STUDY ON FRESHWATER EFFECT ON MECHANICAL PROPERTIES OF AGEING FS3300PA SLS MATERIAL ON FRESH WATER

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A thesis submitted
in fulfillment of the requirements for the degree of
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SESI PENGAJIAN: **2023-2024 Semester 1**

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Signature : ....

Supervisor Name : Ts. Mohd Ruzi Bin Harun

Date : 13 February 2024

DEDICATION

I would like to dedicate my gratitude to my supervisor Ts. Mohd Ruzi Bin Harun for his guide and continuous efforts to assists me in becoming a better student, as well as my co-supervisor, Ts. Mohd Idain Fahmy Bin Rosley who has been guide and together completing this project.

ABSTRACT

In recent years, there has been a gradual decrease in the available water supplies. According to the available data, India, China, and Nigeria are the top three nations in which a high number of people are killed as a direct result of water pollution each year. Pollution of water can have detrimental effects not only on human health but also on the environment and the economy. In addition to this, it may also influence climate change, which, because of an increase in water level, may result in adverse weather conditions. The beverage industries in Malaysia are one of the primary contributors to the country's problematic water quality. Melaka is not immune to any of these issues; it has also been affected. The contamination that is taking place in the Sungai Melaka right now is responsible for the loss of fish diversity. The administration of Melaka state has carried out several initiatives, including the enforcement of laws, the regulation of water resources, and the dissemination of religious and moral teaching regarding the significance of rivers. On the other hand, the execution of such measures has not resulted in a reduction in the amount of water that is contaminated. The problem has reached a higher degree, and the gravity of the situation has increased as a result. Considering this, research and identification of the primary pollutants released by the primary sources of pollution should be carried out, particularly regarding the spatial variation that occurs in the Sungai Melaka. During this investigation, a Hydro Quality Survey System, also known as a HydroQS device, will be put into operation. The PA-12 Nylon powder, FS3300PA, will be utilized as the best selection of material. Because it is compatible with the SS402P SLS 3D Printing machine, which has been chosen for printing the HydroQS housing, PA-12 has been selected as the material to use. In this investigation, a field test will be conducted to investigate the mechanical properties of aged FS3300PA. Additionally, the dimension stability of sintering samples will be measured. The purpose of this study is to evaluate the HydroQS housing based on the sample shape that will be submitted to the 50KN Universal Tensile Machine (UTM), and the sample shape will be tested in Sungai Melaka. It is anticipated that the HydroQS housing that will be manufactured will have a low drag coefficient, high strength, and low weight, and will satisfactorily address and fulfill all Perbadanan Pembangunan Sungai dan Pantai Melaka (PPSPM) issues and requirements.

ABSTRAK

Dalam beberapa tahun kebelakangan ini, terdapat penurunan secara beransur-ansur dalam bekalan air yang ada. Menurut data yang ada, India, China, dan Nigeria adalah tiga negara teratas di mana bilangan orang yang tinggi terbunuh akibat langsung pencemaran air setiap tahun. Pencemaran air boleh mendatangkan kesan buruk bukan sahaja kepada kesihatan manusia tetapi juga kepada alam sekitar dan ekonomi. Di samping itu, ia juga mungkin mempunyai kesan ke atas perubahan iklim, yang, akibat daripada peningkatan paras air, boleh mengakibatkan keadaan cuaca buruk. Industri minuman di Malaysia merupakan antara penyumbang utama kepada masalah kualiti air negara. Melaka tidak terlepas daripada sebarang isu ini; ia juga telah terjejas. Pencemaran yang berlaku di Sungai Melaka sekarang ini menyebabkan kehilangan kepelbagaian ikan. Pentadbiran negeri Melaka telah melaksanakan beberapa inisiatif, termasuk penguatkuasaan undang-undang, pengawalseliaan sumber air, dan penyebaran ajaran agama dan moral mengenai kepentingan sungai. Sebaliknya, pelaksanaan langkah sedemikian tidak menyebabkan pengurangan jumlah air yang tercemar. Masalahnya telah mencapai tahap yang lebih tinggi, dan graviti keadaan telah meningkat akibatnya. Sehubungan dengan ini, penyelidikan dan pengenalpastian bahan pencemar utama yang dikeluarkan oleh sumber utama pencemaran perlu dijalankan, terutamanya berkenaan dengan variasi ruang yang berlaku di Sungai Melaka. Semasa penyiasatan ini, Sistem Tinjauan Kualiti Hidro, juga dikenali sebagai peranti HydroQS, akan beroperasi. Serbuk PA-12 Nylon, FS3300PA, akan digunakan sebagai pilihan bahan terbaik. Kerana ia serasi dengan mesin Pencetakan 3D SS402P SLS, yang telah dipilih untuk mencetak perumahan HydroQS, PA-12 telah dipilih sebagai bahan untuk digunakan. Dalam penyiasatan ini, ujian lapangan akan dijalankan untuk menyiasat sifat mekanikal FS3300PA yang sudah berumur. Selain itu, kestabilan dimensi sampel pensinteran akan diukur. Tujuan kajian ini adalah untuk menilai perumahan HydroQS berdasarkan bentuk sampel yang akan diserahkan kepada Mesin Tegangan Universal (UTM) 50KN, dan bentuk sampel akan diuji di Sungai Melaka. Perumahan HydroQS yang akan dikeluarkan adalah dijangkakan mempunyai pekali seret yang rendah, kekuatan tinggi dan berat yang rendah, dan akan menangani dan memenuhi semua isu dan keperluan PPSPM dengan memuaskan.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBBREVIATIONS

^{o}C	-	Temperature
DO	-	Dissolve Oxygen
DOE	-	Department of Environment
PPSPM	-	Perbadanan Pembangunan Sungai dan Pantai Melaka
HydroQS	-	Hydro Quality Survey System
SLS	-	Selective Laser Sintering
g/cm3	-	Sintered Density
g/mL	-	Absorption rate and Density
g/min	-	Melt Flow Rate (MFR)
NWQS	-	National Wate Quality Standard (ANNEX)
SEM	-	Scanning Electron Microscope
MRC	-	Melaka River Cruise
MgCl2	-	Magnesium chloride
MgSO4	-	magnesium sulphate
CaCO3	-	calcium carbonate
(KCl	-	potassium chloride
PA-12	-	Polyamide 12
PEEK	-	Polyether Ether Ketone
PE	-	Polyethylene
PC	-	Polycarbonates
PS	-	Polystyrene PS
TDS	-	total dissolved solids
WQI	-	Water Quality Index
IoT	-	Internet of Things

CHAPTER 1

INTRODUCTION

1.1 Background

Water is an important resource in human life and supports the global life system. Humans need water to carry out daily activities such as agriculture, fishing, industry, transportation and so on. However, water is becoming more and more polluted due to the irresponsible attitude of some parties. According to the Environmental Quality Act of 1974, water pollution is defined as any direct or indirect change to the physical, thermal, biological, or radioactive properties of any part of the environment that releases, releases, or deposits this waste to the extent that it affects its use. and causing a situation that is dangerous and harmful to the health, safety, and welfare of the public, or other life such as birds, wildlife, fish and aquatic life and water plants.

Based on data released by the Malaysian Environment Department (DOE) , it recorded 52 percent of rivers that were clean, 39 percent of rivers that were found to be lightly polluted, and 9 percent of rivers that were found to be polluted. Therefore, they concluded that the beverage industry in Malaysia is the first source of pollution in the country. In addition, the increase in industrialization, the growth of metropolitan areas and the increase in population are factors that can be attributed to some of the increases in the annual quantity of pollution found in Malaysian rivers. (Muyibi et al., 2008).

Many nations around the world, including both industrialized and developing nations (Singh et al., 2009), have made the prevention of water pollution a top priority. One of the countries with high water pollution levels is China. The rapid industrialization and urbanization in China have led to significant water pollution problems. Industrial waste and agricultural runoff have contaminated rivers and lakes, leading to severe health problems for people living in affected areas. India is another country with significant water pollution issues. The country faces challenges such as untreated sewage and industrial waste, leading to contamination of rivers and lakes. Other countries that have been identified as having significant water pollution issues include Bangladesh, Indonesia, and Brazil. These countries face challenges such as rapid urbanization, industrialization, and weak environmental regulations, which contribute to water pollution.

A Hydro Quality Survey System, also known as a HydroQS device, will be developed through this project. Users will be warned if any abnormalities are detected in the water quality data by this device, which can monitor and analyse it. To reduce water pollution, especially in Sungai Melaka, and to raise public awareness about the importance of preserving a healthy environment, are the main objectives of this project. Perbadanan Pembangunan Sungai dan Pantai Melaka (PPSPM) will undertake this research which will cover a 9km length of Sungai Melaka from Batu Hampar, Peringgit to the mouth of Sungai Melaka near Bandar Hilir. All the information may be given through the internet since HydroQS is coordinates with the internet of things.

The material selected for this project and accompanying study is PA-12 Nylon. Because of its superior material qualities, it was chosen. With high levels of hardness, tensile strength, impact strength, ability to flex without fracture and resistance to abrasion. In addition to this, the PA-12 has a low water absorption rate and a density of 1.01 grams per millilitre. PA-12, in addition to being resistant to stress cracking, also can withstand the effects of chemicals.

The laser sintering route will be used on a Farsoon SS402P Selective Laser Sintering machine to develop the polyamide PA-12 housing for the Hydro Quality Survey System (HydroQS) in this project. To determine the mechanical properties of the housing, its performance will also be investigated. The main objective of this research is to focus on developing and constructing a hydrodynamic housing for the Hydro Quality Survey System by utilizing recycled aged polyamide PA-12. The new concept design will be based on the findings of the field research output, as well as the requirements and concerns of PPSPM.

The housing is a very crucial and essential component of HydroQS that needs to be assembled. Fibre glass was previously the primary material used in a significant number of the product's history. For the purposes of this study, both recycled and unrecycled PA-12 powder will be used. Using recycled PA-12 powder could lead to cost savings and potentially reduce the overall size of the product. Fibre glass is not the ideal choice for the material due to HydroQS being a compact and modular device.

The final design of the HydroQS housing is expected to be a version that is lightweight and has hydrodynamic enhancements. The design will be sent for the prototyping process on the Farsoon SS402P SLS machine after it has been reviewed and approved by PPSPM. Following that, HydroQS will undergo dimensional checking, mechanical testing, surface roughness measurement, and field testing. This will entail positioning it next to the new housing at the locations recommended by PPSPM. The HydroQS housing that will be manufactured is expected to have a low drag coefficient, high strength, and low weight, effectively addressing, and fulfilling all PPSPM issues and requirements.

1.2 Problem Statement

Melaka's river has been polluted since 1970 and it has been severely affected by pollution. Water can quickly become polluted due to toxins originating from industry or cities and farms. To prevent this from happening, the responsible parties need to ensure the cleanliness of the Melaka River water and therefore become a tourist attraction. The quality of the water and the smell of the Melaka River is less appealing, and this investigation will be carried out in collaboration with PPSPM to develop the HydroQS device. If successful it can improve water quality. The water level, pH, total dissolved solids (TDS), dissolved oxygen (DO), turbidity, and current speed of Sungai Melaka are monitored by this device. Temperature of the water, as well as the surface wind speed, temperature, and humidity. The control room's network can be linked to Arduino-based sensors, which can be monitored via mobile apps or online.

Figure 1.1 Melaka River Cruise

Figure 1.2 Pollution kills thousands of fish in Malacca River

HydroQS takes into account specific requirements before proceeding. Being modular, sensor-friendly, lightweight, strong, and low-drag are included. Although the Sungai Melaka stream is typically calm, it can change rapidly. This rapidly fluctuating current is added to by the current that is formed when Batu Hampar and Bandar Hilir are closed or opened as depicted in Figures 1.3 and 1.4.

