EVALUATION OF THE WATER ABSORPTION, TENSILE, AND VIBRATIONAL PROPERTIES OF GTR/RECYCLED POLYPROPYLENE COMPOSITE 3D PRINTING FILAMENT TREATED WITH NaOH

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BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY WITH HONOURS

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NURUL ASYIKIN BINTI OMAR

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DEDICATION

I would like to dedicate this report to the individuals who have supported and inspired me throughout this endeavor.

First and foremost, I dedicate this report to my supervisor Ts. Dr. Yusliza Binti Yusuf whose guidance and expertise have been invaluable. Your unwavering support, constructive feedback, and patience have played a pivotal role in shaping this report. Your dedication to excellence and commitment to my professional growth have inspired me to push beyond my limits.

To my friends and family, thank you for your unwavering encouragement and understanding during the demanding phases of this project. Your belief in my abilities and your constant reminders of my capabilities provided the emotional support I needed to stay focused and motivated.

ABSTRACT

Presently, polypropylene (PP) is a plastic-based material widely used for commercial and household purposes and other thermoplastic materials. PP offers several benefits such as low cost, high melting point, sustainable and most importantly, it is 100% recyclable. However, PP has become a major threat to the environment due to its non-degradable properties. The addition of Grand Tire Rubber(GTR) composite as reinforcement can replace conventional fiberglass and other synthetic fiber composites that have manufacturing hazards. Because GTR is the main component that is one of the elements for the reinforcement polymer composite. In this study, GTR was successfully treated with alkaline treatment using 6% sodium hydroxide (NaOH) solution. Fabrication of 3D printing filaments using a single extruder by incorporating different amounts of Tire Rubber(GTR) loading (1%, 3%, 5%) into a recycled polypropylene(PP) matrix as reinforcement to find the physical properties and their environment such a water absorption. The fundamental objective of this research is to fabricate a new 3D printer filament made from recycle Polypropylene (PP), Ground Tire Rubber (GTR) treated with Sodium Hydroxide Treatment (NaOH). The specific objective is to evaluate the effect of Ground Tire Rubber (GTR) on the water absorption, tensile properties of the composite material and vibrational properties. Although the Ground Tire Rubber was delivered in small pieces, it would through numerous processes before being sieved to 125 microns. Despite the Recycled Polypropylene being in resin or pellet form, this procedure is necessary to prevent any external contaminants from disrupting the compounding process. Recycled polypropylene has manifested in resins. However, before starting the method of mixing, it is important to make sure that the resins are clean and in good condition. Next, Alkali(NaOH) was used to treat the GTR to improve the tensile properties of GTR while decreasing its impact strength. The alkaline solution concentration utilised to treat the GTR varied 6%. 80°C and 24 hours are the temperatures and times used to treat the GTR in the oven, respectively. Hotpress method of combining polypropylene with treated and untreated ground tyres was used to create a strong and durable composite with specific mechanical properties. Then, the composite that has been cool then will go to crush process to make it as pellet form. The extrusion process will be assisted single extruder machine to produce the filament with setting parameter 180 ° C. Several experiments have been conducted to determine the mechanical and physical GTR filaments. Water absorption testing, tensile test and vibrational test were all performed. The data collected during the test have been recorded and analysed. The result revealed 5% water absorption highest value compared the 1% and 3% its because that the material reaches a saturation point at a certain concentration. Then, 1% treated in GTR tensile strength has the highest performance compared the 3% and 5%. While for vibration test, 5% untreated has good performance compared the 1% and 3%. Overall, recycled polypropylene with ground tire rubber are potential alternative to develop a new 3D printing filament material

ABSTRAK

Pada masa ini, polypropylene (PP) adalah bahan berasaskan plastik yang digunakan secara meluas untuk tujuan komersial dan rumah tangga dan bahan termoplastik lain. PP menawarkan beberapa faedah seperti kos rendah, titik lebur yang tinggi, berkelanjutan dan yang paling penting, ia 100% boleh dikitar semula. Walau bagaimanapun, PP telah menjadi ancaman utama kepada alam sekitar kerana sifat-sifatnya yang tidak merosakkan. Tambahan Grand Tire Rubber (GTR) komposit sebagai penguatkuasaan boleh menggantikan serat kaca konvensional dan serat sintetik lain yang mempunyai bahaya pengeluaran. Kerana GTR adalah komponen utama yang merupakan salah satu unsur untuk komposit polimer penguatkuasaan. Dalam kajian ini, GTR telah berjaya dirawat dengan rawatan alkali menggunakan 6% larutan natrium hidroksida (NaOH). Pembuatan filamen percetakan 3D menggunakan ekstruder tunggal dengan menggabungkan jumlah yang berbeza Tire Rubber (GTR) beban (1%, 3%, 5%) ke dalam matriks polypropylene (PP) dikitar semula sebagai penguatkuasaan untuk mencari sifat fizikal dan persekitaran mereka seperti penyerapan air. Matlamat asas penyelidikan ini ialah untuk membina serat percetakan 3D baru yang diperbuat daripada Polypropylene (PP), Ground Tire Rubber (GTR) diperlakukan dengan Sodium Hydroxide Treatment (NaOH). Objektif khusus ialah untuk menilai kesan Ground Tire Rubber (GTR) pada penyerapan air, sifat tegangan bahan komposit dan sifat getaran. Walaupun getah Ground Tire dibekalkan dalam bahagian-bahagian kecil, ia akan melalui banyak proses sebelum disiram kepada 125 mikron. Walaupun Polypropylene dikitar semula dalam bentuk resin atau pelet, prosedur ini diperlukan untuk mengelakkan sebarang pencemaran luaran daripada mengganggu proses kompos. Polypropylene dikitar semula telah ditunjukkan dalam resin. Walau bagaimanapun, sebelum memulakan kaedah campuran, adalah penting untuk memastikan bahawa resin bersih dan dalam keadaan yang baik. Seterusnya, Alkali (NaOH) digunakan untuk merawat GTR untuk meningkatkan sifat tegangan GTR sambil mengurangkan kekuatan kesan. Kepekatan larutan alkali yang digunakan untuk merawat GTR bervariasi 6%. 80 ° C dan 24 jam ialah suhu dan masa yang digunakan untuk merawat GTR dalam larutan, masing-masing. Kaedah hotpress menggabungkan polipropilen dengan ban tanah yang dirawat dan tidak dirawat digunakan untuk mewujudkan komposit yang kuat dan tahan lama dengan sifat mekanikal tertentu. Kemudian, komposit yang telah sejuk kemudian akan pergi ke proses menghancurkan untuk menjadikannya sebagai bentuk pelet. Proses ekstrusi akan dibantu oleh mesin ekstruder tunggal untuk menghasilkan filament dengan parameter tetapan 180 ° C. beberapa percubaan telah dijalankan untuk menentukan filamen mekanikal dan fizikal GTR. Ujian penyerapan air, ujian tegangan dan ujian getaran semua dilakukan. Data yang dikumpulkan semasa ujian telah dicatat dan dianalisis. Hasilnya mendedahkan nilai penyerapan air tertinggi 5% berbanding 1% dan 3% kerana bahan itu mencapai titik saturasi pada kepekatan tertentu. Kemudian, 1% yang diproses dalam kekuatan tegangan GTR mempunyai prestasi tertinggi berbanding 3% dan 5%. Sementara untuk ujian getaran, 3% mempunyai prestasi yang baik berbanding 1% dan 5% kerana Dalam sesetengah kes, respons sistem kepada terapi tidak semestinya mengikuti hubungan linear dengan dos. Terdapat kemungkinan bahawa sesetengah bahan kimia atau proses mempunyai hubungan non-linear dengan kepekatan terapi, dan ia adalah mungkin bahawa kepadatan 3% adalah titik di mana sistem bereaksi dengan tahap ketepatan yang terbesar.

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LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
cm	-	Centimeter
mm	-	Milimeter
Mpa	-	Mega Pascal
%	-	Percent
kN	-	Kilo Newton
Kg	-	Kilogram
g	-	Gram
°	-	Degree
μm	-	Micron
rPP	-	Recycle Polypropylene
PP	-	Polypropylene
GTR	-	Ground Tire Rubber
NaOH	-	Sodium Hydroxide
G	-	Magnitude

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Chapter 1

INTRODUCTION

1.1 Background

Recently, Almost everyone uses plastic goods on a daily basis, whether in bottles, bags, home objects, or other forms. Plastic goods are therefore taking the place of practically all other objects, and as a consequence, they are also endangering the environment. Polypropylene (PP), which accounts for 16% of the plastics industry as a whole, is a typical component used to manufacture consumer goods, such as plastic packaging (Alsabri et al., 2022).

In recent years, the Gulf Cooperation Council (GCC) has been a major exporter of petrochemical commodities, such as chemicals, personal care products, pharmaceuticals, transportation equipment, textiles, and food. This has increased the demand for PP production and raised concerns about the impact of PP refuse on the environment. Combination the life cycle assessment (LCA) research to examine the effects of PP production and waste on the environment (Alsabri et al., 2022).

There are already many new vehicle rubber parts on the market that use some recycled rubber. These include items and tires, where 5% or less may be found in the tread composition in stationary sealing and insulating applications. Design is one technique to increase recycling rates in the automobile industry and other industries. In a variety of automobile sealing profiles, a thermoplastic carrier has taken the role of the metal carrier thanks to a newly developed technology (Forrest et al., 2019).

In order to minimize the abandon of Polypropylene in landfill, this study aims to develop the 3D Printing Filament material using Recycled Polypropylene (PP) and the GTR used as reinforcement material.

1.2 Problem Statement

Increasing refuse tire production and accumulation endanger the ecosystem, posing potential fire hazards, environmental contamination, and health risks to humans. Moreover, there is a substantial economic loss associated with the disposal of used tire rubbers. To obtain waste tire rubber with added value, numerous recycling strategies are being developed. The combination of thermoplastics and ground tire rubber (GTR) is one example. However, obtaining homogeneous dispersion of GTR in matrix is difficult because GTR has little to no affinity for thermoplastics (Archibong et al., 2021).

Hence, to solve this issue, GTR surface treatments, compatibilizers, additives, and energy treatments are utilized. To facilitate GTR dispersion, incorporation of rigid nanoparticles with or without other techniques has been adopted recently. The effect of fillers, specifically nanofillers, on the dispersion of GTR within thermoplastic matrices for the production of competitive materials (Sanusi, Olawale Monsur et al., 2021). Thus to avoid the addition of rubber tire waste its can make this tire wastes as a material for making filaments.

GTR is one of the less commonly used thermoplastic materials along with Polypropylene (PP) available in 3D printing filament. The optimal result of reprocessing waste tire rubber is to obtain a material that is entirely and repeatedly reusable in the production of new tires and other products (Ruwona et al., 2019). GTR is used in the construction industry, especially in the modification of cement or road bitumen. Modification of bitumen with GTR has revealed that the addition of GTR as a modifier to bitumen increases elasticity and fatigue resistance which extends fatigue life. (Karahrodi et al., 2017). Therefore, by adding this GTR, it can obtain elastic filaments because the existing filaments do not have elastic characteristics.

The purpose of this study is to develop 3D printing filament material using recycled PP-reinforced GTR derived from natural resources in order to address an environmental problem and create biodegradable polymers. Secondly, evaluate the effect of Ground Tire Rubber (GTR) on the water absorption, tensile properties and vibrational properties of the composite material.

1.3 Research Objective

The aim of this research is to develop a 3D filament material from recycled polypropylene with usage of Ground Tire Rubber (GTR) in a new class of low-cost, recycled composite materials. Hence, the objectives are as follows:

a) To fabricate a new 3D printer filament made from recycle Polypropylene (PP), Ground Tire Rubber (GTR) treated with Sodium Hydroxide Treatment (NaOH).

b) To evaluate the effect of Ground Tire Rubber (GTR) addition on the water absorption, tensile properties and vibrational properties of the composite material.

1.4 Scope of Research

In this study, recycled polypropylene was used as the host matrix. Recycled polypropylene was developed from recycled factory in the form of pellets. Then, fabricate a new 3D printer filament made from recycle Polypropylene (PP), Ground Tire Rubber (GTR) treated with Sodium Hydroxide Treatment (NaOH). The modification of recycled polypropylene reinforced with performed by inserting different amount of Ground Tire Rubber (GTR) loading (1%, 3%, 5%) into the polymer matrix to evaluate the effect of Ground Tire Rubber (GTR) on the water absorption, tensile properties of the composite material and vibrational properties. The fabrication process will be using a hot press, crusher and single screw extruder to form 3D printing filament. Therefore, the application of the reinforcement of ground tire rubber 3D filament material that produces filaments that have the strength level of material absorbing vibration.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

Over the years, additive manufacturing (AM) which also known as 3D printing is becoming more popular, and new developments are being launched all the time. 3D printing is the technique of layering materials to create a three-dimensional object. In the AM process, there are lots of materials that have been used and pure polymers, polymer matrix composites, polymer ceramic composites, nanocomposites, and fiber-reinforced composites are examples of these materials. These materials have their own specialties and important factors such as material type, texture, cost, etc. However, plastic waste product from petroleum-based is quite pricey and difficult to recycled. This issue should be solved by producing a biodegradable product made from renewable materials such as recycled polypropylene.

2.2 3D printing in general

Additive manufacturing, also known as 3D printing, is a digital fabrication technique that creates physical objects by adding materials to a digital model. It is becoming increasingly common in the agricultural, healthcare, automotive, and locomotive industries. 3D printing technology can build a three-dimensional object layer by layer, using a CAD model as a starting point (Jadhav, Aniket et al., 2022).

Additive manufacturing is the process of combining materials to construct products from 3D model data, typically layer by layer, as opposed to subtractive manufacturing techniques. Additive manufacturing was introduced to the world in 1984 by

Charles W. Hull, and it has been extensively studied over the past three decades. For 3D printing, numerous polymers, metals, ceramics, and composites are utilised. The seven additive manufacturing techniques classified by ASTM/ F2921 include material extrusion, binder jetting, material jetting, powder bed fusion directed energy deposition, sheet lamination, and vat photopolymerization. Additive manufacturing is built to process smart and adaptive materials (Ahuja, B B et al., 2021). Figure 2.1 show the seven additive manufacturing techniques classified by ASTM/ F2921.

Figure 2.1 Classification of Additive manufacturing.

2.2.1 Commonly used 3D printing technology

3D printing offers a unique solution for fabricating complex geometries with high tolerances, but conductive polymers can be processed to enable additive manufacturing of conductive, low-density, and low-cost parts. 3D printing technology has revolutionised the way components and products are manufactured in a wide range of industries, including electronics, aerospace, biomedical, wearable technologies, fashion, culinary, and automotive.

3D printing reduces material waste and labour costs by eliminating the need for tooling and dies. The 3D printing of electrically conductive materials, which can be used in electronics, biomedical devices, and wearable technologies, is one area that has attracted increased attention. Polymeric materials that are electrically conductive and lightweight, versatile, and inexpensive can provide a novel solution (Ryan, Kirstie R et al., 2022). 3D printing of polymers conducting polymers offers a combination of functional materials and precision manufacturing. However, polymers are challenging to process and can be problematic for AM. To achieve excellent printability, conducting polymers are frequently blended with other polymers to facilitate additive manufacturing while preserving their electrical functionality. Conductive additives disseminated in a polymer matrix can be used as an alternative to conjugated polymers to provide electrical conduits to an intrinsically insulating polymer or to increase the conductivity of conducting polymers. The incorporation of these additives can have a profound effect on all composite properties, including optical, mechanical, thermal stability, and electrical properties. The advantage of using conductive additives in a polymer is that a wide variety of polymers can be used as the matrix material, and the polymers can be tailored for particular AM techniques. This provides a degree of flexibility for AM conductive polymer composites employing various technologies (Ryan et al., 2022).

2.2.2 3D printing filament materials

The 3D printing process uses neat thermoplastic filaments such as PLA, PS, ABS, Nylon, PET, and PC, which are the liquefier head is pressurised by drive gearing and bearings with groves. Due to its effortless printability, relatively excellent mechanical properties, biodegradability, biocompatibility, and optical transparency, PLA is one of the most researched printing materials utilised in 3D printing (Ahmad et al., 2023). 3D printing is used to create non-load bearing components, so thermoplastic 3D printers are used to create prototypes and non-load bearing components. To surmount this constraint and limitation, the research focuses on enhancing the strength of FDM-fabricated filament. Carbon fibre reinforced plastic (CFRP) composite filament has been created to manufacture high strength thermoplastic composites (Almeshari et al., 2023).

The composite's tensile strength was substantially enhanced by the incorporation of glass fibres into the ABS matrix. Carbon fibres enhanced the composite's tensile strength and Young's modulus, but lowered its yield strength, ductility, and durability (Zhong et al., 2001). Then,polypropylene is a thermoplastic ‘addition polymer’ formed by combining propylene monomers. It can be found in a variety of contexts, from the household to the workplace. It is indispensable for a wide range of applications due to its unique characteristics and adaptability to a variety of manufacturing techniques. It can also be used as a plastic and a fibre, making it a major participant in the global plastics industry (Girimurugan et al., 2022).

2.3 Polymer as matrix in composite

Composites are materials made up of two or more components combined to create a material with superior qualities. The majority of composites consist of a matrix and reinforcements like fibers. Man-made composites are divided into three primary categories: polymer matrix composites (PMCs), metal matrix composites (MMCs), and ceramic matrix composites (CMCs). Polymer matrix composites (PMC) or fibre reinforced plastics (FRP) are composite materials that employ organic polymers as the matrix and fibres as reinforcement. There are numerous PMC variants based on the polymer type, such as amorphous and semi-crystalline polymers, thermosets and thermoplastic polymers, epoxies, and non-epoxy polymers. These three primary categories of man-made composites are competitive and allow for the replacement of traditional materials (Ramawat et al., 2023).

Thermosets are used to create a wide range of uses at higher temperatures, such as epoxies, vinyl esters, and unsaturated polyesters. Matrix keeps reinforcing fibers together, while reinforcement fibers, which can make up to 70% of the composite, are tougher and more powerful than the matrix (Goodship, 2012). In the past ten years, the demand for carbon-fiber reinforced polymers increased from 60 to 170 kilotons, nearly tripling. Over the next 20 years, the growth rate is anticipated to decelerate, but there is still a possibility that global demand will increase. Only 500 million metric tonnes of the 8,300 million metric tonnes of polymers produced between 1950 and 2015 were recycled, making it vital to devise efficient recycling strategies (Qiao et al., 2023).

