryna give more than I receive, I wanna thank me for tryna do more right than wrong, I wanna thank me for just being me at all times.

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LIST OF SYMBOLS AND ABBREVIATIONS

20WD80P	-	20% Wood Dust and 80% Polyester
40WD60P	-	40% Wood Dust and 60% Polyester
50WD50P	-	50% Wood Dust and 50% Polyester
60WD40P	-	60% Wood Dust and 40% Polyester
80WD20P	-	80% Wood Dust and 20% Polyester
ASTM	-	American Society for Testing and Materials
CAM	-	Computer-Aided Manufacturing
CNC	-	Computer Numerical Control
PMC	-	Polyester Matrix Composites
WDPR	-	Wood Dust Polyester Resin

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CHAPTER 1

INTRODUCTION

1.1 Background

In many years back natural waste materials have become common place in engineering and technology due to their substantial characteristics. In order to break through and reduce costs, the volume and number of uses of composite materials have grown. Waste natural fibre substances that can be used include rice husk, sugarcane bagasse, wood dust, pineapple leaf, coconut leaf, rice straw , eggshell, coconut coir, banana peel, and coconut pulp. The waste material were used in this experiment is wood dust. A important and exciting research issue is the mechanical characteristics of a glass fibre polyester hybrid composite filled with wood dust. Because of their outstanding capabilities compared to conventional substances, composite materials are catching the interest of many different sectors, including aerospace, construction, marine and automotive.

Composite materials have lately gained popularity since they are much simpler to maintain than traditional materials due to their resistance to weather, corrosion, and fire. As a result, they require extremely minimal maintenance, leading to long-term cost benefits.Apart from that, composites are popular due to their excellent strength-to-weight the combination and greater variety of applications than conventional materials. Glass fibre polyester hybrid composites are widely recognised for their great strength and stiffness, making them suitable for a wide range of applications. However, their use has been limited due to the high cost of production. To solve this issue, certain researchers have come up with a method that uses natural fibre reinforcements such as wood dust in order to lower the cost of composites. Wood dust is an usually accessible and easily obtained substance. Nevertheless its impact on the mechanical properties of composite materials, particularly glass fibre polyester hybrid composites, remains contentious.

Wood dust is a low-cost, widely available filler substance that may enhance the mechanical properties of a composite. When mixed with a polymer matrix, wood dust can improve the strength and stiffness of the composite material while also improving its sustainability for the environment. A number of research studies on the effects of fillers in composite materials have been done, but the impact of wood dust as a filler in glass fibre polyester hybrid composites remains unclear.

There are multiple limitations on wood dust that have previously existed, including as Previous research may have concentrated on a narrow range of wood dust filler content. Experimentation can study a larger variety of filler concentrations to discover the appropriate composition with the greatest mechanical property balancing. Previous research may have concentrated on individual mechanical qualities, such as tensile strength or flexural modulus, due to a lack of complete property evaluation. To offer a more thorough knowledge of the performance of the composite material, experimental analysis might attempt to examine a wide variety of mechanical characteristics, such as compression strength, impact resistance, fatigue behaviour, and dynamic mechanical properties.

Aside from that, the difference in wood dust parameters, such as particle size, aspect ratio, and moisture content, might impact the mechanical properties of the composites. The next step is to conduct an experimental investigation to determine the impact of these changes in wood dust properties on composite performance. In addition, there are variations in wood dust features, such as particle size, aspect ratio, and moisture content, which can affect the mechanical properties of composites. Wood dust comes from a variety of sources and has these variations in characteristics. The next step is to conduct an experimental investigation to determine the impact of these changes in wood dust properties on composite performance. While wood dust has traditionally been utilised, there are various natural fibre fillers that might be investigated. Comparative studies of wood dust and other natural fibre fillers can reveal information about their relative performance and applicability for various applications.

The objective of this research is Researchers can measure the changes in these qualities as the proportion of wood dust in the composites varies using experimental analyses. This research aids in the determination of the ideal composition of wood dust filler, which can lead to increased mechanical performance. The capacity of the composite to sustain applied forces without failing may be determined by analysing its mechanical strength. The stiffness of the composites may be analysed to determine their rigidity and deformation resistance. The examination of impact resistance offers information about the composite's capacity to absorb energy and endure unexpected loads. Furthermore, experimental study enables comparison of the wood dust-filled composites with other composite materials, such as standard glass fibre composites or polyester composites. This comparative study helps in identifying the benefits and disadvantages of wood dust-filled composites, assisting in material selection and design standardisation.

Researchers can help to the development of sustainable materials while also improving their performance by examining the impact of wood dust filler on the mechanical characteristics of glass fibre polyester hybrid composites. These discoveries might be useful in a variety of industries, including automotive, construction, and aerospace, where materials with precise mechanical qualities are required. Furthermore, the generated experimental data may be utilised for material characterisation and modelling, making it easier to anticipate composite behaviour in practical situations and assuring that they are safe and reliable.

1.2 Problem statement

In recent years, there has been a substantial increase in the utilization of composite materials across various engineering and construction industries. This surge in popularity can be attributed to their noteworthy properties, including being lightweight, possessing a high strength-to-weight ratio, offering durability, and demonstrating versatility. However, the cost and environmental impact of traditional composite manufacturing methods is a significant challenges to widespread adoption. Over the past few years, there has been an increasing interest in the advancement of sustainable and affordable fillers for composite manufacturing. Especially given the fact that wood dust is inexpensive and commonly available, nothing is known about its influence on the mechanical properties of glass fibre polyester hybrid composites.

The current research is centered on conducting experimental analysis of a hybrid composite material consisting of glass fiber and polyester, with the addition of wood dust as a filler. The objective of this experiment is to analyze the impact of wood dust on the mechanical properties of glass fiber-polyester hybrid composite. The experiment will compare the mechanical properties of the composite material filled with wood dust with different ratios of polyester and wood dust. The independent and dependent variables that will be analyzed include tensile strength, flexural strength, impact strength and water absorption. The experiment will use a testing machine to apply the load to the specimen, and the data analysis will be carried out using statistical methods. The findings of this experiment will contribute to the development of sustainable and cost-effective composite materials and have significant implications for the engineering and construction industries.

1.3 Research Objective

The main objective of the research is to look at the mechanical properties of a glass fibre polyester composite filled with wood dust. The following are the specific objectives:

a) To fabricate a hybrid composite, a glass fibre polyester composite filled with wood dust.

b) To perform the fabricated material into the testing specimen.

c) To investigate the mechanical properties of the fabricated material using tensile , flexural , impact and water absorption test.

1.4 Scope of Research

The objectives of this research are to look into the mechanical characteristics of glass fibre polyester filled with wood dust. The research process will be divided into four steps. The materials are created in the first step applying the hand lay-up technique. The second stage is cutting the fabricated material into the testing specimen using the CNC router machine. The third stage is the testing of the mechanical properties of the specimen using tensile ASTM D3039, flexural testing ASTM D790 , impact tests ASTM D6110 and water absorption ASTM D570. The final stage is the analysis of the results using statistical analysis. Based on the analyzed results of the mechanical properties, we will be obtained the best ratio of glass fiber polyester hybrid composite filled with wood dust.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will expand on a review that highlights the theory or foundation of many topics, as well as historical or modern research on wood dust. This chapter will also detail the procedure and parameters for making a composite material out of wood dust. This study investigated the effects of flaws on natural wastes produced by various procedures. Aside from that, this chapter will establish mechanical characteristics and conventional American Society for tests and Materials (ASTM) tests.

2.2 Agriculture Waste

The growing awareness of environmental issues and the fast growth of the manufacturing sectors indicate the need for more cost-effective and biodegradable materials with superior qualities such as outstanding mechanical capabilities, great chemical resistance, reduced maintenance, and lower cost.(Peretomode, Eboibi, and Fakrogha , 2019). A huge number of wood shavings as waste from woodworking operations such as wood chips, wood dust, overlay boards, and combinations of two or more are created worldwide at such a rapid rate that the degree of recycling is insufficient when compared to the rate of trash formation. It has been stated that between 8% and 50% of all wood-based material is used each year for various purposes before becoming waste. These recyclable wood wastes are commonly thrown in dumps and, on occasion, publicly burned, causing air pollution through open-air burning or burned in a combustion chamber.(Owodunni et al. , 2020).

2.3 Composite

Composites are created by fusing two or more distinct materials, known as the base matrix and reinforcement. Combining diverse materials has the benefit of developing a resulting material with superior properties than the initial materials used (Chak, Chattopadhyay, and Dora , 2020)**.** Natural composites reinforced with natural fibres have grown in popularity and value in recent years. Natural fibres including flax, jute, wood dust, and kenaf are utilised to reinforce polymer-based matrices. Natural fibre composites are becoming increasingly important as a result of environmental restrictions, sustainability principles, environmentally friendly, social, and economic awareness (Sarikaya, Çallioğlu, and Demirel , 2019) .

2.3.1 Hybrid Composite

Hybrid composites are those that are created by combining two or more different types of fibres as reinforcement in a matrix. Hybrid composites have features and characteristics that single-fiber reinforcement doesn't match (Sapuan et al. , 2020) . Other than that the physical and mechanical properties of hybrid composites are determined by the aspect ratio of the fibre, the qualities of the individual fibre, the orientation of the fibre, the length of the individual fibre, the adhesion between the fibre and the matrix, and the stacking sequence of both fibres. The characteristics of hybrid composites of two components may be calculated using the mixtures rule (Karthi et al. , 2019) .

Hybridization is suggested by researchers to solve natural fiber's weaknesses and cut down on non-environmentally friendly synthetic fibers. Hybrid composites have unique benefits like balanced strength, reduced weight and cost, improved fatigue resistance and fracture toughness, and better impact resistance. These synthetic-natural fiber hybrids are used in various applications, attracting the attention of manufacturing industries to switch to this modern material (Suriani, Rapi, et al. , 2021) .

2.4 Work Material

The materials, tools, equipment, components, machineries, apparatus, supplies, and utilities needed to do the task are referred to as work materials. In this project, We presented many materials and approaches in order to get the best possible result.

2.4.1 Wood Dust

Fibers are thin strands that can be twisted into ropes, filaments, or threads. They are valuable components in composite materials and can also be made into sheets for manufacturing felt or paper. Fibers are categorized into three types: natural, man-made, and synthetic. Natural fibers are derived from animals, plants, or minerals and are obtained from nature without causing harm to the environment. Examples of natural fibers derived from animals include feathers, wool, silk, and hair. Plant-based natural fibers like banana, jute, hemp, bamboo, flax, and sisal are commonly used in the production of natural fiber reinforced polymer (NFRP) composites (Suriani, Ilyas, et al. , 2021) . Figure 2.1 shows the classification of natural fiber.

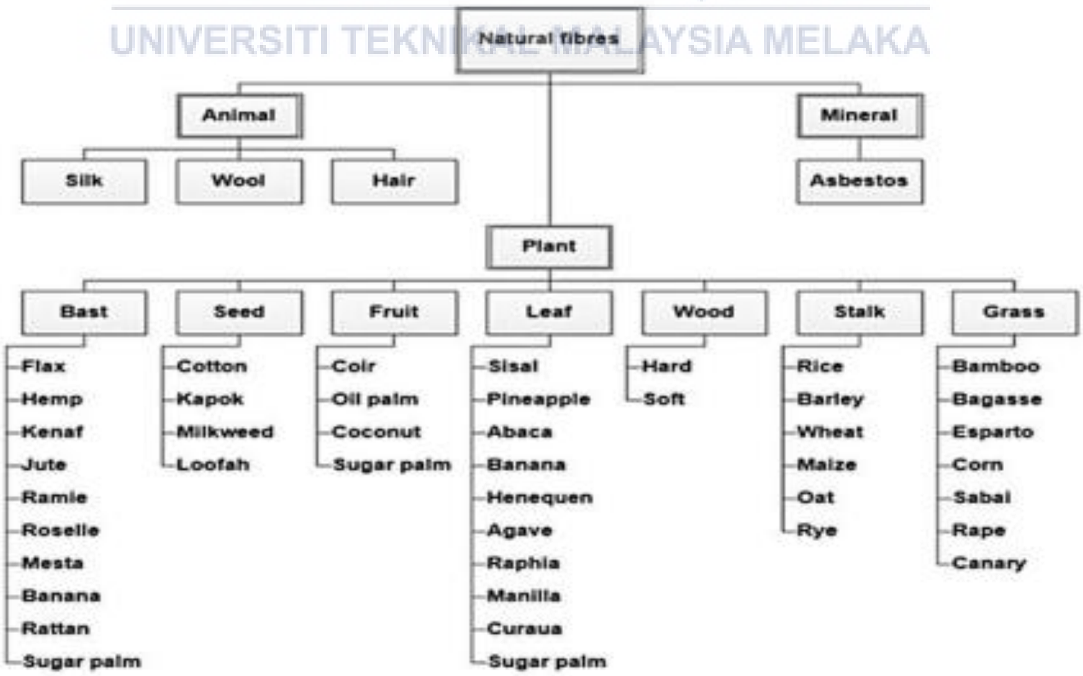

Figure 2.1 shows the classification of natural fiber.

As compared to filers such as nano-clays, nanotubes, and many other inorganic fillers, the widespread availability of wood dust fillers makes it cost-effective in the use of polymer matrices (Dinesh et al. , 2020) . wood dust is an outcome of the wood industry, which causes significant pollution in the surrounding environment. The effective use of eliminated wood dust can help to tackle the environmental problem (Mishra , 2019).

According to experimental research and recommendations, wood fibres captured the interest of many people due to their qualities that are similar to those of polypropylene/glass fibre composites. Because of its visually pleasing qualities and high physical strength, structural wood is the most used structural material (Velmurugan and Babu , 2020) .

2.4.2 Woven Fiber Glass

Nowadays, glass fibres constitute the bulk of the reinforcements most commonly used for the reinforcement of advanced composite materials in a variety of industrial application domains. Glass fibres are necessary for the reinforcement of very big and high performance composite materials (Hsissou et al. , 2021) . Glass fiber is a strong and lightweight material constructed of very thin glass strands. It is made by extruding silica glass into many tiny fibers. These separate fibers are then combined to produce roving. Finally, they are woven by machine to create woven roving, a fabric (Ram, Kumar, and Kumar , 2020) . Tables 2.1 shows glass fiber main constituents.