Figure 1.3 Batu Hampar water barrage

Figure 1.4 Bandar Hilir water barrage

The keys to Batu Hampar and Muara's water barrage gates are the first and most significant. The MRC boat service operates by means of these two gates, which regulate the water level in Sungai Melaka. For the MRC boat service, the river needs to have a depth of 0.8 metres. The Batu Hampar water barrage gate will be opened during low tide in Selat Melaka because the water inlets along the Sungai Melaka between Batu Hampar and Bandar Hilir cannot deliver enough water and the river depth must always be maintained above a certain level. Between the barrages, Sungai Melaka will be exposed to fresh water, debris, and pollution from upstream. The Sungai Melaka will have at least three quarters of its full freshwater capacity from Batu Hampar to Bandar Hilir. The Bandar Hilir water barrage gate is opened during the high tide of Selat Melaka, but Batu Hampar remains closed during the dry season. All of Selat Melaka's floating rubbish and pollution will be dumped here, along with the swift stream. The previous disaster will happen again. The Sungai Melaka will receive murky water and floating debris at the end. These housing criteria are mainly caused by the rapidly fluctuating current of Sungai Melaka that contains both salt and freshwater. To survive the rapidly changing current and waves, the housing design must be lightweight, strong, and have a low drag coefficient, as the HydroQS will be positioned 1 m from the river's steel sheet pile wall.

1.3 Objectives

The objective of this project are stated as below;

1. To identify the significant different in weight and dimension of the Nylon FS3300PA when it is soaking within 1000 hours.
2. To analyse the material properties of the different condition of the testing for the Nylon FS3300PA when soaking into the freshwater
3. To define the best position of the Nylon FS3200PA specimen in the Sintering Laser Selective machine that affect the tensile strength.

1.4 Scope of Research

The scope of this research are as follows:

1. The strength of the FS3300PA nylon 19 material will be assessed in the field using test samples that will be submerged in freshwater for additional tensile tests in order to determine Young's modulus, maximum tensile strength, and elongation at break.
2. Tensile tests were performed on the FS3300PA nylon material both before and after the field test.
3. Literature study of material properties, mechanical properties of hygroscopic aging of FS3300PA nylon powder by using the SLS 3D printer, water pollution and effect of the FS3300PA when soaking into the riverwater

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this section conducts a background research and literature review for the entire project by conducting research using articles, book reviews, and journals. This chapter will be focused on water pollution issues, types of material that will be used for HydroQS housing using Sintering Laser Selective process, and past water quality monitoring product. It will be easier to understand the whole project with the help of a literature review and will be able to learn more about the research and make project-related assessments.

2.2 Water Pollution

According to Adetunde, L.A., and Glover, R.L.K. (2010), water pollution is the contamination of water bodies, which is often brought on by human activity and has a detrimental effect on how they are used. Water bodies include things like lakes, rivers, seas, aquifers, reservoirs, and groundwater. Contamination happens when pollutants are introduced into these sources of water. Water pollution can come from sewage discharges, industrial processes, agricultural practises, and urban runoff, including precipitation. There are two forms of pollution: groundwater pollution and surface water pollution (either freshwater or marine contamination). Aquatic ecosystems may suffer from the discharge of wastewater that has not been adequately treated into natural waterways, for instance. You have a higher risk of getting sick from them if you consume, bathe in, wash in, or irrigate with polluted water. With unclean water, people are more likely to consume it for drinking, bathing, washing, or irrigation. The water body's pay-as-you-go policy is constrained by air pollution, making it difficult to communicate any potential ecosystem services that might be offered.

The water quality index has been divided into five categories by the Department of the Environment (DOE), which are represented in Table 2-1 as Classes I, II, III, IV, and V. The National Water Quality Standards (NWQS), which were developed by the federal government, are reflected in these categories. As you progress down this list, the water quality gets worse from category to category. Based on the standard values of 72 criteria found within six different water consumption classes, surface water quality has the ability to be gradually improved and elevated to a higher water class. This potential is based on the standard values of 72 criteria found within each water consumption class (Huang et al., 2015). Table 2-1 DOE Water Quality Index 1 (Huang et al., 2015)

Table 2.1 Class and Uses of Water Supply

Class	**Uses**
Class I	Conservation of natural environment. Water Supply I – Practically no treatment necessary. Fishery I – Very sensitive aquatic species.
Class IIA Class IIB	Water Supply II – Conventional treatment. Fishery II – Sensitive aquatic species. Recreational use body contact.
Class III	Water Supply III – Extensive treatment required. Fishery III – Common of economic value and tolerant species; livestock drinking.
Class IV	Irrigation
Class V	None of the above.

The National Water Quality Standard (NWQS) and the Water Quality Index (WQI) are used by the Department of Energy (DOE) to assess the quality of Malaysia's rivers (ANNEX). Only 47% of the 477 controlled rivers were declared clean by the 2016 Malaysian Environmental Quality Report, with the remainder 43% being somewhat contaminated and 43% being polluted (10%). Additionally, according to them, there were 224 clean rivers in 2016 as opposed to 276 in 2015 (Norizam et al., n.d.). Figure 2.1 shows three categories of river water quality based on data from 2017 that the researcher evaluated from the Department of the Environment (DOE). Figure 2.2 shows the trend in river water quality from 2008 to 2017.

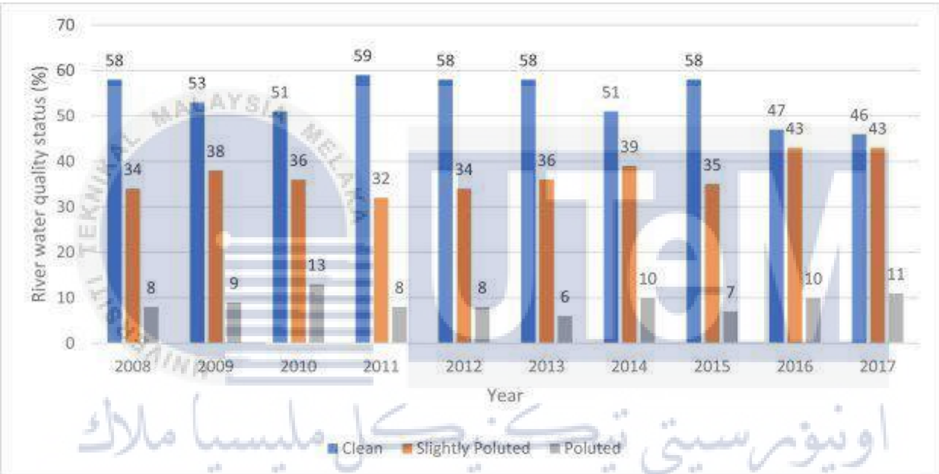

Figure 2.1 River water quality trend for 2008-2017 (Lee Goi, 2020)

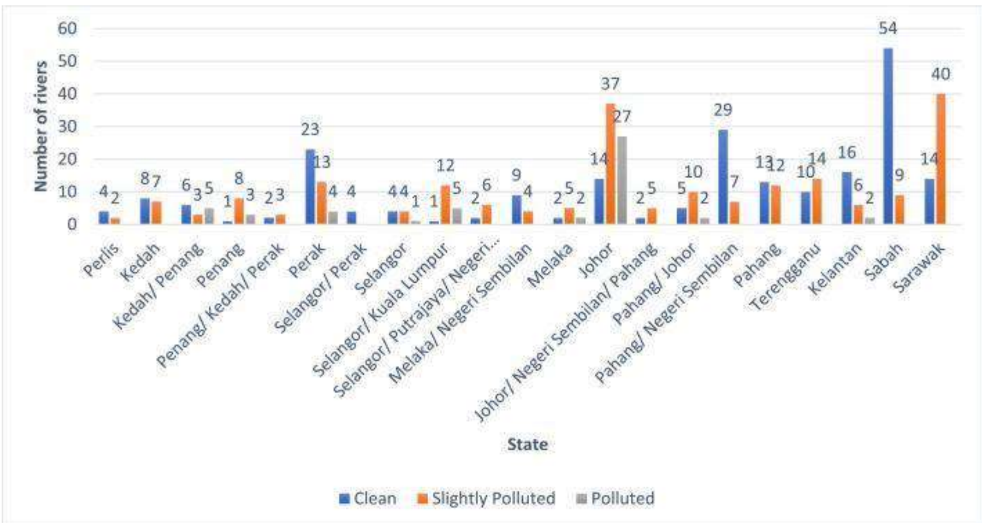

Figure 2.2 River water Quality by States from 2008 to 2017 (Lee Goi, 2020)

2.2.1 Water Pollution In Sungai Melaka

Human activity is currently the primary cause of water contamination in Sungai Melaka. The Melaka River Cruise is a fantastic opportunity to see and hear Melaka at your own pace. These actions have significantly worsened Melaka's water pollution. There are several different sources of water pollution in Sungai Melaka, including waste pollutants and faeces waste. It will taint and lower the quality of the river's water. Residents in Alor Gajah and Melaka Sentral, as well as the state government, have supported the issue that the river's water quality has significantly worsened as a result of trash pollution, according to a research conducted by (Zezhen et al., 2008). Therefore, the goals of the 1920 Water Acts, the 1993 Sewage Service Act, and the 1979 Sewage and Industrial Effluent Act are to prevent any foreign objects from entering the river without authorization, to increase sewage treatment, and to consistently maintain water quality.

Visitors, residents, and the state government of Melaka have all expressed their unhappiness with the water quality issue in Sungai Melaka. According to a study by the Department of Environment (DOE) under Malaysia's Environmental Quality Act, Sungai Melaka is classified as Class IIA and Class IIB. Although the DOE has three monitoring stations for Sungai Melaka—Sungai Tampin, Sungai Dusun, and Sungai Kemunting—these monitoring stations are only situated upstream of Sungai Melaka, where activities like high-density residential, sewage treatment plants, commercial lots, and heavy industrial areas contribute to pollution more than areas downstream.

2.3 Water Quality Monitoring Device

Water is an essential resource for all living organisms, and its quality is crucial for human health and the environment. Freshwater is a worldwide asset that is a gift from nature and essential to horticulture, ventures, and human existence in the world. Monitoring water quality is essential to ensure that it is safe for consumption and to prevent the degradation of aquatic ecosystems. A device known as a water quality monitoring system may be used to measure the levels of pollution, the pH of the water, dissolved oxygen (DO), turbidity meters, chlorine meters and microbial sensors.

One of the most common parameters that is measured in water is ph. pH meters are devices used to measure the acidity or alkalinity of water. The concentration of hydrogen ions determines the pH value of water. The pH of water can be affected by a variety of factors such as acid rain, industrial discharge, and agricultural runoff. If the pH of water is too low or too high, it can have adverse effects on aquatic life and human health.

The quantity of oxygen that has been broken up into the water is referred to as the "dissolved oxygen" (DO). The amount of oxygen dissolved in water is a key indicator of the health of aquatic ecosystems. Dissolved oxygen meters are used to measure the amount of oxygen that is available to aquatic organisms. Low levels of dissolved oxygen can lead to the death of fish and other aquatic life and can also contribute to the growth of harmful algal blooms. The current Industrial Revolution's implementation of monitoring the Water Quality. Several sensors, devices, machinery, and equipment can be used with Internet of Things (IoT) 4.0 technology. Things applications that are electronic and Internet-based can be used to do this (Yasin et al., 2020).