2.3.1 Type of polymer as matrix in composite

The type of reinforcements used in composites is used to classify them. The reinforcements are coated in a matrix that keeps everything together and is made up of thermoset, thermoplastic, elastomers, nanoparticles, glass, carbon, steel or Kevlar fibers. The matrix material is made up of thermoset, thermoplastic, elastomers, nanoparticles, glass, carbon, steel or Kevlar fibers. Polymer matrix composites are made up of thermoset, thermoplastic, elastomers, nanoparticles, glass, carbon, steel or Kevlar fibers.

Synthetic fibers are materials created in a lab, such as polyethylene (PE), polypropylene (PP), polystyrene (PS), polyamides (nylon), polyvinyl chloride (PVC), synthetic rubber, teflon, epoxy, and a variety of other materials. Synthetic polymers are made from petroleum oil in a controlled setting and have a backbone of carbon-carbon bonds. They are used in everyday applications such as thermoplastics, thermosets, elastomers, and synthetic fibers. Table 2.1 illustrates some of the abilities of natural and synthetic polymers.

Table 2.1 Comparison of Natural Polymers and Synthetic Polymers

Natural Polymers	Synthetic Polymers
Occurs naturally	Artificially produced
Have been in used since millions of years	Have been made significant since the last 125 years
Similar but non-identical repeating	Identical repeating unit
Natural reaction controls the properties	Highly engineered properties could be determined by controlling the reaction
Usually, biodegradable	Some synthetic polymers are biodegradable
Similar chain lengths of molecules	Chain lengths could be significantly varied based on the reaction conditions
Backbone could be of carbon, oxygen, and nitrogen	Backbone is mostly carbon
Environmentally friendly	Environmental friendliness
Limited recyclability	Some of the synthetic polymers could be recycled multiple times

2.3.2 Polypropylene (PP) and its recycle

Polypropylene (PP) is the most widely used thermoplastic material due to its exceptional mechanical properties, low cost, processability and chemical stability. It is semicrystalline and is the most widely used due to its high mechanical strength, low cost, processability and chemical stability (Jin et al., 2020). The manufacturing process and shear-induced crystallisation influence the mechanical and thermomechanical properties of PP. Crystallisation of PP results in thermal contraction, which makes 3D printing more difficult because it affects bonding between filament strands, layering interfusion, and adhesion of layers to the build plate (Valino et al., 2019). The inherent properties and market price of polypropylene (PP) make it a prospective material for FFF 3D printing processes; however, additional research is necessary to comprehend the process-structure-property relationship and possible mechanical property enhancements.

Researches have focused on the possibility of using recycled plastic fibers as a matrix for 3D printing filament. Globally, over 335 million tonnes of plastic are manufactured each year, with only 9% recycled, leading to increasing plastic pollution (Das et al., 2021). This method of recycling can save several million dollars each year, as filaments are used for 3D printing polymeric structures. This opens up an entirely new channel for recycling plastic waste and decreasing global plastic pollution (Das et al., 2021).

Waste made of plastic is classified based on its resin identification code, and a recycling code for 3D printed items should be provided. Table 2.2 provides information on the ASTM resin identification code. Recycled material is crushed into flakes, which can be used as raw material in filament extruders.

Table 2.2 Resin identification code based on ASTM D7611

Recycling No.	Material	Applications
1	Polyethylene terephthalate (PET)	Thermoformed sheet polyester fibers
2	High-density polyethylene (HDPE)	Agriculture pipes playground equipment
3	Polyvinyl chloride (PVC)	Pipis, flooring children's toy
4	Low-density polyethylene (LDPE)	Plastic bags, containers laboratory equipment
5	Polypropylene (PP)	Industrial fibers, auto parts food containers
6	Polystyrene (PS)	Plastic utensils packaging peanuts
7	Other plastics (OTHER)	Bottles, headlight lenses safety glasses

The PP recycling process involves three stages: separate PP from other plastics, melt PP, and cool and form into pellets. In the first stage, PP is separated from other plastics and chemicals using sink-float separation. In the second stage, PP is heated in an extruder until it becomes liquid. In the third stage, PP is cool and formed into pellets to be sold to manufacturers for their manufacturing processes.

2.3.3 Polypropylene (PP) as matrix in composite

PP is a composite matrix with outstanding particle size, mechanical properties, thermal and chemical stability, and cost-effectiveness. It has potential applications in the industry and environment, and has quickly embraced synthetic polymers in the packaging, fiber, and injection moulding industries. Polypropylene (PP) is a popular polymer due to its superior mechanical properties and low cost. Efforts have been made to increase the thermal conductivity of PP by controlling the arrangement of thermally conductive additives and generating a robust thermal conduction network in polymer matrix (Cao et al., 2021).

When the graphite content was 21,2 vol%, the thermal conductivity of PP/graphite composites was considerably enhanced due to the construction of an ideal thermally conductive network of graphite granules with large particles surrounding PP resin particles (Cao et al., 2021).

2.3.4 Recycled polypropylene as matrix in composite

Polypropylene is a thermoplastic widely utilized in plastic moldings, stationery folders, packaging materials, plastic tubs, non-absorbable sutures, and diapers. It can be destroyed by ultraviolet light from the sun and oxidized at high temperatures. The creation of polymer blends from recycled components could be a cost-effective solution to reuse mixed waste streams. After the polymerization process, PP is essentially stabilized in a first compounding step to avoid oxidative degradation throughout processing and lifespan. The material's heat stabilizers, especially secondary antioxidants, are lost as a result of repetitive processing during recycling. To increase the quality of recycled material, compatibilizers and impact modifiers such as EPDM and EP copolymer are commonly used. This reduces the detrimental impact of toxins on the environment (Bunjes et al., 2022). Figure 2.3 shows commonly used plastics and their applications.

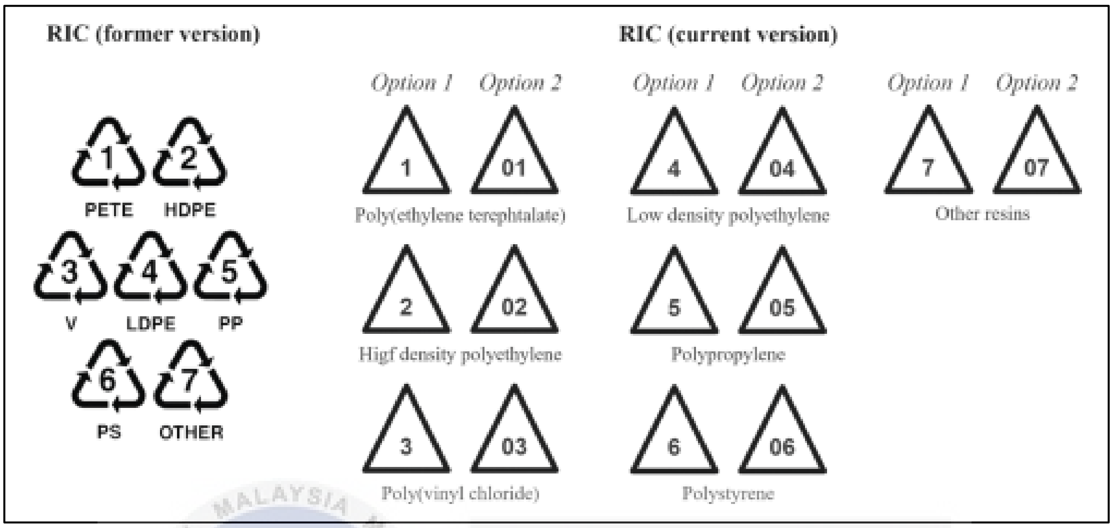

Figure 2.1 Resin identification code based on ASTM D7611

Concluded that the easy degradability of homogeneous PP during processing and recycling methods presents substantial hurdles in its recycling. The bonds between hydrogen and carbon in polypropylene weaken with time due to thermal breakdown, but the timing is dependent on how PP is used. The structure and morphology of PP are also affected by mechanical stress and UV light. Degradation has the greatest impact on elongation at break and impact strength, as it has the third carbon in the chain (Shamsuyeva & Endres, 2021).

2.4 Ground Tire Rubber (GTR)

The end-of-life of automotive tires is a major environmental issue, and innovative solutions are being developed to address it. These include updating life cycle assessments, showing the benefits of recycling and recovery, and considering how waste tires can be converted into a valuable resource (Revelo et al., 2021). Recycling of materials such as tires has been carried out by various processes, such as landfilling, pyrolysis, downcycling, shredding, and electromagnetic separation. When organic materials are heated to 400°C without oxygen, they are broken down into three separate phases: a solid black phase made of ZnO and ZnS, a gaseous phase with aromatic compounds, and a liquid phase made up of heavy and light oils. Downcycling is one example, whereas recycling by shredding entails shredding scrap tires into fragments of various sizes. After shredding, steel fibers and rubber particles are separated using an electromagnetic process so they may be used for creating rubber goods, recycling them in other applications, and replacing fine aggregate in concrete (Herrera-Sosa et al., 2015).

Recycled waste tires have been used in the construction industry, such as mechanical reinforcement of concrete, recovered rubber as replacement of natural aggregates, partial replacement of sand or cement by crumb rubber or powder rubber, and partial replacement of sand or cement by crumb rubber or powder rubber. In Table 2.3 shows, the component of the produced concrete, these uses have improved mechanical performances of concrete, reduced water absorption, and reduced structural weight. Additionally, they have improved fracture characteristics of concrete, but decreased flexural strength and light increment (Herrera-Sosa et al., 2015).

Table 2.3 Components of the concrete for producing 1 m3(Herrera-Sosa et al., 2015)

Mix code	Waste tire (Vol%)	Waste tire (kg)	Portland cement (kg)	Sand (kg)	Gravel (kg)	Water (kg)
M-0	0	0	337.1	758.5	662.6	286.3
M-10-7	10	36.2	337.1	596.4	758.5	278.4
M-20-7	20	72.4	337.1	530.1	758.5	270.6
M-30-7	30	108.7	337.1	463.8	758.5	262.7
M-10-20	10	47.2	337.1	596.4	758.5	278.4
M-20-20	20	94.5	337.1	530.1	758.5	270.6
M-30-20	30	141.7	337.1	463.8	758.5	262.7

2.4.1 GTR chemical, physical and mechanical properties

GTR biodesulfurization process evaluated by molecular microbiological and physico-chemical methods :

i. Microbiological monitoring

The sequencing of 16S rRNA gene by high throughput sequencing was performed to identify the main microbial populations present on the GTR prior and during the treatments as shown in Figure 2.2. ARISA profiles were analysed to determine the changes in microbial community structures during the treatment and to evaluate the persistence of the inoculated strains. qPCR was used to quantify the abundance of total microbes and putative desulfurizing populations (Formela, 2021). The sequencing of the 16S rRNA gene in the untreated GTR revealed that 71% of the bacteria belonged to Gram-positive taxa. The following genera were represented among Firmicutes: Bacillus (16%), Aeribacillus (70%), Staphylococcus (10%), and Paenibacillus (10%).

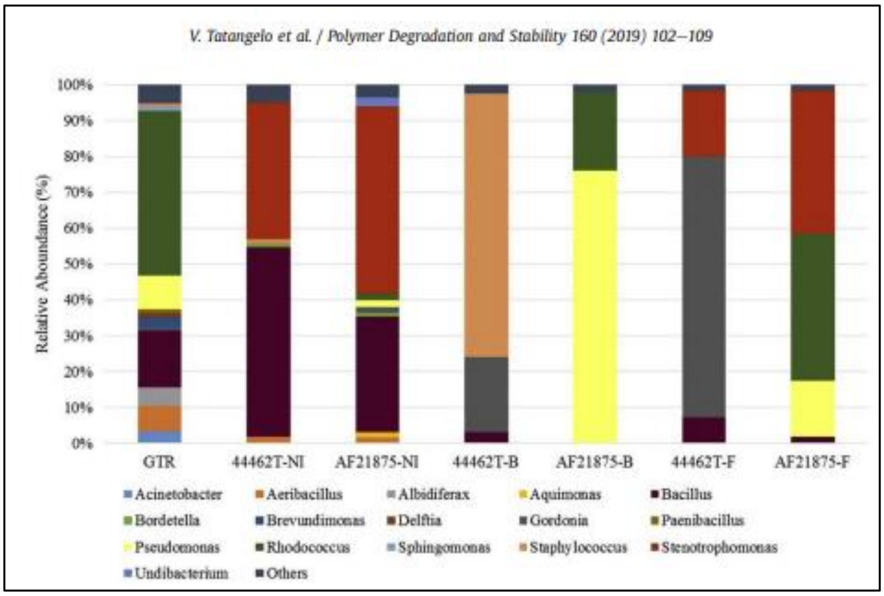

Figure 2.2 The main microbial populations present on the GTR prior and during the treatments (Tatangelo et al., 2019).

In contrast, 24% of bacteria were Gram-Negative taxa (a-, b-, and g-Proteobacteria). After autoclaving, the GTR contained the same genera, but more Stenotrophomonas. The ARISA OTU abundances were utilised to infer the b-diversity of the microbial community structures. PCA revealed that the GTR communities from various bioreactors clustered independently. During treatment with Rhodococcus sp. AF21875, the structure of the microbial community changed over time and appeared to resemble that which existed prior to the addition of the inoculum (Tatangelo et al., 2019).

ii. Physico-chemical

Through sol and gel fraction, crosslink density, mechanical and rheological properties, the physicochemical properties of biodevulcanized GTRs were evaluated. The sample treated with G. desulfuricans DSM 44462T (G-GTR) exhibited a modest increase in the sol fraction content and a decrease in the gel fraction content, suggesting an increase in devulcanization activity. However, all the samples showed similar values of sol and gel fraction. Table 2.4 show , the crosslink density of vulcanizates was measured, with Ref-NR, G-GTR/NR and R-GTR/NR showing the highest crosslink density. GTR/NR vulcanizate showed the lowest crosslink density (Mangili et al., 2015).

Table 2.4 GTR/NR vulcanizate showed the lowest crosslink density

Sol and gel fraction of GTR and X-GTRs samples.

GTR/X-GTR	Gel Fraction wt %	Sol Fraction wt%	SE[a]
GTR	97.7	2.3	0.1
G-GTR	96.7	3.3	0.1
R-GTR	97.1	2.9	0.6

[a] Standard Error (number of observation = 3).

2.4.2 GTR application and characteristics

The use of renewable, waste, and recycled materials as adsorbents is a relatively novel area of study. However, the primary issue with the application of refuse-based materials is the dearth of or extremely limited characterisation of waste materials, which can vary considerably. Therefore, the composition and characteristics of the GTR were emphasised and discussed. The average track tyre is comprised of fourteen different compounds and six distinct steel wire, cables and fabrics. These materials include the tread base, tread chimney, cushion, sidewall, bead region, plies, belts, overlay, shoulder wedge, inner liner, and gum strips. The accumulation of these elements resulted in a high-performing product. However, the methods of bulk preparation and, most importantly, their composition vary based on the functions executed (Smith et al., 1995).

The most common way to recycle old tyres is to cut and grind them. But before cutting, grinding, or pulverising, leftover rubber should be sorted by where it came from (based on its chemical make-up). This step makes it easier to repeat the process and improves the quality of the goods made. Table 2.5 shows a study of what most tyres are made of and how the way tyres are ground affects GTR properties. Car tyres have more carbon black and less natural rubber than truck tyres. Tyres' final performance, such as how well they wear, roll, or don't slip, depends on how their chemical makeup differs. The amount of natural rubber to manufactured rubber has a big effect on how well rubber can be reused or devulcanized. (Fazli & Rodrigue, 2020).

Table 2.5 A comparison of the typical composition of tires and the effect of the tires

Composition	Tire (%wt.)		GTR property	Grinding technology	
	Car	Truck		Ambient	Cryogenic
Natural rubber	22	30	Specific gravity	Same	Same
Synthetic rubbers	23	15	Particle shape	Irregular	Regular
Carbon black	28	20	Surface area	Well-developed	Non-developed
Additives	14	10	Oxidation level	High	Low
Steel	13	25	Product purity	Low	High

2.4.3 GTR as reinforcement in composite material

Thermoplastic vulcanizates, also known as TPVs, are the members of the family of thermoplastic elastomers that are expanding at the quickest rate. These materials are distinguished by the presence of a vulcanization reaction, which gives them their name. Rubber particles that have been cross-linked and are finely dispersed, and they have been spread throughout a continuous thermoplastic matrix . The physicochemical qualities of the mixes may be significantly enhanced by vulcanizing the rubber particles. The exorbitant costs of the elastomeric phase, on the other hand, forced researchers to look for other, less costly solutions. Ground tyre tuber, also known as GTR, is an excellent option for use in reinforcing thermoplastic vulcanization (TPV) materials and reducing the cost of manufacturing components for a variety of applications. In order to achieve one's goals, it is necessary to subject GTR through a process of chemical alteration. In order to create TPVs with improved characteristics and to improve the interfacial adhesion with the polymer matrix (Narro-cespedes & Sol, 2016).

There have been a lot of studies done on the usage of these GTR as reinforcements in composite materials. These studies can be found in many works on physical characterization of polymers with particles of GTR, analysing various composites; however, there has never been specifically a mechanical study and comparison done before of such traits in a variety of contexts. Because of their existence in polymer matrix composite materials be added to the matrix of a variety of polymers (PVC, EVA, HDPE, PP, PA, ABS, and PS), and as long as the mechanical characteristics of the polymer, as well as its initial microstructure, are maintained within an acceptable range of mechanical values, it may be possible to add GTR to a number of different industrial processes in order to modify the mechanical behaviour of the products. Because the pulverisation technological operations of GTR limit the size of the particles, a simple and cost-effective method was selected to acquire the classification in the three needed particle sizes (less than 200 micrometres, between 200 and 500 micrometres, and more than 500 micrometres). It is consequently necessary to establish what proportion of GTR will be used (Marín-genescà et al., 2020)

2.5 Summary of literature review

It is clear from the many research on the gtr, recycled polypropylene, composites, and 3D printing filament that polypropylene makes an excellent polymer matrix for composites since it can be recycled to create new sustainable biodegradable polymers. This is due to polypropylene's great chemical resistance, low density, cheap cost, and outstanding mechanical and melting qualities. Additionally, GTR reinforcement added to polymer composites has made them more elastic. It is evident from the literature that no work has been done to generate 3D printing filament material utilising recycled polypropylene reinforced with GTR, despite the fact that there is a wealth of research on the modification of recycled polypropylene as matrix.

