TO STUDY THE EFFECT OF MECHANICAL PROPERTIES ON THE UV-EXPOSED EXTREMELY USAGE AGED FS3300PA PA-12 POWDER BASED ON YZY 0 DEGREE SINTERING ORIENTATION

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A thesis submitted in fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (BMKM) with Honours

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

DECLARATION

I declare that this Choose an item. entitled ‘’to study the effect of mechanical properties on the UV-exposed extremely aged FS3300PA PA-12 powder based on XYY 0 degree sintering orientation” is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Muhammad Ismal Haqif Bin Ahmad Zahida

Date : 13 January 2025

APPROVAL

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

Signature :

Supervisor Name : Dr Shamsul Faisal Bin Mohd Hussein

Date : 15 January 2025

DEDICATION

Behind my academic success is a journey marked by challenges, growth, and invaluable support. To my beloved parents, your unhesitating inspiration and sacrifices have been the backbone of my success. I want to thank my mother Azimah Binti Awang for the endless love and belief in me that have fueled my determination even in the toughest time. Many thanks to my dad Ahmad Zahida Bin Ismail, their wisdom and guidance have shaped my path and instilled in me the resilience to overcome obstacles. They both deserve my gratitude for all of the sacrifices they made for me when I was a student at this institution and for the assistance they provided in the form of guidance, funding, and encouragement as I prepared this report. Next, I'd want to thank everyone who helped me with this final year project, especially Dr Shamsul Faisal bin Mohd Hussein, my supervisor, Ts. Mohd Idain Fahmy Bin Rosley and my friends.

ABSTRACT

FS3300PA PA-12 powder is a high-performance polyamide 12 (PA-12) material developed for use in powder bed fusion (PBF) additive manufacturing processes. With its excellent mechanical properties, chemical resistance, and thermal stability, FS3300PA PA-12 powder offers a versatile solution for a wide range of applications across various industries. The powder exhibits outstanding layer-to-layer adhesion and part density, ensuring the production of robust and dimensionally accurate components. Its fine particle size distribution enables smooth powder spreading and uniform laser sintering, leading to superior surface finish and intricate part geometry. FS3300PA PA-12 powder demonstrates exceptional mechanical strength, including high tensile and flexural modulus, making it suitable for applications demanding structural integrity and durability. Its inherent toughness and impact resistance further enhance its suitability for end-use parts subjected to dynamic loading and harsh operating conditions. Furthermore, FS3300PA PA-12 powder showcases excellent chemical resistance, maintaining its properties when exposed to oils, greases, fuels, and a variety of chemicals. This feature expands its utility in applications requiring resistance to corrosive environments or contact with aggressive substances. The material's thermal stability ensures reliable performance across a broad temperature range, making it suitable for applications requiring heat resistance or exposure to elevated temperatures during operation. This characteristic is particularly advantageous in automotive, aerospace, and industrial applications where components may experience fluctuating thermal conditions. In conclusion, FS3300PA PA-12 powder offers a compelling combination of mechanical strength, chemical resistance, and thermal stability, making it a preferred choice for additive manufacturing applications where performance and reliability are paramount. Its versatility and consistent processing characteristics make it wellsuited for producing functional prototypes, end-use parts, and tooling across diverse industries, contributing to advancements in additive manufacturing technology and accelerating product development cycles.

ABSTRAK

FS3300PA Serbuk PA-12 adalah bahan poliamida berprestasi tinggi 12 (PA-12) yang dibangunkan untuk digunakan dalam proses pembuatan bahan tambahan “powder bed fusion” (PBF). Dengan sifat mekanikal yang sangat baik, rintangan kimia, dan kestabilan haba, serbuk FS3300PA PA-12 menawarkan penyelesaian serba boleh untuk pelbagai aplikasi di pelbagai industri. Serbuk ini mempamerkan lekatan lapisan ke lapisan dan ketumpatan bahagian yang luar biasa, memastikan pengeluaran komponen yang mantap dan tepat dari segi dimensi. Pengagihan saiz zarah halusnya membolehkan penyebaran serbuk licin dan pensinteran laser seragam, yang membawa kepada kemasan permukaan yang unggul dan geometri bahagian yang rumit. Serbuk FS3300PA PA-12 menunjukkan kekuatan mekanikal yang luar biasa, termasuk modulus tegangan dan lentur yang tinggi, menjadikannya sesuai untuk aplikasi yang menuntut integriti dan ketahanan struktur. Keliatan yang wujud dan rintangan hentaman meningkatkan lagi kesesuaiannya untuk bahagian penggunaan akhir yang tertakluk kepada beban dinamik dan keadaan operasi yang keras. Tambahan pula, serbuk FS3300PA PA-12 mempamerkan rintangan kimia yang sangat baik, mengekalkan sifatnya apabila terdedah kepada minyak, gris, bahan api dan pelbagai bahan kimia. Ciri ini mengembangkan utilitinya dalam aplikasi yang memerlukan ketahanan terhadap persekitaran yang menghakis atau sentuhan dengan bahan agresif. Kestabilan haba bahan memastikan prestasi yang boleh dipercayai merentas julat suhu yang luas, menjadikannya sesuai untuk aplikasi yang memerlukan rintangan haba atau pendedahan kepada suhu tinggi semasa operasi. Ciri ini amat berfaedah dalam aplikasi automotif, aeroangkasa dan industri di mana komponen mungkin mengalami keadaan terma yang turun naik. Kesimpulannya, serbuk FS3300PA PA-12 menawarkan gabungan kekuatan mekanikal, rintangan kimia, dan kestabilan haba yang menarik, menjadikannya pilihan pilihan untuk aplikasi pembuatan bahan tambahan yang prestasi dan kebolehpercayaan adalah yang paling utama. Kepelbagaian dan ciri pemprosesan yang konsisten menjadikannya sangat sesuai untuk menghasilkan prototaip berfungsi, bahagian guna akhir dan perkakasan merentasi pelbagai industri, menyumbang kepada kemajuan dalam teknologi pembuatan aditif dan mempercepatkan kitaran pembangunan produk.

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

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Last but not least, from the bottom of my heart a gratitude to my family, especially my mother Azimah binti Awang and my father Ahmad Zahida bin Ismail for their encouragements and for the moral support they provided me during the time that I was working on my research paper. I am very grateful and thankful to my classmate, and housemate for their patience and understanding. Finally, I would also like to extend my gratitude to my caring parents for the continuous support, love, and prayers they have shown me throughout this difficult time. Lastly, I want to thank everyone who has assisted and motivated me to continue my education in the university.

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LIST OF SYMBOLS AND ABBREVIATIONS

oc - 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/cm^3 - Sintered Density g/mL -

Absorption rate and Density g/min -

Melt Flow Rate (MFR)

NWQS - National Water Quality Standard (ANNEX)

SEM - Scanning Electron Microscope

MRC - Melaka River Cruise

$MgCl_2$ - Magnesium chloride $MgSO_4$ - magnesium sulphate $CaCO_3$ - 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

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CHAPTER 1

INTRODUCTION

1.1 Introduction

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. (Jackson et al, 2001). 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). 2 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.

Material type Nylon 12, regularly known as PA-12, is a basic polymer utilized within the fabricate of the HydroQS framework lodging due to its alluring and unusual physical qualities. PA-12 may be an exceptionally reasonable fabric for an assortment of applications. PA-12's mechanical qualities incorporate hardness, ductile quality, and affect resistance. Another advantage of PA-12 is its great chemical resistance and solidness, which can deliver it great solidness in high-temperature conditions and in an assortment of scenarios. With the development of 3D printing innovation, PA-12 material is progressively being used to make nittier gritty and correct added substances perfect for the fabricating of the HydroQS lodging, making it simpler to connect to other segments of the lodging. PA-12 fabric powder can be reused for taken a toll reserve funds and sintered in powder frame with a particular laser sintering handle. The utilize of PA-12 fabric is additionally advantageous in decreasing the mass of the HydroQS lodging.

Another, the utilize of polyamide powder (PA-12) is chosen to be utilized in creating the lodging for the Hydro Quality Estimation mainbody (HydroQS) since PA-12 is the foremost reasonable fabric after its properties have been inquired about. The Farsoon SS402P Selective Laser Sintering Machine will be used to deliver the HydroQS main body as well as the laser sintering innovation, and the housing's performance will be considered to assess the quality of its mechanical properties.

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.

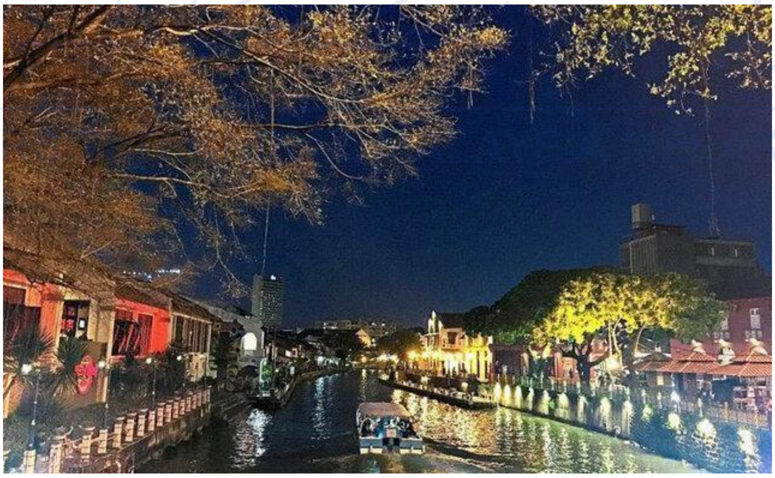


Figure 1.1 Melaka River Cruise **1.3**

Objectives

i. To study the dimensional stability and water absorption of the virgin and extremely aging powder PA-12 based on YZY 0-degree orientation, different laser power 65,70,75 watt and layer thickness 0.09mm, 0.12mm, 0.15mm before and after UV exposure.
ii. To study the mechanical properties of the virgin and extremely aging powder PA-12 based on YZY 0-degree orientation, different laser power 65,70,75 watt and layer thickness 0.09mm, 0.12mm, 0.15mm before and after UV exposure.
iii. To study the fracture behaviour of the virgin and extremely aging powder PA-12 based on YZY 0-degree orientation, different laser power 65,70,75 watt and layer thickness 0.09mm, 0.12mm, 0.15mm before and after UV exposure.