2.4 Types of Water

Without the presence of water, humanity and civilisation cannot exist. Water is regarded as the single most crucial element required for the continuation of life on Earth. Medical practitioners and nutritionists stress the need of making sure that one is constantly well hydrated because the human body is 70% water and because a considerable amount of that water is lost via urine and perspiration. Water aids in a variety of vital activities, including eliminating bacteria from your bladder, facilitating digestion, delivering nutrients and oxygen to cells, relieving constipation, maintaining electrolyte (sodium) balance, and many more. People have emphasised the significance of having access to water for millennia.

2.4.1 Sea Water

Seawater is the type of water that may be found in the world's oceans and seas, which together cover more than 70 percent of the surface of the earth (Balasubramanian, 2011). 96.5 percent of seawater is made up of pure water, 2.5 percent salt, and minor quantities of dissolved inorganic and organic compounds, particles, and a few atmospheric gases. Seawater has an average density of 1.027 gm/cm3, but this varies with temperature and salinity over a range of about 1.020 to 1.029. The average pH for sea water is 8.2 but can range between 7.5 and 8.5 depending on the local conditions. There are several dissolved minerals and salts in sea water. Sodium chloride, sometimes referred to as table salt, is the most prevalent salt. Magnesium chloride ($MgCl_2$), magnesium sulphate ($MgSO_4$), calcium carbonate ($CaCO_3$), and potassium chloride (KCl) are some of the additional salts found in sea water. Seawater also contains traces of many other elements and minerals.

2.4.2 Rainwater

Rainwater is an essential natural resource that is important to the world's water cycle. In many areas, it serves as the main supply of freshwater and helps to replenish lakes, rivers, and groundwater. Due to growing water shortages and the necessity for sustainable water management practises, rainwater harvesting, the practise of collecting and storing rainwater for later use, has become more popular recently. In general, rainwater is pure and devoid of dangerous pollutants, making it ideal for a variety of functions including irrigation, cleaning, and, with the right treatment, drinking. Additionally, rainwater collecting can lessen stormwater runoff, which can cause floods and soil erosion, as well as the strain on municipal water supply. However, a number of elements, such as air pollution and the components utilised in rainwater collecting systems, might have an impact on the quality of rainwater. Therefore, it is important to adopt the proper treatment techniques to guarantee the safety of rainwater for various applications.

2.4.3 Fresh Water

A vital resource for sustaining life on Earth is freshwater. It is employed in a variety of operations, including drinking, farming, and manufacturing. However, issues like population development, climate change, and pollution are limiting the amount of freshwater that is available. An increasing interest in the sustainable management of freshwater resources has resulted from this. Water conservation is one of the most important methods for managing freshwater sustainably. This entails conserving water and utilising it more effectively. For instance, water-saving irrigation methods like drip irrigation may considerably lower water consumption in agriculture, which uses nearly 70% of the world's freshwater.

2.4.4 Brackish Water

Brackish water is a special kind of water that is less salty than saltwater but more salty than fresh water. Estuaries, where rivers flow into the sea, and underground aquifers close to coastlines are where it is most frequently found. Particularly in the context of water shortage and the need for sustainable water sources, brackish water provides a distinctive mix of opportunities and problems. The high salt concentration of brackish water, which renders it unsuitable for most human applications without treatment, is one of the main problems with this type of water. Although brackish water's salinity can vary greatly, it typically has between 0.5 and 30 grammes of salt per litre. This high salt concentration limits the use of brackish water for drinking, irrigation, and other uses since it may be detrimental to both people and most terrestrial plants.

2.5 Position and Angle of Nylon

As shown in Figure 2.3, dog-bone-shaped tensile specimens with gauge sections measuring 80 millimetres in length, 10 millimetres in width, and 4 millimetres in thickness were created in accordance with ISO 527-2:2002 standard and laid in XY/Y, YZ/Y, and YZ/Z directions to determine the anisotropic properties of SLS parts. A specimen's length direction that is parallel to the Y-axis and its thickness direction that is parallel to the building direction are referred to as XY/Y, YZ/Y and YZ/Z, respectively. A specimen's length direction that is parallel to the Y-axis and its width direction that is parallel to the building direction are referred to as YZ/Y and YZ/Y, respectively.

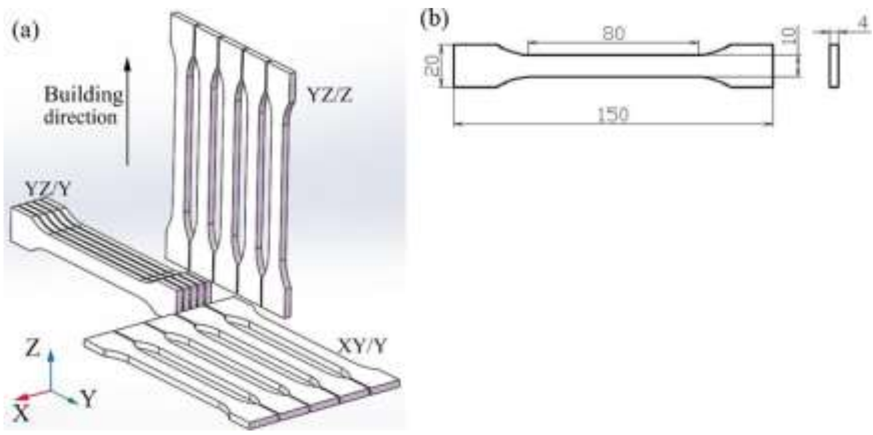

Figure 2.3 Position of the nylon

As a result of the part being constructed utilizing SLS technology in a layer-by-layer fashion, it possesses anisotropic microstructures and mechanical properties in the building as well as in other directions. The residual voids that existed in the interface for the consolidation of the molten polymeric material function as local stress concentrators in the SLS component, which lowers the tensile strength in the building direction. Gibson et al. pointed out that the SLS part's positioning and orientation during manufacture had an impact on the component's mechanical characteristics. The components in the construction directions had much lower tensile and yield strengths than those in the scanning directions, according to Caulfield and colleagues' research. The tensile properties of SLS PA2200 printed at 0 degrees, 30 degrees, 45 degrees, 60 degrees, and 90 degrees, respectively, were studied by Stoia and colleagues. They discovered that the 45-degree direction had the highest tensile strength, although the 0 and 90-degree directions had bigger Young moduli than the 30 and 45-degree directions did, respectively. Fracture toughness is also significantly influenced by the building instructions. The SLS PA2200 has the lowest value and the smallest difference when oriented at a 45° angle. Cracks are created and expanded in a way specific to each orientation when the SLS polymer is printed at various orientations.

2.6 Sintering Laser Selective

The Selective Laser Sintering (SLS) system of the Farsoon 402P series offers quick prototyping and additive manufacturing customers with cutting-edge production capabilities. The 402P is a highly effective and productive solution for the most demanding applications.

For this research, Farsoon SS402P industrial grade Selective Laser Sintering (SLS) machine has been selected to be used. Selective laser sintering (SLS) 3D printer is manufactured by Farsoon model SS402P and located at SLS Laboratory FTKMP of Universiti Teknikal Malaysia Melaka. The SLS machine has an external dimension size of 2660mm x

1540mm x 2150mm and weight of 3000 kg. The maximum build product in the SLS chamber is 400mm x 400mm x 450mm with effective build size 350mm x 350mm x 430mm. CO_2 is used as a laser with maximum output is 100W power while scanning speed is 12.7m/s. The laser wavelength is 0.3mm and 0.1mm thickness of powder layer for every rotating roller.

Figure 2.4 Farsoon SS402P Selective Laser Sintering (SLS) machine.

The sintering process flow for the Farsoon SS403P machine is shown in Figure 2.5. This flow comprises of three stages: the cooling stage, the SLS 3D printing stage, and the post-processing stage. With 400mm x 400mm x 450mm feeder chamber size, the weight required for the FS 3300PA powder to fill up is about 60kg powder. Then (B) the powder will be put into the mixer machine to make sure that the powder blend well (C) before being collected and (D) sent to feeder chamber inside the LS machine. The second stage is (E) printing/sintering process where the parts being sintered using 70watt CO_2 laser. Once the sintering process complete, at post processing stage, (F) the build chamber being drew out from the sintering machine and then, the parts together with the powder cake being pushed out by actuator below the build chamber towards the acrylic casing as shown in Fig 2.5 (G). The powder cake then being moved to powder cleaning machine as to remove all the non-sintered powder before being recycled again for next sintering session.

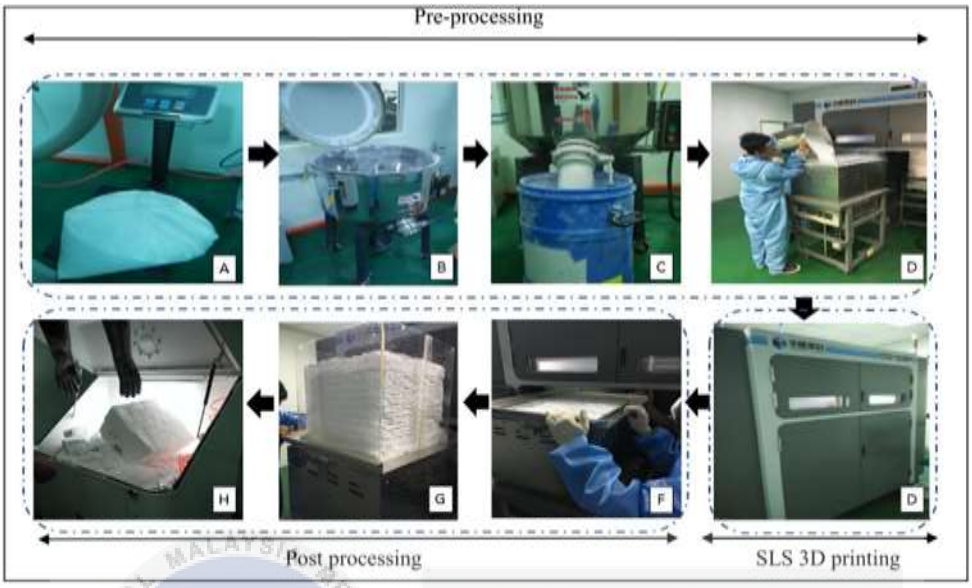

Figure 2.5: Sintering process flow using Farsoon SS402P machine.

2.7 PA-12 material (Nylon)

The following PA-12 materials can be used with Farsoon machines: FS 3200PA and FS 3300PA, both of which are based on PA1212-based powder; FS 3400GF and FS 3401GB, both of which are filled with glass beads; FS 3400CF, which is filled with carbon fibre; FS 3250MF, which is filled with mineral fibre; and FS 4100PA, which is filled with PA11 powder. Recycled materials will be used in the HydroQS housing's manufacture. A powder based on PA-12 is called FS3300PA. Working with nylon of the FS3300PA grade is simple. It is recyclable, has excellent mechanical properties, is antioxidative, has size stability, and absorbs very little water. It also has great colour stability. Additionally, it has all of these qualities while also being antioxidative.

Because it has an affinity for water and is hydrophilic, nylon is frequently used to measure water activity. The quantity of free water that is accessible to enable microbiological growth or chemical reactions in a substance is measured by water activity. Nylon may be used as a membrane to regulate the flow of water vapour into and out of a sample because it has a predictable and constant water vapour transmission rate. The water activity of a sample on one side of a nylon film can be compared to the water activity of a reference material on the opposite side of the film to determine its water activity while the nylon film is being utilised as a barrier. For many reasons, nylon is a preferred material for selective laser sintering (SLS) equipment. Like nylon, which has a high melting point, this property allows it to tolerate high temperatures during the SLS process without melting or deforming. Many different types of polymeric powder material used for SLS have been reported frequently, especially composites based on polymers, such as Polyamide 12 (PA-12), Polyether Ether Ketone (PEEK), Polyethylene (PE), Polycarbonates (PC) and Polystyrene (PS).