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Chapter 3

METHODOLOGY

3.1 Introduction

The research methodology presented in this chapter was used to accomplish the objectives of the study, as depicted in Figure 3.1

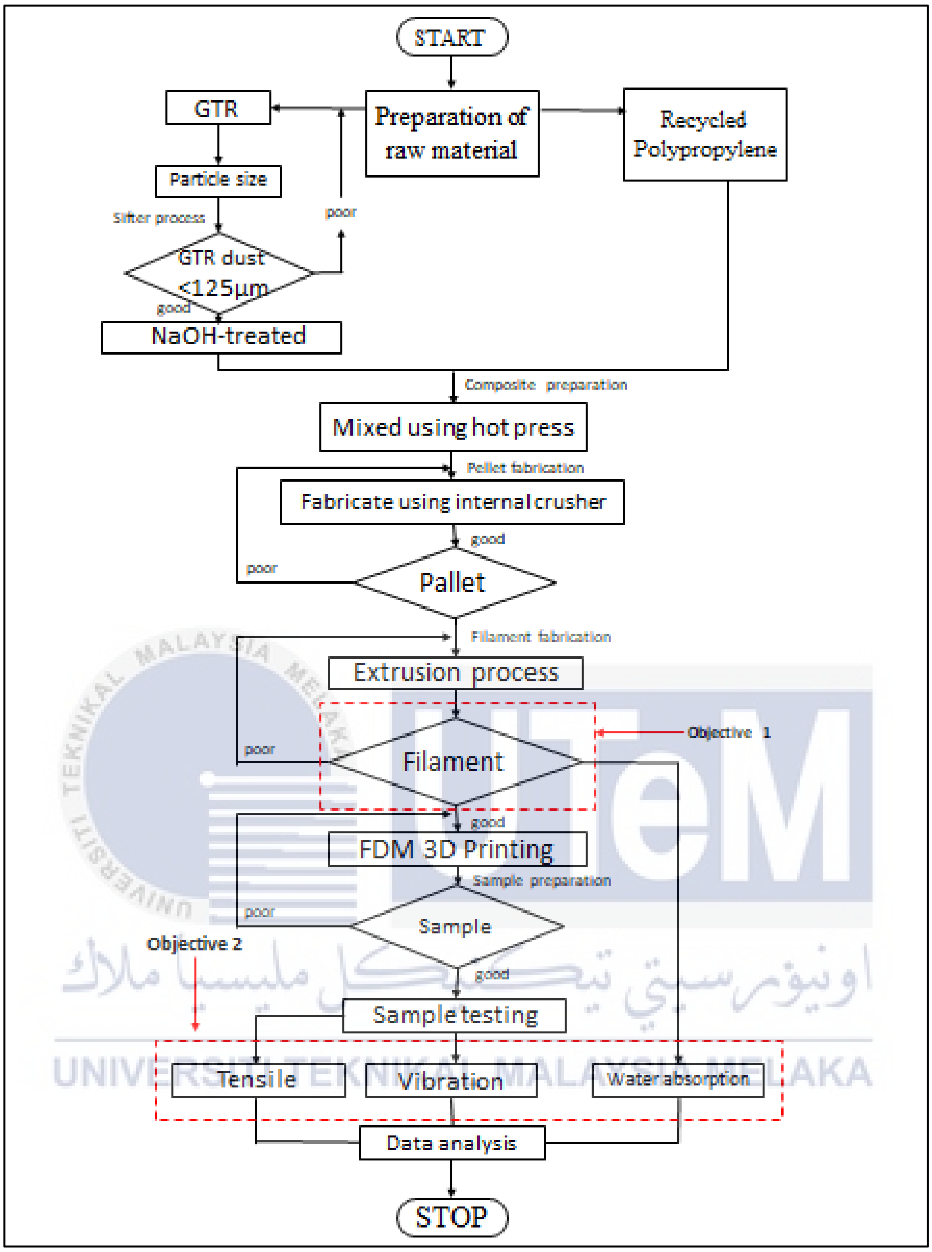


Figure 3.1 The process flow for this study

3.2 Preparation Raw Materials

Ground tire rubber in the form of powder must be sieved multiple times to achieve a particle size of 125 microns. Even though the recycled polypropylene is already in the form of a resin or granule, the process must be adhered to so that foreign particulates do not interfere with the compounding process. The following are the preparation stages for ground tire rubber and recycled polypropylene.

3.2.1 Preparation of Ground Tire Rubber

The ground tyre rubber (GTR) that was utilised for this investigation was sieved using a machine that was similar to the one seen in Figure 3.2. For the purposes of this investigation, ground tyre rubber with a particle size of 125 micron was used. Figure 3.3 shows , GTR after sieving process. It must adhere to the procedure shown in Figure 3.4 in order to achieve a particle size of 125 microns. The first step is obtain a sieve with a mesh size of 125 microns. Ensure that the sieve is clean and in good condition. Then, make sure that the ground tire rubber is properly prepared and free from any dust. Place the sieve on top of the container or tray that is being used for collection and make sure that the sieve is firmly positioned in its position. The process of sieving should be started. This can be accomplished manually by gently shaking the sieve, or it can be accomplished with the use of mechanical sieving equipment. The particles that are smaller than 125 microns will be able to accumulate in the container below after passing through the sieve mesh.

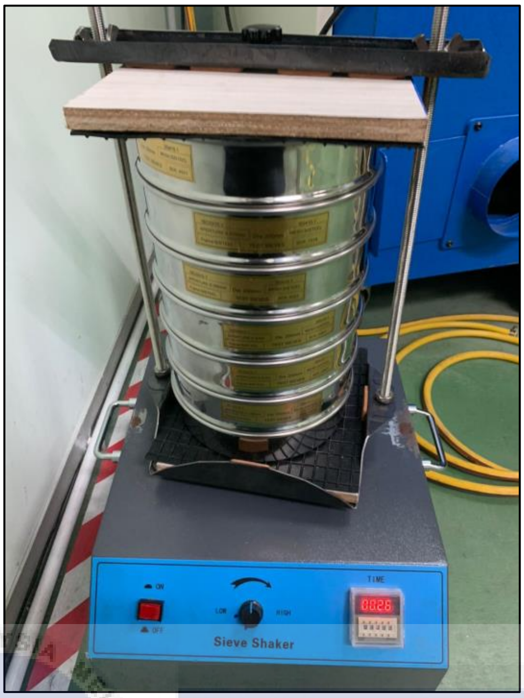


Figure 3.2 Sieving Machine


Figure 3.3 GTR after sieve

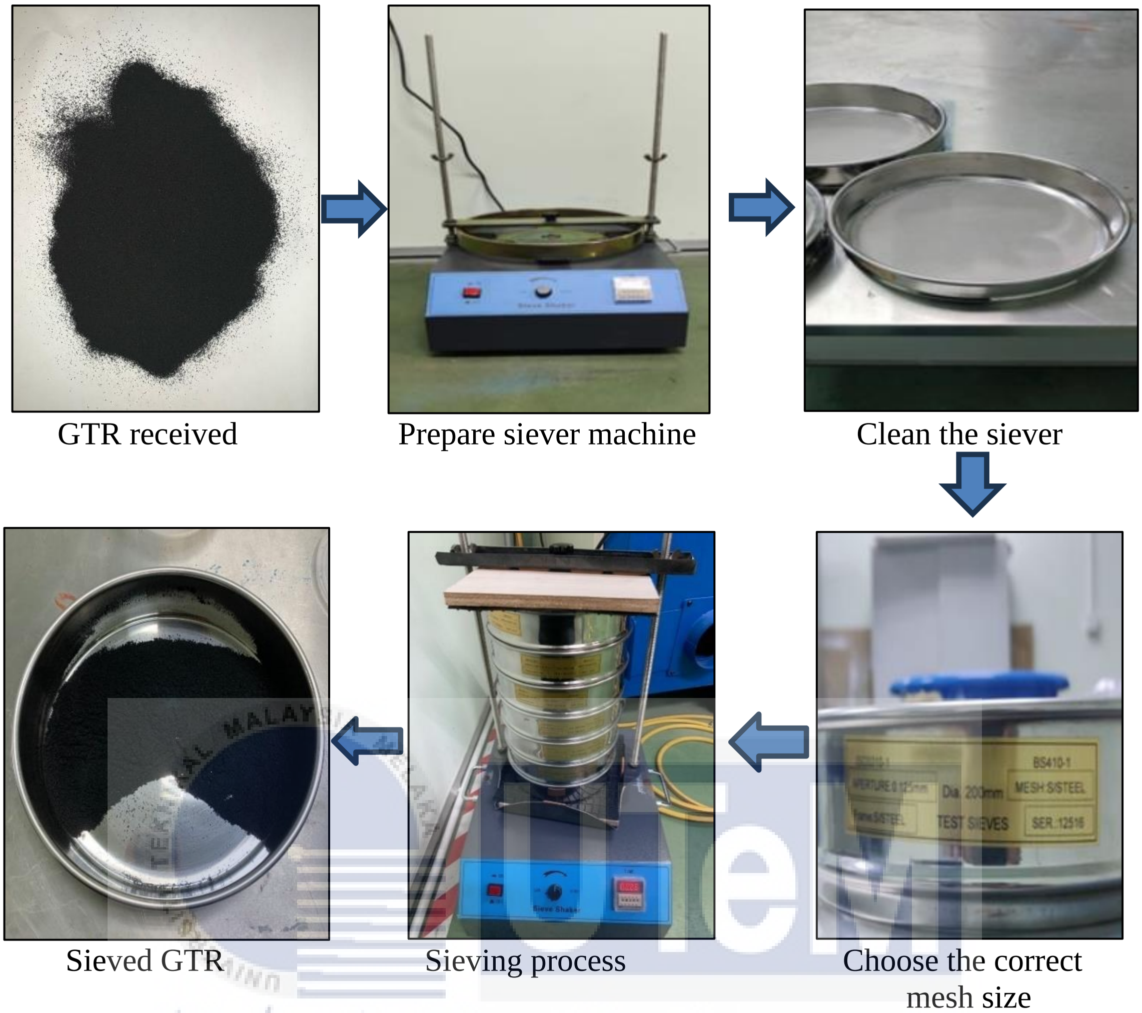


Figure 3.4 Sieving process

3.2.2 Preparation of Recycled Polypropylene

The experimental investigation employed granulated pellets of recycled PP bought from Lotte Chemical with a melt flow rate of 33.8 g/10 min (with a weight of 5000 g at 230 C). The recycled polypropylene was acquired Lotte Chemical in the form of resins and pellets, as indicated in Figure 3.5.

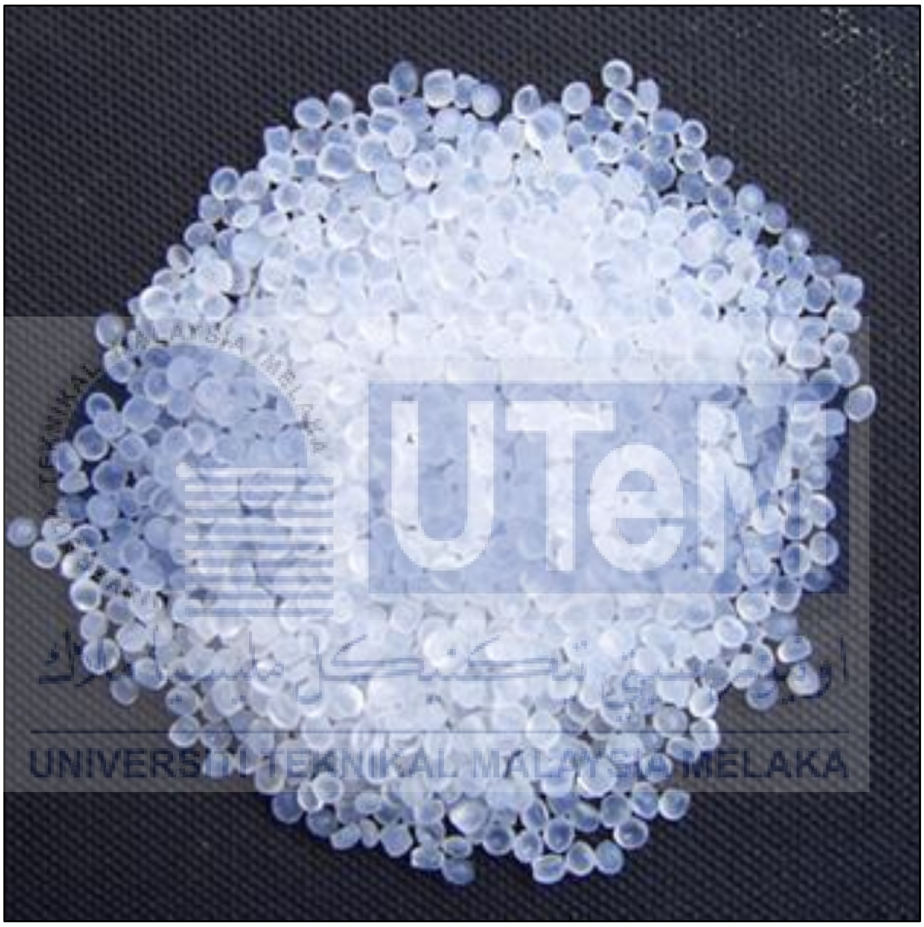


Figure 3.5 Recycle Polypropylene (PP)

Resins are viscous substances that cure into rigid polymers. Resins are present in nature, although they are now routinely synthesized. Some synthetic resins have properties comparable to natural plant resins, whereas many do not. However, before beginning with the mixing procedure, the resins must be cleaned and dried to ensure that they are clean and in excellent condition.

3.2.3 Preparation of Sodium Hydroxide (NaOH) solution

For the purpose of this investigation, the alkaline treatment consisted of applying a NaOH solution that was applied inliquid, as seen in Figure 3.6 then Table 3.1 detailed the product specifications for (NaOH).

Figure 3.6 NaOH on pallete form

Table 3.1 Specification Of Sodium Hydroxide

Items	Specifications
Physical Form	Pallete
Colour	White
NaOH Content	More than 99%
Water Soulbility	100%
Molecular Weight	40 g/mol

Alkali (NaOH) treatment is a simple and efficient surface modification procedure that is extensively used in Ground Tire Rubber (GTR) composites. The weight ratio for water is shown in Table 3.2. The treatment with alkali (NaOH) was shown to increase tensile and characteristics while lowering impact strength(Radzi et al., 2019). In this study, preparation of NaOH solution consist of 6% the concentration of NaOH and 94% of H_2O will be add together to fulfill the 100% of mixture for NaOH solution in Figure 3.7.

Table 3.2 Weight ratio of water

No	Material	Amout(ml)	Amonut(%)
1	NaOH	30	6%
2	Water	470	94%
3	Total	500	100%

Figure 3.7 NaOH Solution

3.3 Treatment of Ground Tire Rubber (GTR) using Sodium Hydroxide (NaOH)

The treatment with alkali (NaOH) is a surface modification procedure that is both simple and efficient. It is often used in the production of GTR composites. It was discovered that treating the material with alkali (NaOH) enhanced the tensile and flexural capabilities while simultaneously lowering the impact strength (Alfatah et al., 2022).

The percentage of alkali solution that was used to treat the GTR varied from 0.5% all the way up to 28%, however the vast majority of researchers utilised a concentration of alkali solution that was less than 10%. The temperature range of 20–180 °C and the amount of time spent soaking in the solution to treat the GTR are, respectively, 3 hours and 20–180 °C as shown in Figure 3.8, NaOH Treatment. The ratio for the alkaline treatment is 6% sodium hydroxide to 94% distilled water.

Figure 3.8 NaOH Treatment

After that, the mixture will be washed by using water that has been distilled. The combination of GTR and NaOH solution is going to be strained through at least three different times after being placed into a strainer. Figure 3.9 provides an illustration of the process that should be followed while cleaning the GTR.

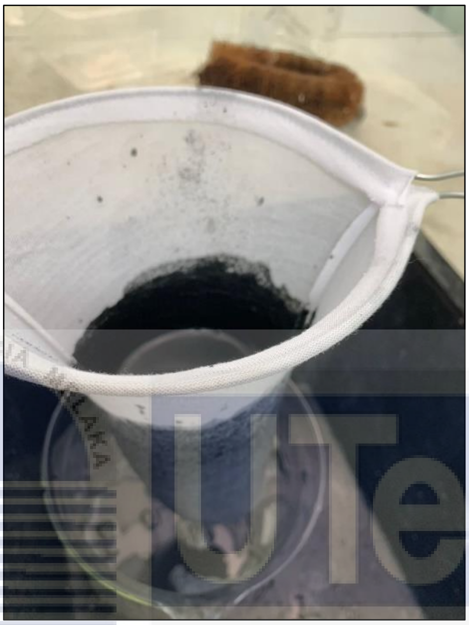


Figure 3.9 Cleaning Ground Tyre Rubber(GTR) using distilled water

Following that, aluminum foil will be used to wrap the GTR as shown in Figure 3.10. Finally, it will be dried in an oven at a temperature of 80 °C for 24 hours. The dreid GTR is depicted in Figure 3.11.

Figure 3.10 Aluminum foil wrap the GTR

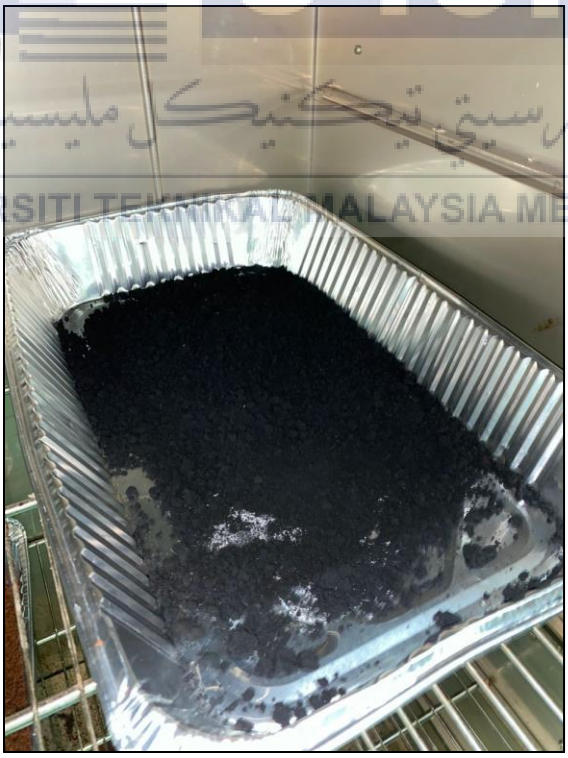


Figure 3.11 The drying process

An application that might be possibly linked to chemical treatment is the recycling or modification of rubber characteristics. Figure 3.12 is a comprehensive outline the process of treatment GTR using NaOH. The quantity of distilled water that required is 470ml for solution 30g of Sodium Hydroxide(NaOH). Then, add the pellets of sodium hydroxide to the water in a slow and steady manner. The addition of water to sodium hydroxide should never be done since it might cause a sudden rise in temperature as well as splattering. In its place, the solid should be added to the solid. Using a spatula or other appropriate equipment, stir the mixture. In the water, the pellets will dissolve. Because the process is exothermic, it generates heat, therefore be wary of temperature fluctuations. Next, immerse the GTR into the solution and soak for 3 hours. After the treatment, rinse the solution using the distilled water in several times and prepair the container to dry. Dry in the oven at 80°C for 24hours.