Tables 2.1 shows glass fiber main constituents (Hsissou et al. , 2021).

Main glass fibers.

Main constituents in %	Types of glasses		
	E	D	R
Silica oxide (SiO_2)	53–54	70	60
Alumina oxide (Al_2O_3)	14–15	–	25
Magnesia oxide (MgO)	20–24	0.5	9
Boron oxide (B_2O_3)	6–9	22	6
Boron oxide (B_2O_3)	6–9	22	6

Glass fiber is a high-quality artificial fiber composed of glass, which generally contains over 50% silica and other mineral oxides like calcium, iron, and aluminum oxides (Ramkumar et al. , 2021) .

2.4.3 Polyester Resin

Polyester matrix composites (PMCs) have become popular in the industrial sectors because of their high fracture toughness, low weight, superior strength-to-weight ratio, high tensile characteristics, high fatigue resistance, and increased corrosion resistance in extreme conditions (Mahmoud Zaghloul, Yousry Zaghloul, and Yousry Zaghloul , 2021) . Polyester resin is less expensive than epoxy resin, but it has lesser temperature capacity, tensile qualities, and environmental durability (Akaluzia et al. , 2021). Polyesters are strong thermoset polymeric materials that can be manufactured or natural and are classified as aromatic or aliphatic based on their basic structure (Mahmoud Zaghloul, Yousry Zaghloul, and Yousry Zaghloul , 2021) .

For the table 2.2 is the basic mechanical characteristics of resins used as matrix between epoxy resin and polyester resin.

Table 2.2 the basic mechanical characteristic of 2 type of resin (Mahmoud Zaghloul, Yousry Zaghloul, and Yousry Zaghloul , 2021).

Properties	Epoxy resin	Polyester resin
Density (g/cm^3)*	1.17	1.5
Tensile Strength (MPa)	39.39 ± 11.84	34.78 ± 4.52
Young's Modulus (GPa)	2.5 ± 0.4	4.97 ± 0.56

The addition of natural fibre particles as reinforcement in a polyester matrix is designed to cut costs while improving mechanical qualities. This might result in the creation of polymer composite materials with high mechanical strength combined with low weight and strong corrosion resistance (Akaluzia et al. , 2021) . Following that, Figure 2.2 illustrates the structure of polyester resin or unsaturated polyester resin (UPR).

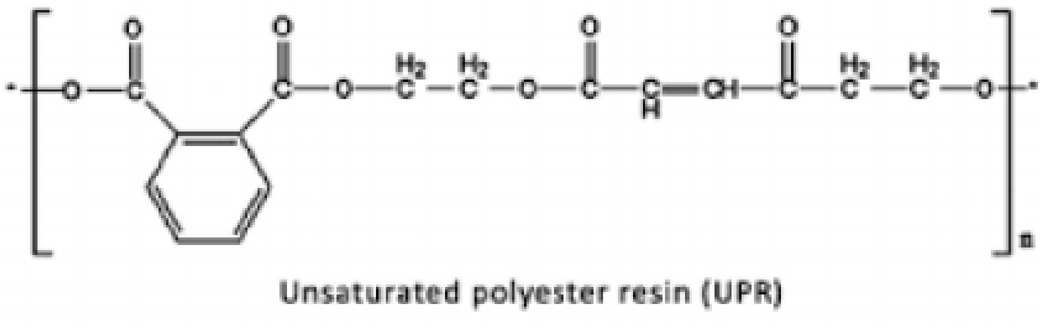

Figure 2.2 Structure of unsaturated polyester resin (UPR).

2.5 Hand Lay Up Method

Hand layup is a traditional manual process for producing laminated composite materials. It is effective for hybrid composites including fibrous components. A weighted steel roller is utilised in the process to exert pressure and promote bonding between layers of fibre and polyester resin. By applying pressure to continuous layers of matrix and reinforcements, the materials are equally dispersed and any trapped gas is eliminated. The technique is repeated until the required thickness is achieved (Sadashiva et al. , 2021) .

The hand lay-up technique is the most common and affordable method for open-moulding because it requires minimal equipment. After completing the hand lay-up, it needs to be cured for 24 hours at room temperature with a pressure of 2.5 MPa (Hemnath et al. , 2020). In the hand lay-up method, resin is initially applied, followed by the placement of fibers based on their orientation. More resin is applied based on the fiber's orientation and requirements, and multiple fiber layers are stacked and molded accordingly. Figure 2.3 shows a simplified illustration of the hand lay-up process (Giridharan , 2019) .

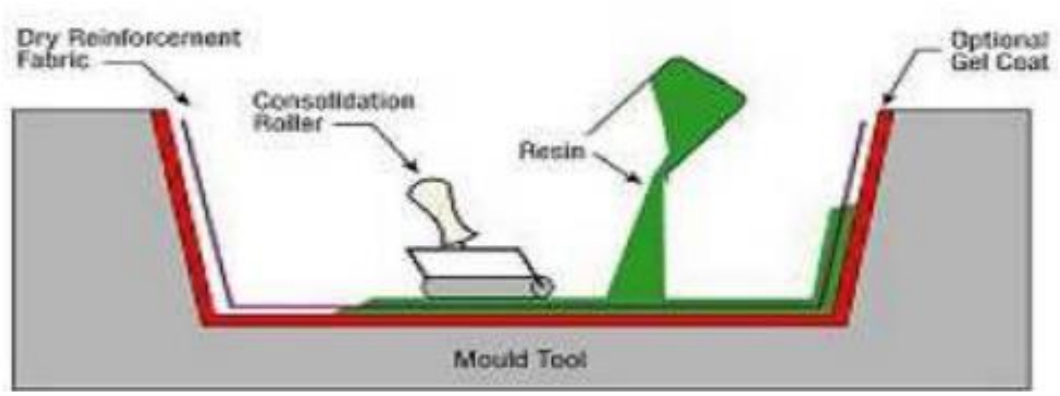

Figure 2.3 shows a simplified illustration of the hand lay-up process (Giridharan, , 2019)

2.6 Cutting Process Machine

In order to accomplish the cutting process in this project, a CNC router machine will be employed. The objective is to cut the specimens within a specific size range, adhering to defined parameters, and ensuring the appropriate tool eye speed is utilized.

2.6.1 CNC Router Machine

CNC machines are now used in many production industries. They come in different types like lathes, mills, and routers. These machines can drill, bore, turn, and mill various materials such as metals, polymers, composites, solid woods, and wood-based products. Furniture companies have started using CNC machines to work on solid wood and wood-based panels. They employ processes like cutting, turning, and milling to treat the materials (Bal and Dumanoğlu , 2019) .

CNC (Computer Numerical Control) is the use of computer programs to automate machine tools and create specific product shapes. A cost-effective CNC machine, suitable for industrial use and engraving, has been designed and constructed. The system is easy to use, providing precise outcomes and can be adjusted according to user requirements. Additionally, the installation of a 3-Axis CNC Router for small-scale industry has been accomplished, along with CAM (Computer-Aided Manufacturing) training (Bangse, Wibolo, and Wiryanta , 2020).

In CNC machining, important parameters like tool speed and size are used during the cutting process. Two different types of end mill tools, spiral and straight, were used on the CNC machine. The roughness of both untreated and thermally treated specimens was significantly influenced by the type of end mill used. When comparing the two, specimens machined with the straight end mill had lower roughness values than those machined with the spiral end mill (Pelit, Korkmaz, and Budakçı , 2021). Table 2.3 shows the CNC router machine's cutting configurations.

Table 2.3 : The CNC router machine's cutting configurations (Pelit, Korkmaz, and Budakçı , 2021).

Cutting Direction	Tangential, radial
End Mill Type	Straight end mill, spiral end mill
Spindle Speed (rpm)	12000, 15000, 18000
Feed Rate (mm/min)	3000, 4000, 6000
Cutting Depth (mm)	4
Tool Diameter (mm)	10

2.7 Mechanical Testing

Mechanical testing on composites involves evaluating how these materials respond to forces and deformations. It helps determine their strength, stiffness, toughness, and resistance to fatigue. This testing is essential for selecting materials, optimizing designs, and ensuring quality control. Tests include tension, compression, bending, shear, impact, fatigue, interlaminar shear, and hardness tests. The results provide valuable information for industries like aerospace, automotive, construction, and sports.

2.7.1 Tensile Test

Tensile properties refer to how materials react when subjected to stretching forces. These properties are important because they provide information about various characteristics, including elasticity, strength, and deformation.

Tensile mechanical properties can be determined using the engineering stress-strain curve, as shown in Figure 2.4. There is another curve called the true stress-strain curve, which can be obtained by applying equations before the material starts to neck or before it reaches the highest point on the engineering stress-strain curve (Zheng et al. , 2020) .

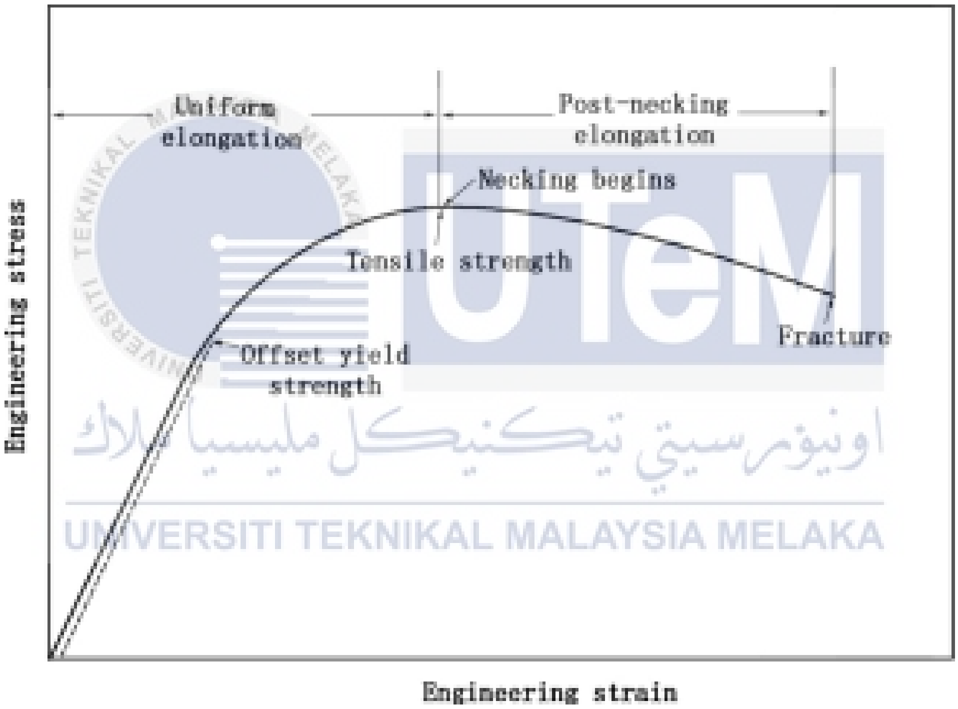

Figure 2.4 shows the engineering stress-strain curve.

Tensile properties are typically measured using tensile testing, which follows ASTM standards. The appropriate standards for the test depend on the type of polymer composite being evaluated. ASTM D638 is recommended for composites with random orientation, low reinforcement volume, or moldable materials. On the other hand, ASTM D3039 is used for composites with highly oriented fibers and high tensile modulus. The specimens used in tensile testing are usually shaped like dumbbells, dog bones, or rectangular bars as in figure 2.5 (Rahman and Putra , 2019).

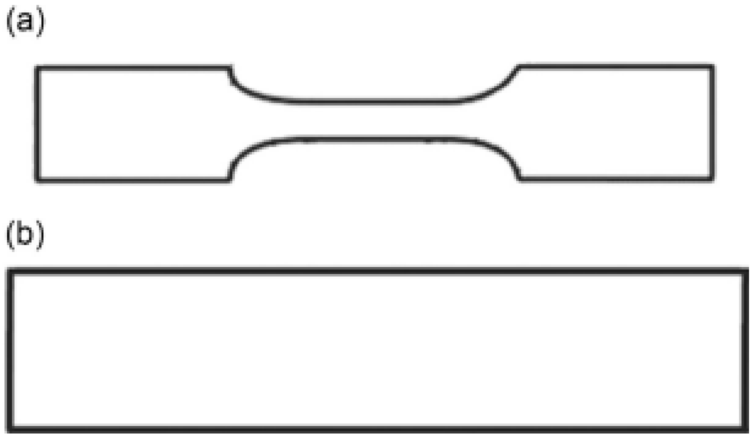

Figure 2.5 shows specimens shape use in tensile test such as dog bone and rectangular (Rahman and Putra , 2019) .

For the tensile testing, the specimens that have been tested were prepared according to the ASTM D3039 standard. The samples had a length of 250mm and a width of 25mm. During the testing, the composite had an overall thickness of 6.8mm, with a slight variation of 0.2mm. The length between the grippers was set to 100mm. The universal testing machine used was the Shimadzu 300 KN, and the cross-head speed was set at 5mm/min. The load was applied to the samples until they failed. The analysis in this experiment was based on the average value of five experimental samples (Abu Shaid Sujon, Habib, and Abedin , 2020)

2.7.2 Impact Test

Charpy impact testing is an affordable and efficient method used for assessing the impact toughness and notch sensitivity of materials. Its simplicity in sample preparation and quick data collection has made it a popular choice for quality control across different industries (Abidin et al. , 2019) . The impact test is intended to assess how a known material, such as polymers, ceramics, and composites, would behave to a rapid application of stress. The impact test is specifically used to assess the toughness, brittleness, notch sensitivity, and impact strength of engineering materials in order to determine their resistance to high-rate loading (Saba, Jawaid, and Sultan , 2019) .

Being able to measure the impact property is highly advantageous when it comes to product liability and safety. Impact tests use different types of specimens as in figure 2.6, such as V-notch, U-notch, and keyhole notch, to assess the material's behavior. The most commonly used impact testing methods are Charpy and Izod tests, which use specific specimen configurations.