Nylon PA-12 has been selected for the SLS 3D printing equipment in this HydroQS project. Due of its excellent accuracy and inexpensive cost, this material is suitable for both seasoned designers and newcomers (Carmel, 2019). High strength, stiffness, a great resistance to cracking under stress, and excellent long-term consistent behaviour are all characteristics of this material. In addition, Nylon PA-12 absorbs extremely little moisture and is great at resisting chemical, oil, and highly processable materials because to its lower concentration of amides (nitrogen-containing organic compounds) than any other commercially available polyamide (S.C. Ligon, 2017).

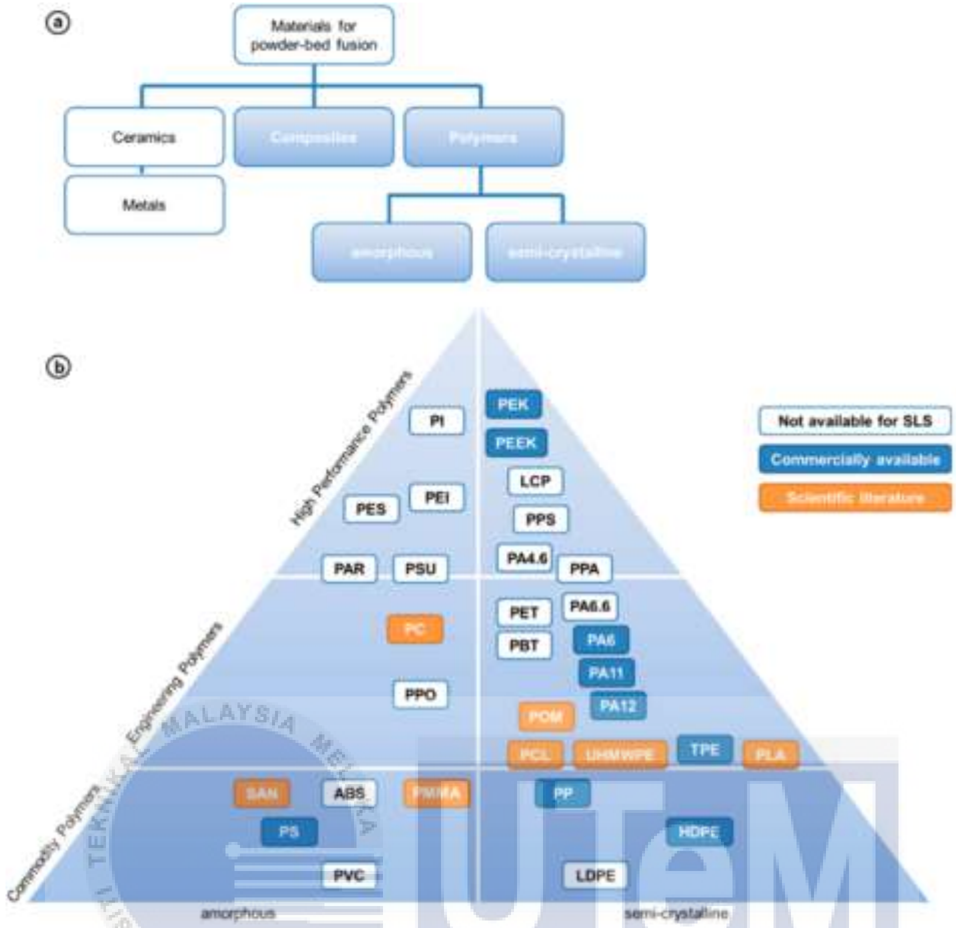

Figure 2.6: Classification of materials for SLS additive manufacturing (a) according to inorganic or polymeric content; and (b) according to the so-called pyramid of polymeric materials

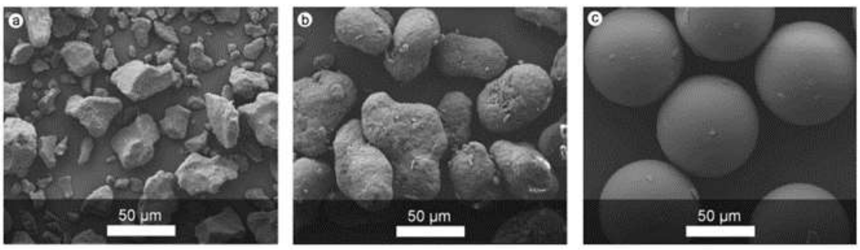

Figure 2.7: Morphology of laser sintering powder. (a) Cryogenically ground, rough particles (PA-11 powder); (b) potato-shaped particles precipitated from ethanol solution (PA-12 powder); and (c) spherical particles produced by means of emulsion polymerization (PS powder)

There are numerous different types of PA-12 materials that have been certified for use with Farsoon machines, including FS3200PA and FS3300PA, which are PA1212-based powder, FS3400GF and FS3401GB, which are glass bead and glass fibre filled, FS3400CF, which is carbon fibre filled, FS3250MF, which is mineral fibre filled, and FS4100PA, which is PA11 powder. In this study, the manufacture of the HydroQs housing will mostly be done with recycled, ageing FS3300PA that is based on PA-12 powder. Producing functional components and prototypes is a good fit for the robust and long-lasting FS3300PA material. This material has good heat resistance with a glass temperature (Tg) of about 175 oC. This recycled ageing powder originates from the surface of the component, often from the bottom, where there is a lot of heat. higher part shrinkage due to porosity of the part and also deterioration of surface finish which being called as 'Orange Peel'

However, all these issues except the 'Orange Peel' texture as shown at Figure 2.7, can be controlled, or improved by proper part arrangement before sintering process held as shown on Figure 2.8. For the 'Orange Peel' texture, it can be removed only by adding additional post heat process with extra 300secs after the sintering process as to improve the surface quality by maximizing the coalescence and consolidation, and a well-consolidated surface. As the stated issues can be solved, another reasons the selection of this recycled aging PA-12 powders for this research are due to abundancy of this material and to reduce the raw material cost as recycled powder always considered as waste.

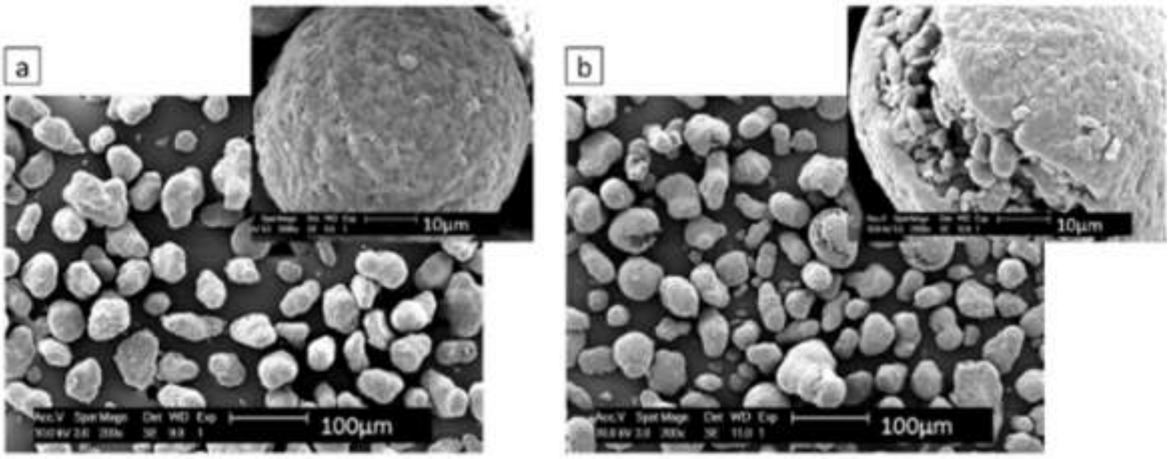

Figure 2.8: SEM images of (a) virgin and (b) aged PA12 powder used for SLS showing cracking on the particle.

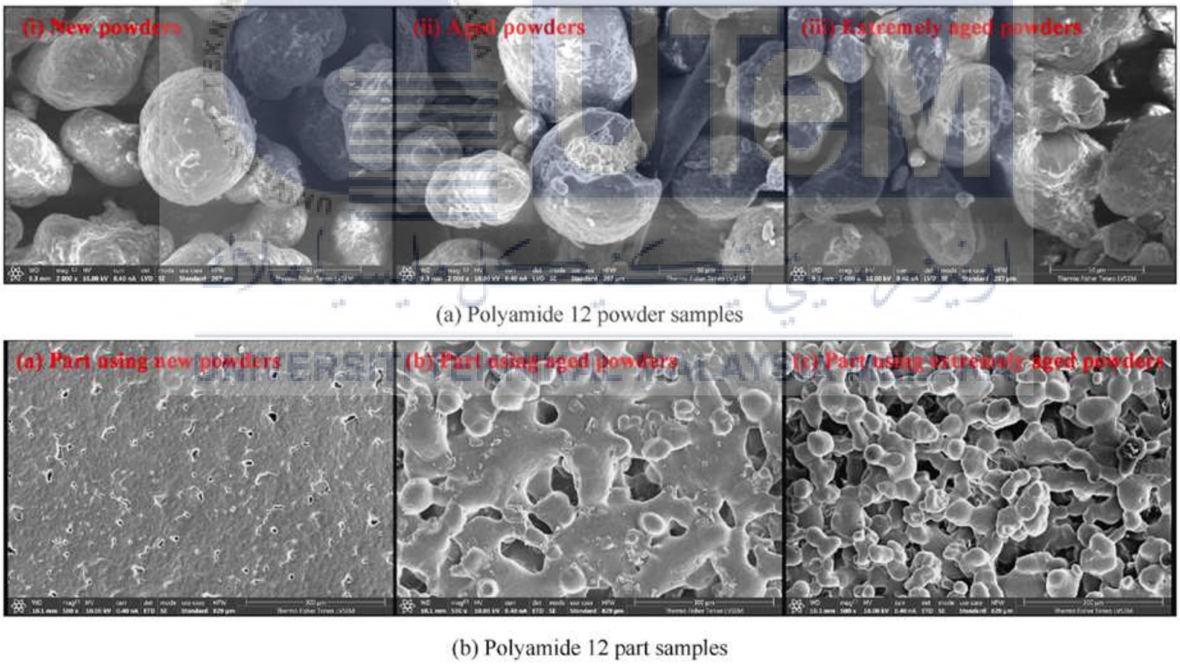

Figure 2.9: SEM test results of polyamide 12 powders (a) and parts using polyamide 12 powders (b).

Figure 2.10: Laser sintering part with 'Orange Peel' texture

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology is a term used to describe the systematic approach or process used to conduct research or solve a problem. It is a critical component of any research project and involves a series of steps that are designed to ensure that the research is conducted in a structured, efficient, and reliable manner. This study will provide an overview of the complete process, including field research, sample collecting, and outcomes analysis.

3.2 Field Testing Process

This component of the field testing will show the thesis by soaking a sample in river water and creating four various types of Nylon FS3300PA (virgin, recycle, sealant recycle, and sealant spray recycle). Four unique Nylon FS3300PA coating samples were submerged in fresh water for 1000 hours. The fresh water was taken from the Air Sungai Melaka, which is located near Melaka Sentral. This data is collected on a weekly basis in order to track the dimensions and weight of Nylon FS3300PA. The supplementary test that looked at the sample's strength and reduction analysis throughout the tensile test method to see if it was flexible.