Figure 3.12 Process of treatment GTR using NaOH

3.4 Fabrication Filament

Ground tire rubber (GTR) and recycled polypropylene will be separated and weighed based on their GTR loading content and compared to the aim of 1kg GTR filaments.

3.4.1 Mixing the ground tire rubber (GTR) with recycled polypropylene (PP)

Ground Tire Rubber (GTR) and recycled polypropylene will be weighed according to their GTR loading as shown in Table 3.3**.** The treated GTR will also be loaded with the same quantity. The operation will be carried out manually, with the two ingredients being mixed together as shown in Figure 3.13 prior to the extrusion process. Before mixed together the material ensure that both are clean.

Table 3.3 Mixing Ratio

Mixing Ratio Ground Tire Rubber (GTR) with Recycle Polypropylene (PP)			
Ratio (%)	1%	3%	5%
GTR Loading (g)	13.8g	41.1g	67.9g
Recycle PP (g)	986.2g	958.9g	932.1g

Weigh PP and GTR — Mixed the rPP and GTR — Mixed together the material

Figure 3.13 Process of mixing the GTR with rPP

3.4.2 Hotpress Process

Several procedures make up the hotpress method of combining polypropylene with treated ground tyres. In the first step, polypropylene and rubber rubber are processed and prepared for future use. After that, the rubber and polypropylene are carefully blended together so that the rubber particles are evenly distributed throughout the polypropylene. To aid the melting and flow of the polypropylene, the combined material is subsequently warmed to a particular temperature.

When the hotpress machine in Figure 3.14 is ready, the mixture is between two heated plates or moulds. The polypropylene is heated till it melts and flows, but not to the point where it degrades, and then subjected to uniform pressure throughout the whole surface. This helps the rubber particles to get embedded in the molten polypropylene and strengthens the link between them.

After being heated and compressed for a certain amount of time, the material is cooled slowly while the pressure is held constant. As the composite material cools, the rubber particles get well dispersed throughout the polypropylene matrix. After the composite has set, it is taken out of the moulds and allowed to cool to room temperature. Cutting, moulding, and polishing are all examples of post-processing operations that may be carried out shown in Figure 3.15.

Figure 3.14 Hotpress Machine

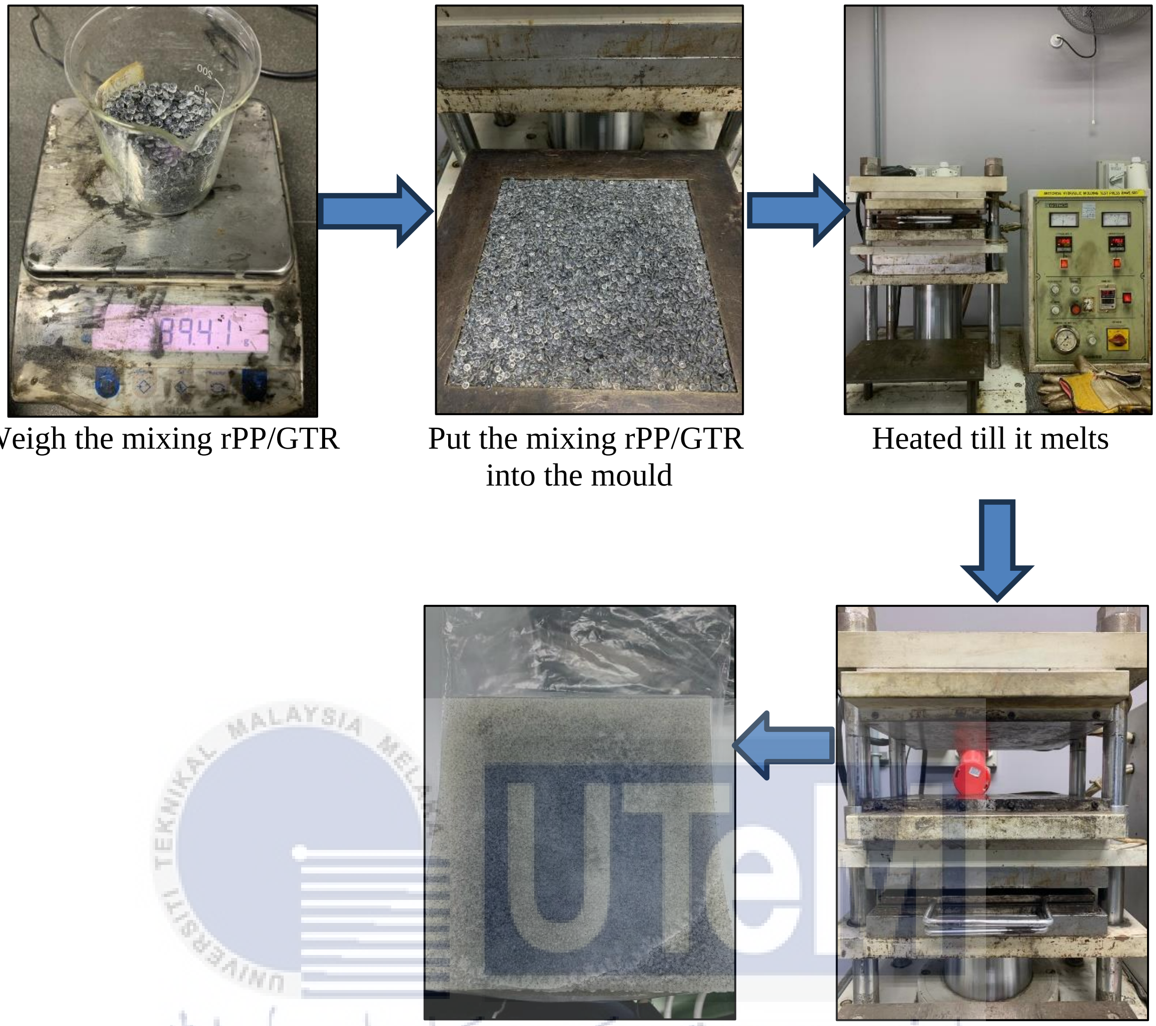
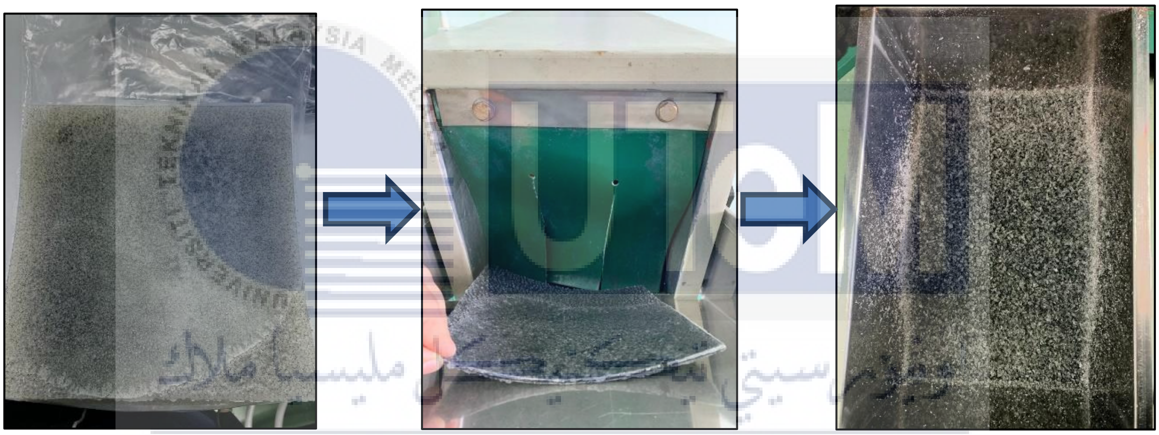


Figure 3.15 Hotpress process

3.4.3 Crusher Process

The composite that has been cool then will go to crush process to make it as pellet form. This process will be repeated 2 or 3 times to make sure the size of the pellet small. Figure 3.16 show the Cheso Crusher Machine. The crushed material is supplied into the crusher by a hopper, conveyor, or other feeding system. The size and kind of material used might range from rocks to repurposed materials as shown in Figure 3.17.

Figure 3.16 Cheso Crusher Machine



Composite rPP/GTR Put into the machine Pellet rPP/GTR

Figure 3.17 Crusher process

3.4.4 Extrusion Process

The filament was made using a single extruder, as depicted in the Figure 3.18. A single screw extruder equipped with a die nozzle with a diameter of 1.75 millimeters was used to extrude the filament of the composite material, and the material was then fed into three different heating zones. It was discovered that 180°C were the appropriate starting preheating temperatures for the barrel and die nozzle zones, respectively. Before it can be used, the composite material has to be heated. Inside the hopper's confines. In addition, molten material was being forced upwards into its die nozzle at a forward barrel screw rotation speed of 170 revolutions per minute (rpm). In order to preheat the pellets or mixture, the temperature in the feed cooling zone was also lowered to a lower setting. once reaching the required temperatures for the production of composite filaments, a certain weight of composite material was fed into the barrel at each feeding interval. This took place once the temperatures had been attained. The rollers of the filament reducer were set to a speed of 13-17 revolutions per minute, and they were responsible for forcing the hot extruded filament. During the course of the extrusion process, researchers experimented with a variety of different cooling systems. The modifications that were made to the processing parameters of the filament extrusion in order to maintain the filament diameters within tolerable boundaries are detailed in Table 3.5 below.

Figure 3.18 Single extruder machine

Table 3.4 The filament extrusion processing parameters

Categories	(r-GtrPPc) Filament
	Value
Barrel Temp (˚C)	200
Die/nozzle Temp (˚C)	180
Screw extrusion speed (rpm)	170-210
Filament pulling roller speed (mm/s)	13-17
Filament winding roller speed (mm/s)	200

A single extrusion is a manufacturing process in which a material, usually plastic, is forced through a single screw extruder to produce a continuous profile, sheet, or other shapes. This method is extensively used in the manufacture of plastic items like as pipes, tubes, sheets, and other profiles. Figure 3.20 shows a quick rundown of the single extrusion process details. Raw material GTR/rPP in pallets has been provided by following defined processes such as sieve, treatment, mixing the material and hotpress. The prepared material is put into the extruder's hopper. The material is fed into the single screw extruder via the hopper. The rotating screw in the extruder not only delivers the material but also mixes and shears it. This aids in obtaining a homogeneous melt and correct mixing of any additives or pigments. The pressure within the extruder rises as the material progresses along the screw. The temperature profile was set at 180°C, which comprised the barrel and nozel temperatures. This level of pressure is required to force the burning material through the extruder. The extruder's die is a specialised instrument that forms the molten material into the correct profile.

Figure 3.19 Extrusion process

3.5 3D Printing Process

To manufacture the filaments (of either kind), an FDM 3D printing apparatus was employed. Figure 3.20 shown process 3D Printing sample. The first step open-source program Ulti maker Cura 4.8.0 was used to construct the files needed for 3D printing (.stl). A simulation of the standard tensile test specimen (Type 1, ASTM D638) was carried out with the help of SolidWorks 2021 (ASTM D790). Total of 36 sample were printed consist of 18 sample for dog bone and 18 sample for rod. The 18 samples of dog bone have consistant layer thickness of 0.3 mm and filling percentages 100%. The shape and dimension of the dog bone sample are shown in Figure 3.20.

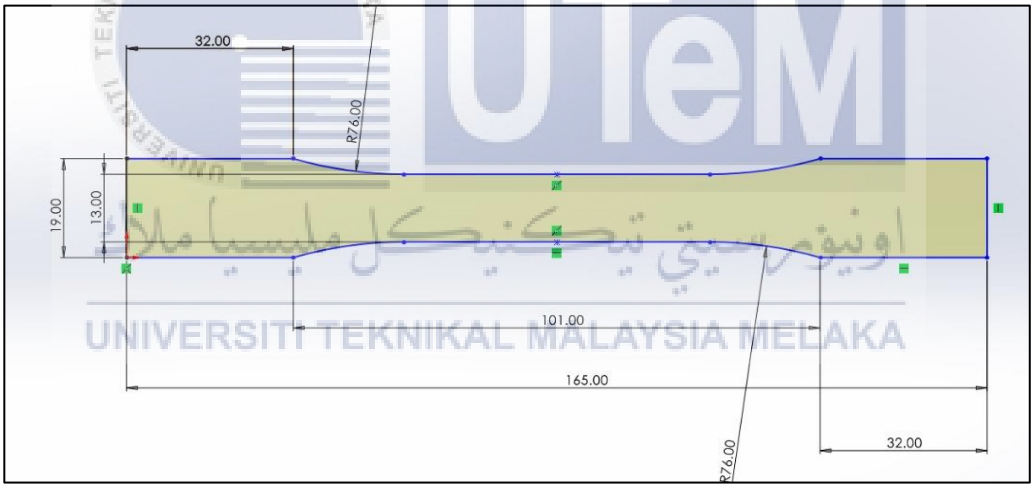


Figure 3.20 Dimension details-Dog bone sample

Table 3.5 shown the printing setting tensile test samples, we used a total of three different composite filaments. During the process of printing using rPP/GTR filaments, nozzles with diameters of 0.8 mm were used as shown in Table 3.6 printing setting. The printing options are available with an 100% infill and the [0, 90] degrees printing technique. When printing with filament, the bed must be heated to 75°C, and the nozzle temperature must be between 190°C and 220°C. The layer is 0.30 millimeters in thickness after being brought to the point of melting by heating the filament to that temperature and then passing it through a needle that is 1 millimeter in diameter at a pace of 20 meters per minute.

Table 3.5 Printing setting for dogbone sample

Parameters	Values
Temperature of printing (°C)	195
Initial layer temperature (°C)	195
Build plate temperature (°C)	75
Build plate temperature, inital layer (°C)	75
Infill pattern	Zig Zag
Infill flow (%)	100
The height of the layer (mm)	0.3
Line width (mm)	0.38
Top and bottom layers (layers)	2
The print speed (mm/s)	100
The speed of initial layer (mm/s)	15

Whenever 18 sample of rod have consistant layer thickness 0.2 mm and filling percentages 80%. The shape and dimension of the rod sample are shown in Figure 3.21.

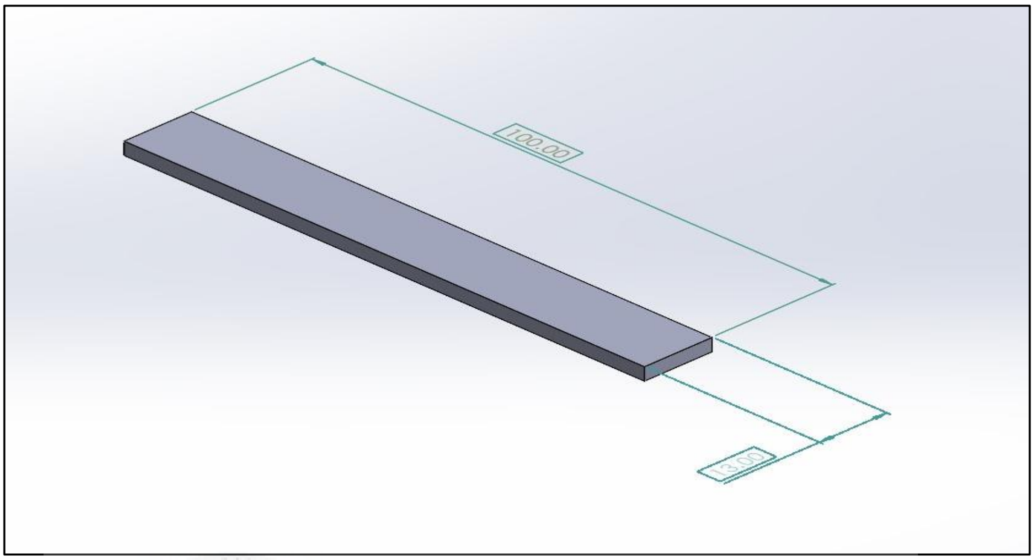


Figure 3.21 Dimension details-Rod sample

To build vibration test samples, we used a total of three different composite filaments. During the process of printing using rPP/GTR filaments, nozzles with diameters of 0.8 mm were used as shown in Table 3.6 printing setting. The printing options are available with an 80% infill and the [0, 90] degrees printing technique. When printing with filament, the bed must be heated to 85°C, and the nozzle temperature must be between 190°C and 220°C. The layer is 0.30 millimeters in thickness after being brought to the point of melting by heating the filament to that temperature and then passing it through a needle that is 1 millimeter in diameter at a pace of 20 meters per minute. The first layer of the 3D-printed specimen had a tough time sticking to the printer build plate. To lessen the likelihood of warping, the PP filaments that are available on the market often take the shape of a mix or composite. The first print layer did not stick to the printer bed when using Pritt adhesive and Kapton tape, which caused the printing process to end prematurely (Kristiawan et al., 2022).