1.4 Scope of Research

i. To define the dimensional stability and water absorption of the virgin and extremely aging powder PA-12 based on YZY 0-degree orientation, different laser power 65,70,75 watt and layer thickness 0.09mm, 0.12mm, 0.15mm before and after UV exposure.
ii. To define the mechanical properties of the virgin and extremely aging powder PA-12 based on YZY 0-degree orientation, different laser power 65,70,75 watt and layer thickness 0.09mm, 0.12mm, 0.15mm before and after UV exposure.
iii. To define the fracture behaviour of the virgin and extremely aging powder PA-12 based on YZY 0-degree orientation, different laser power 65,70,75 watt and layer thickness 0.09mm, 0.12mm, 0.15mm before and after UV exposure.

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 Additive Manufacturing

Additive manufacturing (AM), also known as 3D printing, is a revolutionary technology that creates three-dimensional objects by adding successive layers of material. Unlike traditional subtractive manufacturing methods that involve cutting away material from a solid block, additive manufacturing builds up layers until the final object is formed. Additive manufacturing works by slicing a digital 3D model into thin layers, typically using software like CAD (Computer-Aided Design). (Reichenbach S.,2021). These layers are then sequentially printed one on top of another until the complete object is formed. A wide range of materials can be used in additive manufacturing, including plastics, metals, ceramics, and even living cells for bioprinting applications. The choice of material depends on the specific requirements of the printed object, such as strength, flexibility, heat resistance, or biocompatibility.

2.2.1 Types of Additive Manufacturing

Additive manufacturing encompasses several types of technologies, each with its own unique approach to building three-dimensional objects layer by layer. Here are some of the main types of additive manufacturing processes:

2.2.1.1 Fused Deposition Modeling (FDM):

FDM extrudes thermoplastic filament through a heated nozzle, which melts the material. The nozzle moves along a predefined path to deposit the material layer by layer, solidifying as it cools. Common materials include ABS, PLA, PETG, and various engineering-grade plastics and use to prototyping, concept modeling, low-volume production of plastic parts.

2.2.1.2 Stereolithography (SLA)

SLA uses a UV laser to cure liquid resin layer by layer on a build platform. The laser selectively traces the cross-section of the object on the surface of the resin, solidifying it. The SLA help to make high-detail prototypes, jewelry, dental applications, and custom parts with smooth surface finishes.

2.2.1.3 Selective Laser Sintering (SLS):

SLS uses a high-powered laser to selectively fuse powdered material (typically plastic, metal, or ceramic) into a solid structure layer by layer. The unsintered powder acts as support for the object during printing and use material such as nylon, polyamide, metals such as aluminum, titanium, and cobalt-chrome alloys. The SLS make a functional prototype, end-use parts, tooling inserts, and complex geometries.

2.2.1.4 Direct Metal Laser Sintering (DMLS):

Similar to SLS but specifically for metals, DMLS uses a high-powered laser to sinter or melt metal powder particles together layer by layer, forming solid metal parts and use various metals including stainless steel, titanium, aluminum, and nickel alloys and in produce aerospace components, medical implants, automotive parts, and high-performance industrial components requiring metal strength and durability.

2.2.1.5 Material Jetting

Material jetting operates similarly to inkjet printing but uses multiple print heads to jet photopolymer materials onto a build platform. Each layer is cured with UV light to solidify the material such as photopolymer resins with various properties and colors. The Material jetting produce a high-detail prototypes, dental molds, and parts requiring multi-material properties or full-color printing capabilities.

2.2.2 Advantages of Additive Manufacturing

The advantages of additive manufacturing are complex geometries can be created without the constraints of traditional manufacturing techniques. Furthermore, additive manufacturing can be more material-efficient compared to subtractive methods since it adds material only where needed. The speed and efficiency of prototyping and production can be faster and more cost-effective for low-volume batches. Also, Objects can be printed on-demand, reducing storage needs and allowing for just-in-time manufacturing.

2.3 3D Printing

3D printing, also known as additive manufacturing (AM), is a process of creating threedimensional objects from a digital model. Unlike traditional manufacturing methods that involve subtracting material from a solid block to achieve the desired shape, 3D printing builds objects layer by layer from the bottom up. This additive process allows for greater design flexibility and complexity, making it suitable for a wide range of applications across various industries. (T.C. Lee,. 2019). 3D printing has a wide range of applications across various industries and sectors such as prototyping and product development, customization, manufacturing, education and research, and art and design. Overall, 3D printing continues to evolve and expand its capabilities, offering new opportunities for innovation, efficiency, and creativity in manufacturing.

2.3.1 Difference 3D Printing and Additive Manufacturing

The terms "3D printing" and "additive manufacturing" (AM) are often used interchangeably, but they can have slightly different connotations depending on context. Here are the main differences between 3D printing and additive manufacturing. The 3D Printing is more commonly used in casual or consumer contexts to refer to the process of creating threedimensional objects layer by layer from a digital model. It tends to emphasize the accessibility and ease of use of the technology. For additive manufacturing (AM) it encompasses all processes and technologies that build objects layer by layer through the addition of material. AM is often used in industrial and technical contexts, emphasizing the wide range of materials, processes, and applications beyond just plastics. (N. Shahrubudin, 2019).

2.4 Powder Bed Fusion

Powder bed fusion (PBF) is a type of additive manufacturing (AM) technology that builds parts layer by layer from powdered materials. It is particularly known for its ability to produce complex geometries and functional prototypes with high precision. Here’s how powder bed fusion works and its key characteristics. The process begins with a digital 3D model created using Computer-Aided Design (CAD) software. This model is sliced into thin layers (crosssections) using slicing software, which generates the instructions for the printer. Powder bed fusion typically uses a fine layer of powdered material (such as metal, plastic, or ceramic) spread evenly over a build platform. A high-energy source, such as a laser or an electron beam, selectively melts or sinters the powdered material according to the sliced design. (Vishal T., 2023).

2.4.1 Type of Powder bed blends (PBF)

Powder bed blends (PBF) are a kind of additive manufacturing (AM) innovation that makes things by specifically intertwining powdered materials layer by layer employing a warm source. The PBF prepare is well-known for its capacity to produce complicated geometries with awesome exactness, making it suited for a wide extend of applications in segments like aviation, car, and therapeutic. PBF is classified into various sorts, which incorporate:

i. Selective Laser Sintering (SLS)
ii. Direct Metal Laser Sintering (DMSL)
iii. Selective Laser Melting (SLM)
iv. Electron Beam Melting
v. Multi Jet Fusion (MJF)

2.4.2 Advantages of PBF in 3D Printing

Powder bed fusion (PBF) is a type of additive manufacturing technology that offers several distinct advantages, making it highly suitable for various industrial applications. Here are the key advantages of PBF in 3D printing. PBF enables the creation of highly complex geometric shapes that are difficult or impossible to achieve with traditional manufacturing methods. This includes intricate internal structures, lattices, and organic shapes, which can be crucial in industries like aerospace and biomedical where lightweight and optimized designs are essential. PBF supports a wide range of materials, including metals (such as titanium, aluminum, stainless steel, and nickel alloys), plastics (like nylon and polyamide), and ceramics. (Di Cataldo et al., 2021). This versatility allows for the production of parts with specific material properties such as strength, durability, heat resistance, and biocompatibility, catering to diverse industry needs. PBF is capable of producing parts directly from digital designs without the need for tooling or molds, significantly reducing lead times and costs associated with traditional manufacturing processes. This makes it ideal for rapid prototyping and low to medium volume production of customized or specialized components. PBF utilizes a powder bed as the raw material, where only the material that is sintered or melted becomes part of the finished object. Unused powder can be recycled and reused in subsequent builds, minimizing material waste compared to subtractive manufacturing methods. (Dzetzit et al., 2019). Overall, the advantages of powder bed fusion in 3D printing underscore its capability to revolutionize manufacturing processes by offering enhanced design freedom, efficiency, material versatility, and quality control across a wide range of applications and industries.

2.5 Selective Laser Melting (SLM)

Selective laser melting (SLM) may be a strategy that includes applying metallic powder materials that are destitute of folios and fluxing specialists, at that point warming until reach to dissolving temperature with a laser bar such that the layer of metallic powder is completely liquefied all through. SLM is very comparable to specific laser sintering (SLS), which utilizes sintering or partial softening to bond powder particles rather than totally dissolving (Džugan & Novy, 2017).