Table 3.1 Material properties of FS3300PA powder

Characteristic	FS3300PA
Tensile Strength	48.2MPa
Elongation at break	22%
Part Density	1.02 g/cm3
Bulk Density	0.52 g/cm3
Melting Point	184 ◦c

3.3 Data Gathering Process Before and After Field Testing for Samples

SLS testing samples are labelled and separated into four groups, each of which has a set of five samples that will be submerged in fresh water for a thousand hours. The nylon FS3300PA were produced by the SLS machine with a 70-kw power supply and the thickness, breadth, and the length of the nylon were measured by using the vernier calliper before it submerged in fresh water. Before the initial reading, the sample was immersed for seven days. The method was repeated up until week 6 to analyse data between weeks. Each nylon sample's weekly weight from week one to week six was recorded. By using Shimadzu Ultimate Tensile Machine, it can conduct tensile testing on each sample to determine its mechanical properties, such as Young's modulus, tensile strength, and elongation at break after being submerged in fresh water. After that, the data can be analysed by using the excel.

3.4 Flow Chart

3.4.1 Project Flow Chart for Testing Materials

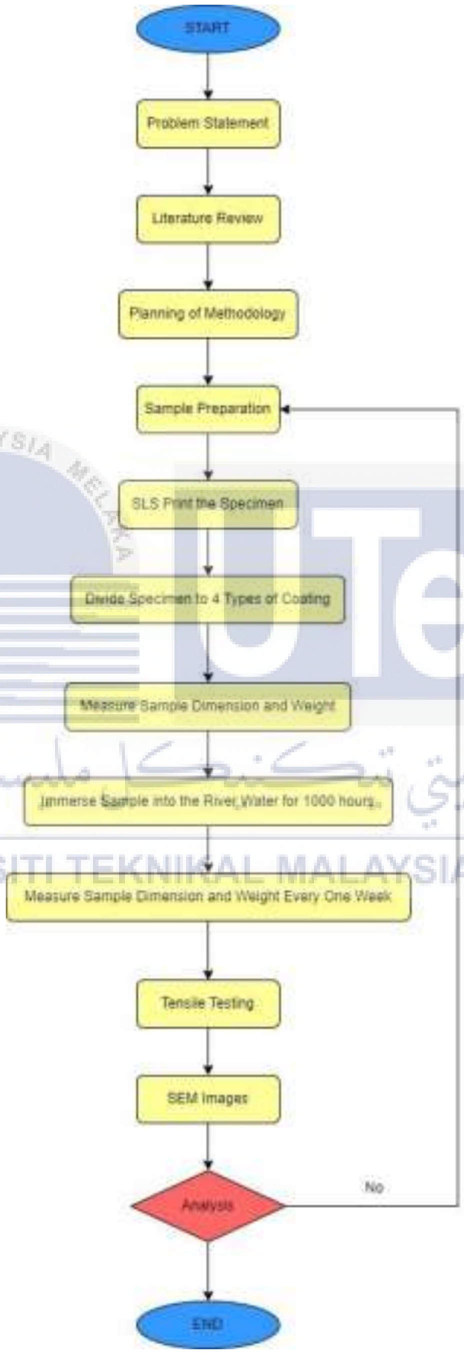

Figure 3.1 Flow chart for Methodology

3.5 Shimadzu Universal Tensile Machine

The printed nylon FS3300PA sample specimen will be divided into four unique coats and tested on a Shimadzu Universal Tensile Machine. The tensile machine is also connected to the programme Trapzium Lite X, which will determine the Young's modulus and the strain-stress graph. During the test, the machine would record the force applied to the specimen and the resulting deformation or elongation of the specimen. These data points can be used to calculate important mechanical properties of the nylon FS3300PA, such as its tensile strength, Young's modulus, and elongation at break.

Corporation produces a special class of testing device known as a universal testing machine under the name AGS-100kNX. With a 100 kN maximum load capacity, the AGS-100kNX is appropriate for evaluating high-strength materials. It has a high-precision load cell and displacement sensor that make it possible to detect load and deformation values precisely. Additionally, it includes a range of grips and fasteners that may be quickly adjusted to accommodate various specimen kinds and testing needs. The machine is controlled by user-friendly software that makes it simple to programme and control test parameters including loading rate, test length, and frequency of data sampling.

Figure 3.2 Shimadzu Universal Tensile Machine

Figure 3.3 Shimadzu Universal Tensile Machine at the FTMKP Laboratory

3.5.1 Shimadzu Universal Tensile Machine AGS-100kNX Equipment

1. Tensile Test Jig.

   A. Upper Jig

   B. Lower Jig

Figure 3.4 Upper and Lower Jig of the Shimadzu Universal Tensile Machine

2. Test Space

   A. Tension.

   B. Compression.

3. Crosshead

   A. Tension.

   B. Compression

4. Smart Control Panel.

Figure 3.5 Smart Control Panel of the Shimadzu Universal Tensile Machine

5. Notched Column.

6. Screw Column.

7. Load Cell.

8. Main Frame.

9. Table

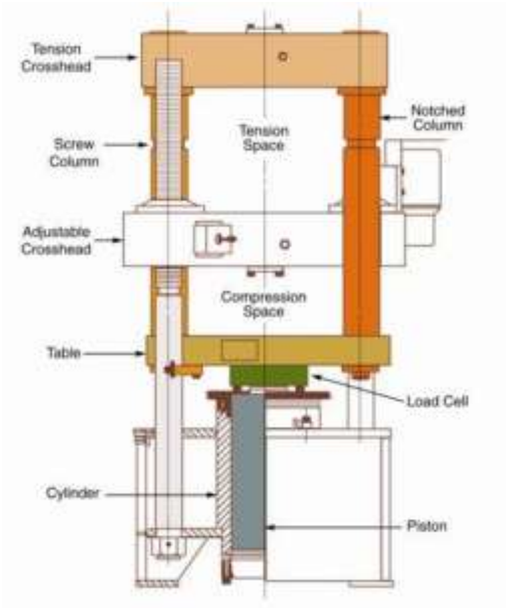

Figure 3.6 Part of Universal of Shimadzu Universal Tensile Machine

3.5.2 Shimadzu Universal Tesnile Machine Procedure

The following is how the test device is set up;

1. Power on the Shimadzu Universal Tensile Machine and adjust the upper jig properly.
2. The Trapezium Lite X software has been set up first before running the experiment of the tensile test. The Trapezium Lite X has been connected to the machine to observe the data of the tensile.

Figure 3.7 Trapezium-X Lite that connect with the Shimadzu Universal Tensile Machine

3. The specimen of the nylon FS3300PA has been measured to ensure the specimen can be fit into the location that want to put the specimen at the test space tensile machine.

    A. The specimen as been measured again by using vernier caliper.

    B. The specimen of the Nylon FS3300PA need to be clean up to ensure the specimen fit to the tensile machine.

4. Then, the specimen has been set up to the middle of the tensile machine.

5. The upper jig will be move slowly to fit the specimen after the lower part of the specimen has been tightly wit the lower jig.

    A. The movement of the jig will control by the main operational panel of the machine.The upper jig can be adjust to move upward or downward but the lower jig just stay at the original position.

    B. The upper jig needs to be ensure that grip the specimen because to generate the high accuracy of the tensile strength.

Figure 3.8 Specimen has been Setup Before the Tensile Test

C. Calibrate the main operational panel until the number of the become zero before running the machine by pushing the start button.

D. This calibration method actually has been done to ensure the graph of stress-strain start from the origin.

6. The software has been run when the specimen has been stretched.

    A. The test speed of the tensile test is 5mm/min.

7. The signal for this test has been done which is the specimen breakout at the middle of the specimen.

Figure 3.9 Specimen Broken when undergo the Tensile Test

8. During the period of time that tensile test has been run, the graph will be construct automatically from the origin until makes their curve.

   A. The curve of the graph stress-strain will define the Young's modulus value, maximum tensile strength and elongation to break of the specimen.
   B. The data also has been display when the specimen breakout in the middle of the tensile test machine and the graph will extremely drop.

9. The specimen has been taken out of the tensile machine by unripe the specimen using the loose the upper and lower jig.
10. Repeat the test with another sample.

3.6 3D Printing Process

Using 3D printing three main steps made up the operation setup: (i) the preprocess stage (Figure 3.10 A-B), (ii) the 3D printing process stage (Figure 3.10 C-D), and (iii) the postprocess stage (Figure 3.10 E-G). The SLS 3D printer is made up of four primary chambers: the feeder chamber, the construction chamber, the collector chamber, and the powder overflow chamber with levelling roller (Figure 3.11). Based on how many copies of each component were required, Materialise Magics software was used to compute the material volume and weight. The key constant settings for the SLS 3D printer were set throughout the 3D printing process phase. The material block was moved from the SLS Effect of Polyamide-12 Material Compositions on Mechanical Properties 63 machine-building chamber to the sieve machine during the following post-processing phase, as shown in (Figure 3.10 E-G). All of the finished specimens that were ready for testing are shown in Figure 3.10 H. The Farsoon FS4092P SLS 3D printer that was utilised to create all of the specimens is shown in Figure 3.11.

Figure 3.10 SLS 3D printing process flow

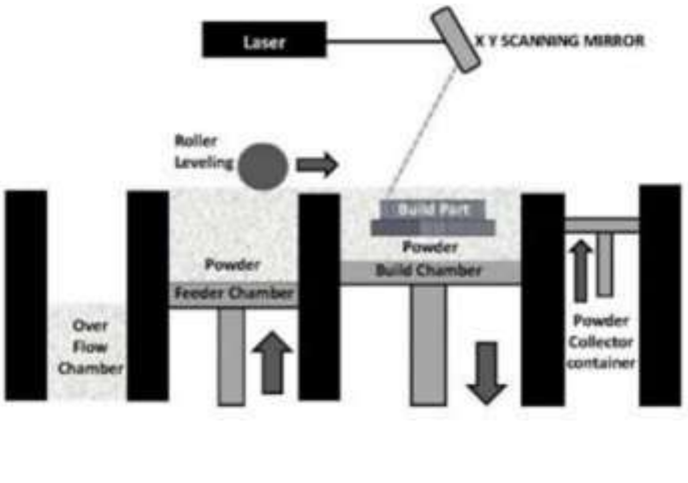

Figure 3.11 SLS process for Farsoon FS402P

3.7 Mettler Toledo Analytical Balance

An analytical balance is a very accurate measuring tool that is used to calculate the mass of small samples precisely and accurately. It is frequently used in applications such as quality control, analytical chemistry, and scientific research where small variations in weight can have a big impact. Mettler Toledo analytical balances are ideal for sensitive applications like density determination, sample preparation, differential weighing, formulation, and pipette calibration. Their capacities range from 52 to 520 g, and their readability ranges from 0.002 to 1 mg.

The analytical balance has enhanced output and productivity, optimum user protection, and flexible dual operation. The balance can be used for all manual weighing applications as usual because the dispensing head can be clicked back to its home position. The highest user protection function prevents spills and eliminates manual sample handling by directly discharging hazardous samples into the appropriate container. Your analytical balance can prepare up to 30 samples automatically in a single run if you install the sample changer, giving you up for focusing on other critical tasks.