Table 3.6 Printing setting for rod sample

Parameters	Values
Temperature of printing (˚C)	200
Initial layer temperature (˚C)	200
Build plate temperature (˚C)	75
Build plate temperature, initial layer (˚C)	75
Infill pattern	Grid
Infill density (%)	80
The height of the layer (mm)	0.2
Top and bottom layer (layers)	0.8
The print speed (mm/s)	100
Build plate adhesion type	Brim
Support placement	Touching buildplate
Support overhang angle (˚C)	0

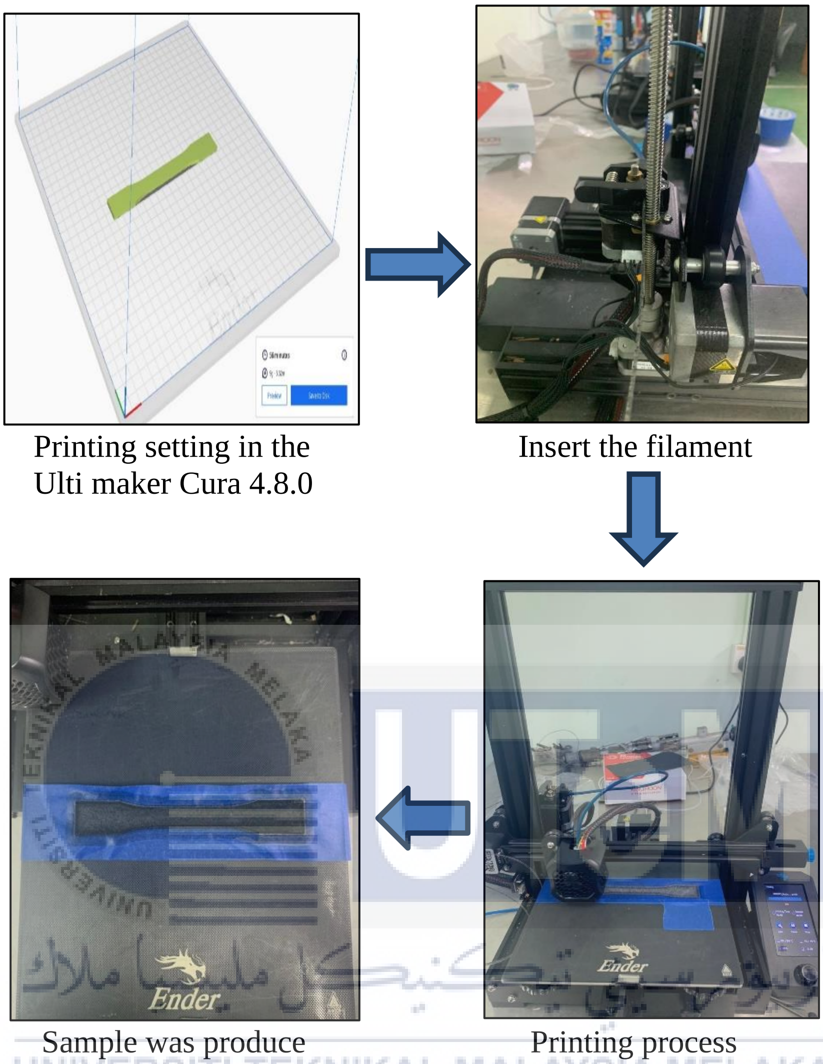


Figure 3.22 Process 3D Printing Sample

3.6 Characterization Process

3.6.1 Water absorption test of filament

The demand for GTR has always remained high owing to its distinctive attributes such as strength, lightweight nature, widespread availability, and biodegradability (Radzi et al., 2019). The composite specimens used to evaluate the behavior of water absorption were submerged in room-temperature distilled water in accordance with the filaments. To get a uniform weight prior to testing, the composite specimens were dried in an oven at 110 °C for 24 hours as shown in Figure 3.23. After the specimens being cooled the weight of specimens were measured, later the samples were submerged for 1 day at room temperature in distilled water. After that, the surface was wiped using the microfiber handkerchief and reweighed. The weight of the absorbed water was divided by the dry weight of the specimen to get the water intake (percentage). As shown in the following equations, respectively (Begum et al., 2021):

$$\text{Water Absorption \%} = \frac{weight\ after\ immersion - weight\ before\ immesion}{weigh\ before\ immersion}\ x\ 100\%$$

Figure 3.23 The composite filaments were dried in an oven

For conducting a water absorption test shown in Figure 3.24, eighteen samples of filament were created, each measuring 2.5 centimeters in length. These samples were then dried in an oven at a temperature of 110° for 24 hours to absorb any moisture. This is the only method that can guarantee that the filament itself will remain dry. Following drying the sample, the original weight of the sample, denoted by the symbol Wi, was measured before it was submerged. After that, the whole sample was submerged in distilled water for a period of 24 hours and then stored in a room. Immediately after the passage of 24 hours, the samples were extracted from the container, and a microfiber hand towel was used to extract any residual water. Weighing will be performed on the sample. A calculation was made using the following equation to determine the amount of water that was absorbed by the sample.

Cut the filament

Dried the filament

Weight the sample after dried

Immerse the filament

Weight the sample after submerged in distilled water

Figure 3.24 Water absorpton Methodology

3.6.2 Tensile test 3D printing sample.

The uniaxial tensile test as shown in Figure 3.25 is a fundamental and widely used engineering test that is conducted to determine material properties such as ultimate strength, yield strength, percentage elongation, percentage area of decrease, and Young's modulus. The crucial characteristics derived from routine tensile testing are valuable for choosing engineering materials for various applications (Khayal, 2019).

Tensile testing involves the application of a longitudinal or axial load, at a predetermined extension rate, a total of three samples were made for each filament, with GTR loadings of 1%, 3%, and 5% with defined parameters (including gauge length and cross-sectional area perpendicular to the load direction) until it fails. The tensile load and extension are measured during the test to calculate stress and strain. The procedure of conducting a tensile test is shown in Figure 3.26, which utilizes a SHIMADZU universal tensile testing machine.

Figure 3.25 Tensile Test machine

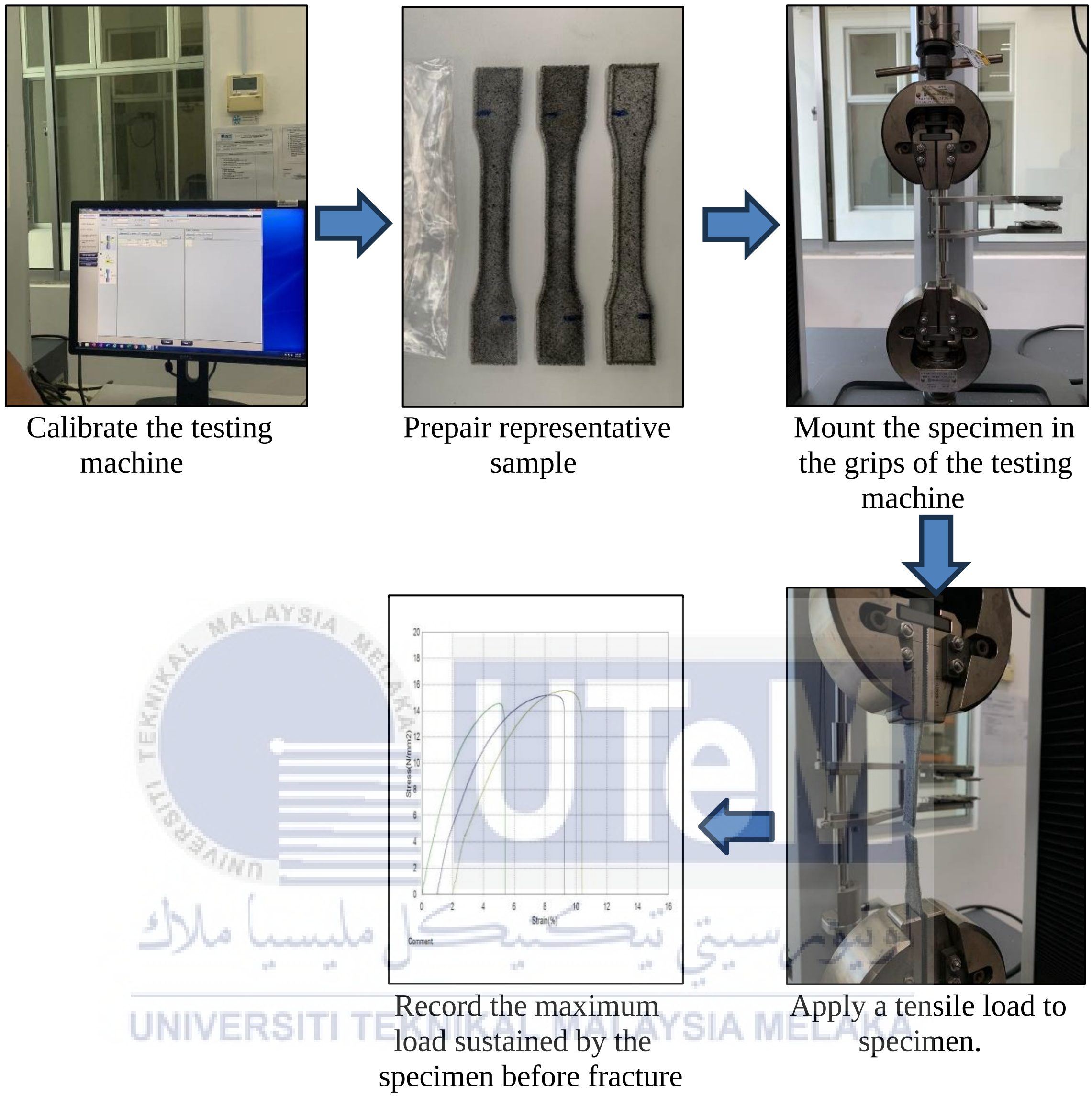


Figure 3.26 Tensile Test process

3.6.3 Vibration test 3D printing sample

The usage of GTR optic cables in hostile settings, during which they are exposed to vibration, is becoming more common. For incorporating the GTR into the mentioned application, it is vital to have a solid understanding of the performance deterioration that occurs under such conditions. To accommodate the removal or assembly of subsystems according to the requirements of the system, optical connections are often required. Both the rapid change in optical transmission and the steady-state variation that occurred after the incident were investigated in the current study by monitoring in-situ a variety of GTR optic connections while they were being subjected to vibration testing as shown in Figure 3.27. At certain intervals during the testing process, the GTR end faces and connections were subjected to inspection.

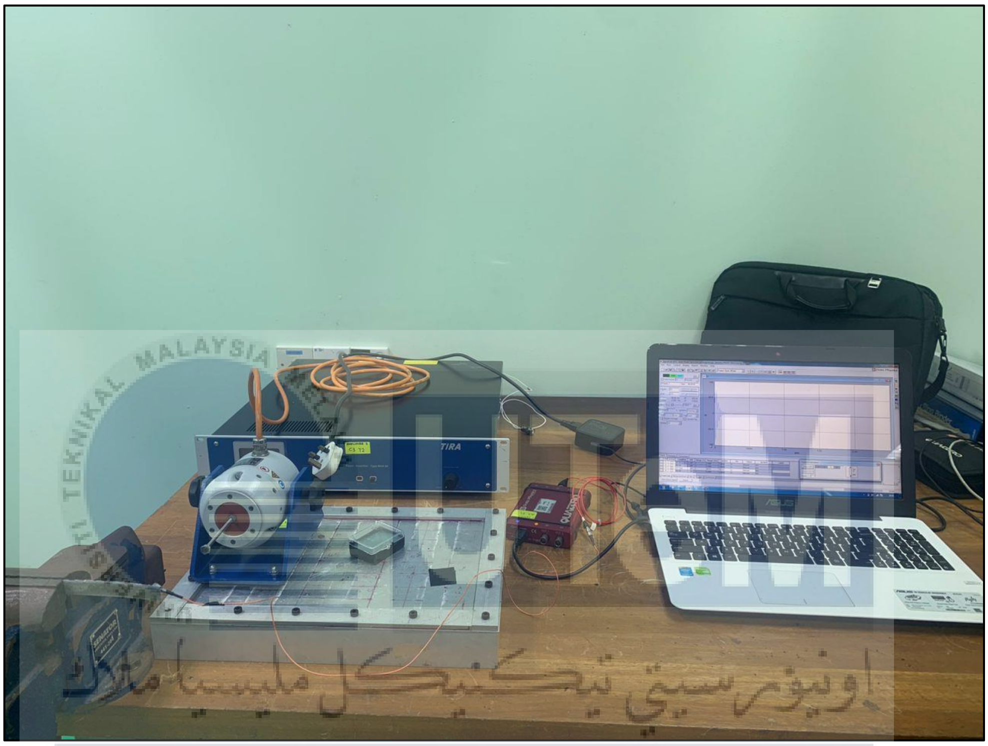


Figure 3.27 Experimental equipment utilised for modal analysis and vibration

Vibrational test and the modal analysis were performed the process of set up vibration testing shown in Figure 3.28. The apparatus consists of the Software data physics, data logger (QUATRO), accelerator sensor and a laptop. The 3D printed GTR-rPP composite specimen used in these vibration testing. For this testing, the sample was vibrated, and the displacement of its tip was measured. The accelerator sensor was provided with the power to detect the vibration sample by using the wax. The laptop received the data from the data logger. The data were provided in Software data physics to estimate the result vibration.

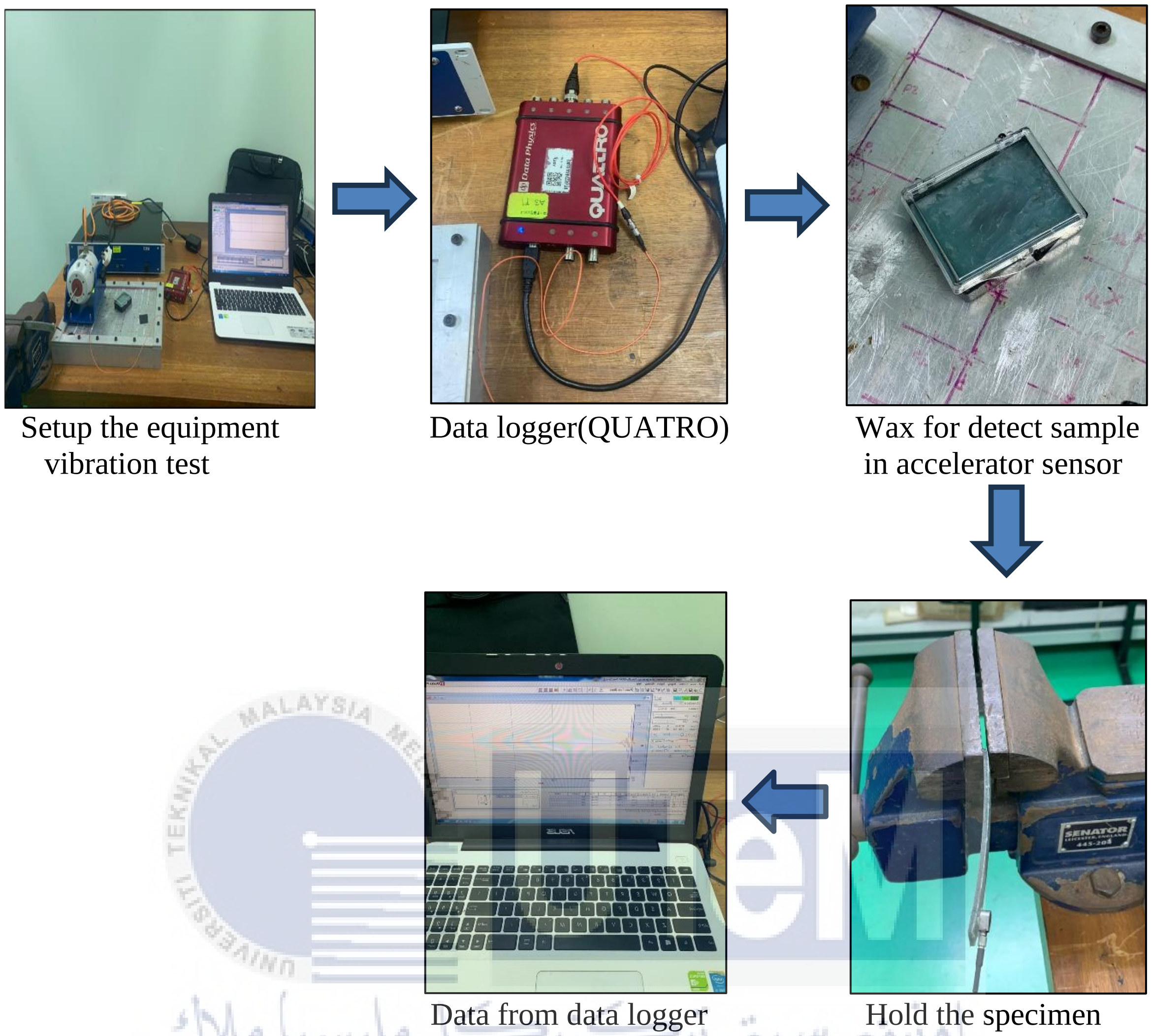


Figure 3.28 Process of set up vibration testing

3.6 Summary

This chapter concludes by discussing the proposed method for creating a novel 3D printing filament material from recycled polypropylene reinforced with ground tire rubber. This study's primary objective is to attain success and fulfil the study's objectives. Importantly, to attain a particulate size of 125 µm, GTR must go through a number of processes, ranging from the preparation of GTR powder to the sieving process. The GTR must then endure an alkaline treatment with a 6% NaOH solution for two hours, during which time it must be thoroughly submerged in the NaOH solution. After being immersed in a NaOH solution for 3 hours, the GTR will be desiccated in an oven for 24 hours. Despite this, rPP pellets are already available. Finally, to develop 3D printing filament, rPP and GTR will be mixed with varying GTR loading contents (1%, 3%, 5%) and forced through a single extruder machine until 3D printing filament and 3D printing sample was formed.

Chapter 4

RESULTS AND DISCUSSION

4.1 Introduction

The findings and evaluation of the research and development of 3D printing filament materials made from recycled polypropylene and ground tire rubber, that was done in the chapter, are detailed in this chapter. After combining the GTR with recycled polypropylene in accordance with the methodology outlined in the previous chapter, the resulting mixture will go through an extrusion procedure using a single extruder machine, as elaborated in the subsequent chapter. The palete rPP/GTR will subsequently be extruded to generate a filament. The filaments exhibited a diameter spanning from 1.7 to 1.8 mm. It is necessary to regulate the motor speed to guarantee that the resulting filament size aligns with the intended dimension.

A sample of filaments made from ground tire rubber and recycled polypropylene has been tested and analyzed, and the results have been published. Following the extrusion of the composite, the maximum force that the material could bear was established using tensile test analysis. Other data, like as shear stress and strain, might be collected throughout the testing procedure. An absorption test was performed on the composite material to measure how much water it absorbs under circumstances.