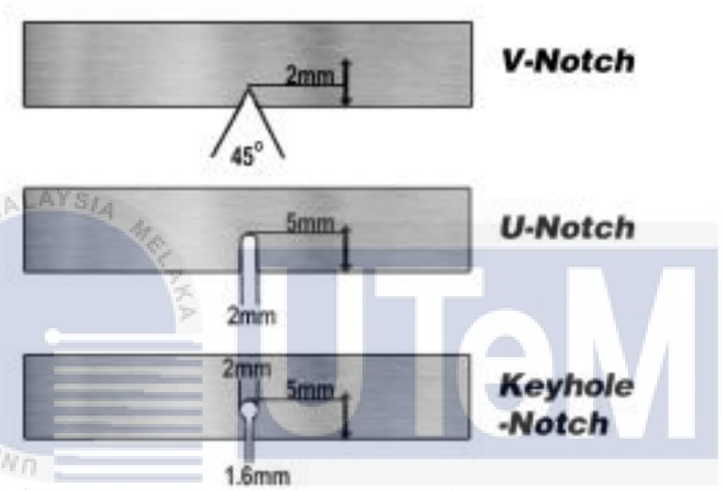

figure 2.6 , shows V-notch, U-notch, and keyhole notch (Saba, Jawaid, and Sultan , 2019) .

2.7.3 Flexural Test

Flexural strength of a composite is described as a material's capacity to bear maximal tensile stress in bending before failure (Walte, Bhole, and Gholave , 2020) **.** The flexural test assesses the bending force required for materials like rigid and semi-rigid substances, resins, and laminated fiber composites., The specimen is supported and loaded at the center, creating three-point bending at a controlled rate. Flexural testing also provides some information about the strength of the bond between fibers and the matrix in a composite. The test yields data on parameters such as flexural stress and strain at yield, flexural stress and strain at break, flexural stress at a specific deflection point (3.5% for ISO or 5.0% for ASTM), flexural modulus, and stress/strain curves (Saba, Jawaid, and Sultan , 2019).

To evaluate the hybrid composite, three-point bending or flexural tests, which are highly effective, can be conducted following the guidelines of ASTM D 790. The specimens used had a width of 250mm and a length of 25mm. During testing, all samples were subjected to a cross-head speed of 5mm/min, with a span length of 100mm between the supports. Five identical samples were tested, and the average results obtained were used for analysis purposes (Abu Shaid Sujon, Habib, and Abedin , 2020) .

2.7.4 Water Absorption Test

According to ASTM D570, water absorption, also known as water absorption 24-hour/equilibrium, is a key test for materials designed for external applications. This test determines how much water a substance absorbs under specified conditions. Water absorption is influenced by a number of parameters, including the kind of plastic, additives, temperature, and time of contact (Saba, Jawaid, and Sultan , 2019) .

The samples were fully placed in distilled water and taken out after 24 hours. After drying the surface with a clean cloth, the samples were weighed using 4 digit weighing balances (Thiagamani et al. , 2019) . This process was repeated at specific time intervals (24, 48, 98, 196, and up to 312 hours). The percentage of water absorption is calculated using a specific equation as in figure 2.7 (Abu Shaid Sujon, Habib, and Abedin , 2020).

$$\text{Water absorption (\%)} = \frac{m_2 - m_1}{m_1} \times 100$$

figure 2.7 shows equation for water absorption

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter contains in-depth information about the methods or processes used to seek, select, and evaluate material on this subject. The reader is given the option to examine the full technique and dependability employed by these researchers to accomplish the present work aim in the methodology section of this chapter. This research will be conducted in three parts. The first stage is to create experiment material using the hand lay-up technique in five different volume ratios which is 20% wood dust and 80% polyester (20WD80P), 40% wood dust and 60% polyester (40WD60P), 50% wood dust and 50% polyester (50WD50P), 60% wood dust and 40% polyester (60WD40P), and 80% wood dust and 20% polyester (80WD20P). The material is then cut into the experiment specimen using a CNC router machine in the second stage. The specimen size will be consistent with (ASTM D3039) for tensile testing, (ASTM D256) for impact testing, (ASTM D790) for flexural testing and (ASTM D 570) for water absorption. The final stage involves statistical analysis of the experiment material. This chapter will provide a broad overview of the experiment and technique used to achieve a precise result.

3.2 Process Flowchart

The flowchart shows a technique in which the steps are done sequentially. Flowcharts are also a visual representation of algorithms and related to employment procedures. The flow of the process can be seen in Figure 3.1, from start to finish.

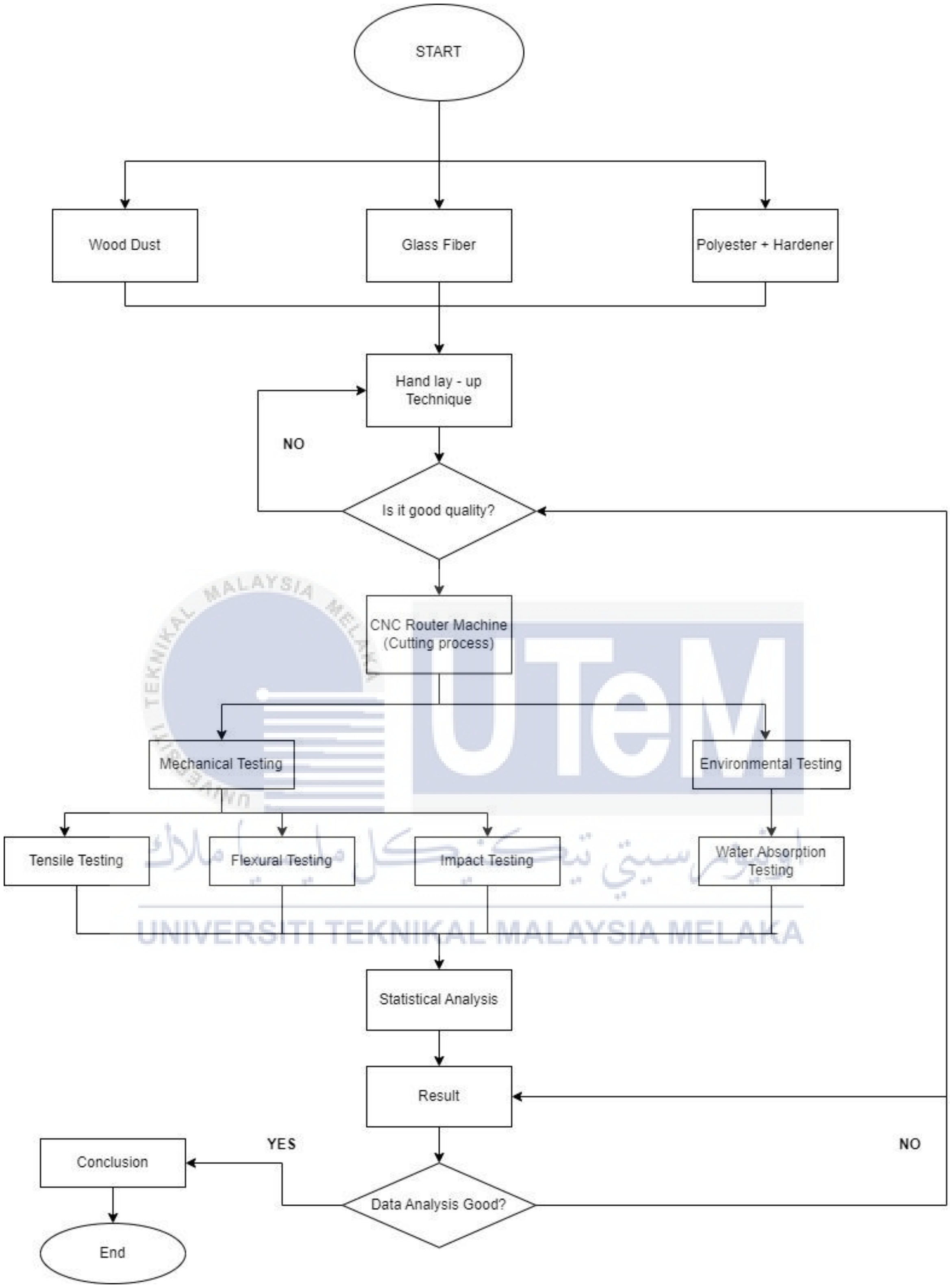

Figure 3.1 Process Flowchart

3.3 Measurement Process

Wood dust size is measured using laboratory test sieves. The laboratory test sieves used are shown in Figure 3.2. The machine's electricity is switched on to begin the procedure. The wood dust must be poured into the top of the sieves before the procedure can begin as shown in figure 3.3. Figure 3.4 tells us that the wood dust's size is 35 mehs.

Figure 3.2 laboratory sieves test machine

Figure 3.3 Wood dust were poured into the top of sieves

Figure 3.4 Mesh size of wood dust is at 35 mesh

3.4 Fabrication process

For the starting ratios, Wood dust will be manually combined with polyester resin based on volume (20WD80P, 40WD40P, 50WD50P, 60WD40P and 80WD20P) and poured into the mould that had fiber glass on it for the hand lay-up process. The mixing and lay up procedure is shown in Figure 3.5 . The mixture will be left for 24 hours to allow for drying

The fabricated composite for tensile and flexural samples will be produced in a single mould with dimensions of 212 mm width 312 mm length 12 mm thick for a total of 10 samples per ratio. This is done to cut down on manufacturing time and waste. The impact sample will be done in the same mould as the previous tests.

Figure 3.5 The fabrication and drying procedure

3.4 CNC Router Machine Process

For mechanical testing samples, a CNC router machine will be used to cut the specimen to a precise size. I need to give 5 samples per ratio for each mechanical test, for a total of 100 samples. The sample size for the tensile and flexural testing is 250mm 25 mm per sample, whereas the sample size for the impact test is 60mm 15mm, as illustrated in Figure 3.6 and 3.7. The CNC router machine's spindle speeds will be set at 100rpm, 200rpm, and 300rpm, and the cutting tool diameter will be 3mm. The material test should then be placed over the vice to secure it. The computer control panel must be properly positioned, and the coordinate axis must be set to zero. Once the coordinates are in the proper place, start the machine by clicking the "output" button on the control panel. Figure 3.8 depicts the cutting process and outcomes of a CNC router machine.

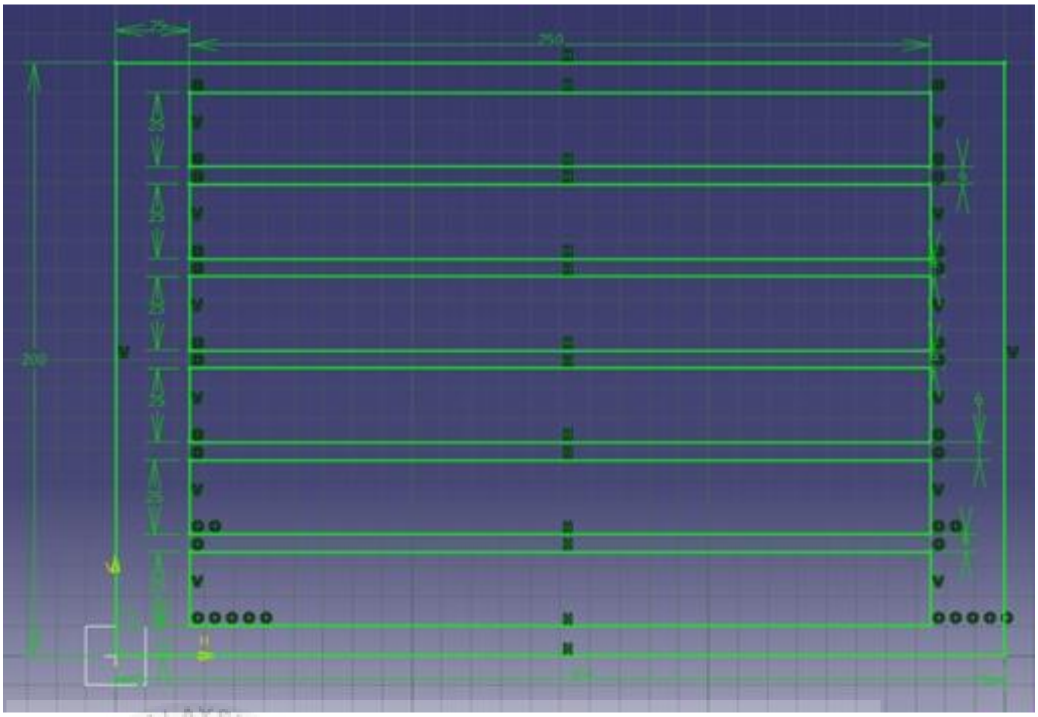

Figure 3.6 The parameter design of specimens for tensile and flexural testing

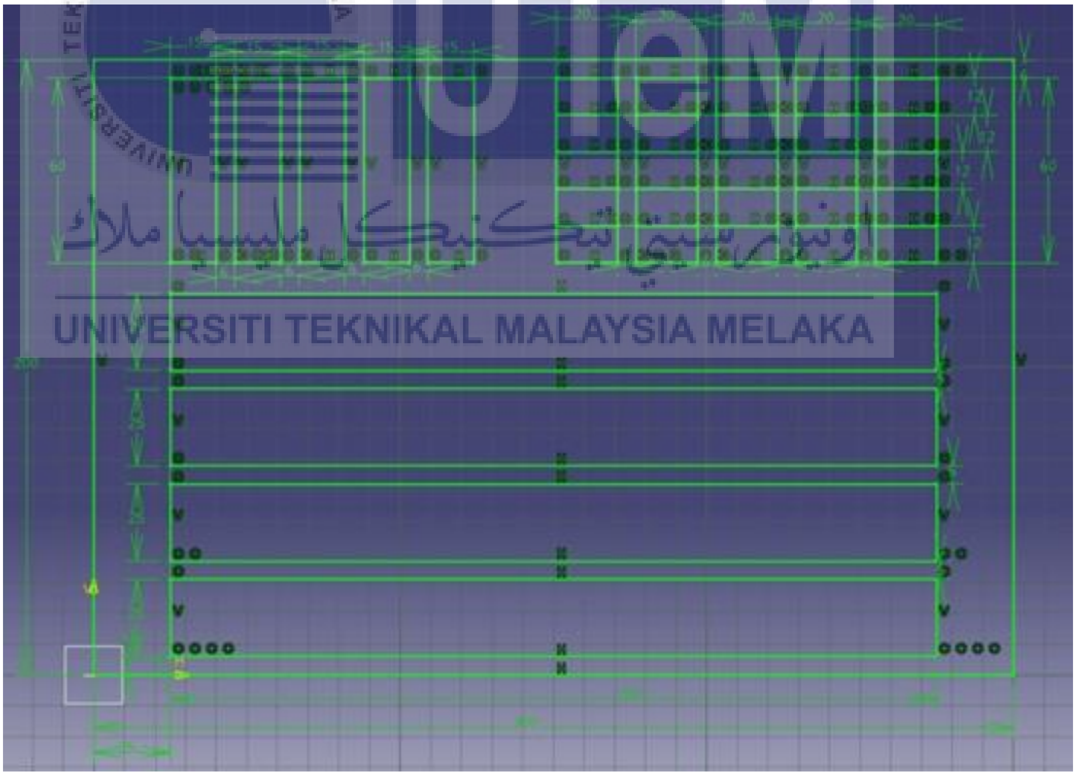

Figure 3.7 The parameter of specimens for flexural, impact and water absorption testing