3.7.1 Analytical Balance Equipment

1. Balance Pan
2. Button
3. Display
4. Door Handle
5. Level Adjustment Feet
6. Draft Shield
7. Glass Door

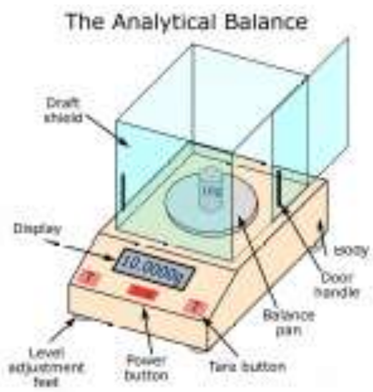

Figure 3.12 Analytical Balance

3.7.2 Analytical Balance Procedure

The step by step using the analytical balance:

1. Turn on the balance and open the doors of the weighing chamber.
2. The analytical balance needs to be calibrated by pressing the button tare and place the sample on the center of the weighing pan.
3. Close the doors of the weighing chamber.
4. Wait for the balance to stabilize before taking the reading.
5. Record the weight of the sample.

Figure 3.13 The sample are weighted by analytical balance.

3.8 Sputter Coater

A sputter coater is a device used in materials science and microscopy to apply a thin coating of metal onto a sample surface. The primary purpose of sputter coating is to enhance the sample's conductivity and improve imaging in electron microscopy. The process involves the physical deposition of metal atoms onto the specimen's surface through a technique called sputtering.

The coater allows for controlled coating thickness by adjusting parameters such as sputtering time and power, catering to a range of applications from electron microscopy to surface analysis techniques. The versatility of sputter coaters lies in their ability to enhance sample conductivity and improve imaging quality, contributing significantly to the advancement of research in various scientific disciplines. Additionally, safety measures are integral to the operation of sputter coaters due to the vacuum environment and high-voltage components.

Figure 3.14 Sputter Coater

3.8.1 Sputter Coater Equipment

1. Vacuum Chamber
2. Sample Holder
3. Control Panel
4. High-Voltage Power Supply
5. Thickness Monitor
5. Gas Supply System

3.8.2 Sputter Coater Procedure

The step by step using the sputter coater.

1. Turn on the switch power supply.
2. Open the sputter coater cover.
3. Put the material to be made into a platinum coating layer on top of the base.
4. Adjust the time accordingly and wait until the internal space is sufficiently vacuum.
5. When you hear the sound "buzzer", press the start button.
6. Then when it is finished according to the adjusted time, the buzzer will sound again and immediately turn off the machine and wait until the vacuum is released.
7. Open the cover of the sputter coater and remove the workpiece.

Figure 3.15 The sample in the sputter coater

3.9 Scanning Electron Microscope

An electron beam focused on a specific area of a surface is utilized by a scanning electrode microscope (SEM) to create images of the material. The interaction between the electrons and the atoms in the sample results in a variety of signals that provide details on the sample's composition and surface topography. An image is created by combining the position of the electron beam and the strength of the detected signal as it scans in a raster scan pattern. Using a secondary electron detector (Everhart–Thornley detector), secondary electrons released by atoms encouraged by the electron beam are found in the most popular SEM mode. Specimen topography is one factor that influences the quantity of secondary electrons that may be detected and, consequently, the signal intensity.

Resolutions better than one nanometre can be attained by certain SEM. Using specialized instruments, specimens are examined in a variety of cryogenic or extreme temperatures, high vacuum in a traditional SEM, low vacuum or wet conditions in a variable pressure or environmental SEM, and at both.

Figure 3.16 Showing the equipment that will be used.

(a) Carl Zeiss IMT Contura G2 CMM. (b) Portable Surface Roughness Tester Surf test SJ-41
(c) Joel JSM 6010 PLUS/LV Scanning Electron Microscope (SEM)

3.10 Gantt Chart

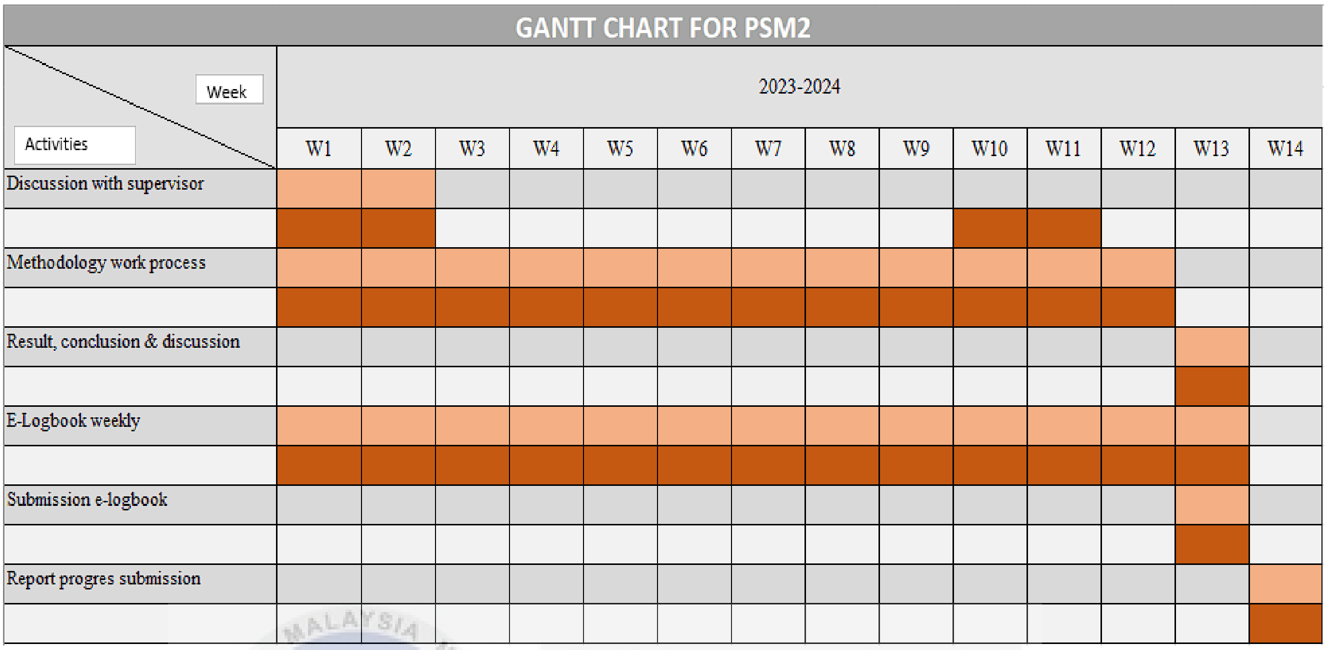

Table 3.2 Gantt Chart

3.11 Summary

The methodology for examining the impact of freshwater on the mechanical characteristics of ageing FS3300PA SLS material with various coating conditions is presented in this chapter. The specimen created with the SS402P SLS 3D Printing Machine will be weighed, and its measurements measured prior to the tensile test. A methodological strategy is necessary for a well-organized workflow. knowing how to properly operate the machine and devices also requires knowing the technique. The specimen will undergo field testing for 1000 hours before being transported to the Shimadzu Universal Tensile Machine for a tensile test. The data gathering will result in the creation of a regression analysis because of the tensile test and sample size. Soon, Sungai Melaka could have a new look and its water quality could be improved with the help of HydroQS and this new housing.

CHAPTER 4

Result And Discussion

4.1 Introduction

This chapter provides the results and analysis of the weight increase, elongation to break, young's modulus, maximum tensile strength, and impact toughness that were conducted on the dimension nylon FS3300PA in the methods section. The process for evaluating the nylon FS3300PA tensile test results, which were produced with the SS402P SLS 3D printer. Understanding and assessing the material's efficacy in a few areas, including the mechanical characteristics and dimensions of the sintering specimen samples, depends on the data and analysis provided here. This covers the outcomes of all laboratory tests, including material scanning and tensile testing. The behavior changes from ductile to brittle, which is explained by the interaction of the plasticizing effect, the hydrolysis of PA12 molecules, and the crystallinity increase that inhibits this process. Remarkably, under high-temperature water conditioning, the addition of stiff particles like glass spheres and ceramic fibers works well to stop the ductile-to-brittle transition.

4.2 Result and Analysis

The results of this data will be show by the bar graph diagram. This research consists of two tasks. The first involves using an SLS machine to compare a print cycle to virgin powder. With an SLS printer, cycle print was used to gather this data in the print YZY and XYY orientations. In this task, the print quality that assess the visual appearance and structural integrity of the printed parts. For the mechanical properties that can evaluate the mechanical performance, such as tensile strength, flexibility or hardness and depending on the application requirements. Lastly for the dimensional accuracy that any deviations from intended dimensions in both orientations.

In the second task, data was collected from surface roughness data per cycle print and SEM (scanning electron microscope) was used to observe various mechanical properties and structure. The objective was to determine which YZY orientation cycle had the best roughness and surface effect on PA-12. In this task the surface roughness analysis that focusing on the YZY orientation. That is crucial for application where surface finish it critical. In the SEM it easy to view analyze the mechanical properties. For the material structure, that very important to understand how to print the process and orientation affect the material's internal composition. Lastly the comparative analysis, the different YZY orientations to identify which one exhibits the best mechanical properties and structural characteristics.

So far, the sample test comes from the SLS printer and is a test at the PA-12 XYY angle from the 0-degree angle. In addition, the sample is printed with a total laser power of 70 watts. One cycle of fresh powder PA-12 is printed, along with 11 cycles of recycled powder PA-12. The virgin powder results sample will be compared to the 11 cycles of recycling powder PA-12. According to the data collection method, the best results will be acquired among the 11 cycles. Here, an SLS 3D printer with constant data configuration is used to produce a sample once each cycle.

The tensile tester's load and displacement data were collected and analyzed in Microsoft Excel. We determined the Young's modulus, tensile strength, elongation at break, and energy at break. As a measure of toughness, the fracture energy absorbed by the pieces during the tensile tests (area under the stress/strain curves) was determined. When run the experiment, determining the slope of the initial linear portion of the stress-strain curve. It represents the material's stiffness or rigidity for the young' modulus. In tensile strength the maximum stress specimen can withstand while being stretched or pulled before necking. For the elongation at break, the percentage increase in length of the specimen at the point of fracture and it about the ductility and ability to deform before breaking. While for the energy at break, the total energy absorbed by the material during the tensile test until fracture. It covers the area under the stress-strain curve. Lastly, the fracture energy also the same with energy at break but it is representing the material's toughness.