4.2 Filament Produced

Figure 4.1 shows the figure of the filament composite 1% GTR loading untreated and treated. Polymer composites are known to have mechanical characteristics that are dependent on the polymer matrix, the reinforcing filler, the surface chemistries between the components, and the manufacturing circumstances (Ridzuan et al., 2019). GTR loading 1% untreated may have reduced adhesion and dispersion inside the polymer matrix compared to 1% treated. The lack of chemical compatibility between GTR and the polymer may result in even though the rubber particle dispersion and poor interfacial interaction. 1% treated GTR loading may be more stable throughout the extrusion process compared to 1% untreated, lowering the risk of deterioration. Improved stability adds to more constant processing conditions and better control over the quality of the extruded filament 1.7 – 1.8 mm which is the ideal size. Thus, 1% untreated GTR may influence the polymer's melt flow properties, resulting in non-uniform flow across the extrusion die. This is because inadequate melting flow can cause the filament size to be inconsistent compared to the treated in the extruded filament.

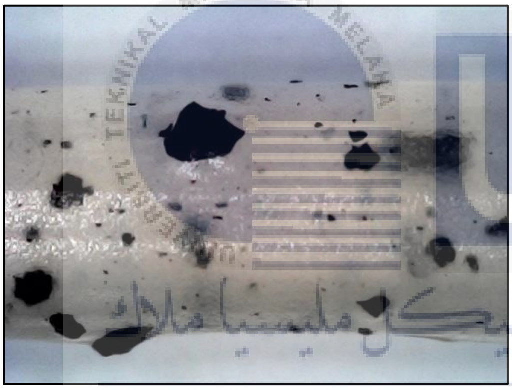
1 % Untreated	1% Treated
	
	GTR particle  Matrix PP

Figure 4.1 Filament composite 1% GTR loading untreated and treated

Figure 4.2 shows the figure of the filament composite 3% GTR loading untreated and treated. Achieving accurate extrusion with 3% untreated GTR loading may be more difficult compared to 3% treated its because to probable agglomeration, processing issues, and changes in material flow through the extruder. 3% untreated is the first GTR loading in extrude so its hard to consistent the temperature setting. 3% treated procedures serve to strengthen the bond between GTR and the polymer matrix, thereby facilitating improved dispersion. This results 3% treated in an extrusion-stable material that is more uniform in appearance compared to 3% untreated.

Figure 4.2 Filament composite 3% GTR loading untreated and treated

As a result of the greater rubber content shown in Figure 4.3, extracting with a 5% GTR load presents additional obstacles compared to 1% and 3% GTR loading. These concerns include the possibility of mispersion, melt flow, and extrusion stability issues. Nevertheless, it enhanced either the flexibility or the impact resistance. GTR has features that are inherently thermally insulating. It is possible that a filament with a GTR loading of 5% may provide increased thermal insulation, making it appropriate for applications that need heat resistance or insulation. 5% treated techniques facilitate the attainment of a homogeneous dispersion of GTR, leading to standardised material characteristics. The uniformity of these surface qualities enhances the overall smoothness of the finish compared to 5% untreated.

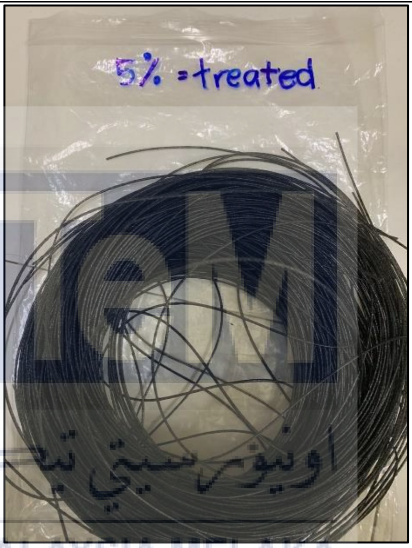
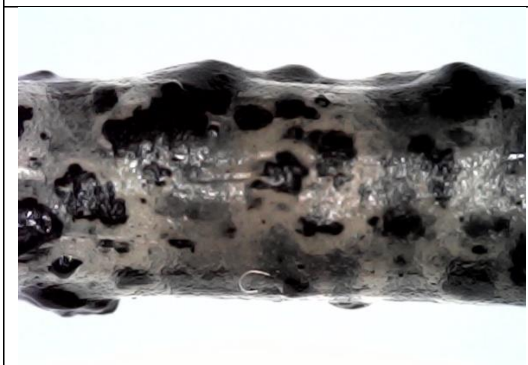
5 % Untreated	5% Treated
	
	

Figure 4.3 Filament composite 5% GTR loading untreated and treated

4.3 Water Absorption

Analysing the amount of water that is absorbed under certain circumstances is what is meant by the term "water absorption." The diameter of the filament, the weight of the filament, the void/pore ratio, the viscocity of the matrix that is being utilised, and the GTR content ratio are all parameters that might influence water absorption refer to the Table 4.6 . Depending on the GTR loading of the filament, a water uptake test was carried out to determine the amount of water that was taken in between the samples of filament that were exposed to water. The absorbed water can effect the integrity of thr GTR epoxy interface (Sugiman et al., 2023a).

Table 4.1 Result of the water absorption for 1% , 3% and 5% GTR loading untreated

Sample	Initial Weigth (g)	Weigth After Immerge (g)	Total Absorb Weigth (g)	Water Absorption (%)
1% untreated	0.053	0.054	0.001	1.85
1% treated	0.049	0.050	0.007	2.00
3% untreated	0.051	0.052	0.001	1.92
3% treated	0.060	0.062	0.002	3.23
5% untreated	0.047	0.049	0.002	4.08
5% treated	0.055	0.058	0.003	5.17

As shown in Figure 4.7, the proportion of water that is absorbed by the rPP/GTR filament is shown. The 5% fibre loading for treated GTR showed 5.17% of the maximum water absorption after 24 hours of immersion in distilled water, followed by 3.23% (3 percent treated GTR) and 2.00% (one percent treated GTR). This is something that can be seen. The water intake for rPP/treated GTR demonstrates a consistent rise when additional GTR loadings were combined with rPP, as shown by the observation which was made. In addition, the increase in the quantity of water absorbed is proportional to the amount of GTR loadings that are used. This is as a result of the extensive usage of GTR, which is more water absorbent. According to (Sugiman et al., 2023), the capacity to capture water is in fact associated with the thickness of the GTR, the presence of holes, and the adhesion between the GTR matrix itself. The accumulation of water in the void that was created within the filament as a consequence of these variables has led to an increase in the weight of the composite material. In spite of the fact that the GTR was subjected to an alkaline treatment with a solution of 6% sodium hydroxide, the results demonstrate that the NaOH treatment is unable to decrease the GTR, which means that the water intake is increased (Sugiman et al., 2023a).

As a result of the addition of GTR loadings, however, the water absorption of the rPP/untreated GTR filament shows a consistent reduction. The largest water uptake occurs at 5% of GTR loadings, which results in a water absorption rate of 4.08%. This is followed by 3% of GTR loadings, which results in a water absorption rate of 1.92%. Finally, 1% GTR loadings have a water absorption rate of 1.85%. Based on this pattern, it is evident that the quantity of water absorbed reduced as the number of GTR loadings that were added to rPP/untreated continued to grow. This is the case even in the absence of the alkaline treatment (Sugiman et al., 2023).

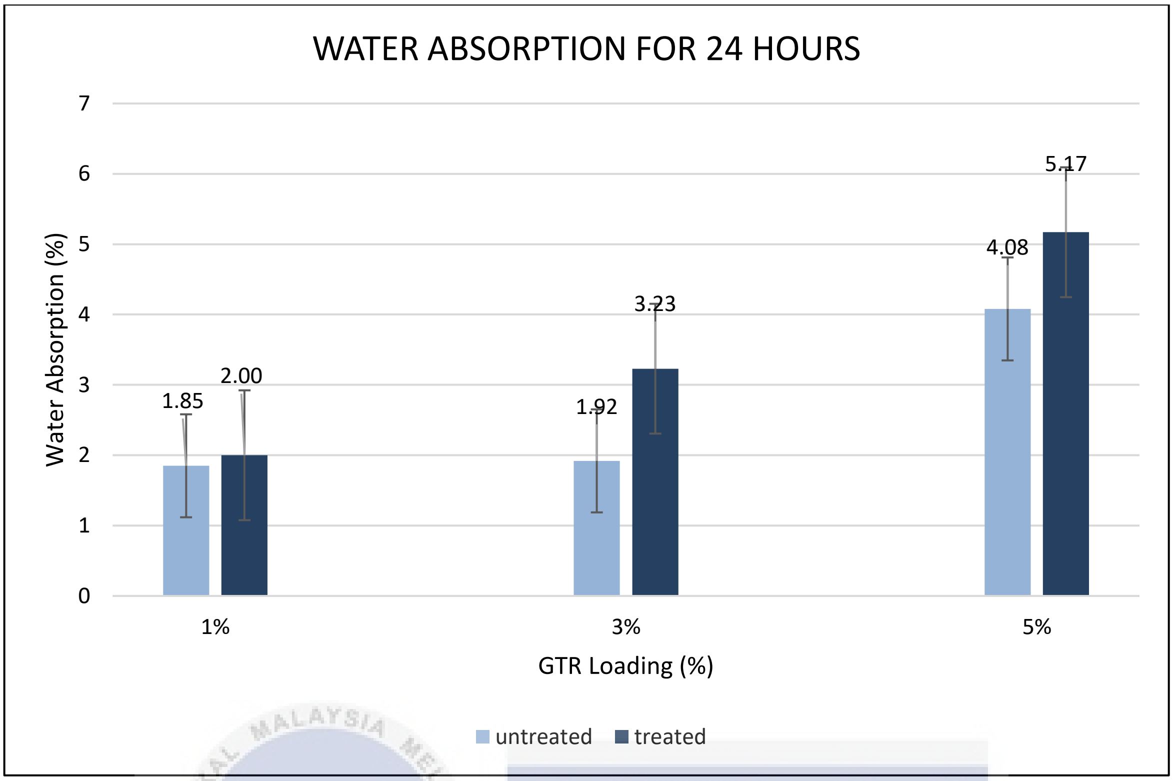


Figure 4.4 Percentage of Water absorption for 24 Hours

4.4 3D Printing Sample Properties

4.4.1 Dog bone sample

The final outcome is heavily influenced by printer variables like as layer height, print speed, temperature, and infill density. These parameters must be calibrated and adjusted properly in order to get the required quality as shown in Figure 4.5 results of dog bone sample 1%,3% and 5% GTR loading untreated and treated. The geometry, supports, and layer orientations of the dog bone model may all have an impact on printability and structural integrity. A well-designed model with enough supports increases the likelihood of a successful print (Zisopol et al., 2023). Figure 4.6 shown the sample are warping its because environment. To keep a constant temperature, 3D printers, particularly those printing materials prone to warping, should preferably be in an enclosed, heated environment.

Besides that, having the cooling fan on too early or at a high speed is cause the sample dog bone warping.

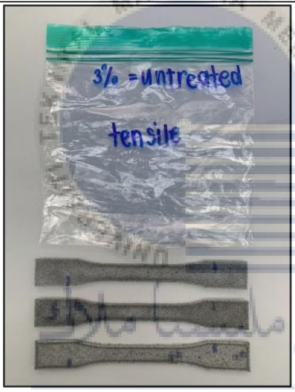
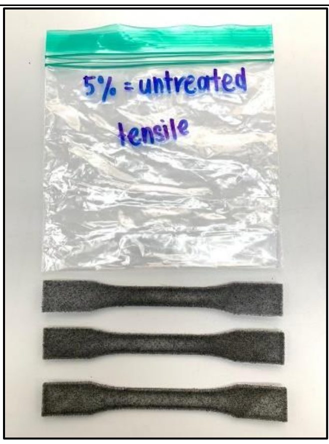
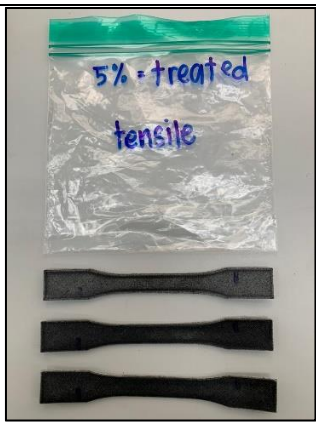
1% Untreated	1% Treated
	
3 % Untreated	3% Treated
	
5% Untreated	5% Treated
	

Figure 4.5 Dog bone sample 1%,3% and 5% GTR loading untreated and treated

Figure 4.6 Sample dog bone warping

4.4.2 Rod sample

A rod sample for vibration testing would normally provide an evaluation of its dynamic response to applied vibrations as shown Figure 4.7. The specimens parameter employed in the printing process such a 220°C for the nozzle and 85°C for the bed. The setting parameter consistent for rod sample 1%,3% and 5% GTR loading untreated and treated. When the sample is completed, it becomes a warping as shown in Figure 4.8. Its because due to the fact that the atmosphere is below room temperature, the printed layers may experience fast cooling, which may result in warping. In addition to that, it is necessary for it to adjust the temperature of the mattresses from 220°C for the nozzle become 200°C and 85°C for the bed become 75°C as shown in Figure 4.9. Then, infill that is less thick shown in Figure 4.10 may result in a less sturdy interior structure and loss of the weight of specimens. It is because of use the reduce material waste. So that, consider varied infill settings, which allow for changing infill densities in various areas of the printed product.

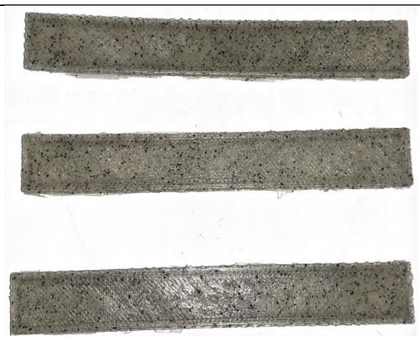
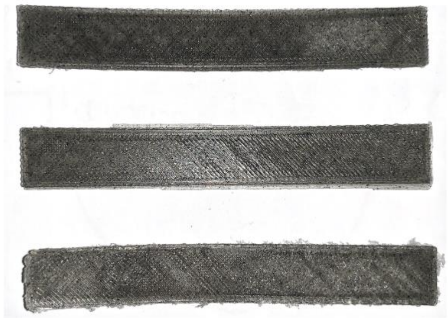
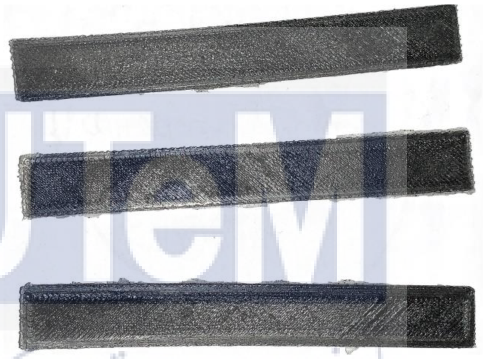
1% Untreated	1% Treated
	
3 % Untreated	3% Treated
	
5% Untreated	5% Treated
	

Figure 4.7 Rod sample 1%,3% and 5% GTR loading untreated and treated

Figure 4.8 Sample rod for vibrational testing are warping

Figure 4.9 Parameter setting nozzle and bed after change

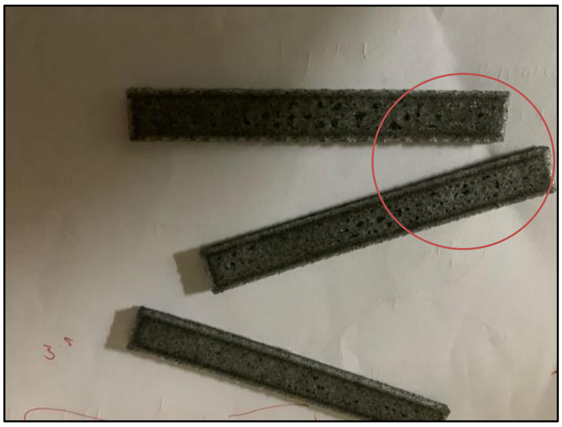


Figure 4.10 A less dense infill pattern comes decreased print quality and part success.

4.5 Tensile Properties

The tensile strength is the most essential mechanical property because it determines the maximum tensile stress that may be applied to the material of interest (Shamsuri & Darus, 2020). The test showed that the graph of stress (N/mm2) vs. strain (%). At the FTKIP main site, a SHIMADZU universal tensile testing machine was used to test three samples of each GTR loading. A tensile test was done on all three samples, each with a different amount of GTR loading untreated and treated (1%, 3%, and 5%). The speed was 5 mm per minute. For 1% GTR loading untreated as shown in Figure 4.11, specimen 2 has a lower tensile strength which is 15.2143 N/mm2. However, for specimen 1 and specimen 3 has show the nearest value tensile strength 16.0476 N/mm2 and 16.1702 N/mm2. The different between specimen 1 and specimen 3 is 0.1226 N/mm2. The average for this tensile strength of 1% GTR loading untreated is 15.8107 N/mm2.

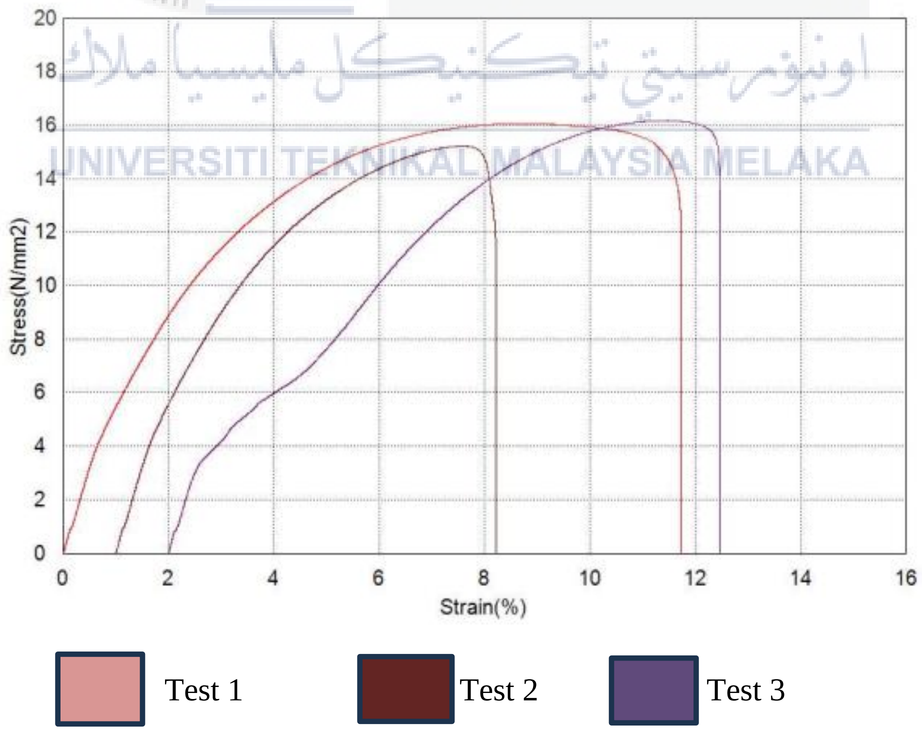


Figure 4.11 Tensile Strength of 1% GTR loading untreated

Then, for the tensile strength 1% GTR loading treated shown in Figure 4.12, the highest value of the tensile strength is 15.5270 N/mm2 for specimen 3 but it nearest with specimen 2 which is 15.1959 N/mm2. These different two specimen 3 and 2 is 0.3311N/mm2. While, for the specimen 1 has a lowest value compared to specimen 2 and specimen 3 which is 14.5541N/mm2. The average for 1% GTR loading treated is 15.0923N/mm2. To compared the average of tensile strength 1% untreated and 1% treated found that the 1% untreated is highest then 1% treated. This is a possibility that the treatment technique may not be successful in raising the strength of the tension. Processing may fail to alter the quality of the material adequately or may cause errors, thereby reducing its strength.