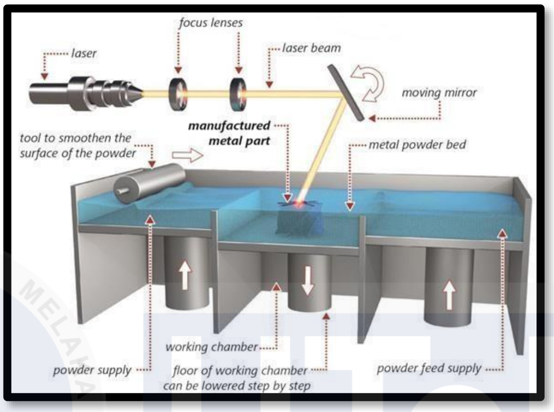


Figure 2. 1: Selective Laser Melting

2.5.1 Work Process of SLM

First, designing a 3D model of the part using CAD software is the initial step. After the 3D model is complete, it is transformed into an STL file, which includes all the necessary part geometry information in a series of triangles. After that, involves using cutting software to slice the STL file into thin horizontal layers. Every layer corresponds to the intersection of the part that will be printed. The cutting software also creates a tool path for the laser beam to follow on each layer. Then, print the parts using the SLM machine. The SLM machine is comprised of four primary components: the powder bed, the flour delivery system, the laser source, and the scanning system. In addition, involves the cooling of the components within the machine. The cooling process may require a significant amount of time, varying based on the dimensions and shape of the component. The cooling process is crucial in preventing thermal pressure and distortion, which could potentially compromise the quality and precision of the components.

Removing the part from the machine. This component is typically connected to the base plate, which is constructed using metal powder. This part is typically separated from the base plate using wire electrical discharge processing (EDM) or a tape knife. The excess powder surrounding the part can be effectively removed through the use of a brush or air explosion. Unused powder can be repurposed and utilized for future printing. Lastly, processing the next part to enhance surface coverage, mechanical properties, and dimensional accuracy. Postprocessing methods typically involve various techniques such as heat treatment, tumbling, machining, polishing, and coating. The post-processing method is determined by the material, application, and specifications of the part.

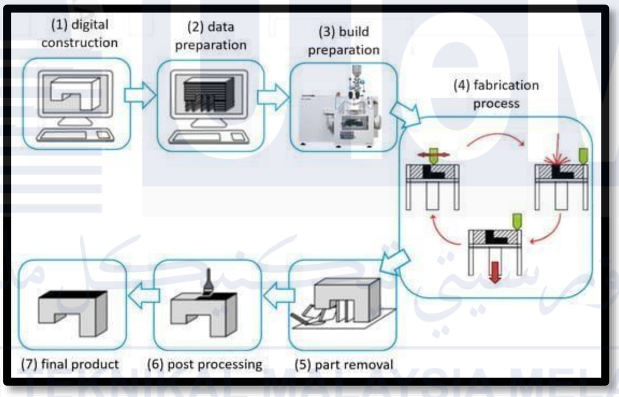


Figure 2.2: Process of Selective Laser Melting

2.5.2 Material Used in SLM

Selective Laser Melting (SLM) is an additive manufacturing (AM) technology that makes a complex three-dimensional (3D) protest by softening powder materials with a laser bar. SLM is regarded one of the foremost flexible innovations since it can treat a wide run of materials, particularly metals and combinations. Its best-suited employments are within the aviation, car, development, and jewelry segments (İndap, S. & Tanyaş, S. 2023).

Various materials exhibit distinct properties that cater to a wide range of applications across industries. Steel and iron-based alloys are renowned for their high corrosion resistance, considerable strength, rough surface texture, and a relative density exceeding 90%. These characteristics make them highly suitable for medical implants, orthodontic products in dentistry, heat exchangers, and lightweight structures such as honeycomb designs (William D. Callister Jr.,2020).

Titanium-based alloys offer exceptional properties including a high relative density exceeding 98%, greater shear strength comparable to or better than alternatives, specific surface roughness, and low absorbency. These attributes reduce them indispensable in medical applications such as body prosthetic device and dental implants, as well as in lightweight structural components like shells (Igor S. Golovin, 2022).

Nickel-based alloys, characterized by high temperature resistance, fatigue strength, good corrosion resistance, and excellent weld material, approach almost perfect density levels. This makes them decisive in high-demand environments such as aircraft engines and combustion chambers (Roger C. Reed, 2021).

Additionally, other metals like aluminium and cobalt-chrome, with relative densities exceeding 96%, stand out for their high strength and suitability in biomedical applications such as crowns, bridges, and implants. Aluminium, known for its strength at 400 MPa, and the enhancement of material toughness with powdered copper, find extensive use in heat exchangers, automotive components, and jewellery (Michael F. Ashby, 2022).

Ceramics, despite being fragile and characterized by high melting temperatures and surface roughness, serve critical roles in medical and dental fields for bone substitution implants, as well as in thin-wall structures, electrical or thermal insulation, and wear-resistant coatings (Barryand, C. and Grant Norton M., 2021). Each material type thus contributes uniquely to technological advancements and industrial applications, driven by their specific properties personalized to diverse engineering needs.

2.5.2 Advantages and Disadvantages of SLM

Selective Laser Melting (SLM) is a powerful additive manufacturing technology that offers several advantages and, like any manufacturing process, comes with its own set of challenges. There are the main advantages and disadvantages of SLM.

2.5.2.1 Advantages

The SLM allows for the production of highly complex geometries, including internal structures and intricate designs, that are difficult or impossible to achieve with traditional manufacturing methods. This capability is crucial in industries such as aerospace and biomedical where lightweight and optimized designs are essential. The additive nature of SLM enables designers to create parts with intricate features and integrated functionalities, reducing the need for assembly of multiple components. This flexibility supports rapid prototyping and the customization of parts according to specific requirements. SLM can process a wide range of materials, including various metals and alloys such as titanium, aluminium, stainless steel, nickel-based superalloys, and cobalt-chrome alloys. This versatility allows for the production of parts with specific mechanical, thermal, and chemical properties suitable for different industrial applications.

2.5.2.2 Disadvantages

SLM machines are complex and expensive, requiring significant initial investment and ongoing operational costs for maintenance, energy consumption, and materials. This can be a barrier for smaller businesses or startups. Parts produced by SLM often have rough surfaces that require post-processing such as machining, polishing, or heat treatment to achieve the desired surface finish and dimensional accuracy. This adds to the overall production time and cost. SLM machines have limitations on the size of parts that can be produced due to the size of the build chamber and constraints related to thermal stresses and distortion during the printing process. Large or oversized parts may require multiple print runs and assembly. (Wang et al., 2020).

2.6 Selective Laser Sintering (SLS)

Specific Laser Sintering (SLS) may be a powder-based added substance fabricating innovation that employments a laser to liquefy and combine fine polymer particles, making complicated 3D objects. It has a place to the control bed combination AM category and is known for its reasonableness, productivity, capacity to print complex shapes, and wide fabric choices. SLS 3D printing is perfect for rapidly making models, amassing utilitarian models, creating pre-production parts, and building test rigs. Its capacity to print parts with lean dividers and complex inside structures makes it a well-known choice in businesses like aviation, car, and restorative gadgets.

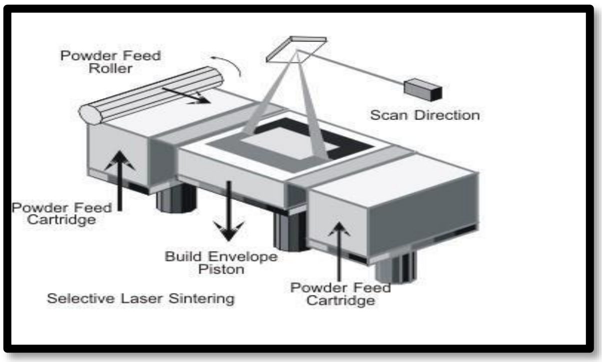


Figure 2.3: Selective Laser Sintering

2.6.1 Work Process of Selective Laser Sintering (SLS)

Selective Laser Sintering (SLS) is an additive manufacturing technology that builds parts layer by layer from powdered materials, typically polymers or metals. Here's a step-by step outline of the SLS process. The process begins with the creation of a 3D computer-aided design (CAD) model of the part to be manufactured. This digital model defines the geometry and specifications of the final part. A thin layer of powdered material is evenly spread onto the build platform inside the SLS machine. The thickness of each layer can range from tens to hundreds of microns, depending on the material and desired resolution. (Yadav P., 2020).

A high-powered laser selectively scans and sintering the powdered material according to the cross-sectional shape of the part from the CAD model. The laser selectively heats and melts or sinters the powder particles together to form a solidified layer. After the first layer is sintered, the build platform is lowered by one layer thickness, and a new layer of powder is spread over the previously sintered layer. The laser then sinters this new layer onto the previous one. This process of spreading a layer of powder, selectively sintering it with a laser, and repeating continues until the entire part is built.

Once the printing process is complete, the build chamber is allowed to cool down. The built parts are then removed from the surrounding powder bed. Post-processing steps may include removing excess powder from the parts, thermal treatment to improve material properties, and finishing processes such as sanding or polishing.

In some cases, support structures may be added during the printing process to support overhanging features. These supports are typically made from the same material as the part and are removed after printing through mechanical or chemical means. The printed parts undergo inspection and testing to ensure they meet the desired specifications and quality standards. This may include dimensional accuracy checks, mechanical property testing, and surface finish evaluations.