4.2.1 The benchmarking data comparison

Specimen Type	Max Tensile (Mpa)
Freshwater	12.7022
Virgin	31.7226
0.15mm 75-Watt 0 Degree	37.3328

Table 4.1 Max Tensile Data

Specimen Type	Impact Toughness (J/CM2) ASTM
Freshwater	0.84
Virgin	2.07
0.15mm 75-Watt 0 Degree	2.37

Table 4.2 Impact Toughness Data

Specimen Type	Elongation To Break (%)
Freshwater	8.8134
Virgin	23.3412
0.15mm 75 Watt 0 Degree	17.2438

Table 4.3 Elongation to Break Data

Specimen Type	Young's Modulus (Gpa)
Freshwater	0.9675
Virgin	0.8763
0.15mm 75-Watt 0 Degree	0.7272

Table 4.4 Young' Modulus Data

Specimen Type	% Increase Weight Before Vs After XYY
Freshwater	24.28
Virgin	0.078
0.15mm 75-Watt 0 Degree	0.35

Table 4.5 % Increase Weight Before Vs After XYY Data

4.3 Max tensile strength

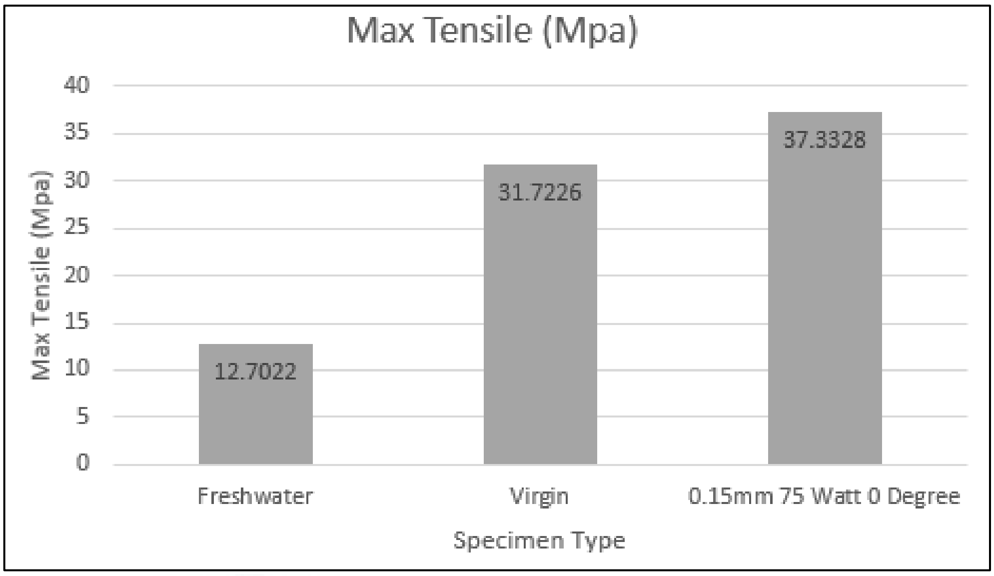

Figure 4.1 Max Tensile graph

The maximum tensile strength of material PA-12 SLS under various circumstances is displayed in this graph. The amount of force a material can withstand before breaking when stretched is known as its tensile strength. This condition involves treating the PA-12 SLS material with a laser beam of 75 watts at a 0-degree angle. The modification of the surface or structure through laser treatment likely contributes to the observed mechanical properties. The highest tensile strength of approximately 37.3328 MPa indicates that the material, when treated with a 75-watt laser at a 0-degree angle, exhibits superior resistance to force before breaking. The superior tensile strength suggests that the laser treatment at specific parameters enhances the material's mechanical properties, making it suitable for applications where high strength is crucial.

For the virgin sample, it represents the material in its original state without exposure to external factors. With a tensile strength of about 31.72 MPa, the virgin sample demonstrates a moderate resistance to force before breaking. The moderate tensile strength of the virgin sample provides a baseline understanding of the material's inherent properties.

For the freshwater, the data shows 12.722 is smaller than the virgin and 0.15mm 75-watt 0 degree. That is because conditions of the river water, such as temperature, chemical composition, and the presence of contaminants, can influence how nylon interacts with the water. Harsh environmental conditions may accelerate the degradation of the material.

4.4 Impact Toughness

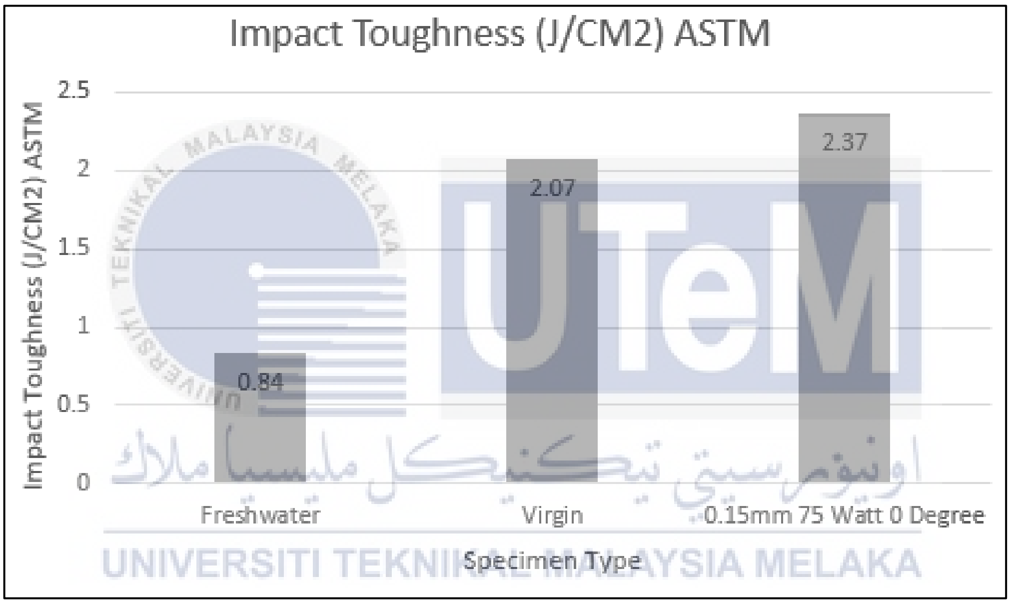

Figure 4.2 Impact Toughness Graph

This sample has undergone a specific treatment involving a thickness of 0.15mm, exposure to a 75-watt laser with an angle of 0 degrees. With an impact toughness of approximately 2.37 J/cm2, it signifies the highest ability among the conditions to absorb energy before breaking upon sudden impact. The high impact toughness suggests that this material is particularly resilient to sudden shocks or impacts. This could make it suitable for applications where resistance to impact is crucial, such as in structural components or materials subjected to dynamic loading.

The virgin sample represents the baseline material, untouched by any external factors or treatments. With an impact toughness of about 2.07 J/cm2, it indicates a moderate ability to absorb energy before breaking upon sudden impact. impact toughness suggests that the virgin sample has a balanced resistance to sudden impacts. It may find applications in scenarios where moderate impact resistance is sufficient, and the material hasn't been subjected to external factors that could affect its properties.

For impact toughness of freshwater, it has smaller than a virgin and 75-watt laser with an angle of 0 degrees. This is because the decrease in impact toughness can be attributed to the water absorption characteristics of nylon. Nylon is hygroscopic, meaning it tends to absorb moisture from the surrounding environment, including water from rivers. The absorbed water molecules can weaken the molecular structure of the nylon material and introduce additional stress concentrations, making it more susceptible to impact-induced fractures.

4.5 Elongation To Break

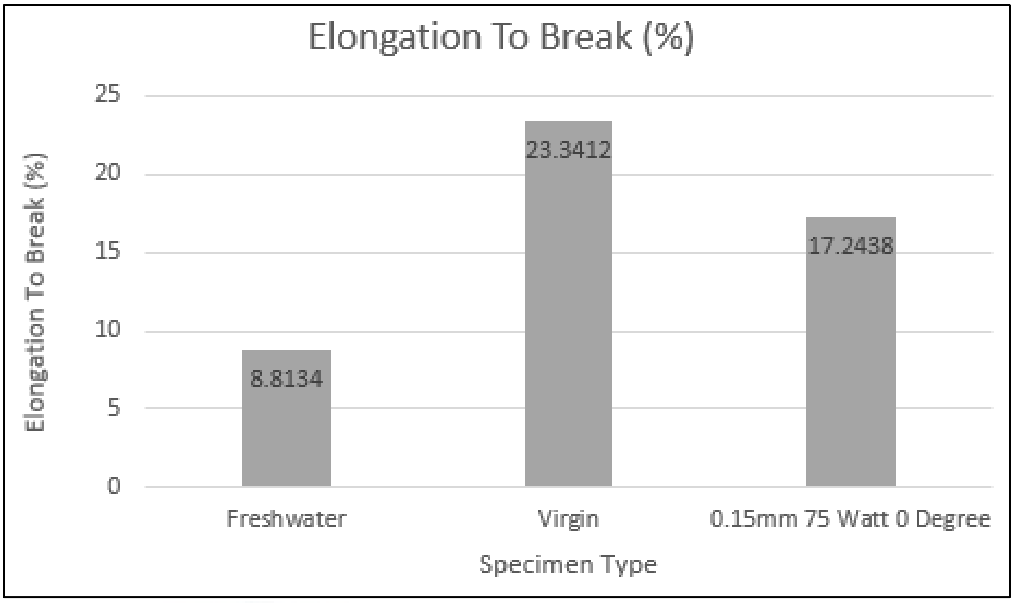

Figure 4.3 Elongation To Break Graph

This sample has undergone treatment with a laser beam, involving specific parameters like a power of 75 watts and an angle of 0 degrees. With an elongation to break percentage of about 17.24%, it falls between the virgin and brackish water samples, indicating a moderate level of flexibility. The moderate elongation to break suggests that the material, after laser treatment, maintains a balance between flexibility and potential structural modifications. This sample may find use in applications where a combination of flexibility and modified material properties is desirable**.**

The virgin sample represents the baseline material, free from exposure to external factors or treatments. With an elongation to break percentage of approximately 23.34%, it demonstrates high flexibility. This suggests that the material can stretch significantly before reaching its breaking point. The high elongation to break makes the virgin sample suitable for applications where flexibility is crucial. It might be ideal for scenarios where the material needs to undergo deformation or stretching without breaking, such as in certain manufacturing processes or products that require resilience.

The freshwater has smaller which is 8.8134 % other than else because of the water absorption may be causing changes in the internal structure of the nylon material. This could result in reduced flexibility and ductility, leading to a lower elongation at the point of fracture. The interaction between water and the nylon polymer chains may also introduce chemical changes, impacting the material's ability to withstand stress and strain.

4.6 Young' Modulus

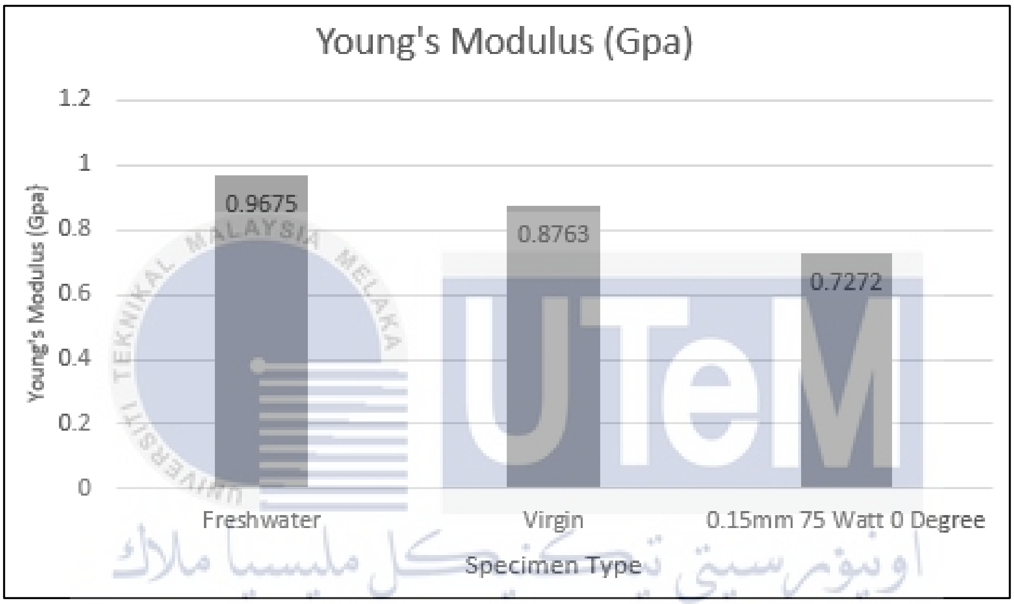

Figure 4.4 Young's Modulus Graph

0.15mm 75-Watt 0-Degree Sample approximately 0.73 GPa, signifying the lowest stiffness and rigidity among the conditions. The low Young's modulus suggests that the 0.15mm 75-Watt 0-Degree sample, treated with a laser beam, has become the least stiff and most flexible among the conditions. The modification from the laser treatment may have influenced the material's structure, resulting in reduced stiffness.