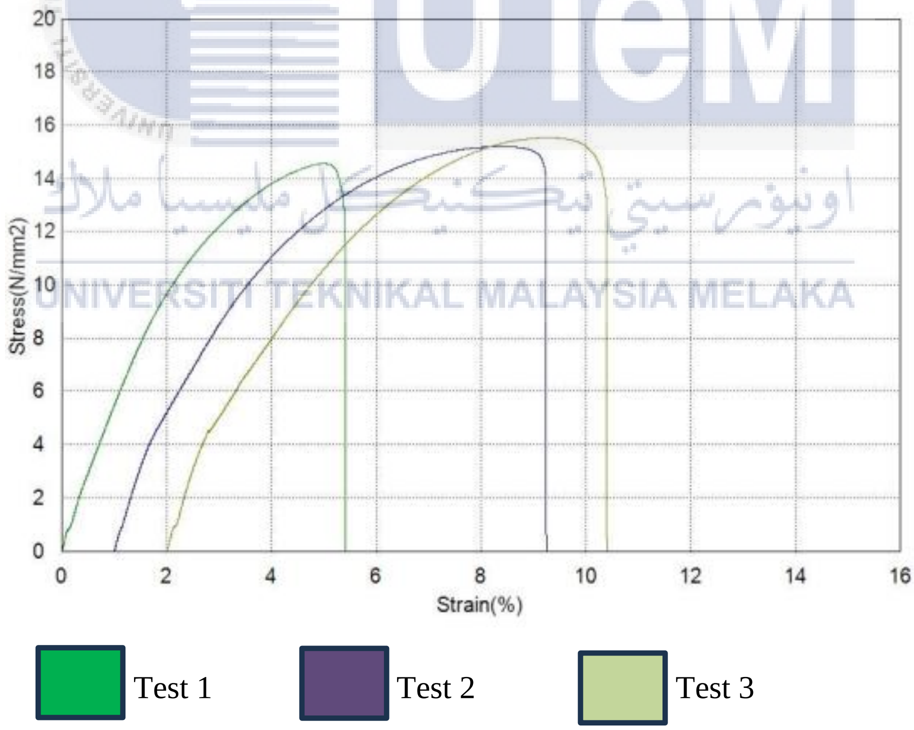


Figure 4.12 Tensile Strength of 1% GTR loading treated

Figure 4.13 show the tensile strength of 3% GTR loading untreated. Specimen 2 has shown the highest value of tensile strength which is 12.6914N/mm2. While, specimen 3 has proximity value with specimen 2 which is 11.5316N/mm2. The different for value specimen 2 and specien 3 is 1.1598N/mm2. For the specimen 1 has significant different value with specimen 2 and specimen 3. The value specimen 1 is 9.14199N/mm2 and this is the lowest value compared to specimen 2 and specimen 3. This could be owing to the curvature caused by the printing process, This could be owing to the curvature caused by the printing process.

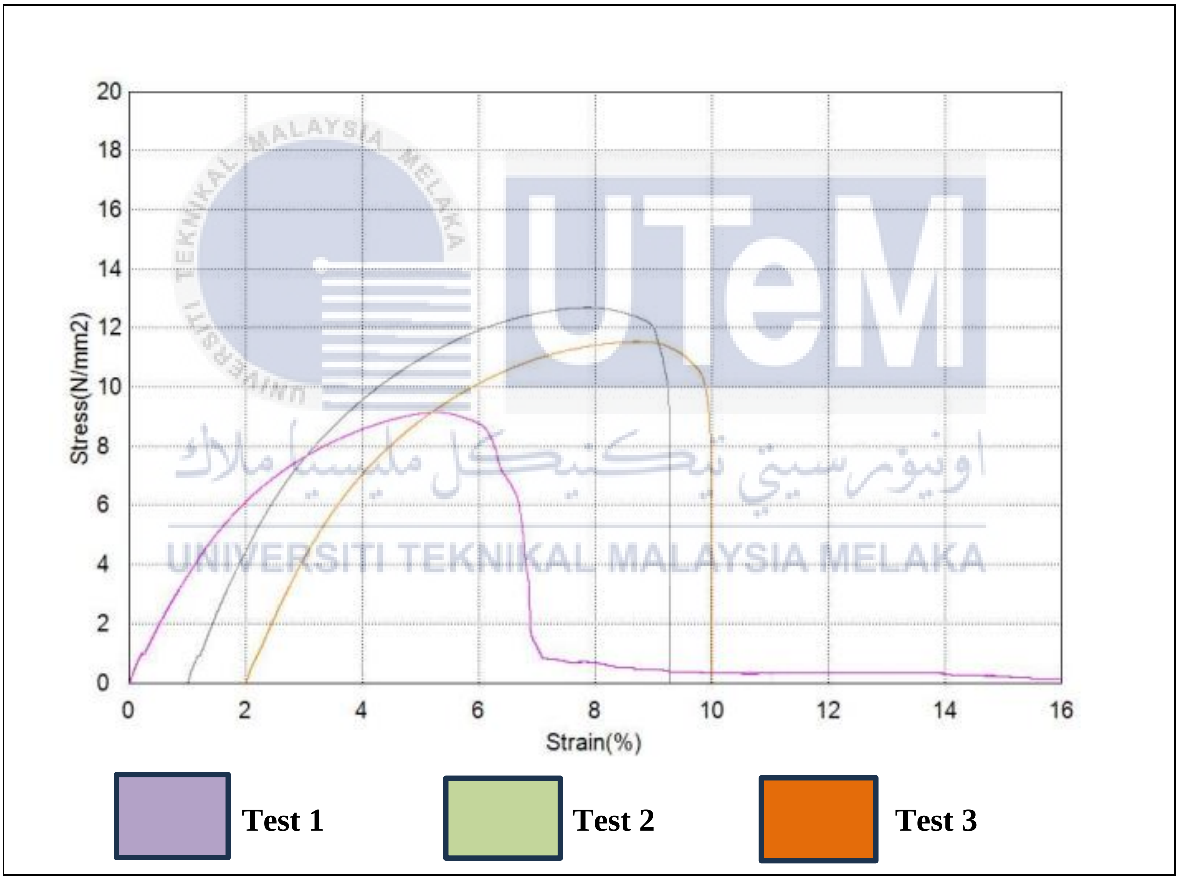


Figure 4.13 Tensile Strength of 3% GTR loading untreated

For 3% GTR loading treated, specimen 3 has the highest tensile strength value of the three other specimens. Specimen 3 has a value of 15.7822 N/mm^2. The tensile strength value for the specimen 1 is 13.6785 N/mm^2, which is the lowest of the three specimens. The third specimen was tested, and the result was 13.9238 N/mm^2. The tensile strength value of speciment 1 and speciment 2 is nearly exact since three distinct samples have values that are quite similar to each other. The average value of tensile strength of 3% GTR loading treated is 14.4615 N/mm^2. Figure 4.14.

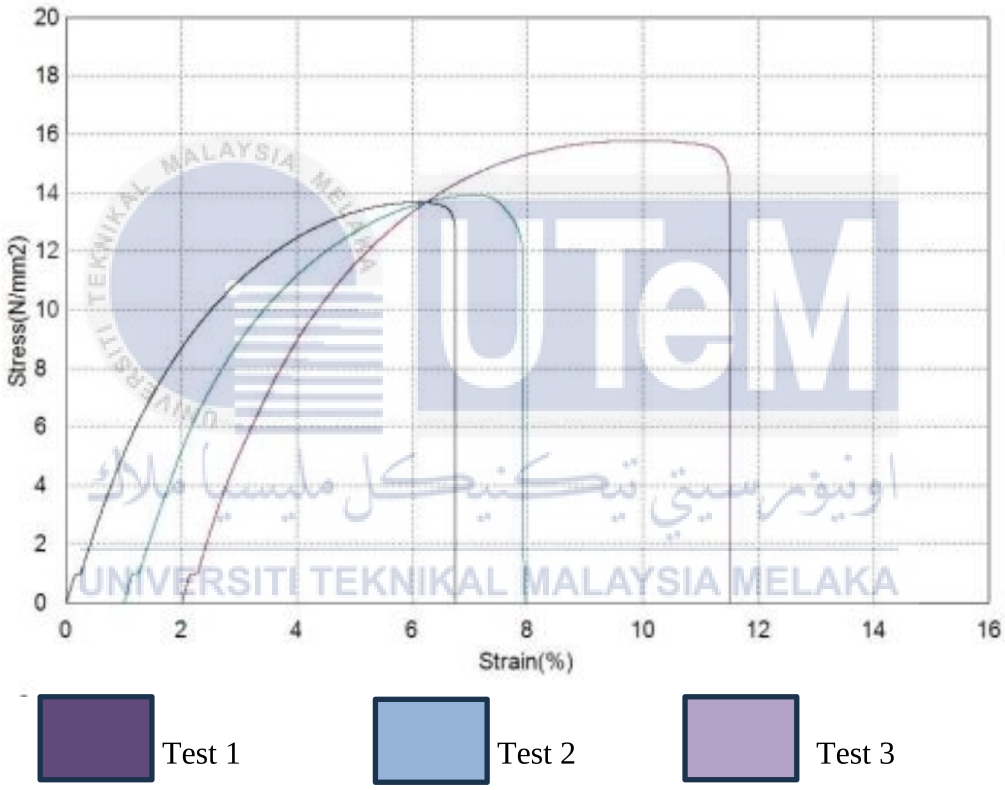


Figure 4.14 Tensile Strength of 3% GTR loading treated

For 5% GTR loading untreated as shown in Figure 4.15, specimen 1 has a highest tensile strength which is 13.1773 N/mm2. However, for specimen 2 and specimen 3 has show the nearest value tensile strength 11.2816 N/mm2 and 11.9077 N/mm2. The different between specimen 2 and specimen 3 is 0.6261 N/mm2. The average for this tensile strength of 1% GTR loading untreated is 12.1222 N/mm2.

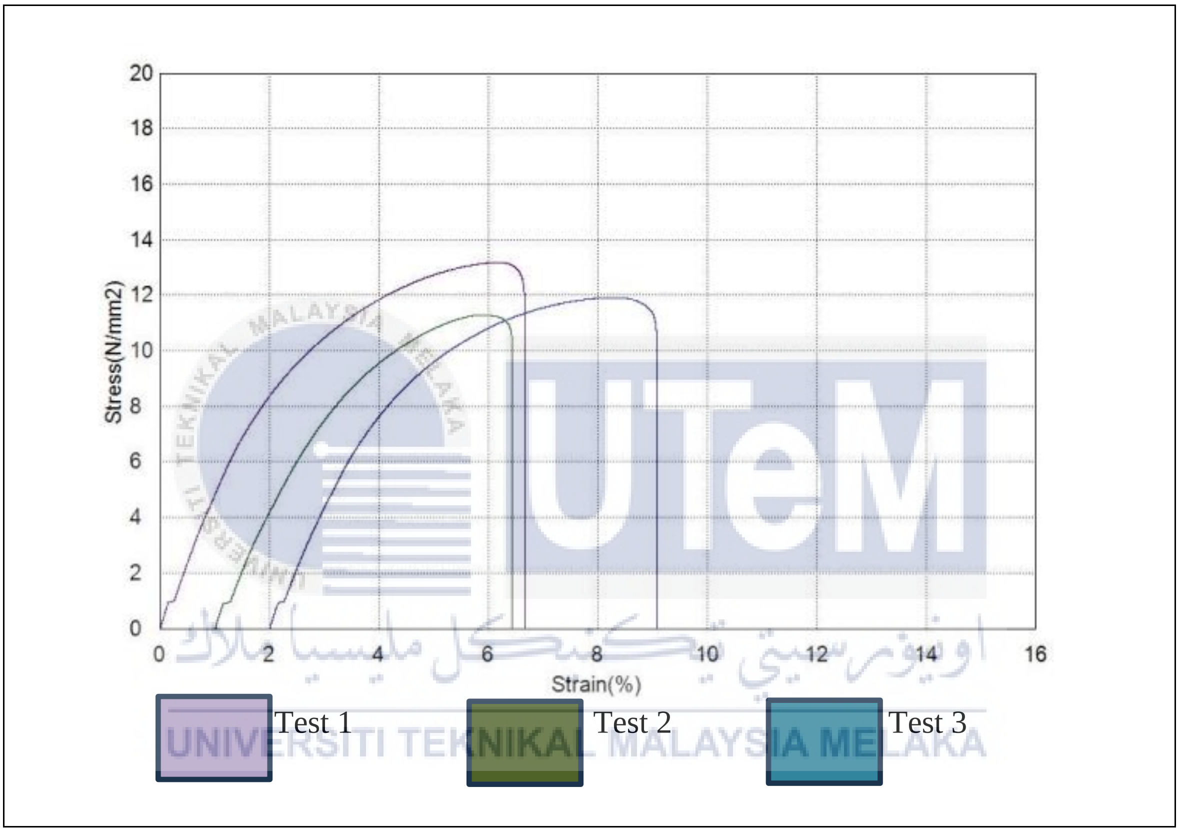


Figure 4.15 Tensile Strength of 5% GTR loading untreated

Next, 5% of GTR loading treated,specimen 1 shows the highest value of tensile strength which 14.8885 N/mm^2. The followed by specimen 2 by 13.1429 N/mm^2 and the lowest value is specimen 3 with 12.1007 N/mm^2. In this case, one of the specimen does not fully break which is specimen 3. The result of the specimen 2 shown in Figure 4.16 there was the only one different reading from the others. Based on this three values, the average can be calculated which is 13.3774 N/mm^2. Its shown the average of tensile strength 5% GTR loading treated is highest then 5% untreated. The bonding between the GTR particles and the matrix material may have enhanced as a result of the treatment procedure. Bonding effectively guarantees greater stress transmission between components, resulting in increased tensile strength.

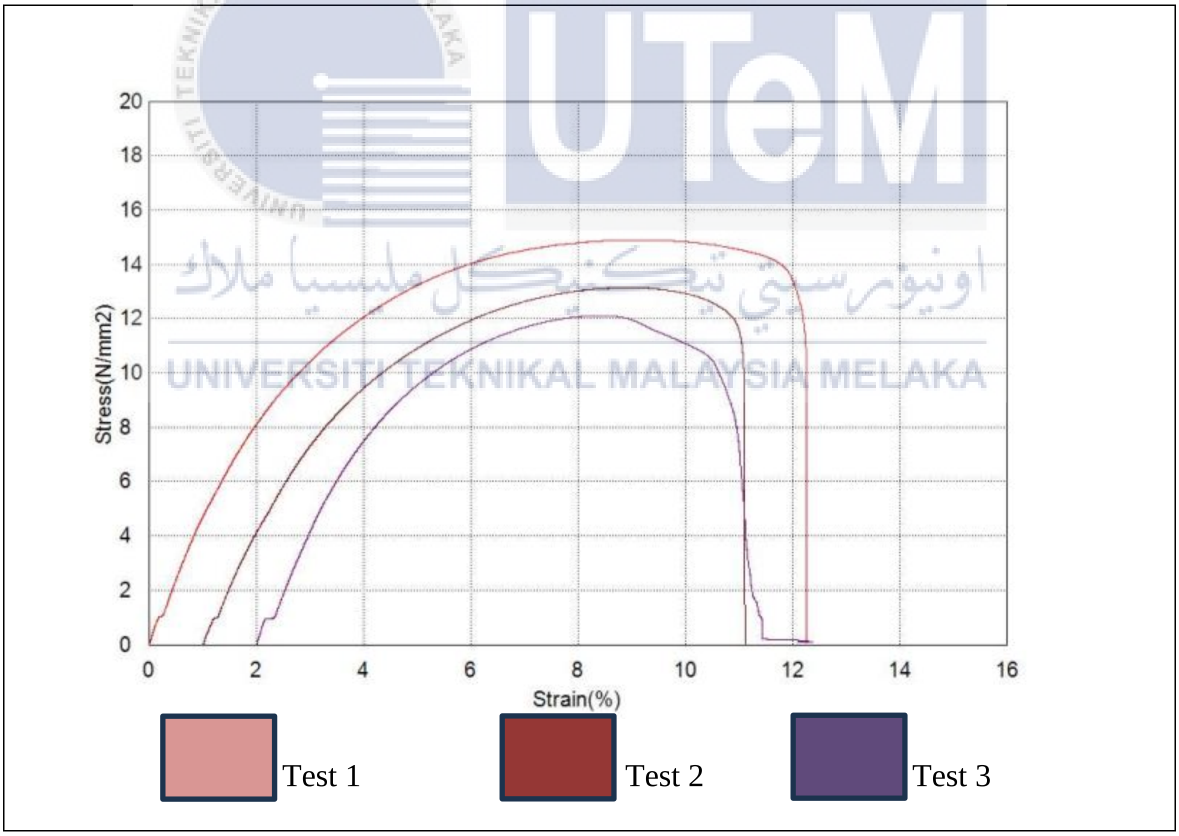


Figure 4.16 Tensile Strength of 5% GTR loading treated

The graphs that follow indicate the influence that NaOH treatment has on the tensile test for rPP/GTR composites. Figure 4.17 and Figure 4.18 are shown below. Alterations have been made to the mechanical characteristics of rPP/treated GTR composites as a consequence of the tensile strength. Even when the lignin and hemicellulose components were removed, the structure or surface of the treated GTR produced a reduction in the tensile strength of the material overall. Figure 4.17 demonstrates that the outcome of NaOH treatment on treated GTR leads to a minor loss in tensile strength when compared to the rPP/ GTR untreated. This is shown by the fact that the tensile strength of treated GTR is slightly lower. The incorporation of GTR loading percentage resulted in a decrease in the tensile strength of composites that were treated with rPP and GTR. On the other hand, it is evident that the NaOH treatment has the potential to do some harm to the structure or surface of the GTR that is being treated. It is possible that this will have an effect on the mechanical behaviour of the composites. In addition, the composites constructed with a 5% GTR loading content and treated with GTR were found to have the lowest tensile strength value, which was measured at 13.3774 MPa. The filament has been shown to become more fragile after being treated with NaOH (Shahzad & Zhao, 2022). This was brought about by the presence of a large number of voids inside the filament, which resulted in the filament being brittle and readily snapped.