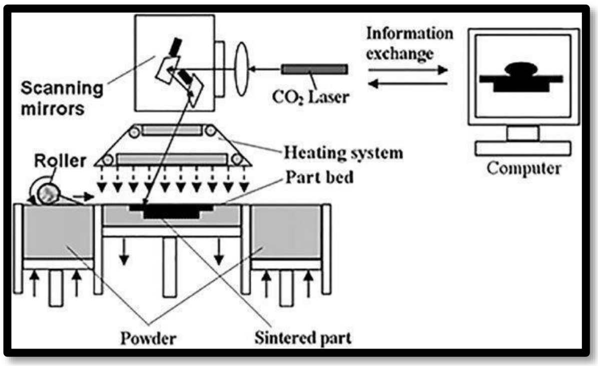


Figure 2.4: Process of Selective Laser Sintering

2.6.2 Material Used in SLS

Selective Laser Melting (SLM) is a powder bed fusion additive manufacturing (AM) technology used for metals. The materials used in SLM must meet specific requirements to ensure proper melting, solidification, and mechanical properties of the printed parts. PA-11 is one of the materials that use in SLM and it resists impact well. Comparison between PA11 and PA12 reveals that PA11 can withstand greater temperatures and more deformation before breaking. Other than that, PA-12 the material is biocompatible, that is strong, stiff, and has good chemical resistance. Compared to PA-11, PA-12 has reduced heat resistance. The most often utilized material in SLS printing is PA-12. Furthermore, thermoplastic Urethane (TPU) also one of the materials, the TPU melt-processable thermoplastic elastomer and has unique features that enable enhanced processing, particularly when exposed to SLS 3D printing. TPU can be broken down and reused, making it more environmentally friendly and recyclable. Has a smooth finish and great wear resistance. Also, Thermoplastic elastomers (TPE), the material possesses rubber-like elasticity, that is strong and abrasion resistant. It may also be adjusted to have varying hardness on the Shore A scale. Lastly, the Polypropylene (PP) are the most frequent types of polyethylene used in 3D printing, owing to its strength, flexibility, durability, and recyclable nature.

2.6.3 Advantages and Disadvantage of SLS

Selective Laser Sintering (SLS) is another additive manufacturing technology that uses a highpowered laser to sinter powdered materials into solid parts. There are some main advantages and disadvantages of SLS.

2.6.3.1 Advantages

Selective Laser Sintering (SLS) is another additive manufacturing technology that uses a high-powered laser to sinter powdered materials into solid parts. The SLS no need for support structures unlike some other 3D printing technologies, SLS does not require support structures because the unsintered powder acts as a self-supporting material during printing. This reduces material waste and simplifies post-processing. The SLS can process a variety of materials, including thermoplastics, ceramics, and metal powders. This versatility allows for the production of parts with different mechanical, thermal, and chemical properties suitable for various applications. Other than that, SLS enables the fabrication of complex geometries, including internal structures and intricate designs, without the need for assembly of multiple components. This capability is beneficial for producing lightweight parts with optimized designs. (Han et al., 2022).

2.6.3.2 Disadvantages

Parts produced by SLS often have a rough surface finish compared to other additive manufacturing technologies like Stereolithography (SLA) or Fused Deposition Modeling (FDM). Additional post-processing such as sanding, polishing, or coating may be required to achieve a smoother surface. Then, While SLS materials offer good mechanical properties, they may not always match the properties of injection-molded parts or parts produced by traditional manufacturing methods. Material shrinkage and warping during cooling can affect dimensional accuracy and part performance. Also, Handling and managing fine powders used in SLS require careful attention to safety protocols due to potential health risks associated with powder inhalation and fire hazards. Proper ventilation, protective equipment, and powder containment systems are necessary in SLS facilities. (Tamez & Taha, 2021).

2.7 PA-12 Virgin Powder

The following PA-12 materials can be used with Farsoon machines: FS 3200PA and working with PA-12 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 color stability. Additionally, it has all of these qualities while also being antioxidative. Because it has an affinity for water and is hydrophilic, PA-12 is frequently used to measure water activity. PA-12 may be used as a casing to regulate the flow of water vapour into and out of a sample because it has a predictable and constant water vapour transmission rate. For many reasons, PA-12 is a preferred material for selective laser sintering (SLS) equipment. Like PA12, which has a high melting point, this property allows it to tolerate high temperatures during the SLS process without melting or deforming (Carmel, 2019). Many different types of powder material used for SLS have been reported frequently, especially composites based on polymers, such as PA-12. 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. High strength, stiffness, a great resistance to cracking under stress, and excellent long-term consistent behavior 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 (nitrogencontaining organic compounds) than any other commercially available polyamide (S.C. Ligon, 2017).

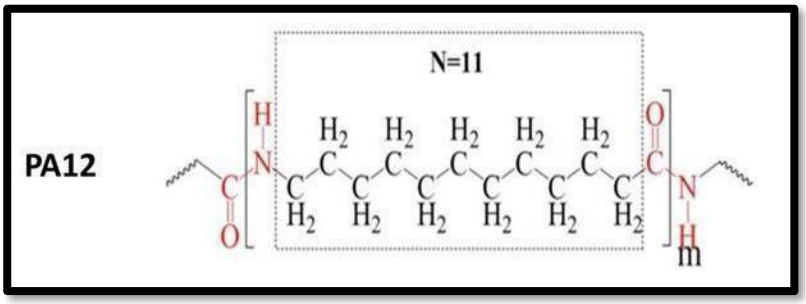


Figure 2. 5: Crystal Structure of PA-12

2.7.2 Extremely Ageing in PA-12

PA-12 is a thermoplastic polymer known for its resilience and durability. However, like many polymers, PA-12 can undergo changes over time due to various environmental factors and stresses, leading to what is often referred to as extreme aging. Extreme aging in PA-12 typically shows as degradation of its mechanical properties and physical appearance. This degradation can be accelerated by exposure to ultraviolet (UV) radiation, high temperatures, humidity, and chemical exposure. UV radiation, for example, can cause photo-oxidation, leading to surface cracking, discoloration, and reduced strength. (Wei, X.F., 2019).

To reduce extreme aging in PA-12, additives such as stabilizers and UV radiation are often combined into the polymer during manufacturing. These additives help enhance the material's resistance to environmental factors and extend its lifetime. Proper design considerations, such as avoiding long exposure to harsh environmental conditions, also play a critical role in maintaining the durability of PA-12 mechanisms. In industrial applications where PA-12 is used extensively, such as automotive parts, electrical components, and plumbing systems, understanding and managing extreme aging are essential for ensuring long-term reliability and performance of the manufactured products. (De Vico, L.,2019).

2.8 Polyamide 12 (PA-12), Powder Grade FS3300PA

Polyamide 12 (PA-12), Powder Grade FS3300PA, is a specific formulation of polyamide 12 designed for powder-based additive manufacturing processes like selective laser sintering (SLS). This material is known for its robust mechanical properties, which include high strength, impact resistance, and durability. PA-12 FS3300PA is chosen for its excellent chemical resistance and thermal stability, making it suitable for a variety of industrial applications. These include automotive components, aerospace parts, medical devices, and various consumer goods where reliable performance and dimensional accuracy are crucial. For precise technical details and specifications about PA-12 FS3300PA, it's best to consult the manufacturer's product literature, technical datasheets, or contact them directly for comprehensive information tailored to specific application needs. (Kausar, 2019).

2.8.1 Mechanical Properties of PA-12

PA 12 is a thermoplastic polymer known for its excellent mechanical properties, including high tensile strength, flexibility, and impact resistance. FS3300 PA-12 powder is designed specifically for use in selective laser sintering (SLS) processes in additive manufacturing. PA12 is known for its toughness, strength, impact resistance, and fracture resistance under deformation (Petousis et al., 2022). The ability of FS3300 PA-12 to produce parts with high dimensional accuracy and fine detail resolution is one of its primary features.

"The results showed that the composition of 100% virgin PA-12 material appeared to be stiffer, with lower plastic deformation at maximum tensile 7 stress and smoother surface roughness. (Rafi Omar et al., 2022). This study examines the effects of significant Selective Laser Sintering (SLS) 3D printer parameters on the material strength of PA-12. Various virgin materials, reheat materials, and recycled materials were used for the PA-12 material compositions. The tensile strength, surface roughness, and surface morphology were tested. Figure 1 below shows the comparison of tensile properties between PA11 and PA12 which indicates PA12 has higher Ultimate Strength and Young Modulus when compared to PA11.

2.8.2 Application of PA-12

3D printing applications and the Specific Laser Sintering Prepare (SLS) as often as possible utilize thermoplastic polymer, especially Polyamide 12, particularly FS3300PA, to deliver an item or application. The generation of items from different businesses, such as car, aviation, customer merchandise, and therapeutic gadgets, appears that there's a tall request for the utilize of PA-12 fabric (Kausar, 2019).

Figure 2. 6: Application for PA-12 Polymer

Polyamide 12 (PA12) is commonly utilized in selective laser sintering processes, known for its processability and mechanical properties, chemical resistance, and durability (du Maire et al., 2023). It is perfect for under-the-hood applications like fuel lines, brake hoses, and cable sheathing because it can tolerate extreme weather conditions, such as exposure to fuels, oils, and high temperatures. Because PA-12 is lightweight, it helps reduce overall vehicle weight, which increases fuel efficiency. PA12 stands out due to its excellent mechanical and physical properties, making it well-suited for automotive applications." (Kondo et al., 2022) For sports equipment applications, Polyamide 12 (PA 12) is a great choice because of its special blend of qualities, which include toughness, flexibility, and resistance to abrasion and impact. Because it is lightweight and strong at the same time, this thermoplastic material is perfect for sports equipment that needs to be robust and easy to use, like protective gear, shoe soles, and other molded components. For instance, a study by (Goodridge et al., 2012) highlights that PA-12 materials maintain excellent performance under repetitive loading conditions, which is essential for sports gear such as protective helmets, footwear, and racket strings. Additionally, PA-12's ability to absorb shocks and vibrations contributes to enhanced safety and comfort for athletes, further cementing its relevance in sports applications.