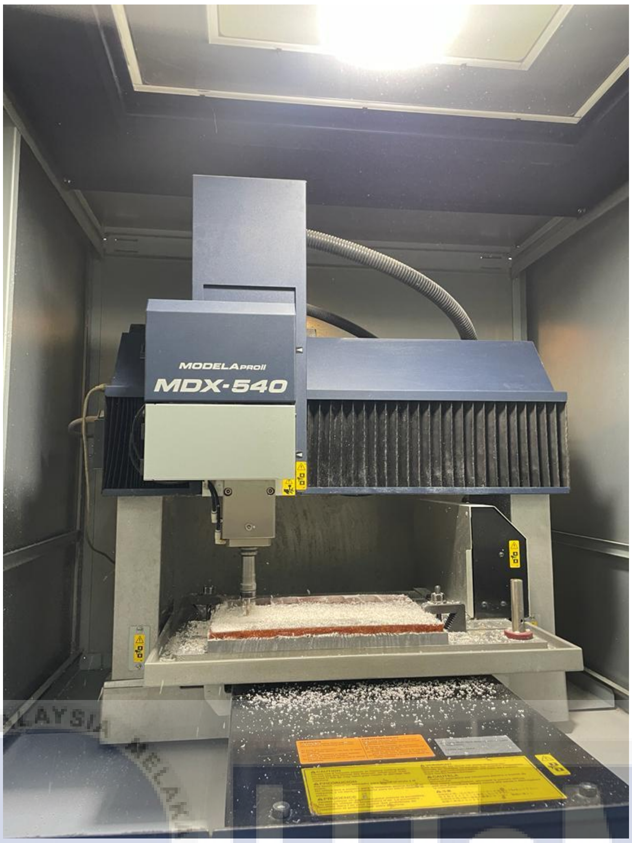

Figure 3.8 depicts the cutting process

3.5 Tensile Testing

The produced composite samples of size 250 mm 25 mm will be tensile tested utilising an ASTM D 3039 universal testing equipment with a load cell range of 100 kN. Insert all sample data, such as material thickness, length, and material type, into a tensile test software programme. Place the samples in the lower and higher clamps in their correct positions to avoid material fracture in the gripped region. Run the programme, and the results will be shown as stress-strain curves . Figure 3.9 Tensile testing process .

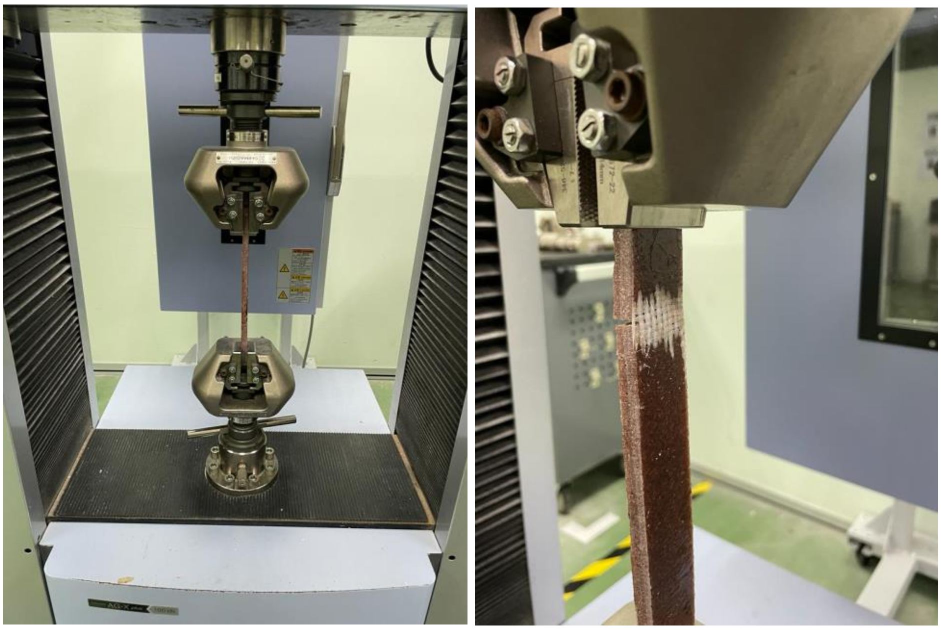

Figure 3.9 Tensile testing process

3.6 Impact testing

The Charpy impact test will be used in line with the ASTM D6110 standard to analyse the toughness of the materials and strength at the yield point. To assess the notch toughness of the test material, a V notch will be made to the body of the sample. The average values will then be calculated using data from all twenty five samples. Figure 3.10 shows the process of impact testing.

Figure 3.10 shows the process of impact testing.

3.7 Flexural Testing

The produced composite samples of size 250 mm 25 mm will also be subjected to flexural testing utilising an ASTM D 790 universal testing equipment. The flexural test (three-point bending) programme will be chosen, and all sample data will be entered. The crosshead speed was set to 50 mm and 1.25 mm/min for the support span, respectively. The flexural property of the samples was measured by taking the average of five samples. Figure 3.11 shows the process of flexural testing.

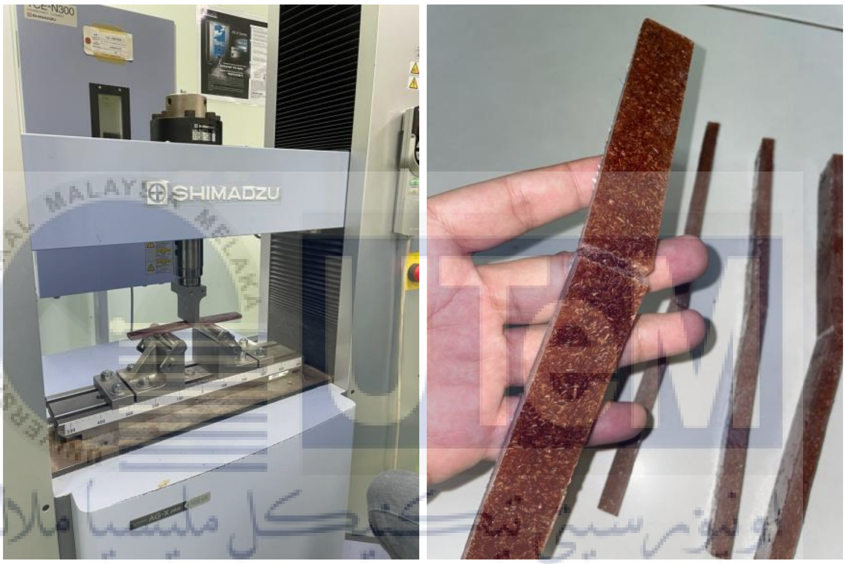

Figure 3.11 shows the process of flexural testing.

3.8 Water Absorption

Water absorption testing is the final sample for testing. We must utilise ASTM. Following that, we used a leftover sample from the previous tests for our test. For the best results, the sample will be soaked for 25 days. Figure 3.12 shows the process of water absorption testing.

Figure 3.12 Shows the process of water absorption testing.

3.9 Statistical Analysis

In this study, Microsoft Excel will be utilized to perform statistical analyses on the collected data. The analysis will involve determining the mean, median, and variance of the sample values to obtain a single representative value. Additionally, an Analysis of Variance (ANOVA) method will be employed to assess the strength of the specimens following the cutting process using a CNC router machine. To visually represent the data, bar charts will be created for each sample. These bar charts provide a graphical depiction of the data points and facilitate easy comparison between different samples.

The results of the ANOVA process will be presented, which includes several statistical parameters. The table will display the sum of squares (SS), degree of freedom (df), mean squares (MS), test statistic (F), and significant value (P). These values are essential for evaluating the significance of the observed differences among the samples. Table 3.1 shows the example Analysis of variance (ANOVA) method.

Table 3.1 shows the example Analysis of variance (ANOVA) method.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
20WD80P	5	18.167	3.6334	0.015766
40WD60P	5	13.695	2.739	0.796694
50WD50P	5	7.154	1.4308	0.054933
60WD40P	5	6.584	1.3168	0.021895
80WD20P	5	4.722	0.9444	0.751486

3.10 Summary

In order to successfully achieve the objectives of the project, it is crucial to ensure that all procedures and preparations are executed accurately and in alignment with the process planning. Throughout this chapter, the planning, methods, and preparations have collectively played a significant role in attaining the desired outcomes and results. To obtain accurate and reliable results from these tests, it is imperative to meticulously follow all the prescribed methods without any errors. Adhering to the defined procedures will contribute to obtaining the correct and valid outcomes.

3.11 Gantt Chart

3.12 Gantt Chart PSM 1

As shows in APPENDIX A

3.13 Gantt Chart PSM 2

As shows in APPENDIX B

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

The results of the tests that were conducted, as well as the calculation that was used, will be analysed and explained in this chapter. To assess the mechanical properties of glass fiber polyester hybrid composite filled with wood dust, four distinct testing methods will be used which is impact, tensile, flexural testing and water absorption testing . In all testing processes, the specimen size is typically determined by following the ASTM standard.

4.2 Tensile Test Result

To assess the mechanical characteristics of the experiment, a tensile test will be conducted on the specimen to gauge both its tensile strength and elasticity. Tensile strength and elasticity values for each WDPR ratio are depicted in Figures 4.1 and 4.2. It was observed that the 20WD80P composite ratio displayed superior tensile strength and elasticity compared to the other WDPR composite ratios. Conversely, the 80WD20P ratio exhibited the lowest values for both tensile strength and elasticity. This observation prompted the inference that an increase in the proportion of wood dust to 20% in WDPR composites enhances both tensile strength and elasticity values. The conclusive results of the specimen after the tensile test are illustrated in Figure 4.3.

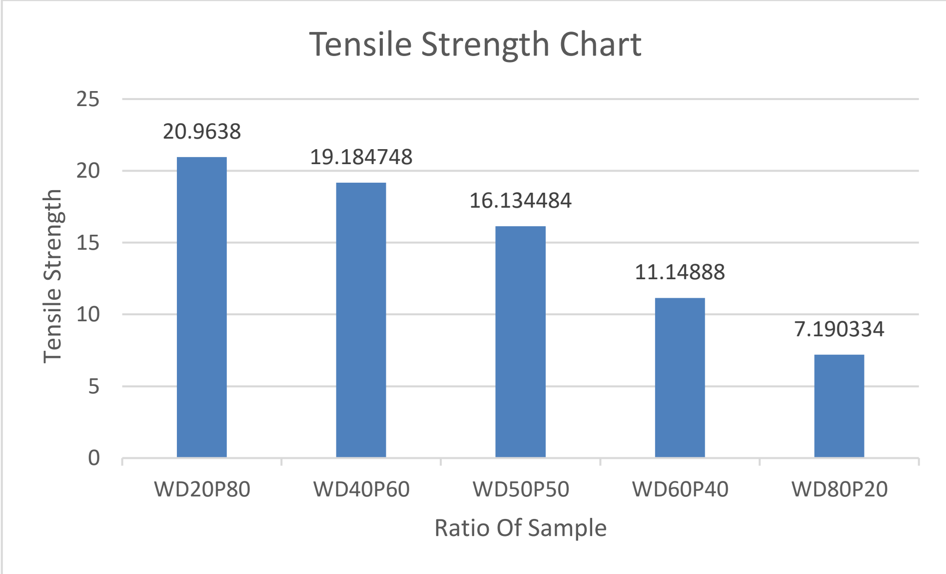

Figure 4.1 Tensile strength for five ratios of WDPR composites

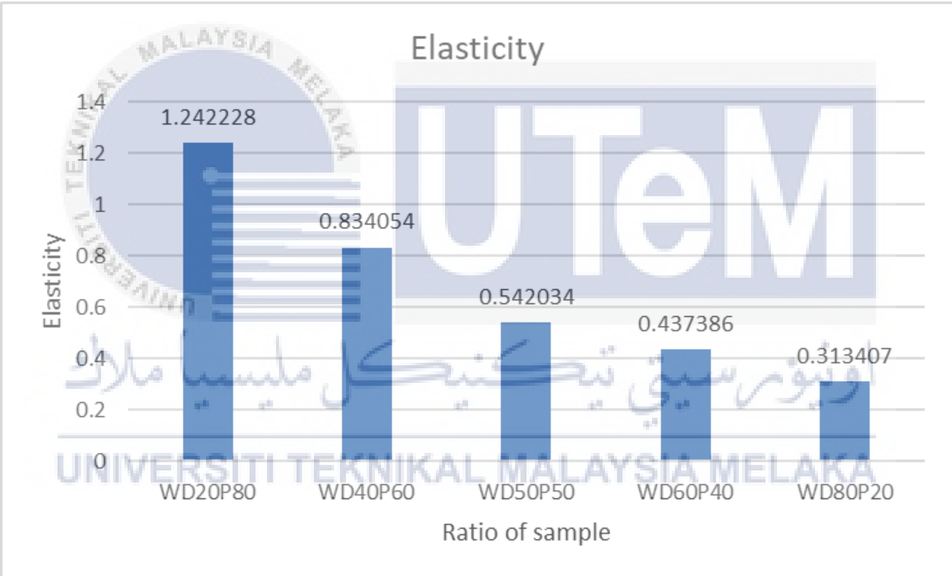

Figure 4.2 Elasticity for five ratios of WDPR composites

Figure 4.3 The tensile testing specimen

Subsequently, a one-way analysis of variance (ANOVA) was employed to examine the tensile strength and elasticity of the WDPR composites, as detailed in Tables 4.1 and 4.2, respectively. The outcomes revealed that the tensile strength and elasticity of the WDPR composites across all five ratios remained statistically significant, with the P-value falling below the designated significance threshold of $\alpha = 0.05$. This indicates that the average values of tensile strength and elasticity differ among the five ratios of WDPR composites. Consequently, combining wood dust with polyester resin in proportions of 20% and 80%, respectively, yields the most favorable tensile

Table 4.1 SUMMARY of tensile strength for five ratios of WDPR composites

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
WD20P80	5	104.819	20.9638	0.643712
WD40P60	5	95.92374	19.18475	0.636019
WD50P50	5	80.67242	16.13448	0.409557
WD60P40	5	55.7444	11.14888	0.669824
WD80P20	5	35.95167	7.190334	0.820339

We can see from table 4.1 that the mean is the average of a group of values, the variance indicates how much each value in a dataset deviates from the mean, and the standard

deviation is the variance squared, which gives us an idea of how widely distributed the data are overall.