Figure 4.18, on the other hand, illustrates a distinct trend in which the tensile strength of rPP/untreated GTR composites demonstrates a 1% has a greatest value, which is 15.8107MPa respectively. The graph reveals that the tensile strength value of 3% of GTR loadings is lower than that of 5% of fibre (12.2222MPa), which is 11.1217 Mpa. This is because for the sample 3% untreated have a isuess warping while print.

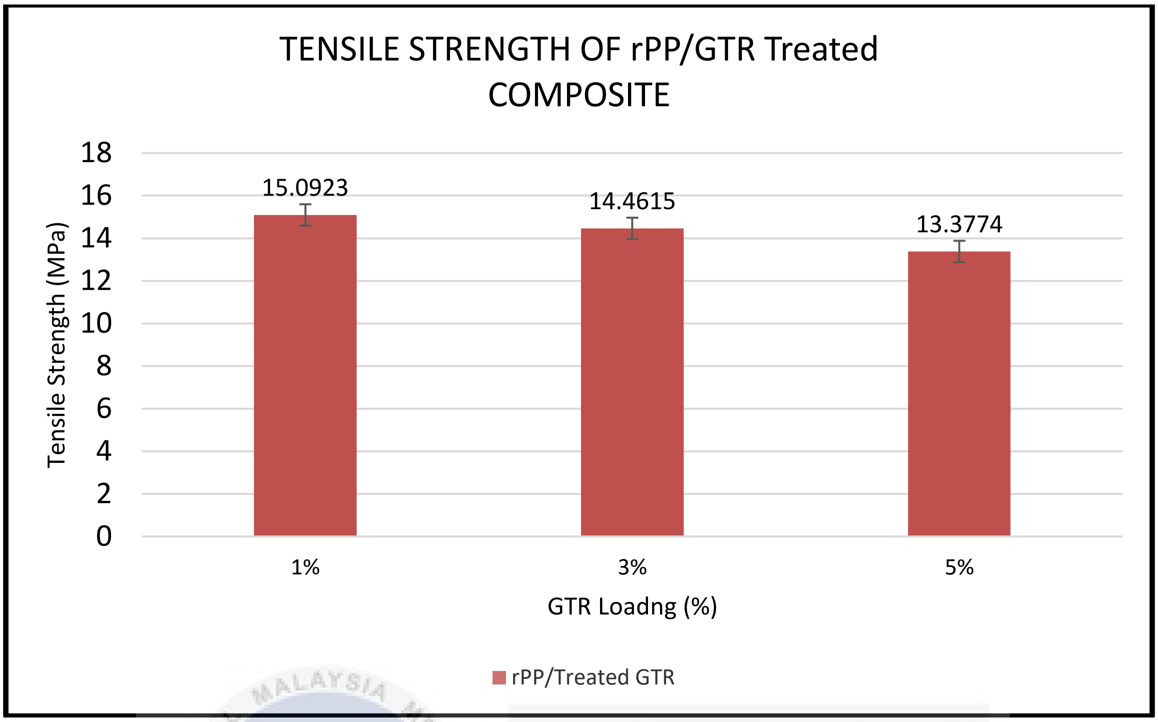


Figure 4.17 Tensile strength of rPP/Treated GTR composite

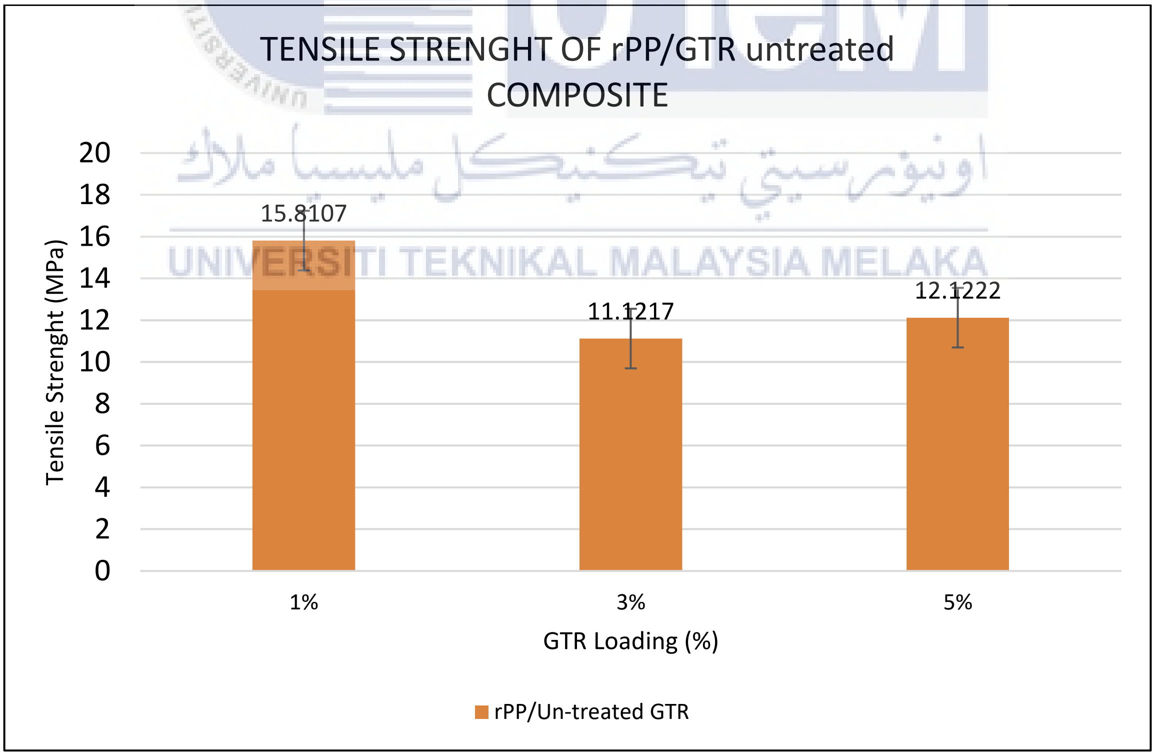


Figure 4.18 Tensile strength of rPP/untreated GTR composite

4.6 Vibration Properties

A waveform is an illustration of the amplitude of a signal as it changed over the course of time. It is a graphical representation of the changes that occur in a signal over a certain time period. Waveforms are used extensively in a variety of domains, including physics, engineering, and signal processing, for the purpose of analysing and comprehending the features of communications signals. Vibration response and characteristics of the 3D printed rPP/GTR composites are examined in Figure 4.19. Results demonstrate the time taken wavelength for (a) has a value of 5, in contrast the wavelength value of (b) has 4 wavelengths, whereas the wavelength value of the time that passed between 0 seconds and 0.1 seconds. Thus, due to the fact that this takes place above the factor Sodium hydroxide, often known as NaOH, is a powerful base that has the capacity to change the chemical composition of the target material when it is introduced to it. When tire rubber is subjected to treatment with sodium hydroxide, it is possible that the molecular structure or surface qualities of the rubber may modifications. Then,wavelength for 4.19(c) and 4.19(d) have approximately the same value with 4.19(a) and 4.19(b) which is 4.19(c) have 5 wavelength while 4.19(d) have 4 wavelength. Then, results wavelength for 4.19(e) and 4.19(f) have a different value compared to others which is the wavelength for 5% unreated less wave while 5% treated have long wave. From this results 5% treated have highest value which is 79.48401 G. There may be an optimal concentration for a particular property or behaviour. However, the observed magnitude increase of 5% treated could potentially be attributed to a saturation effect (Nguyen et al., 2022). The treatment may not have had a complete impact on the system at lower concentrations, while at higher concentrations, the effect may have reduced

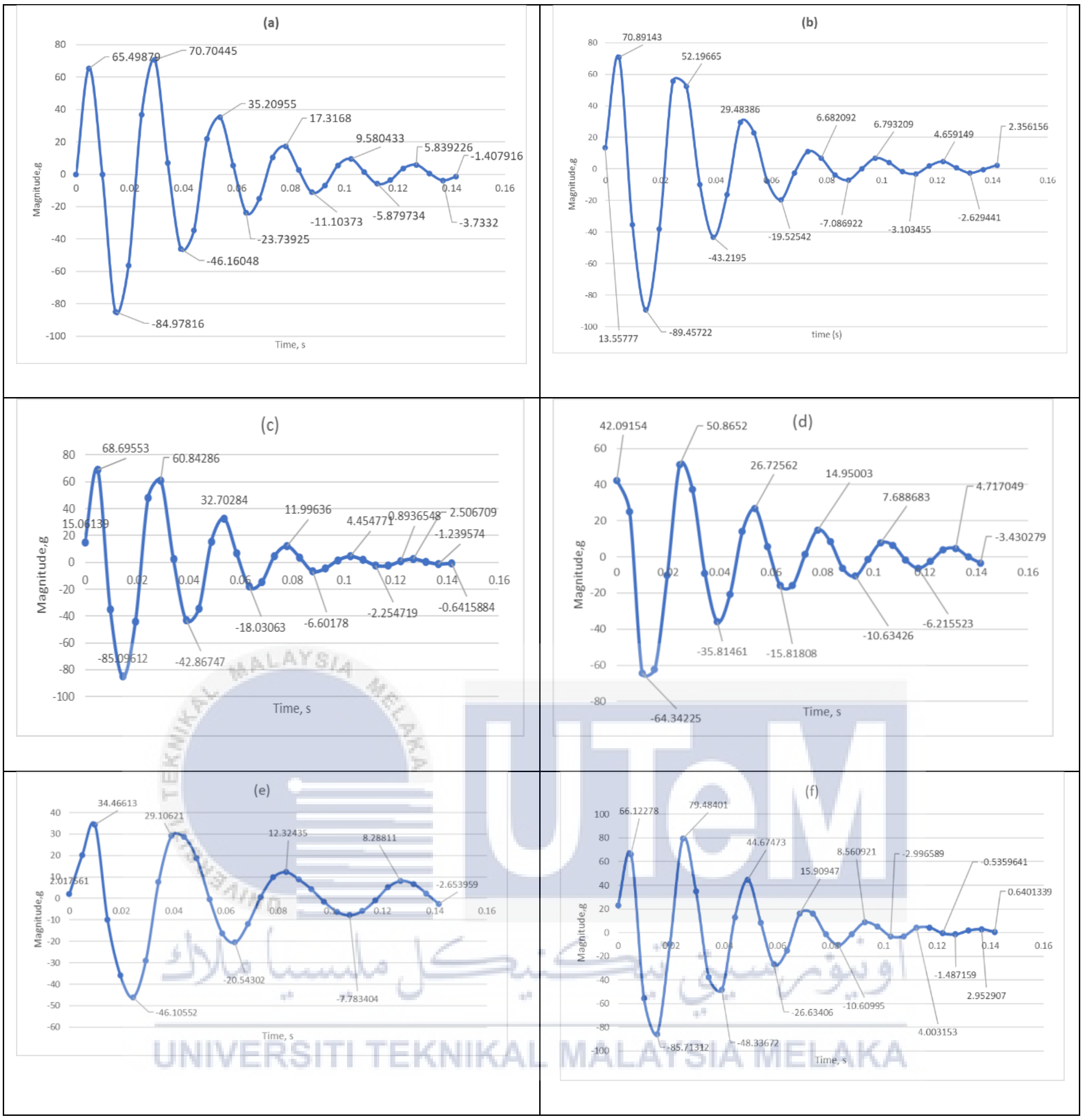


Figure 4.19 The ringdown waveform from 3D printed rPP/GTR specimen (a) 1%untreated (b) 1%treated (c) 3%untreated (d) 3%treated (e) 5%untreated (f) 5%treated

4.7 Summary

The study aimed to create a 3D printer filament using recycled Polypropylene (PP) and Ground Tire Rubber (GTR) treated with Sodium Hydroxide Treatment (NaOH). The treatment was applied at different concentrations of 6% sodium hydroxide, 1%, 3%, and 5%. The results showed that the incorporation of GTR resulted in increased water absorption and lower tensile strength compared to untreated composites. The strain at break of the treated GTR was also lower than that of the untreated one.

Vibrational testing on untreated and treated specimens revealed significant impacts on the vibrational characteristics of the material. The treated specimens showed noticeable enhancements in vibrational characteristics compared to their untreated counterparts, suggesting that the therapy has a beneficial effect on dampening vibrations. However, when the concentration was increased to 5%, the improvement in vibrational characteristics seemed to plateau or decrease, potentially indicating a threshold that may no longer provide any advantages or have unexpected implications on the material's vibrational behaviors.

The findings underscore the importance of precisely optimizing the concentration of the treatment for producing desired vibrational properties. Future research could explore the underlying processes of the treatment's impacts on vibrational qualities and its potential applications in sectors where precise control over vibrations is crucial.

Chapter 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

To accomplish the study, aim of (1) fabricate a new 3D printer filament made from recycled Polypropylene (PP), Ground Tire Rubber (GTR) treated with Sodium Hydroxide Treatment (NaOH). (2) to evaluate the effect of Ground Tire Rubber (GTR) on the water absorption, tensile properties, and vibrational properties of the composite material. In both dry and wet situations, an investigation of the impacts of GTR treatment on the water absorption and tensile characteristics of GTR was taken. In the treatment, 6% sodium hydroxide was used for GTR loading at 1%, 3%, and 5%. For treated composites, the incorporation of GTR resulted in a considerable increase in water absorption as compared to the untreated composites. Because of the hydrophilic character of the GTR that was treated with NaOH, there was a significant increase in the amount of water that was absorbed by the substance. In comparison to the untreated GTR composites, the treated GTR seemed to have a tensile strength that was somewhat lower. In line with the increases in elastic modulus, the strain at break of the treated GTR was found to be lower than that of the untreated one. Within the treated GTR, the strain at break has the maximum value, which is to be anticipated. It is possible to get significant insights into the influence that treatment has on the vibrational characteristics of the material by conducting vibrational testing on untreated and treated specimens at different concentrations (1%, 3%, and 5%). Regarding the vibrational features of the specimens, the findings suggest that the treatment does, in fact, have an impact that can be seen.

The treated specimens demonstrate observable enhancements in vibrational characteristics when compared to their counterparts that have not been treated, even at lower concentrations (including 1% and 3%). It would seem from this that the therapy has a beneficial effect on dampening vibrations, which is an important characteristic to have in situations where vibration control is vital. When the concentration is increased to 5%, however, the improvement in vibrational characteristics seems to reach a plateau or perhaps decrease. This is an intriguing observation to make. When this occurs, it may be an indication of a threshold that, if exceeded, the treatment may no longer give any more advantages or may even have unforeseen implications on the vibrational behaviors of the material. When it comes to producing the vibrational properties that are sought in the material, these results highlight how important it is to precisely optimize the concentration of the treatment. future investigation into the underlying processes of the treatment's impacts on vibrational qualities and its prospective uses in sectors where precise control over vibrations is essential is also made possible by the findings, which open new possibilities for future investigation.

5.2 Recommendations

There are a few recommendations that have to be taken into consideration in order to make this project substantially more successful in the future. These recommendations are based on the study and findings that were gained in the process of manufacturing 3D printing filaments from recycled polypropylene reinforced with GTR. As a starting point, it would seem that the use of NaOH as a bonding agent for the GTR in this project is not successful, as seen by the lower strength of the filaments. It is possible that the quality and qualities of the GTR might be enhanced by using a different bonding agent, such as silane. In the subsequent step, the particle size of the GTR should be decreased from 125 microns to 100 microns in order to guarantee that the GTR is mixed with the recycled polypropylene in an appropriate manner. On result of this, it is possible that the GTR filaments will see an improvement in their physical characteristics.

5.3 Project Potential

This study's research has a high potential for commercialization in industry as a commercial bio composite filament. This filament has the ability to be utilised in any sort of FDM 3D printer, and its pellet may be extruded using any type of extruder.

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APPENDIX A Gant Chart for PSM 1

NO.	TASK PROJECT	WEEK													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	PSM Briefing														
2.	Overview Project Background														
3.	Problem Statement Identification						M								
							I								
4.	Define Objective and scope						D								
5.	Literature Studies						T								
							E								
6.	Methodology						R								
							M								
7.	Preliminary Study														
							B								
8.	Preparation for Presentation						R								
							E								
9.	Report Final Improvement						A								
							K								
10.	Report PSM1 Submission														
11.	Slide Presentation														

PLAN ACTUAL

APPENDIX B Gant Chart for PSM 2

NO.	TASK PROJECT	WEEK													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	MEETING AND DISCUSSION														
2.	PREPARATION OF RAW MATERIAL														
3.	CONDUCTING THE EXPERIMENT						M I								
4.	COLLECT DATA AND MAKE ANALYSIS ON SAMPLE						D								
5.	DISCUSS ON RESULT EXPERIMENT						T E								
6.	START DRAFT REPORT AND WRITING UP CHAPTER 4						R M								
7.	START DRAFT REPORT AND WRITING UP CHAPTER 5						B								
8.	SUBMISSION OF FIRST DRAFT PSM 2						R E								
9.	RECHECK FIRST DRAFT						A K								
10.	WRITING UP CONCLUSION FOR THIS STUDY														
11.	SUBMISSION OF FULL REPORT														
12.	FINALIZE THE CORRECTION OF FULL REPORT														
13	PREPARATION AND PRESENTATION OF PSM 2														

PLAN ACTUAL

PSM ASYIKIN

ORIGINALITY REPORT

16%	7%	12%	4%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Valeria Tatangelo, Ivan Mangili, Paola Caracino, Giuseppina Bestetti et al. "Microbial desulfurization of ground tire rubber (GTR): Characterization of microbial communities and rheological and mechanical properties of GTR and natural rubber composites (GTR/NR)", Polymer Degradation and Stability, 2019 Publication	2%
2	e-space.mmu.ac.uk Internet Source	1%
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