2.8.3 Comparison of PA-12 with Other Polyamides

PA-12 is well-suited for additive manufacturing processes like Selective Laser Sintering (SLS) due to its excellent flow properties and thermal stability during sintering while PA-6 is widely used in injection molding and extrusion processes due to its ease of processing and good flow characteristics and PA-11 Similar to PA-12, PA-11 is suitable for injection molding and extrusion processes and can also be used in powder-based additive manufacturing techniques.

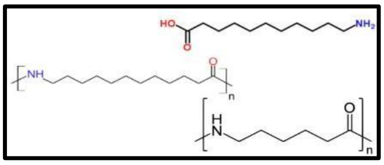


Figure 2.7: Crystal Structure of PA-6, PA-11 and PA-12

2.8.3.1 Comparison of PA-12 and PA-6

When comparing PA-12 and PA-6, PA-12 exhibits good chemical resistance, high impact strength, and excellent abrasion resistance. It has a relatively low water absorption compared to other polyamides, making it suitable for applications requiring dimensional stability and moisture resistance while PA-6 is known for its toughness, strength, and stiffness. It has good resistance to abrasion and chemicals. PA-6 has higher water absorption compared to PA-12 but offers good fatigue resistance and can be easily processed. PA-12 common applications include automotive components, medical devices, and consumer goods but PA-6 used in a wide range of applications including automotive parts, industrial components, and consumer products. (Rydz, J., 2019).

2.8.3.2 Comparison of PA-12 and PA-11

PA-12 exhibits good chemical resistance, high impact strength, and excellent abrasion resistance. It has a relatively low water absorption compared to other polyamides, making it suitable for applications requiring dimensional stability and moisture resistance. PA-11 combines high mechanical strength with excellent resistance to impact and chemicals. It has lower water absorption than PA-6 and PA-12, making it suitable for applications requiring moisture resistance. PA-11 also offers good UV resistance and is often used in outdoor applications. PA-12 common applications include automotive components, medical devices, and consumer goods while PA-11 Applications include automotive fuel lines, oil and gas pipeline coatings, electrical cable insulation, and outdoor equipment. (Weerg S., 2021).

2.8.4 Ultraviolet Radiation (UV)

Ultraviolet (UV) radiation refers to electromagnetic radiation with wavelengths shorter than visible light but longer than X-rays, falling in the range of approximately 100 to 400 nanometers (nm). UV light is not visible to the human eye but has important biological and industrial applications. (K. Srivastava, P. 2022). UV light is categorized into three main types based on wavelength UVA (320-400 nm), UVB (280-320 nm), and UVC (100-280 nm). UV light is used in application such as disinfection, phototherapy, and industrial (Firdaussi, A., Shaik, Dr. N., and Tiwari, G. 2020).

2.8.5 Effect of Ultraviolet Radiation on PA-12

Ultraviolet (UV) radiation can have several effects on PA-12 (Polyamide 12), particularly when exposed to sunlight or other sources of UV light over time. The main effects of UV radiation on PA-12 are degradation and yellowing, PA-12 polymers are vulnerable to UVinduced degradation, which can lead to chemical changes in the material. This degradation often shows as yellowing or discoloration of the plastic surface. The UV radiation breaks down the polymer chains, causing a loss of mechanical strength and structural integrity. Second is reduced mechanical properties, continuous exposure to UV radiation can weaken the mechanical properties of PA-12. This includes a decrease in tensile strength, impact resistance, and elongation at break. These changes can compromise the performance and durability of PA12 components in outdoor or UV-exposed applications. Surface cracking and brittleness, the UV radiation can induce surface cracking and increase the brittleness of PA-12. (Shackleford A., 2021) This occurs due to the degradation of polymer chains and the formation of free radicals, which promote micro-crack formation and propagation within the material. Loss of dimensional stability also effect PA-12 parts exposed to UV radiation may experience dimensional changes, such as deforming or shrinkage. These changes are attributed to the thermal effects induced by UV absorption and subsequent degradation processes. Then, it also can impact color stability on PA-12 materials used in applications requiring color stability, such as automotive components or outdoor equipment, can experience fading or changes in color intensity due to UV exposure. UV radiation accelerates the breakdown of pigments and dyes used in coloring PA-12. Understanding the effects of UV radiation on PA-12 is crucial for designing and selecting materials for applications where prolonged exposure to sunlight or outdoor conditions is anticipated. Protective coatings, proper design considerations, and material selection based on UV stability are essential in mitigating UV-induced degradation in PA-12 components. (Rhys J.W., 2021).

2.8.6 Impact of Climate Change on PA-12

PA-12 can have several impacts of climate change and its applications, particularly in relation to environmental conditions and performance requirements. Higher Temperatures can increase ambient temperatures associated with climate change can affect the thermal properties of PA-12. Higher temperatures may accelerate thermal degradation processes, leading to reduced mechanical strength and dimensional stability over time. Also, temperature fluctuations on PA-12 may experience stress from cyclic temperature changes, which can affect their fatigue resistance and long-term durability, especially in automotive, aerospace, and outdoor applications. Increased humidity levels can lead to increased water absorption in PA12, impacting its dimensional stability and mechanical properties. High moisture content can also accelerate hydrolytic degradation of the polymer chains, affecting long-term performance. Furthermore, PA-12 components exposed to moisture and humidity over extended periods may experience swelling, dimensional changes, and reduced mechanical strength, particularly in critical applications requiring moisture resistance. (Venoor et al., 2020). Strengthened UV Exposure can change in climate patterns may result in increased UV radiation exposure due to reduced ozone layer protection or alterations in sunlight intensity. UV radiation can accelerate the degradation of PA-12 polymers, leading to surface cracking, color fading, and reduced mechanical properties over time. (Touris et al., 2020).

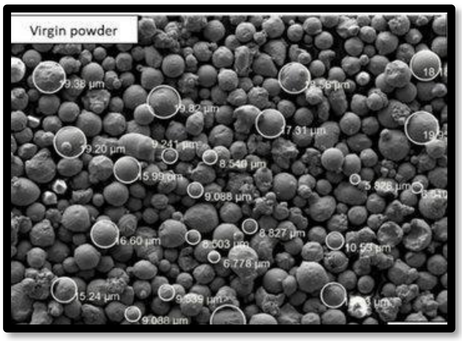
In conclusion, the mechanical and physical properties of polyamide 12 may be greatly affected by climate change, which will reduce the overall material performance, flexibility, and durability. It highlights how important it is to understand any possible impact of climate change on polyamide 12 to maintain its function and suitability.

2.8.7 Effects of Ageing and Degradation Mechanism on PA-12

Polyamide 12, like other materials, ages and degrades with time (Zhang et al., 2020). These forms may incorporate oxidative weakening, warm debasement, hydrolytic corruption, and mechanical wear. These maturing and corruption pathways may cause changes in polyamide 12 qualities such as lower quality, firmness, and dimensional solidness. To restrain the impacts of maturing and disintegration, it is basic to get it the basic forms and execute reasonable medications. A few conceivable ways to decrease maturing and disintegration in polyamide 12 incorporate the utilize of added substances or stabilizers to progress resistance to oxidation and warm corruption, as well as visit review and support to identify and treat pointers of mechanical wear. Customary testing and consider of the material's qualities may moreover help distinguish early indications of maturing or debasement, permitting for incite activity to maintain a strategic distance from advance disintegration.

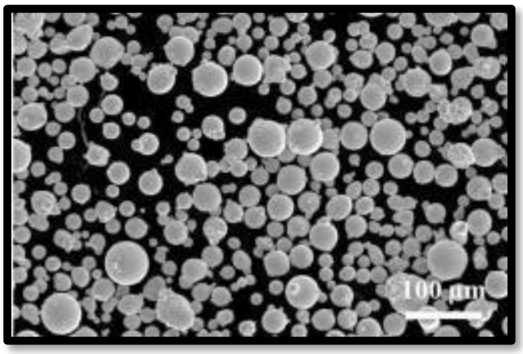
2.8.9 Difference between Virgin, Recycle, and Extreme Ageing Powder

Virgin powder in additive manufacturing typically exhibits a consistent and narrow particle size distribution. The particle size distribution is controlled to optimize the build quality and dimensional accuracy of printed parts. The chemical composition is precisely controlled to meet specific application requirements, ensuring reliable performance and consistency in mechanical properties. Virgin powders maintain excellent mechanical properties such as high tensile strength, impact resistance, and fatigue resistance. These properties are crucial for ensuring the durability and functionality of printed parts in various applications such as aerospace, automotive, medical, consumer goods.