Table 4.2 ANOVA of tensile strength for five ratios of WDPR composites

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	650.7977	4	162.6994	255.861	7.23E-17
Within Groups	12.7178	20	0.63589		
Total	663.5155	24			

Given that the P-value falls below the predetermined significance threshold of $\alpha = 0.05$, it is necessary to conduct Tukey's test to identify means that exhibit significant differences. The formula for Tukey's test is provided below.

$$T_{\alpha} = q_{\alpha}(k, v)\sqrt{\frac{MS_{\varepsilon}}{n}}$$

With α = 0.05 and f =20 degrees of freedom for error, Appendix C upper of percentage points of the studentized range statistic gives $q0.05(5,20) = 4.24$. Therefore,

$$T_{0.05} = q_{0.05}(5,20)\sqrt{\frac{0.63589}{5}} = 4.24\sqrt{\frac{0.63589}{5}} = 1.512069$$

The respective pair of population means would be considered significantly different if any two treatment average pairings differed in absolute value by more than 1.512069. The given ratio averages are :

$\bar{y}_1 = 20.9638$

$\bar{y}_2 = 19.1847$

$\bar{y}_3 = 16.1344$

$\bar{y}_4 = 11.1488$

$$\bar{y}_5 = 7.1903$$

and the differences in averages are;

$$\bar{y}_1 - \bar{y}_2 = 20.9638 - 19.1847 = 1.7791^*$$

$$\bar{y}_1 - \bar{y}_3 = 20.9638 - 16.1344 = 4.8294^*$$

$$\bar{y}_1 - \bar{y}_4 = 20.9638 - 11.1488 = 9.815^*$$

$$\bar{y}_1 - \bar{y}_5 = 20.9638 - 7.1903 = 13.7735^*$$

$$\bar{y}_2 - \bar{y}_3 = 19.1847 - 16.1344 = 3.0503^*$$

$$\bar{y}_2 - \bar{y}_4 = 19.1847 - 11.1488 = 8.0359^*$$

$$\bar{y}_2 - \bar{y}_5 = 19.1847 - 7.1903 = 11.9944^*$$

$$\bar{y}_3 - \bar{y}_4 = 16.1344 - 11.1488 = 4.9856^*$$

$$\bar{y}_3 - \bar{y}_5 = 16.1344 - 7.1903 = 8.9441^*$$

$$\bar{y}_4 - \bar{y}_5 = 11.1488 - 7.1903 = 3.9585^*$$

The marked values indicate pairs of means that exhibit significant differences. It is crucial to emphasize the assertion made by the Tukey procedure, asserting the distinctiveness of every pair of means. Therefore $\bar{y}1 - \bar{y}2$,$\bar{y}1 - \bar{y}3$, $\bar{y}1 - \bar{y}4$, $\bar{y}1 - \bar{y}5$, $\bar{y}2 - \bar{y}3$, $\bar{y}2 - \bar{y}4$, $\bar{y}2 - \bar{y}5$, $\bar{y}3 - \bar{y}4$, $\bar{y}3 - \bar{y}5$ and $\bar{y}4 - \bar{y}5$ power setting results in a mean etch rate that differs from the mean etch rate at any other power setting.

Table 4.3 SUMMARY of elastic strength for five ratios of WDPR composites

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
WD20P80	5	6.21114	1.242228	0.005529
WD40P60	5	4.17027	0.834054	0.004316
WD50P50	5	2.71017	0.542034	0.004722
WD60P40	5	2.18693	0.437386	0.001072
WD80P20	5	1.567035	0.313407	0.001262

We can see from table 4.3 that the mean is the average of a group of values, the variance indicates how much each value in a dataset deviates from the mean, and the standard

deviation is the variance squared, which gives us an idea of how widely distributed the data are overall.

Table 4.4 ANOVA of elastic strength for five ratios of WDPR composites

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	2.759644	4	0.689911	204.0944	6.58E-16
Within Groups	0.067607	20	0.00338		
Total	2.827251	24			

Similar to Table 4.3, given that the P-value falls below the designated significance cutoff of α = 0.05, it is necessary to conduct Tukey's test to identify means that exhibit significant differences. The formula for Tukey's test is provided below.

$$T_\alpha = q_\alpha(k, v)\sqrt{\frac{MS_\varepsilon}{n}}$$

With α = 0.05 and f =20 degrees of freedom for error, Appendix C upper of percentage points of the studentized range statistic gives q0.05(5,20) = 4.24. Therefore,

$$T_{0.05} = q_{0.05}(5{,}20)\sqrt{\frac{0.00338}{5}} = 4.24\sqrt{\frac{0.00338}{5}} = 0.11024$$

Therefore, any pairs of treatment averages with absolute value differences more than 0.11024 would suggest that the associated pair of population means deviate significantly. The given ratio averages are:

$\bar{y}_1 = 1.2422$

$\bar{y}_2 = 0.8340$

$\bar{y}_3 = 0.5420$

$\bar{y}_4 = 0.4373$

$\bar{y}_5 = 0.3134$

and the differences in averages are;

$$\bar{y}_1 - \bar{y}_2 = 1.2422 – 0.8430 = 0.3992*$$

$$\bar{y}_1 - \bar{y}_3 = 1.2422 – 0.5420 = 0.7002*$$

$$\bar{y}_1 - \bar{y}_4 = 1.2422 – 0.4373 = 0.8049*$$

$$\bar{y}_1 - \bar{y}_5 = 1.2422 –0.3134 = 0.9288*$$

$$\bar{y}_2 - \bar{y}_3 = 0.8430 – 0.5420 = 0.301*$$

$$\bar{y}_2 - \bar{y}_4 = 0.8430 – 0.4373 = 0.4057*$$

$$\bar{y}_2 - \bar{y}_5 = 0.8430 – 0.3134 = 0.5296*$$

$$\bar{y}_3 - \bar{y}_4 = 0.5420 – 0.4373 = 0.1047$$

$$\bar{y}_3 - \bar{y}_5 = 0.5420 – 0.3134 = 0.2286*$$

$$\bar{y}_4 - \bar{y}_5 = 0.4373 – 0.3134 = 0.1239*$$

The marked values indicate all of means that exhibit significant differences. It is crucial to emphasize the assertion made by the Tukey procedure, asserting the distinctiveness of every pair of means. Therefore $\bar{y}1 - \bar{y}2$,$\bar{y}1 - \bar{y}3$, $\bar{y}1 - \bar{y}4$, $\bar{y}1 - \bar{y}5$, $\bar{y}2 - \bar{y}3$, $\bar{y}2 - \bar{y}4$, $\bar{y}2 - \bar{y}5$, $\bar{y}3 - \bar{y}5$ and $\bar{y}4 - \bar{y}5$ power setting results in a mean etch rate that differs from the mean etch rate at any other power setting.

4.3 Flexural Test Result

In this experiment, the flexural test was conducted on the specimen to ascertain its maximum force and maximum stress. This test utilized a three-point bend fixture on a universal testing machine, with the convenience of specimen preparation and testing being a key advantage of the three-point flexural test. Figures 4.4 illustrate the maximum flexural strength values for each WDPR ratio. The 20RH80P composite ratio exhibited higher maximum flexural forces and stress compared to the other WDPR composite ratios, while

80WS20P demonstrated the lowest values for maximum flexural forces and stresses. This observation led to the conclusion that in WDPR composites, the maximum flexural force and maximum stress values increase when the wood dust content is 20%. Figure 4.5 presents the results of the specimen after flexural testing.

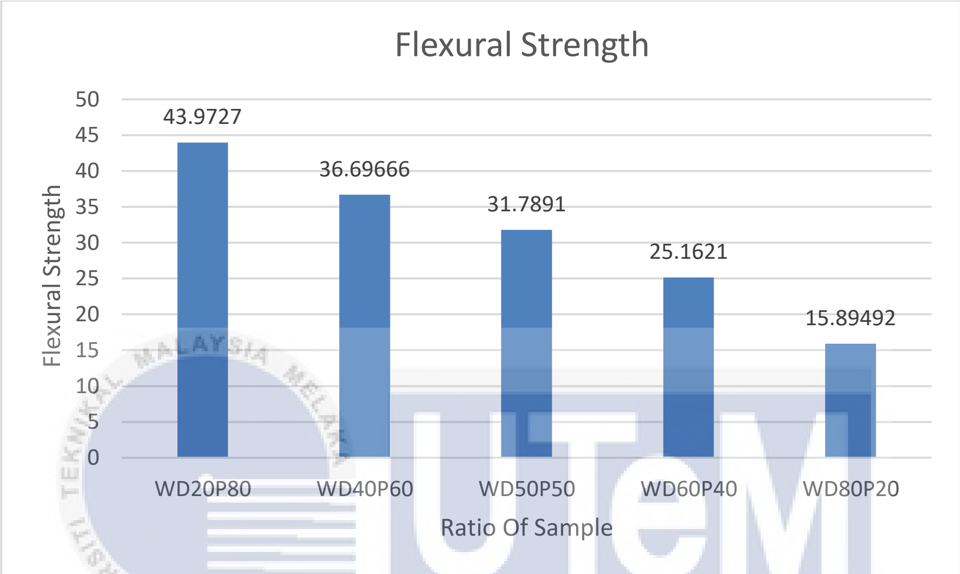

Figure 4.4 Flexural strength for five ratios of WDPR composites

Figure 4.5 presents the results of the specimen after flexural testing.

Table 4.5 SUMMARY of flexural strength for five ratios of WDPR composites

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
WD20P80	5	219.8635	43.9727	0.186076
WD40P60	5	183.4833	36.69666	0.804986
WD50P50	5	158.9455	31.7891	0.118008
WD60P40	5	125.8105	25.1621	0.313594
WD80P20	5	79.4746	15.89492	0.640229

We can see from table 4.5 that the mean is the average of a group of values, the variance indicates how much each value in a dataset deviates from the mean, and the standard deviation is the variance squared, which gives us an idea of how widely distributed the data are overall.

Table 4.6 ANOVA of flexural strength for five ratios of WDPR composites

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	2315.847	4	578.9616	1403.277	3.49E-24
Within Groups	8.251568	20	0.412578		
Total	2324.098	24			

Similar to Table 4.5, given that the P-value falls below the designated significance cutoff of α = 0.05, it is necessary to conduct Tukey's test to identify means that exhibit significant differences. The formula for Tukey's test is provided below.

$$T_{\alpha} = q_{\alpha}(k, v)\sqrt{\frac{MS_{\varepsilon}}{n}}$$

With α = 0.05 and f =20 degrees of freedom for error, Appendix C upper of percentage of the studentized range statistic gives q0.05(5,20) = 4.24. Therefore,

$$T_{0.05} = q_{0.05}(5,20)\sqrt{\frac{0.412578}{5}} = 4.24\sqrt{\frac{0.412578}{5}} = 1.2179$$

Therefore, any pairs of treatment averages with absolute value differences more than 1.2179 would suggest that the associated pair of population means deviate significantly. The given ratio averages are:

$$\bar{y}_1 = 43.9727$$

$$\bar{y}_2 = 36.6966$$

$$\bar{y}_3 = 31.7891$$

$$\bar{y}_4 = 25.1621$$

$$\bar{y}_5 = 15.8949$$

and the differences in averages are;

$$\bar{y}_1 - \bar{y}_2 = 43.9727 - 36.6966 = 7.3361^*$$

$$\bar{y}_1 - \bar{y}_3 = 43.9727 - 31.7891 = 12.1836^*$$

$$\bar{y}_1 - \bar{y}_4 = 43.9727 - 25.1621 = 18.8106^*$$

$$\bar{y}_1 - \bar{y}_5 = 43.9727 - 7.1903 = 36.7824^*$$

$$\bar{y}_2 - \bar{y}_3 = 36.6966 - 31.7891 = 4.9075^*$$

$$\bar{y}_2 - \bar{y}_4 = 36.6966 - 25.1621 = 11.5345^*$$

$$\bar{y}_2 - \bar{y}_5 = 36.6966 - 15.8949 = 20.8017^*$$

$$\bar{y}_3 - \bar{y}_4 = 31.7891 - 25.1621 = 6.627^*$$

$$\bar{y}_3 - \bar{y}_5 = 31.7891 - 15.8949 = 15.8942^*$$

$$\bar{y}_4 - \bar{y}_5 = 25.1621 - 15.8949 = 9.2672^*$$

The marked values indicate all of means that exhibit significant differences. It is crucial to emphasize the assertion made by the Tukey procedure, asserting the distinctiveness of every pair of means. Therefore $\bar{y}1 - \bar{y}2$,$\bar{y}1 - \bar{y}3$, $\bar{y}1 - \bar{y}4$, $\bar{y}1 - \bar{y}5$, $\bar{y}2 - \bar{y}3$, $\bar{y}2 - \bar{y}4$, $\bar{y}2 - \bar{y}5$, $\bar{y}_3 - \bar{y}_4$, $\bar{y}3 - \bar{y}5$ and $\bar{y}4 - \bar{y}5$ power setting results in a mean etch rate that differs from the mean etch rate at any other power setting.