The virgin sample approximately 0.88 GPa, representing a moderate level of stiffness and rigidity. The moderate Young's modulus indicates that the virgin sample, which has not been exposed to environmental or mechanical factors, maintains a balanced level of stiffness. It is moderately rigid, suggesting that it can resist deformation to a reasonable extent while still retaining some flexibility.

The freshwater has higher which is 0.9675 other tan else. This is because water molecules within the nylon matrix can weaken the intermolecular forces that contribute to the material's original stiffness. Water acts as a plasticizer, reducing the overall stiffness of the material and causing a decrease in the Young's modulus.

4.7 % Increase Weight Before Vs After XYY

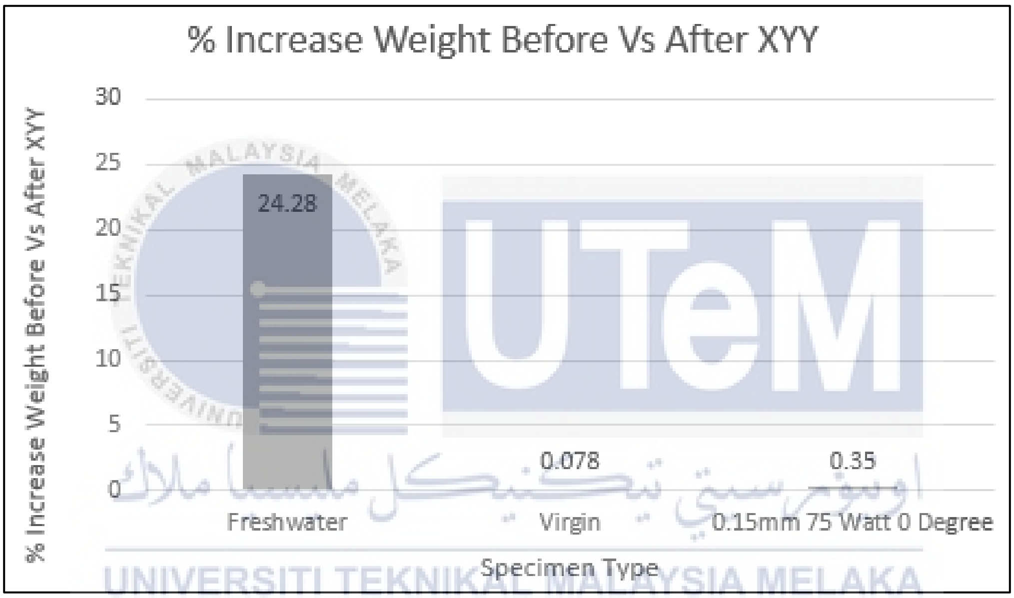

Figure 4.5 % Increase Weight Before Vs After XYY Graph

The percentage of 15mm 75 Watt 0-Degree Condition (Recycled PA12) Approximately 0.35%. The material, made from recycled PA 12 powder, underwent a treatment involving a laser beam with specific parameters (15mm, 75 watts, 0-degree). The moderate percentage increase in weight suggests that the laser treatment had a limited impact on water absorption compared to the freshwater condition. The material shows a moderate increase in weight, indicating a moderate level of water absorption under the specific treatment condition.

For the virgin sample it has lower percentage, which is 0.0078%. That is affect the virgin powder, which was not previously exposed to environmental factors, exhibited minimal absorption of tiny particles when soaked in fresh water. The low percentage increase in weight suggests that the material did not absorb much water and experienced limited expansion. This condition indicates that the virgin material has low water absorption characteristics, likely due to its pristine state.

For the fresh water, it has higher percentage which is 24.28%. The absorbed water molecules can weaken the polymer chains, affecting the overall performance of the material. Additionally, the dimensional stability of nylon may be compromised, leading to changes in size and shape.

4.8 Scanning Electron Microscope

To investigate the micro mechanisms leading to the failure of Selective Laser Sintering (SLS) materials, the fracture surfaces were meticulously examined through electron scanning micrography (SEM). The surfaces underwent gold coating to enhance conductivity and were scrutinized using a SEM ZEISS EVO MA15 in secondary electron mode. The images were captured from the fractured surfaces of samples post-tensile testing. Notably, the tensile fracture surfaces exhibited significant changes after a 40-day immersion in fresh water, as revealed by the SEM analysis. Subsequent inspection of these samples showcased obvious alterations. Moreover, the density of the parts, crucial for understanding structural changes, was documented, and can be referenced in the provided table. This comprehensive approach sheds light on the microstructural transformations and failure mechanisms occurring in SLS materials, particularly when subjected to extended periods of exposure to fresh water.

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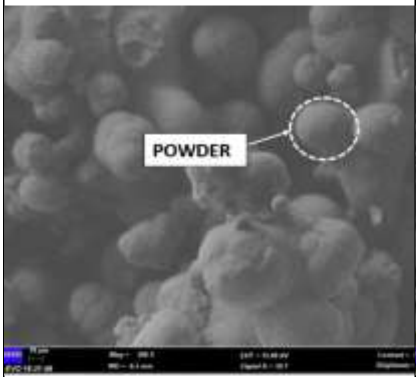
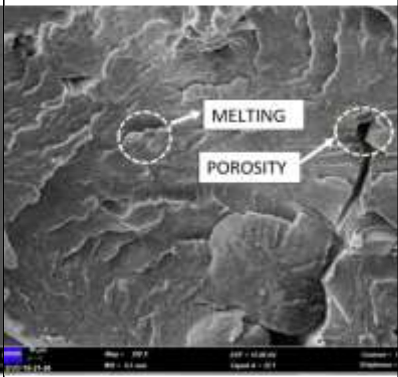
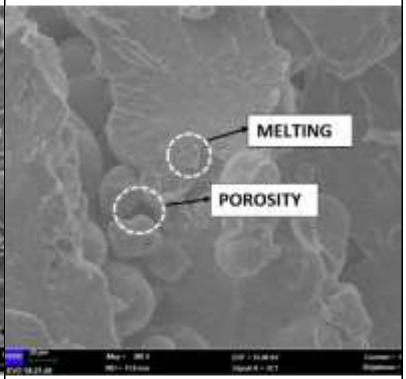
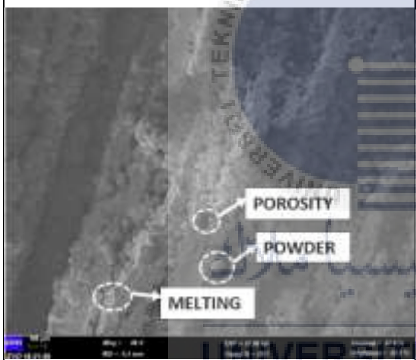
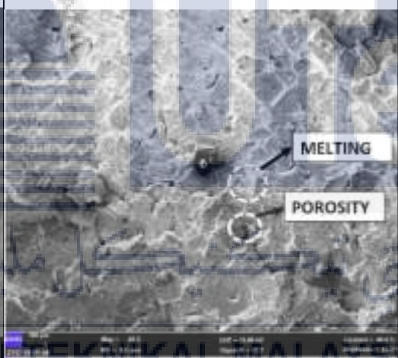
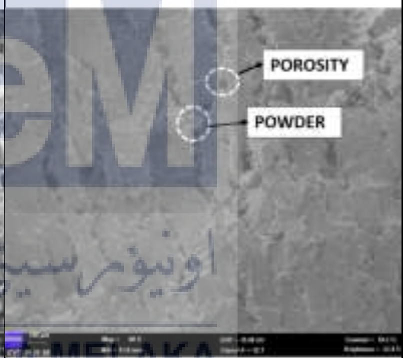
<table>
<tr><th>Virgin</th><th>Before Soaked River Water</th><th>After Soaked River Water</th></tr>
<tr>
<td>(a) Zoom in (300x magnification)
</td>
<td>(b) Zoom in (300x magnification)
</td>
<td>(c) Zoom in (300x magnification)
</td>
</tr>
<tr>
<td>(d) Zoom out (40x magnification
</td>
<td>(e) Zoom out (40x magnification)
</td>
<td>(f) Zoom out (40x magnification)
</td>
</tr>
</table>

Table 4.6 The picture of SEM between Virgin, before soaked River Water and After Soaked River Water

CHAPTER 5

Conclusion And Recommendation

5.1 Conclusion

This investigation's structure is comparable to another thesis in this study. There are differences in the equipment selected, the research approach used during the investigation, and the use of PA-12 material as the analysis subject. Significantly, when recycled PA-12 powder was tested, encouraging results were found, confirming the recycled material's ongoing suitability for usage in every printing cycle.

This thesis explores experiments designed to maximize the performance of recycled SLS materials and shows that they perform almost as well as virgin materials. Weighing considerations including weight, poundage, flexibility, and strength (durability) is part of the decision-making process. The research focuses on material testing for the HydroQS housing, highlighting the importance of selecting a material that is both acceptable and lightweight. Over several printing cycles, the inquiry on the ideal print orientation, namely XYY0, has shown consistently positive results.

By comparing the XYY0 orientation print cycle with virgin powder using the SLS machine, the experiment achieves its goal. The XYY0 orientation cycle has the best surface roughness and has a beneficial effect on PA-12.

5.2 Recommendation

To enhance the nylon FS3300PA study, future research can focus on exploring the cyclic behaviour of the printed samples to identify the optimal printing cycle. Additionally, thorough investigation into the drying process duration of the samples is crucial to guarantee consistent weekly weight readings. The study can be extended to include measurements of water parameters such as pH-value, turbidity, and electrical conductivity to assess their potential impact on the nylon FS3300PA samples. Furthermore, it is imperative to refine the accuracy of measurements by utilizing a fixed vernier caliper to minimize any zero errors associated with the equipment. These improvements collectively contribute to a more comprehensive understanding of the material's behavior and the factors influencing its properties, facilitating more accurate and reliable results in future studies.

To enhance the outcomes of recycled prints in this report, several key measures can be implemented. Firstly, a valuable addition would involve comparing the recycled prints with orientations printed using Selective Laser Sintering (SLS) technology, providing a broader perspective on the material's performance. Secondly, exploring the use of different PA-12 materials within the same orientation print can offer insights into variations and optimal choices. Thirdly, advocating for the application of the best recycled prints in manufacturing HydroQS housings can not only contribute to sustainability but also result in cost savings without compromising quality when compared to virgin prints. Additionally, the implementation of coatings to prevent the absorption of tiny particles into the material is crucial for enhancing durability. Lastly, assessing SLS prints with varying printed power during each recycle print cycle can further refine the understanding of the material's behaviour. Collectively, these recommendations, based on the research findings, are particularly well-suited for improving the quality and cost-effectiveness of HydroQS housings.

5.3 Project Potential

This paper introduces a vital avenue of material research aimed at enhancing water monitoring equipment development, specifically focusing on a device constructed from nylon FS3300PA in Malaysia, known for its rapid water absorption properties. The proposal suggests a crucial direction for further exploration, emphasizing the need to minimize water absorption in both the prototype and actual product. Leveraging the capabilities of a Selective Laser Sintering (SLS) machine, the research aims to optimize the tensile strength of the final product or prototype. Beyond the manufacturing aspects, the study extends to investigating the impact of fresh water on the characteristics and structure of nylon FS3300PA after 1000 hours of immersion. By delving into this comprehensive research framework, the paper offers a valuable foundation for advancing the effectiveness and durability of water monitoring devices, with potential applications and implications for environmental monitoring in fresh ecosystems, particularly in the context of Malaysia.

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