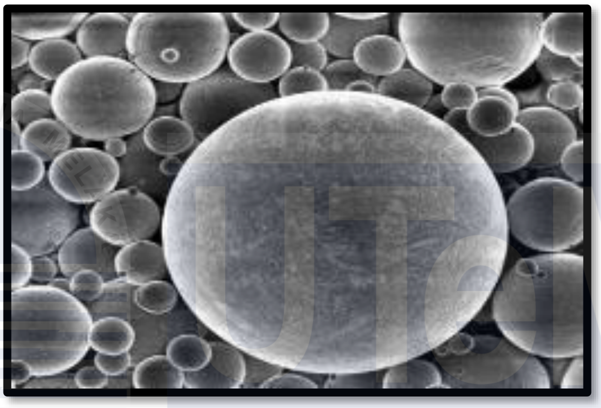
2.1 Picture of Virgin Powder Particle

Recycled powder in additive manufacturing typically exhibits a broader and less uniform particle size distribution compared to virgin powder. This variation can arise from multiple recycling cycles and irregularities in particle shape and size. The chemical composition may different due to contamination from previous builds or processing remains, potentially affecting material properties. The mechanical properties of recycled powder can be influenced by the degradation of material during previous use cycles. This can result in reduced tensile strength, impact resistance, and fatigue resistance compared to virgin powder and use in various applications, prototyping, educational and Research.



2.2 Picture of Recycle Powder Particle

Extreme aging powder may show a mixed and irregular particle size distribution due to degradation over time. The particles can become fragmented, agglomerated, or irregular in shape, affecting flowability and packing density during the printing process. The chemical composition of extreme aging powder can be changed due to long exposure to environmental factors such as UV radiation, high temperatures, and humidity. Extreme aging powder typically experiences significant degradation that include reduced tensile strength, impact resistance, and fatigue resistance. The material may become brittle, prone to cracking, and exhibit poor dimensional stability. Applications that use in extreme ageing powder are experimental use, non-critical components, education and training.



2.3 Picture of Extreme Ageing Powder Particle

2.9 Effect of the Orientation on the Mechanical Properties of Weight, Dimension on PA-12

The orientation of parts during additive manufacturing, such as Selective Laser Sintering (SLS) of PA-12, can significantly influence their mechanical properties, weight, dimensions, and surface morphology.

2.9.1 Mechanical Properties

Parts printed in different orientations may exhibit anisotropic mechanical properties, meaning their strength, stiffness, and other mechanical characteristics vary depending on the direction of loading relative to the build layers. Parts printed vertically (along the z-axis) tend to have higher strength in the z-direction compared to horizontally printed parts. (Rodríguez et al. 2023). This is because the inter-layer bonding in the z-direction is typically stronger due to better fusion between successive layers. The orientation can affect the impact resistance of the part. Parts printed with the building layers perpendicular to the impact direction may exhibit better resistance to impact forces compared to those printed with the layers parallel to the impact direction. Flexural strength and modulus can vary with orientation due to differences in layer bonding and the orientation of reinforcing fibres within the material structure. (Razaviye et al., 2022).

2.9.2 Weight

The orientation can affect the density of the printed part. Generally, parts printed vertically with higher layer heights may have slightly lower density compared to parts printed horizontally with finer layer heights. This variation is due to differences in the amount of material deposited and the packing density of the powder layers. Parts printed in optimal orientations can minimize material waste, as unused powder can be recycled. However, intricate designs or specific orientations may require support structures, which can affect material efficiency and post-processing requirements. (Magri et al., 2022)

2.9.3 Dimensions

The orientation can influence dimensional accuracy and tolerances of the printed parts. Parts printed vertically may have better dimensional accuracy in the z-axis due to more controlled layer deposition and minimal warping during cooling. Parts may experience shrinkage and warping during cooling, especially in large and complex geometries or when printed horizontally. Proper orientation and part orientation optimization can minimize these effects. (Wudy & Drummer, 2019)

CHAPTER 3

METHODOLOGY

3.1 Introduction

For modern materials to be used in harsh situations, it is essential to comprehend how environmental factors affect their mechanical properties. In this work, the mechanical characteristics of FS3300PA PA-12 powder—a kind of polyamide, after extended immersion in seawater, is commonly used in additive manufacturing. Its objective is to evaluate samples orientated at 0 degrees (XYY orientation) in order to comprehend how extended exposure to a maritime environment affects the material's durability and performance. This work closes a significant knowledge gap regarding the long-term robustness of 3D-printed polyamide parts in submerged settings, which is crucial for applications ranging from underwater robotics to maritime engineering.

The present study's approach entails an extensive battery of tests aimed at assessing the alterations in mechanical characteristics, including tensile strength, elongation at break, and young's modulus, of the FS3300PA PA-12 powder subsequent to its aging in a UV test. Standard test specimens are first prepared and orientated at 0°. Next, they are carefully immersed in UV light in particular circumstances meant to mimic severe 35 aging. Following immersion, the samples will undergo comprehensive mechanical testing using normal operating protocols. A statistical study will then be carried out to identify noteworthy alterations and correlations, providing insightful insights into the processes behind the material's declining performance and potential solutions. The study aims to provide important information to the field of materials science and engineering, using this thorough methodological approach.

3.2 Research Flowchart

The process activity in this study is shown in Figure 3.1 Research Flowchart where it shows the whole research from beginning to end to complete this research. Each description can be found in the table of contents where every subtopic from beginning to end of this research about study performance collector of water on hydro panel device.

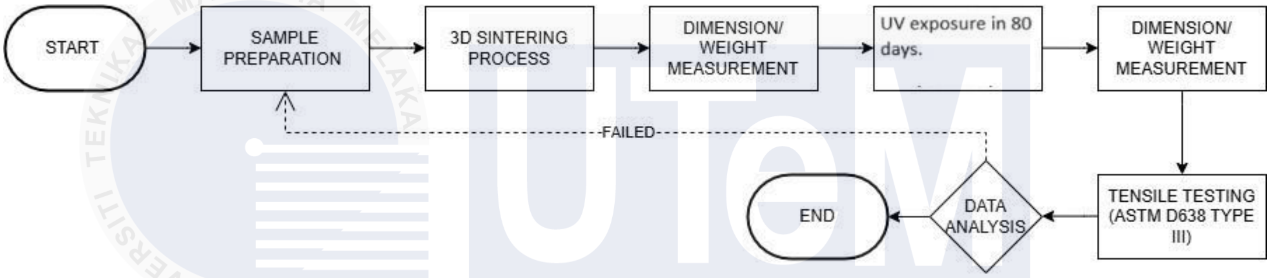


Figure 3.1: Flowchart complete for PSM

The methodology presented in the flowchart provides a methodical approach to the production and testing of these materials. It concentrates on the performance of 3D-printed samples following exposing in UV. Sample preparation comes first, and then the sample is designed with an YZY 0-degree orientation. Standardizing the mechanical characteristics and printing direction of the samples is probably the aim of this orientation. The samples are designed, then 3D printed to produce measurable test specimens that follow the specifications. The samples are submerged in seawater after printing to replicate environmental factors that could affect their mechanical qualities.

3.3 PSM Gantt Chart

No.	Task	Implementation	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1	PSM 1 briefing online	Plan	13/3													
		Actual	13/3													
2	Meeting with supervisor	Plan		20/3	27/3											
		Actual		20/3	27/3											
3	Preparation report	Plan			27/3											
		Actual			27/3											
4	Chapter 1 writing	Plan				3/4	10/4									
		Actual				3/4	10/4									
5	Chapter 2 writing	Plan						17/4	24/4	1/5	8/5					
		Actual						17/4	24/4	1/5	8/5					
6	Chapter 3 writing	Plan										15/5	22/5	29/5	5/6	
		Actual										15/5	22/5	29/5	5/6	
7	Design planning	Plan			27/3	3/4	8/4	15/4								
		Actual			27/3	3/4	8/4	15/4								
8	Design development	Plan					8/4	15/4	22/24	29/4	6/5					
		Actual					8/4	15/4	22/24	29/4	6/5					
9	Preliminary results	Plan														
		Actual														
10	Report Writing	Plan				3/4	9/4	17/4	24/4	1/5	8/5	15/5	22/5	29/5	5/6	
		Actual				3/4	9/4	17/4	24/4	1/5	8/5	15/5	22/5	29/5	5/6	
11	Slide presentation preparation	Plan											23/5	30/5	5/6	
		Actual											23/5	30/5	5/6	
12	Presentation	Plan														
		Actual														

Plan (P)	
Actual (A)	

Figure 3.2: PSM Gantt Chart

3.5 Proposed Methodology

This study will utilize a methodical approach to examine how absorption in UV light affects the mechanical characteristics, fracture behavior, dimensional stability, and water absorption of sintered PA-12 samples. Three main steps will be involved in the methodology: testing, analysis, and sample preparation. First, using selective laser sintering (SLS) in a YZY 0-degree orientation, samples for PA-12 will be fabricated at different laser power (65, 70, and 75 watts) and layer thicknesses (0.09, 0.12, and 0.15 mm). The samples will be classified into two separate states of material degradation: extremely aged and virgin. A CMM and vernier caliper will be used to test the samples' dimensional stability and water absorption both before and after they are expose in UV light. This will make it practicable to evaluate the material's reaction to UV light exposion as well as its capacity for dimensional changes and water absorption. After that, tensile testing will be performed on the samples using a Universal Test Machine (UTM) in coordination with ASTM D638-III to assess their mechanical properties. Important mechanical characteristics like tensile strength, elongation at break, and elastic modulus can then be determined through this. The effect of UV light on the mechanical performance of the material can be evaluated by contrasting the outcomes of the virgin and severely aged samples before and after seawater immersion. Lastly, scanning electron microscopy (SEM) will be used to examine the fracture behavior of the samples. This method will clarify the mechanism behind the observed failure modes and offer in-depth insights into the fracture surfaces. By combining these findings with the mechanical test results, a thorough understanding of the material's response to seawater exposure can be gained.