4.4 Impact Test Result

To assess the mechanical properties of the experiment, impact testing was conducted to gauge the material's ability to withstand impact. This involves evaluating the material's resilience and its capacity to absorb energy under rapid loading conditions. The material's capability to absorb energy when subjected to a shock or impact load is referred to as impact energy. Therefore, when assessing the suitability of composite materials for specific applications, it is crucial to consider their impact capabilities alongside standard design requirements. Figure 4.5 illustrates the fluctuation of impact energy for all five composite ratios of WDPR. The results indicate that the 20WD80P composite ratio exhibits higher energy absorption compared to the other WDPR composite ratios. It can be inferred that the energy absorbed by WDPR composites decreases as the percentage of wood dust decreases. Figure 4.7 presents the outcomes of specimen analysis following impact testing.

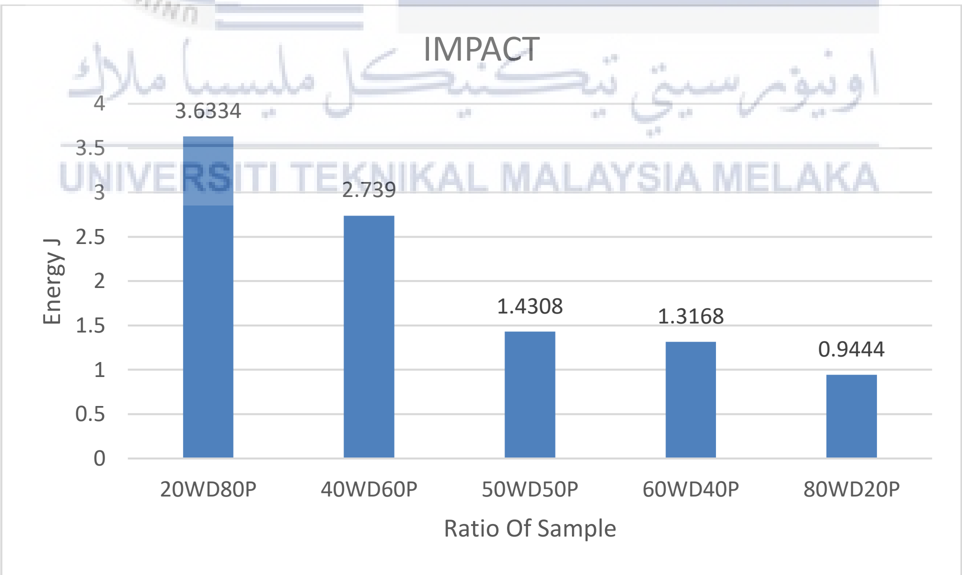

Figure 4.6 Impact strength for five ratios of WDPR composites

Figure 4.7 presents the outcomes of specimen analysis following impact testing

Table 4.7 SUMMARY of impact strength for five ratios of WDPR composites

SUMMARY

Groups	Count	Sum	Average	Variance
20WD80P	5	18.167	3.6334	0.015766
40WD60P	5	13.695	2.739	0.796694
50WD50P	5	7.154	1.4308	0.054933
60WD40P	5	6.584	1.3168	0.021895
80WD20P	5	4.722	0.9444	0.751486

We can see from table 4.7 that the mean is the average of a group of values, the variance indicates how much each value in a dataset deviates from the mean, and the standard deviation is the variance squared, which gives us an idea of how widely distributed the data are overall.

Table 4.8 ANOVA of impact strength for five ratios of WDPR composites

ANOVA

Source of Variation	SS	df	MS	F	P-value
Between Groups	25.59165	4	6.397912	19.49663	1.12E-06
Within Groups	6.563096	20	0.328155		
Total	32.15474	24			

Similar to Table 4.7, given that the P-value falls below the designated significance cutoff of α = 0.05, it is necessary to conduct Tukey's test to identify means that exhibit significant differences. The formula for Tukey's test is provided below.

$$T_\alpha = q_\alpha(k, v)\sqrt{\frac{MS_\varepsilon}{n}}$$

With α = 0.05 and f =20 degrees of freedom for error, Appendix C upper of percentage of the studentized range statistic gives q0.05(5,20) = 4.24. Therefore,

$$T_{0.05} = q_{0.05}(5{,}20)\sqrt{\frac{0.328155}{5}} = 4.24\sqrt{\frac{0.328155}{5}} = 1.0862$$

Therefore, any pairs of treatment averages with absolute value differences more than 1.0862 would suggest that the associated pair of population means deviate significantly. The given ratio averages are:

$\bar{y}_1 = 3.6334$

$\bar{y}_2 = 2.739$

$\bar{y}_3 = 1.4308$

$\bar{y}_4 = 1.3168$

$\bar{y}_5 = 0.9444$

and the differences in averages are;

$\bar{y}_1 - \bar{y}_2 = 3.6334 – 2.739 = 0.8944$

$\bar{y}_1 - \bar{y}_3 = 3.6334 –1.4308 = 2.2026$*

$\bar{y}_1 - \bar{y}_4 = 3.6334 – 1.3168 = 2.3166$*

$\bar{y}_1 - \bar{y}_5 = 3.6334 – 0.9444 = 2.689$*

$$\bar{y}_2 - \bar{y}_3 = 2.739 - 1.4308 = 1.3082^*$$

$$\bar{y}_2 - \bar{y}_4 = 2.739 - 1.3168 = 1.4222^*$$

$$\bar{y}_2 - \bar{y}_5 = 2.739 - 0.9444 = 1.7946^*$$

$$\bar{y}_3 - \bar{y}_4 = 1.4308 - 1.3168 = 0.114$$

$$\bar{y}_3 - \bar{y}_5 = 1.4308 - 0.9444 = 0.4864$$

$$\bar{y}_4 - \bar{y}_5 = 1.3168 - 0.9444 = 0.3724$$

The marked values indicate all of means that exhibit significant differences. It is crucial to emphasize the assertion made by the Tukey procedure, asserting the distinctiveness of every pair of means. Therefore $\bar{y}1 - \bar{y}3$, $\bar{y}1 - \bar{y}4$, $\bar{y}1 - \bar{y}5$, $\bar{y}2 - \bar{y}3$, $\bar{y}2 - \bar{y}4$, and $\bar{y}2 - \bar{y}5$ power setting results in a mean etch rate that differs from the mean etch rate at any other power setting

4.5 Water Absorption Result

The purpose of the water absorption test is to determine the specimen's water resistance and the acceptability of the materials for outdoor applications. The guidelines provided by ASTM D 570 standard were adhered to while determining the maximum water absorption content of the hybrid composites. Distilled water was used to completely immerse each of the 25 samples. after 5, 10, 15, 20, and even up to 25 days of exposure at regular intervals. After being removed from the water and patted dry with a clean cloth, their weights were determined. After mass-weighing, the samples of five distinct ratios were submerged in distilled water.

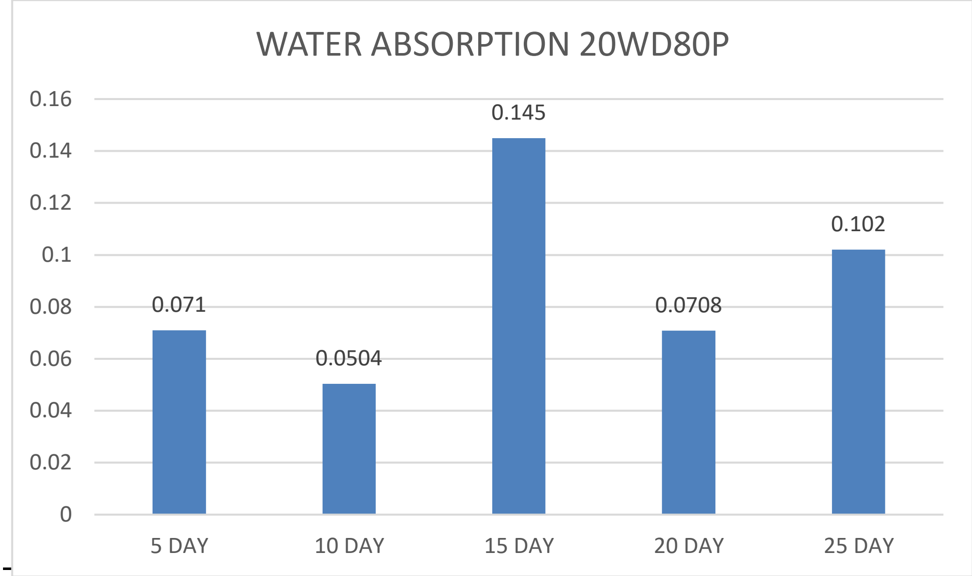

Figure 4.8 The water absorption testing specimen 20WD80P

From the Figure 4.8 show the results indicate that the highest water content is observed in 20RH80P after 15 days, while the lowest water content for water absorption occurs at 10 days based on this observation.

Table 4.9 SUMMARY of water content in 25 days of 20WD80P composites

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
5 DAY	5	0.355	0.071	0.001189
10 DAY	5	0.252	0.0504	2.28E-05
15 DAY	5	0.725	0.145	0.000671
20 DAY	5	0.354	0.0708	0.000219
25 DAY	5	0.51	0.102	7.35E-05

We can see from table 4.9 that the mean is the average of a group of values, the variance indicates how much each value in a dataset deviates from the mean, and the standard deviation is the variance squared, which gives us an idea of how widely distributed the data are overall.

Table 4.10 ANOVA water content in 25 days of 20WD80P composites

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.027217	4	0.006804	15.63857	5.97E-06	2.866081
Within Groups	0.008702	20	0.000435			
Total	0.035919	24				

As in Table 4.9, given that the P-value falls below the designated significance cutoff of α = 0.05, it is necessary to conduct Tukey's test to identify means that exhibit significant differences. The formula for Tukey's test is provided below.

$$T_\alpha = q_\alpha(k, v)\sqrt{\frac{MS_\varepsilon}{n}}$$

With α = 0.05 and f =20 degrees of freedom for error, table of percentage points of the studentized range statistic gives q0.05(5,20) = 4.24. Therefore,

$$T_{0.05} = q_{0.05}(5{,}20)\sqrt{\frac{0.000435}{5}} = 4.24\sqrt{\frac{0.000435}{5}} = 0.0395$$

Therefore, any pairs of treatment averages with absolute value differences more than 0.0395 would suggest that the associated pair of population means deviate significantly. The given ratio averages are:

$\bar{y}_1 = 0.071$

$\bar{y}_2 = 0.0504$

$\bar{y}_3 = 0.145$

$\bar{y}_4 = 0.0708$

$\bar{y}_5 = 0.102$

and the differences in averages are;

$$\bar{y}_1 - \bar{y}_2 = 0.071 – 0.0504 = 0.0206$$

$$\bar{y}_1 - \bar{y}_3 = 0.071 – 0.145 = -0.074$$

$$\bar{y}_1 - \bar{y}_4 = 0.071– 0.0708 = 0.0002$$

$$\bar{y}_1 - \bar{y}_5 = 0.071 – 0.102 = -0.031$$

$$\bar{y}_2 - \bar{y}_3 =0.0504 – 0.145 = -0.0946 *$$

$$\bar{y}_2 - \bar{y}_4 = 0.0504 – 0.0708 = -0.0204$$

$$\bar{y}_2 - \bar{y}_5 = 0.0504 – 0.102 = -0.0516$$

$$\bar{y}_3 - \bar{y}_4 = 0.145 – 0.0708 = 0.0742*$$

$$\bar{y}_3 - \bar{y}_5 = 0.145 – 0.102 = 0.043*$$

$$\bar{y}_4 - \bar{y}_5 = 0.0708 – 0.102 = -0.0312$$

The marked values indicate all of means that exhibit significant differences. It is crucial to emphasize the assertion made by the Tukey procedure, asserting the distinctiveness of every pair of means. Therefore $\bar{y}2 - \bar{y}3$, $\bar{y}3 - \bar{y}4$, and $\bar{y}3 - \bar{y}5$ power setting results in a mean etch rate that differs from the mean etch rate at any other power setting

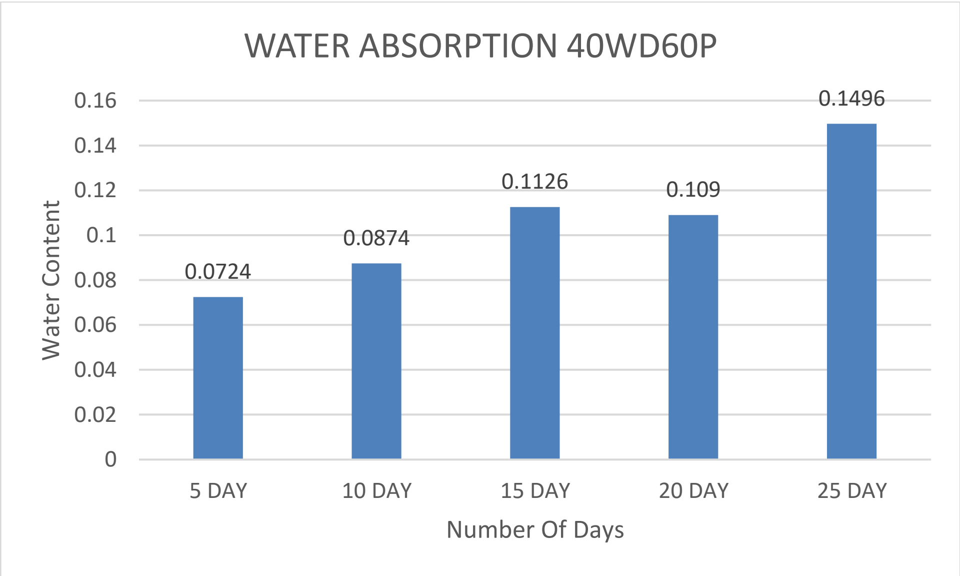

Figure 4.9 The water absorption testing specimen 40WD60P

From the Figure 4.9 show the results indicate that the highest water content is observed in 40RH60P after 25 days, while the lowest water content for water absorption occurs at 5 days based on this observation.