3.5.1 Research Design

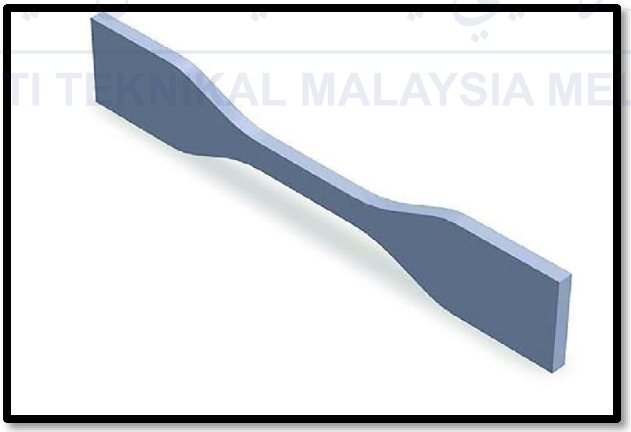


Figure 3.3: Printed samples oriented in YZY 0 ° plane

Tensile strength testing is a fundamental engineering and materials science test that is widely utilized in a range of manufacturing processes, including injection molding, machining, and industrial-grade 3D printing (additive manufacturing). In terms of 3D printing, the test offers information about the mechanical properties and quality of a material to ascertain how it will respond to loads. A frequently used design for testing 3D-printed material mechanical properties is shaped like dog bones. Tensile testing uses a dog bone with two opposing shoulders joined by a smaller cross section. Each end of the specimen is held in a tensile testing machine, which applies tension until it breaks. In a tensile test, this narrower cross section is meant to be a predictable point of failure. The shape of the cross section might be either circular or rectangular.

3.5.2 Data Measurement & Calibration

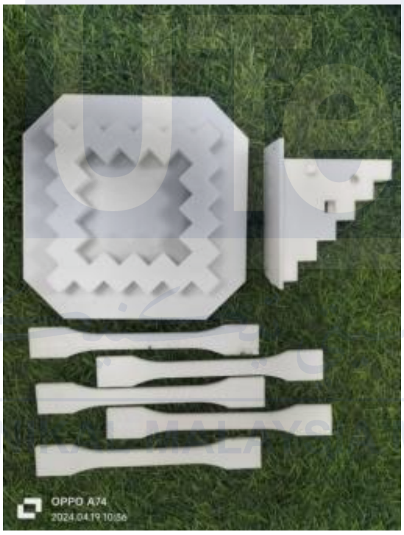


Figure 3.4: (A)(B) Calibration Block (C) Printed Specimen

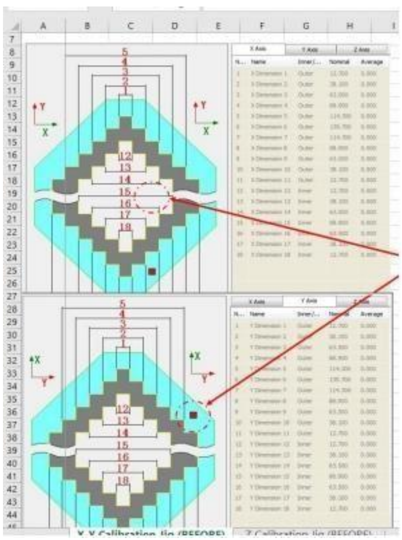


Figure 3.5: Parts Measurement Data

As attached in Figure 3.3 above is the example of fabricated PA-12 specimen through SLS process. (A) and (B) in Figure 3.4 are the calibration block of the real sample (C). Besides, Figure 3.5 shows the specimen measurement data that has been decided before the sintering process.

3.6 Experimental Setup

An experiment is setup to examine the effects of mechanical characteristics on extremely aged FS3300PA PA-12 powder UV test in the YZY 0° orientation, a well-organized experimental setup is needed. First, the powder known as FS3300PA PA-12 was selected for the investigation because of its potential for environmental degradation and extensive industrial application. To ensure uniformity and dependability, defined testing techniques like as impact, tensile, and hardness testing will be employed to evaluate the mechanical properties of the powder. The drying test procedure under sunlight will also be thoroughly monitored and regulated, with variables like temperature, salinity, and exposure time being closely examined and altered in order to match real-world conditions. In order to evaluate long-term stability, wear resistance, and durability, real-world situations were recreated.

This organized inquire about plan guarantees an exhaustive understanding of FS3300PA PA-12 powder's capabilities and ideal utilization in added substance fabricating. The exploratory setup will from there on center on carrying out an arrangement of systematic tests to characterize the mechanical conduct of the inundated FS3300PA PA-12 powder. To survey the specimens' reaction in terms of pliable quality, affect resistance, and hardness, they will be subjected to a extend of mechanical stresses. The XYY 0° introduction was chosen explicitly to disentangle comprehension of directional contrasts in mechanical properties whereas too being reliable with visit mechanical employments. All through the testing stage, information will be collected and factually assessed to discover any relationships between mechanical qualities and submersion circumstances, as well as to evaluate the degree of corruption. By following to a thorough test technique, this thinks about points to supply important experiences into the conduct of FS3300PA PA-12 powder beneath extraordinary natural conditions, subsequently encouraging educated decision-making in mechanical applications.

3.7 Accelerated weathering

The accelerated weathering unit comprises a carbon arc, xenon arc, or fluorescent lamps, a heater, humidity control, and sometimes a water spray unit to simulate dew. Carbon arc lamps produce an unrealistic spectrum as compared to natural sunlight with narrow wavelength peaks and emit more on the most harmful UV-C portion of light normally filtered out by the Earth atmosphere. Xenon arc lamps have a good overall correlation with the whole spectrum of natural sunlight but require altering and active monitoring for lamp decay. Fluorescent lamps do not require as much maintenance and follow closely the lower and higher energy UV-B and UV-A portion of sunlight most often responsible for degradation effects. However, they hardly emit in the wavelengths of visible light that also contribute to the overall degradation. Clear thin-film coating is employed for environmental material protection where optical transparency is desired, for example on wood paneling to reveal the aesthetic beauty of the surface or on metal surfaces to better resist corrosive environments. In the context of polymer protection against weathering, such coating provides barrier against water absorption, reduces oxygen diffusion, inhibits surface erosion and absorbs or scatters a portion of harmful radiation. These combined effects retard the degradation of the underlying material.

3.8 Equipment

3.8.1 Selective Laser Sintering (SLS)

Figure 3.7.1: Selective Laser Sintering (SLS)

Equipment for Selective Laser Sintering (SLS) and Ultraviolet (UV) curing in additive manufacturing varies depending on the specific process and materials used. Here's an overview of the typical equipment required for each process. SLS 3D Printer, a high-quality SLS 3D printer is the core equipment for the process.

3.8.2 UV Radiation

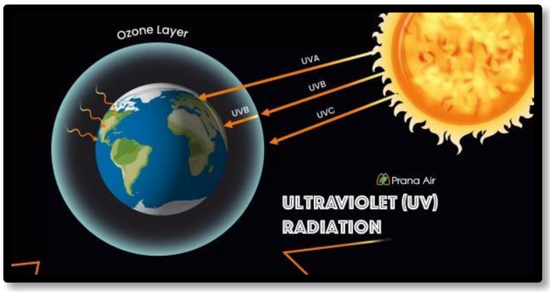


Figure 3.8.2: Ultra violet (UV) chamber

Ultraviolet (UV) light emits from the sun into the atmosphere. Since, UV rays are present in the sunlight and emit electromagnetic radiation from the sun. For the most part, it is invisible to the naked eye. However, some insects like bumblebees can see the UV rays. With it, UV radiation is a form of energy. It is measured on a scientific scale known as the electromagnetic (EM) spectrum.

Moreover, UV rays are divided into three sub parts UV-A, UV-B, and UV-C. These UV rays are absorbed in the atmosphere or absorbed by the Ozone. UV-C rays are the most harmful. With it, UV-B rays cause sunburn to the human. And UV-A rays affect the DNA in the living organisms. These rays have shorter wavelengths than visible light and longer than X-rays. UV rays' existence discovered by Johann Ritter in 1801. It also has some health benefits. As it helps in Vitamin D creation in the human body. But exposure also leads to some risks. Because, UV rays can cause sunburn, premature aging, skin cancer, etc. It can be controlled by protecting yourself from UV radiation exposure.

3.8.3 Vernier Caliper

Figure 3.8.3: Vernier Calliper

The Vernier calliper, is precision measurement tools used in various fields such as engineering, manufacturing, and quality control.

3.8.4 Analytical/Scientific balance

Figure 3.8.4: Analytical/Scientific balance

An analytical/scientific balance is a precision instrument used to measure mass with high accuracy, often to a fraction of a milligram. It is essential in scientific research and laboratory settings for weighing small samples and substances where precise measurements are crucial.

3.8.5 Universal Testing Machine

Figure3.6.5: Universal Testing Machine

A Universal Testing Machine is a device commonly used in engineering to apply various types of loads to materials in order to measure their strength and other physical properties. The UTM is capable of measuring various mechanical properties of materials.