Table 4.11 SUMMARY of water content in 25 days of 40WD60P composites

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
5 DAY	5	0.362	0.0724	0.000191
10 DAY	5	0.437	0.0874	8.23E-05
15 DAY	5	0.563	0.1126	0.000182
20 DAY	5	0.545	0.109	0.00036
25 DAY	5	0.748	0.1496	0.002894

We can see from table 4.11 that the mean is the average of a group of values, the variance indicates how much each value in a dataset deviates from the mean, and the standard deviation is the variance squared, which gives us an idea of how widely distributed the data are overall.

Table 4.12 ANOVA water content in 25 days of 40WD60P composites

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.017141	4	0.004285	5.775026	0.002944	2.866081
Within Groups	0.014841	20	0.000742			
Total	0.031982	24				

Similar to Table 4.11, given that the P-value falls below the designated significance cutoff of α = 0.05, it is necessary to conduct Tukey's test to identify means that exhibit significant differences. The formula for Tukey's test is provided below.

$$T_{\alpha} = q_{\alpha}(k, v)\sqrt{\frac{MS_{\varepsilon}}{n}}$$

With α = 0.05 and f =20 degrees of freedom for error, Appendix C upper of percentage of the studentized range statistic gives q0.05(5,20) = 4.24. Therefore,

$$T_{0.05} = q_{0.05}(5{,}20)\sqrt{\frac{0.000724}{5}} = 4.24\sqrt{\frac{0.000724}{5}} = 0.0510$$

Therefore, any pairs of treatment averages with absolute value differences more than 0.0510 would suggest that the associated pair of population means deviate significantly. The given ratio averages are:

$\bar{y}_1 = 0.0724$

$\bar{y}_2 = 0.0874$

$\bar{y}_3 = 0.1126$

$\bar{y}_4 = 0.109$

$\bar{y}_5 = 0.1496$

and the differences in averages are;

$\bar{y}_1 - \bar{y}_2 = 0.0724 – 0.0874 = -0.015$

$\bar{y}_1 - \bar{y}_3 = 0.0724 – 0.1126 = -0.0402$

$\bar{y}_1 - \bar{y}_4 = 0.0724 – 0.109 = 0.0366$

$\bar{y}_1 - \bar{y}_5 = 0.0724 – 0.1496 = -0.0772$

$\bar{y}_2 - \bar{y}_3 = 0.0874 – 0.1126 = -0.0252$

$\bar{y}_2 - \bar{y}_4 = 0.0874 – 0.109 = -0.0216$

$\bar{y}_2 - \bar{y}_5 = 0.0874 – 0.1496 = -0.0622$

$\bar{y}_3 - \bar{y}_4 = 0.1126 – 0.109 = 0.0036$

$\bar{y}_3 - \bar{y}_5 = 0.1126 – 0.1496 = -0.037$

$\bar{y}_4 - \bar{y}_5 = 0.109 – 0.1496 = -0.0406$

The marked values indicate all of means that exhibit significant differences. It is crucial to emphasize the assertion made by the Tukey procedure, asserting the distinctiveness of every pair of means. Therefore ȳ1 - ȳ2 ,ȳ1 - ȳ3 , ȳ1 - ȳ4 , ȳ1 - ȳ5 , ȳ2 - ȳ3 , ȳ2 - ȳ4 , ȳ2 - ȳ5 , ȳ3 - ȳ4 , ȳ3 - ȳ5 and ȳ4 - ȳ5 power setting results in a mean etch rate that differs from the mean etch rate at any other power setting

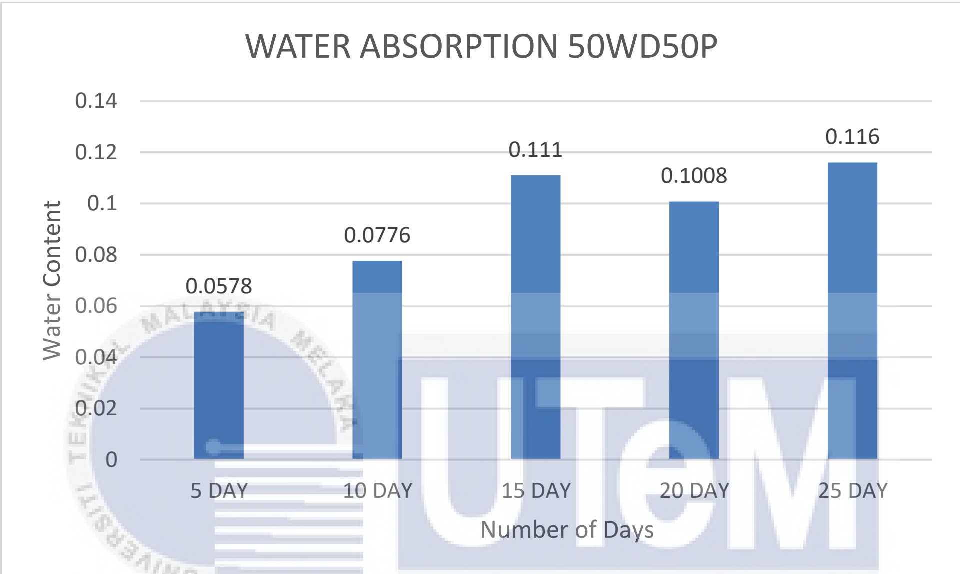

Figure 4.10 The water absorption testing specimen 50WD50P

From the Figure 4.10 show the results indicate that the highest water content is observed in 50RH50P after 15 days, while the lowest water content for water absorption occurs at 5 days based on this observation.

Table 4.13 SUMMARY of water content in 25 days of 50WD50P composites

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
5 DAY	5	0.289	0.0578	2.92E-05
10 DAY	5	0.388	0.0776	0.000394
15 DAY	5	0.555	0.111	0.00037
20 DAY	5	0.504	0.1008	0.000154
25 DAY	5	0.58	0.116	0.000127

We can see from table 4.13 that the mean is the average of a group of values, the variance indicates how much each value in a dataset deviates from the mean, and the standard

deviation is the variance squared, which gives us an idea of how widely distributed the data are overall.

Table 4.14 ANOVA water content in 25 days of 50WD50P composites

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.011947	4	0.002987	13.9216	1.39E-05	2.866081
Within Groups	0.004291	20	0.000215			
Total	0.016238	24				

Similar to Table 4.13, given that the P-value falls below the designated significance cutoff of α = 0.05, it is necessary to conduct Tukey's test to identify means that exhibit significant differences. The formula for Tukey's test is provided below.

$$T_{\alpha} = q_{\alpha}(k, v)\sqrt{\frac{MS_{\varepsilon}}{n}}$$

With α = 0.05 and f =20 degrees of freedom for error , Appendix C upper of percentage of the studentized range statistic gives q0.05(5,20) = 4.24. Therefore,

$$T_{0.05} = q_{0.05}(5{,}20)\sqrt{\frac{0.000215}{5}} = 4.24\sqrt{\frac{0.000215}{5}} = 0.0278$$

Therefore, any pairs of treatment averages with absolute value differences more than 0.0278 would suggest that the associated pair of population means deviate significantly. The given ratio averages are:

$\bar{y}_1 = 0.0578$

$\bar{y}_2 = 0.0776$

$\bar{y}_3 = 0.111$

$$\bar{y}_4 = 0.1008$$

$$\bar{y}_5 = 0.116$$

and the differences in averages are;

$$\bar{y}_1 - \bar{y}_2 = 0.0578 – 0.0776 = -0.0198$$

$$\bar{y}_1 - \bar{y}_3 = 0.0578 – 0.111 = -0.0532$$

$$\bar{y}_1 - \bar{y}_4 = 0.0578 – 0.1008 = -0.043$$

$$\bar{y}_1 - \bar{y}_5 = 0.0578 – 0.9444 = -0.8866$$

$$\bar{y}_2 - \bar{y}_3 = 0.0776 – 0.111 = -0.0334$$

$$\bar{y}_2 - \bar{y}_4 = 0.0776 – 0.1008 = -0.0232$$

$$\bar{y}_2 - \bar{y}_5 = 0.0776 – 0.116 = -0.0384$$

$$\bar{y}_3 - \bar{y}_4 = 0.111 – 0.1008 = 0.0102$$

$$\bar{y}_3 - \bar{y}_5 = 0.111 – 0.116 = -0.005$$

$$\bar{y}_4 - \bar{y}_5 = 0.1008 – 0.116 = -0.0152$$

The marked values indicate all of means that exhibit significant differences. It is crucial to emphasize the assertion made by the Tukey procedure, asserting the distinctiveness of every pair of means. Therefore, in 50WD50 theres no significant power setting results in a mean etch rate that differs from the mean etch rate at any other power setting

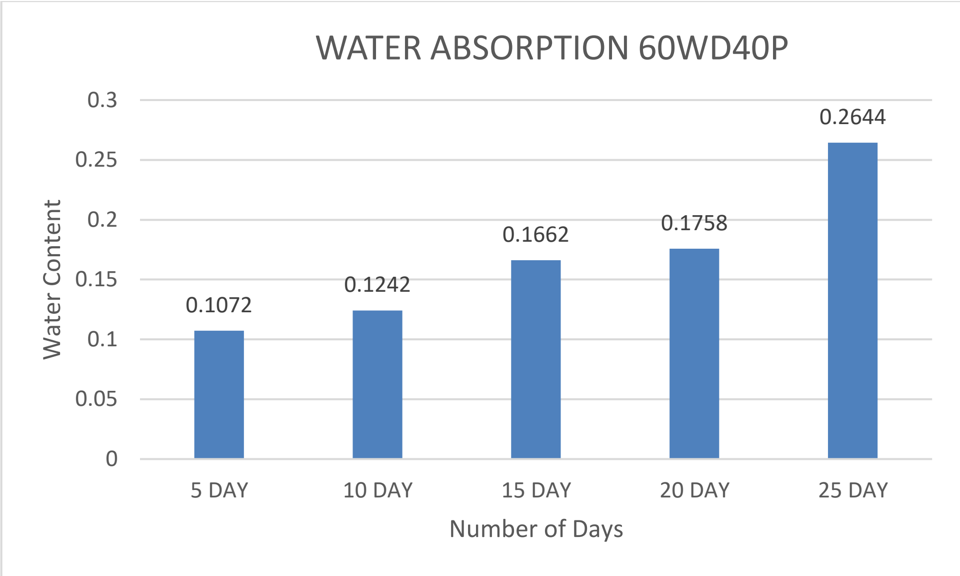

Figure 4.11 The water absorption testing specimen 60WD40P

From the Figure 4.11 show the results indicate that the highest water content is observed in 60RH40P after 25 days, while the lowest water content for water absorption occurs at 5 days based on this observation.

Table 4.15 SUMMARY of water content in 25 days of 60WD40P composites

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
5 DAY	5	0.536	0.1072	6.77E-05
10 DAY	5	0.621	0.1242	0.000131
15 DAY	5	0.831	0.1662	0.0015
20 DAY	5	0.879	0.1758	0.000102
25 DAY	5	1.322	0.2644	0.001374

We can see from table 4.15 that the mean is the average of a group of values, the variance indicates how much each value in a dataset deviates from the mean, and the standard deviation is the variance squared, which gives us an idea of how widely distributed the data are overall.

Table 4.16 ANOVA water content in 25 days of 60WD40P composites

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.074856	4	0.018714	29.48377	3.92E-08	2.866081
Within Groups	0.012694	20	0.000635			
Total	0.08755	24				

Similar to Table 4.15, given that the P-value falls below the designated significance cutoff of α = 0.05, it is necessary to conduct Tukey's test to identify means that exhibit significant differences. The formula for Tukey's test is provided below.

$$T_\alpha = q_\alpha(k, v)\sqrt{\frac{MS_\varepsilon}{n}}$$

With α = 0.05 and f =20 degrees of freedom for error, Appendix C upper of percentage of the studentized range statistic gives $q0.05(5,20)$ = 4.24. Therefore,

$$T_{0.05} = q_{0.05}(5,20)\sqrt{\frac{0.000635}{5}} = 4.24\sqrt{\frac{0.000635}{5}} = 0.0477$$

Therefore, any pairs of treatment averages with absolute value differences more than 0.0477 would suggest that the associated pair of population means deviate significantly. The given ratio averages are:

$\bar{y}_1 = 0.1072$

$\bar{y}_2 = 0.1242$

$\bar{y}_3 = 0.1662$

$\bar{y}_4 = 0.1758$

$\bar{y}_5 = 0.2644$

and the differences in averages are;

$$\bar{y}_1 - \bar{y}_2 = 0.1072 – 0.1242 = -0.017$$

$$\bar{y}_1 - \bar{y}_3 = 0.1072 – 0.1662 = -0.059$$

$$\bar{y}_1 - \bar{y}_4 = 0.1072 – 0.1758 = 0.0686^*$$

$$\bar{y}_1 - \bar{y}_5 = 0.1072 – 0.2644 = -0.1572$$

$$\bar{y}_2 - \bar{y}_3 = 0.1242 – 0.1662 = -0.042$$

$$\bar{y}_2 - \bar{y}_4 = 0.1242 – 0.1758 = -0.0516$$

$$\bar{y}_2 - \bar{y}_5 = 0.1242 – 0.2644 = -0.1402$$

$$\bar{y}_3 - \bar{y}_4 = 0.1662 – 0.1758 = -0.0096$$

$$\bar{y}_3 - \bar{y}_5 = 0.1662 – 0.2644 = 0.0982^*$$

$$\bar{y}_4 - \bar{y}_5 = 0.1758 – 0.2644 = -0.0886$$

The marked values indicate all of means that exhibit significant differences. It is crucial to emphasize the assertion made by the Tukey procedure, asserting the distinctiveness of every pair of means. Therefore, $\bar{y}1 - \bar{y}4$ and $\bar{y}3 - \bar{y}5$ power setting results in a mean etch rate that differs from the mean etch rate at any other power setting

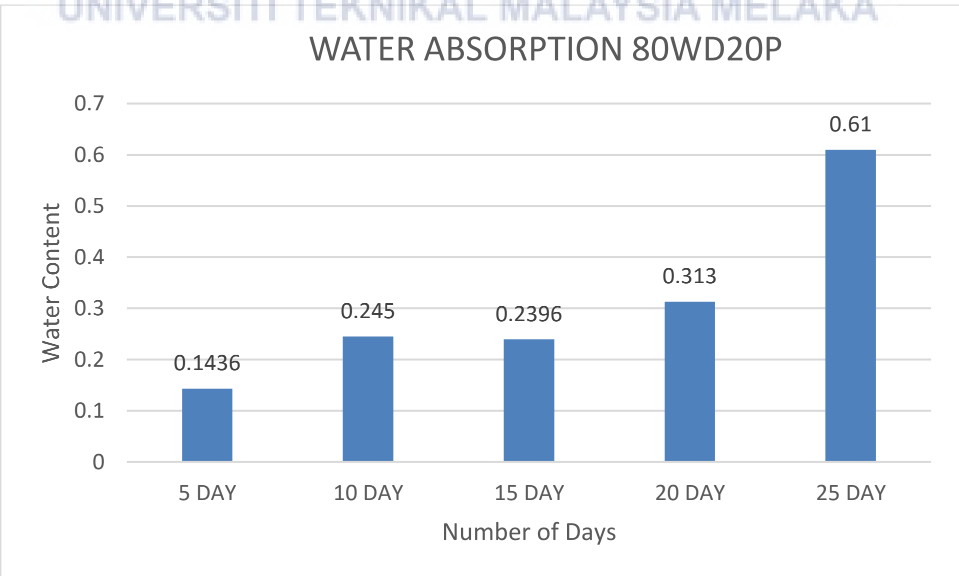

Figure 4.12 The water absorption testing specimen 80WD20P

From the Figure 4.12 show the results indicate that the highest water content is observed in 80RH20P after 25 days, while the lowest water content for water absorption occurs at 5 days based on this observation.

Table 4.17 SUMMARY of water content in 25 days of 80WD20P composites

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
5 DAY	5	0.718	0.1436	0.005073
10 DAY	5	1.225	0.245	0.004534
15 DAY	5	1.198	0.2396	0.003191
20 DAY	5	1.565	0.313	0.008413
25 DAY	5	3.05	0.61	0.029062

We can see from table 4.17 that the mean is the average of a group of values, the variance indicates how much each value in a dataset deviates from the mean, and the standard deviation is the variance squared, which gives us an idea of how widely distributed the data are overall.

Table 4.18 ANOVA water content in 25 days of 80WD20P composites

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.634394	4	0.158599	15.77354	5.61E-06	2.866081
Within Groups	0.201094	20	0.010055			
Total	0.835489	24				

Similar to Table 4.17, given that the P-value falls below the designated significance cutoff of α = 0.05, it is necessary to conduct Tukey's test to identify means that exhibit significant differences. The formula for Tukey's test is provided below.

$$T_\alpha = q_\alpha(k, v)\sqrt{\frac{MS_\varepsilon}{n}}$$

With α = 0.05 and f =20 degrees of freedom for error Appendix C upper of percentage of the studentized range statistic gives q0.05(5,20) = 4.24. Therefore,

$$T_{0.05} = q_{0.05}(5{,}20)\sqrt{\frac{0.010055}{5}} = 4.24\sqrt{\frac{0.010055}{5}} = 0.1901$$

Therefore, any pairs of treatment averages with absolute value differences more than 0.1901 would suggest that the associated pair of population means deviate significantly. The given ratio averages are:

$$\bar{y}_1 = 0.1436$$

$$\bar{y}_2 = 0.245$$

$$\bar{y}_3 = 0.2396$$

$$\bar{y}_4 = 0.313$$

$$\bar{y}_5 = 0.61$$

and the differences in averages are;

$$\bar{y}_1 - \bar{y}_2 = 0.1436 – 2.739 = -2.5954$$

$$\bar{y}_1 - \bar{y}_3 = 0.1436 – 0.2396 = -0.096$$

$$\bar{y}_1 - \bar{y}_4 = 0.1436 – 0.313 = -0.1694$$

$$\bar{y}_1 - \bar{y}_5 = 0.1436 – 0.61 = -04664$$

$$\bar{y}_2 - \bar{y}_3 =0.245 – 0.2396 = 0.0054$$

$$\bar{y}_2 - \bar{y}_4 = 0.245 – 0.313 = -0.068$$

$$\bar{y}_2 - \bar{y}_5 = 0.245 – 0.61 = 0.365*$$

$$\bar{y}_3 - \bar{y}_4 = 0.2396 – 0.313 = 0.0734$$

$$\bar{y}_3 - \bar{y}_5 = 0.2396 – 0.61 = -0.3704*$$

$$\bar{y}_4 - \bar{y}_5 = 0.313 – 0.61 = -0.297$$

The marked values indicate all of means that exhibit significant differences. It is crucial to emphasize the assertion made by the Tukey procedure, asserting the distinctiveness of every pair of means. Therefore, $\bar{y}2 - \bar{y}5$ and $\bar{y}3 - \bar{y}4$ power setting results in a mean etch rate that differs from the mean etch rate at any other power setting

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study analysed the mechanical properties of the WDPR at five different ratios: 20WD80P, 40WD60P, 50WD50P, 60WD40P, and 80WD20P. Analysis of variance (ANOVA) and Turkey's methods have also been used to examine the statistical analysis of the experiment material. The following conclusions can be made in relationship to the analysis's findings and the experimental data:

i. Based on the tensile data, the WDPR composite of 20WD80P showed greater tensile strength and elasticity, outperforming the other WDPR composites in these domains.

ii. It was shown that the maximum flexural force and maximum stress values in WDPR composites increase when wood dust content is 20%. The WDPR composite of 20WD80P exhibited higher maximum flexural forces and stresses than the other WDPR composite ratios.

iii. It was shown that 20WD80P WDPR composites have superior impact properties.

iv. It was shown that in 20WD80P had absorb water more on 15 days.

v. It was shown that in 40WD60P had absorb water more on 25 days.

vi. It was shown that in 50WD50P had absorb water more on 15 days.

vii. It was shown that in 60WD40P had absorb water more on 25 days.

viii. It was shown that in 80WD20P had absorb water more on 25 days.

ix. Also, the P-values for all tests were shown to be less than the significant cut-off level, which is 0.05, according to ANOVA findings.

x. The Tukey test needs to be run in order to determine which means differ substantially from one another.

Finally, all WDPR composite ratios showed improved mechanical performance when the percentage of wood dust in the total percentage of WDPR composites was about 20%.

5.2 Recommendation

The research findings indicating that the incorporation of 20% wood dust in Wood Dust-Polyester Resin (WDPR) resulted in improved mechanical qualities highlight a key aspect of composite material optimization. The balance achieved in this specific ratio, denoted as 20WD80P, suggests that the combination of wood dust and polyester resin at these proportions leads to enhanced mechanical properties.

Mechanical properties play a crucial role in determining the performance and durability of composite materials. The optimal ratio of 20WD80P, determined through analysis, signifies a sweet spot where the composite material exhibits favorable qualities in terms of impact resistance, flexural strength, and tensile strength. This ratio represents a careful balance that maximizes the benefits derived from both wood dust and polyester resin, showcasing the synergistic effects of the two components.

However, the research acknowledges the need for further investigation and analysis to identify peak values of mechanical characteristics. Specifically, there is a call for exploring ratios beyond the established 20WD80P. The suggestion to examine ratios between 25% and 30% wood dust indicates a desire to understand whether higher concentrations of wood dust could lead to even more favorable mechanical properties.

Conducting impact, flexural, and tensile tests at varying ratios allows researchers to create a comprehensive profile of the material's behavior under different conditions. The exploration of these additional ratios aims to pin point whether there exists an optimal concentration of wood dust that results in the maximum peak values of mechanical characteristics. This investigation would provide valuable insights into the material's performance range and help refine the composition for specific applications.

In essence, the research is emphasizing a significant approach to composite material design, recognizing that the optimal composition may vary depending on the mechanical property of interest. This iterative process of analysis and refinement is essential for tailoring the WDPR composite material to meet specific performance criteria, ensuring its suitability for a wide range of practical applications.

5.3 Project Potential

In the field of machinery and vehicle manufacturing, composite materials find application in crafting a diverse range of components. This includes panels, frames, and interior parts, showcasing the adaptability of these materials in creating both structural and aesthetic elements of vehicles and machinery.

Moreover, the adoption of composites in construction represents a significant shift from traditional materials. The versatility of WDPR composites allows for the replacement of conventional materials in fixtures, doors, wall panels, roofs, window frames, and even swimming pools. This adoption not only brings about innovation in construction practices but also contributes to both commercial and residential architecture. The use of composite materials in construction offers advantages such as durability, lightweight properties, and potentially enhanced sustainability, depending on the specific composition of the composites.

The passage suggests that the outcomes from using WDPR composites are indisputable, emphasizing their tangible benefits across different applications. By promoting increased utilization of natural fibers, these composites align with environmentally conscious practices, as they make use of existing resources more efficiently.

Lastly, the application of WDPR composites is positioned as a contributor to the country's economy. The adoption of such materials in various industries can lead to economic benefits through increased efficiency, cost-effectiveness, and potentially fostering growth in related sectors.

In summary, the versatility of WDPR composites, their applications in machinery, vehicle manufacturing, and construction, as well as their potential economic benefits, make them valuable and impactful materials in various sectors.

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APPENDICES

APPENDIX A GANTT CHART PSM 1

APPENDIX A
GANTT CHART FOR PSM 1

No.	Task	Status	Week 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Supervisor Selection and Registered PSM Tittle.	Plan	■													
		Actual	■													
2	Briefing for PSM Tittle	Plan	■													
		Actual	■													
3	Chapter 1: Introduction and Background Project	Plan		■	■											
		Actual		■	■											
4	Discuss Problem Statement / Objective and Scope of Res	Plan				■	■	■								
		Actual				■	■	■	■							
5	Chapter 2: Project Literature Review	Plan						■	■	■						
		Actual						■	■	■						
6	Drafting and Writing in Chapter 2	Plan						■	■							
		Actual						■	■	■						
7	Chapter 3: Research Methodology	Plan								■						
		Actual								■						
8	Drafting and Writing in Chapter 3	Plan								■	■					
		Actual								■	■					
9	Chapter 4: Research Preliminary Results	Plan										■	■			
		Actual										■	■			
10	Results and Project Analysis	Plan										■	■			
		Actual										■	■			
11	Drafting and Writing in Chapter 4	Plan											■	■		
		Actual												■		
12	Recheck Chapter 1,2,3 and 4	Plan													■	
		Actual													■	
13	Preparation and Presentation For PSM 1	Plan														■
		Actual														■

APPENDIX B GANTT CHART PSM 2

APPENDIX B

GANTT CHART FOR PSM 2

No.	Task	Status	Week 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Meeting and Discussion	Plan	■													
		Actual	■													
2	Conducting Experiment	Plan		■	■											
		Actual		■	■											
3	Collecting Data and Anlysis on Sample	Plan			■											
		Actual			■											
4	Make Discussion on Result	Plan				■										
		Actual				■	■									
5	Drafting and Writing Chapter 4	Plan						■	■							
		Actual						■	■							
6	Drafting and Writing Chapter 5	Plan							■	■						
		Actual								■	■					
7	First Submission Draft's PSM 2	Plan									■					
		Actual									■					
8	Second Submission Draft's PSM 2	Plan										■				
		Actual											■			
9	Submission Full Report	Plan											■			
		Actual												■		
10	Make a Correction of Full Report	Plan												■	■	
		Actual												■	■	
11	Oral Presentation	Plan														■
		Actual														■

APPENDIX C Upper Percentage Points Of The Studentized Range Distribution

Table A.12 Upper Percentage Points of the Studentized Range Distribution: Values of $q(0.05; k, v)$

Degrees of	Number of Treatments k								
Freedom, v	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	18.0	27.0	32.8	37.2	40.5	43.1	15.1	47.1	49.1
2	6.09	5.33	9.80	10.89	11.73	12.43	13.03	13.54	13.99
3	4.50	5.91	6.83	7.51	8.04	8.47	8.85	9.18	9.46
4	3.93	5.04	5.76	6.29	6.71	7.06	7.35	7.60	7.83
5	3.64	4.60	5.22	5.67	6.03	6.33	6.58	6.80	6.99
6	3.46	4.34	4.90	5.31	5.63	5.89	6.12	6.32	6.49
7	3.34	4.16	4.68	5.06	5.35	5.59	5.80	5.99	6.15
8	3.26	4.04	4.53	4.89	5.17	5.40	5.60	5.77	5.92
9	3.20	3.95	4.42	4.76	5.02	5.24	5.43	5.60	5.74
10	3.15	3.88	4.33	4.66	4.91	5.12	5.30	5.46	5.60
11	3.11	3.82	4.26	4.58	4.82	5.03	5.20	5.35	5.49
12	3.08	3.77	4.20	4.51	4.75	4.95	5.12	5.27	5.40
13	3.06	3.73	4.15	4.46	4.69	4.88	5.05	5.19	5.32
14	3.03	3.70	4.11	4.41	4.65	4.83	4.99	5.13	5.25
15	3.01	3.67	4.08	4.37	4.59	4.78	4.94	5.08	5.20
16	3.00	3.65	4.05	4.34	4.56	4.74	4.90	5.03	5.05
17	2.98	3.62	4.02	4.31	4.52	4.70	4.86	4.99	5.11
18	2.97	3.61	4.00	4.28	4.49	4.67	4.83	4.96	5.07
19	2.96	3.59	3.98	4.26	4.47	4.64	4.79	4.92	5.04
20	2.95	3.58	3.96	4.24	4.45	4.62	4.77	4.90	5.01
24	2.92	3.53	3.90	4.17	4.37	4.54	4.68	4.81	4.92
30	2.89	3.48	3.84	4.11	4.30	4.46	4.60	4.72	4.83
40	2.86	3.44	3.79	4.04	4.23	4.39	4.52	4.63	4.74
60	2.83	3.40	3.74	3.98	4.16	4.31	4.44	4.55	4.65
120	2.80	3.36	3.69	3.92	4.10	4.24	4.36	4.47	4.56
∞	2.77	3.32	3.63	3.86	4.03	4.17	4.29	4.39	4.47

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