3.9 3D Printing Process

The operation setup consisted of three stages: pre-processing (figure A-B), 3D printing (figure C-F), and post-processing (figure G-I). The four main chambers of the SLS 3D printer are the feeder chamber, building chamber, collector chamber, and powder overflow chamber with figure leveling roller. Initially, the material weight and volume were determined using Materialise Magics software, taking into consideration the quantity of the component that required printing. At the start of the 3D printing process, the SLS 3D printer's primary constant parameters were set. Afterwards, as illustrated in figure 12 (G-I), the material block was taken out of the SLS machine building chamber and moved to the sieve machine during the postprocessing stage. Figure 12 (J) displays every completed specimen that was prepared for examination. The Farsoon model FS4092P SLS 3D printer, depicted in Figure 12, was utilised to fabricate every specimen, with a maximum usable area measuring 350x350x400mm.

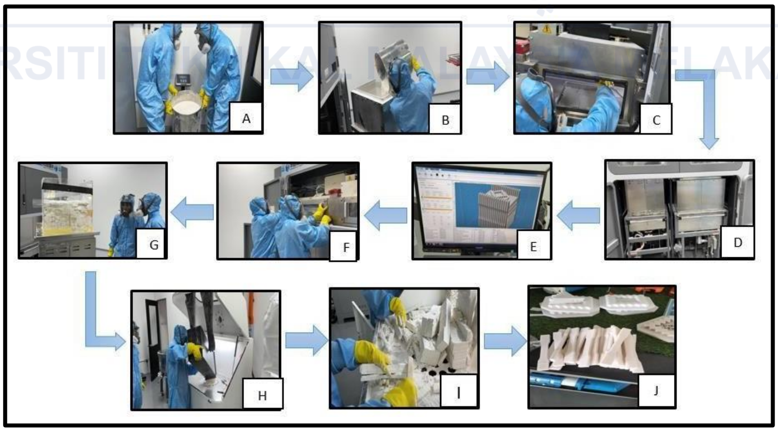


Figure 3.7: 3D Printing Process

3.9 Wifi Weather Station

Figure 18: WiFi Weather Station

A weather station is a facility, either on land or sea, with instruments and equipment for measuring atmospheric conditions to provide information for weather forecasts and to study the weather and climate. The weather station comes with an outdoor sensor and console. This way you'll receive data from your sensor right to your console quickly. The wireless 7-in-1 sensor will tell you specific details happening outside like temperature, humidity, wind speed, wind direction, UV, light intensity, and more. Monitor weather conditions in your area like never before.

3.11 Test Setup

For an intensive examination of how UV presentation and maturing affect the mechanical properties of FS3300PA PA-12 powder, it is pivotal to have a comprehensive test setup that includes arrangement, 3D printing, and mechanical testing. At to begin with, the test arrangement from FS3300PA PA-12 powder compact remained reliable all through the 3D-printing prepare. Once the printing handle is total, the mechanical tests are conducted in understanding with the ASTM D638 benchmarks. Tensile tests are performed utilizing dog bone shaped examples in a testing machine to decide the tensile strength, elongation at break, and Young's modulus.

3.8.1 Weight Measurement

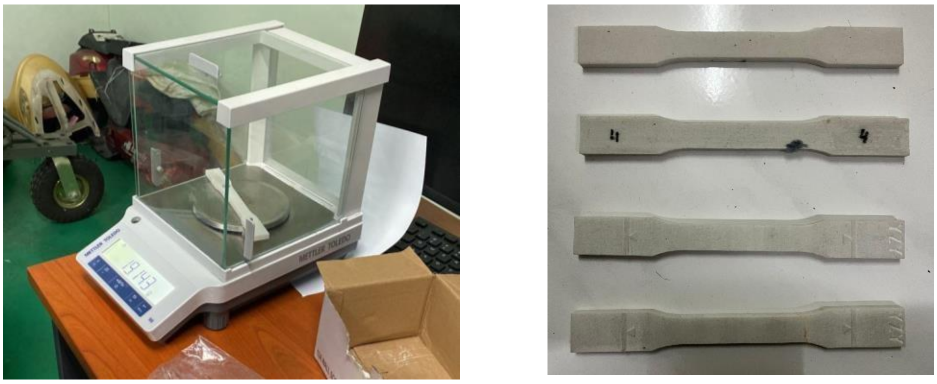


Figure 19 Sample Weighing Process

Figure 19 shows the process of measuring the weight of the specimen. The first weight measurement was taken before the UV exposure. This provided a baseline for comparison. The second measurement, which included both weight and dimensions, was taken after the samples had undergoing UV exposure 80 days. This was done to identify any changes caused by long term UV exposure. A scientific weighing scale was used to ensure accurate weight readings, and each sample was carefully labelled to prevent any mix-ups during the tensile testing process. This step is crucial for understanding how the material change after UV exposure.

3.8.2 Dimension Measurement

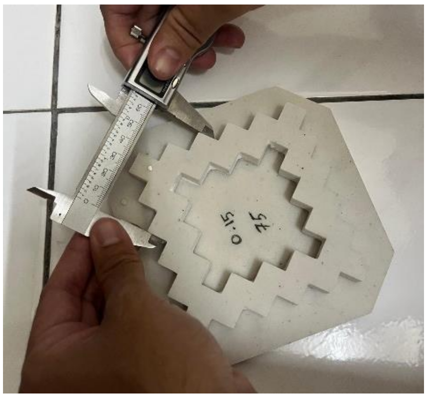


Figure 20 Sample Dimension Measurement Process

Figure 20 shows the process of measuring dimensions before and after the UV exposure. In this process, calibration blocks were used as samples for each sintering setting to check the dimensional stability of PA 12 after 80 days of UV exposure. Unlike the dog bone samples, which are used for tensile testing, the calibration blocks are specifically used to measure changes in length, width, and thickness before and after UV exposure. This helps to evaluate the UV exposure rate and any resulting shrinkage or swelling. A vernier calliper was used to measure the dimensions of the calibration blocks, and the data was analysed to identify changes in their stability.

3.8.3 UV exposure

Figure 21 UV exposure of specimen

The illustration in figure 21 shows the immersion process of the sintered sample. The sintered PA12 specimens are exposed in UV radiation for extended durations as part of the test procedure. This procedure is to imitate real UV radiation conditions and assess the long-term performance of the samples. The 80-day UV exposure provides an opportunity to examine the materials. Additionally, this test aims to evaluate critical factors such as dimensional stability, UV radiation effect, and any possible degradation over time.

3.8.4 Tensile Testing

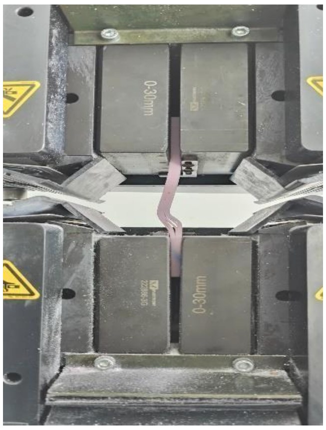


Figure 22 Tensile Test Process

Figure 22 illustrates that the tensile test method was carried out utilizing a Universal Testing Machine (UTM). This procedure took place after obtaining the final measurements for dimensions and weight, once the soaking test was finalized. A total of 45 samples were assessed following ASTM D638 Type III standards, which outline the method for measuring the mechanical properties of plastics, with 5 samples for each parameter. This test aims to assess key mechanical properties like tensile strength, elongation at break, and Young's modulus to examine how prolonged exposure to seawater has compromised the material's structural integrity. The information gathered from tensile testing is subsequently examined to assess the material's durability over time.

3.12 Limitation of Proposed Methodology

While the study is comprehensive, there are still a few limitations within the technique utilized to look at the effect of UV exposure on the mechanical properties of FS3300PA PA-12 powder, especially within the YZY 0-degree introduction. When it comes to 3D printing, accomplishing a YZY 0-degree is considered ideal. However, there can be varieties in fabric properties between diverse clumps of FS3300PA PA-12 powder. These varieties might possibly affect the reproducibility and generalizability of the comes about. Furthermore, the performance of 3D printing can be influenced by factors such as calibration, maintenance, and operational status. These variables can lead to variations in the quality of print samples and potentially impact the reliability of mechanical test results.

An examination exclusively on the YZY 0-degree introduction test uncovers varieties within the mechanical properties of the other introductions, XYY 0-degrees, and YZY 90-degrees. The coming about accentuation on the YZY 90-degree test will lead to noteworthy discoveries. Moreover, indeed in spite of the fact that mechanical tests are conducted following set up conventions, there's a potential confinement in capturing the mechanical properties of intricate geometries found in real-world scenarios. This is often since the tests are conducted on standardized test shapes and beneath controlled conditions. Conventional mechanical testing strategies frequently come up short to capture the complicated mechanical conduct of complex geometries commonly found in real-world applications. This test is conducted on a standardized test frame and beneath controlled conditions. These impediments can influence the appropriateness of discoveries to real-world components.

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 of tensile testing. The behaviour 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 UV exposed, the addition of stiff particles like glass spheres and ceramic fibres 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. This involves using an SLS machine to compare a print cycle. 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.

So far, the sample test comes from the SLS printer and is a test at the PA-12 YZY angle from the 0-degree angle. In addition, the sample is printed with a total laser power of 65, 70, 75 watts and thickness of 0.09, 0.12, 0.15mm. One cycle of fresh powder PA-12 is printed, along with 9 cycles of recycled powder PA-12. The virgin powder results sample will be compared to the 9 cycle types of specimens. According to the data collection method, the best results will be acquired among the 9 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 analysed in Microsoft Excel. We determined the Young's modulus, tensile strength, elongation at break. As a measure of toughness, the fracture energy absorbed by the pieces during the tensile tests 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.

Figure 23: Specimen test on Tensile Machine

4.3 Tensile strength

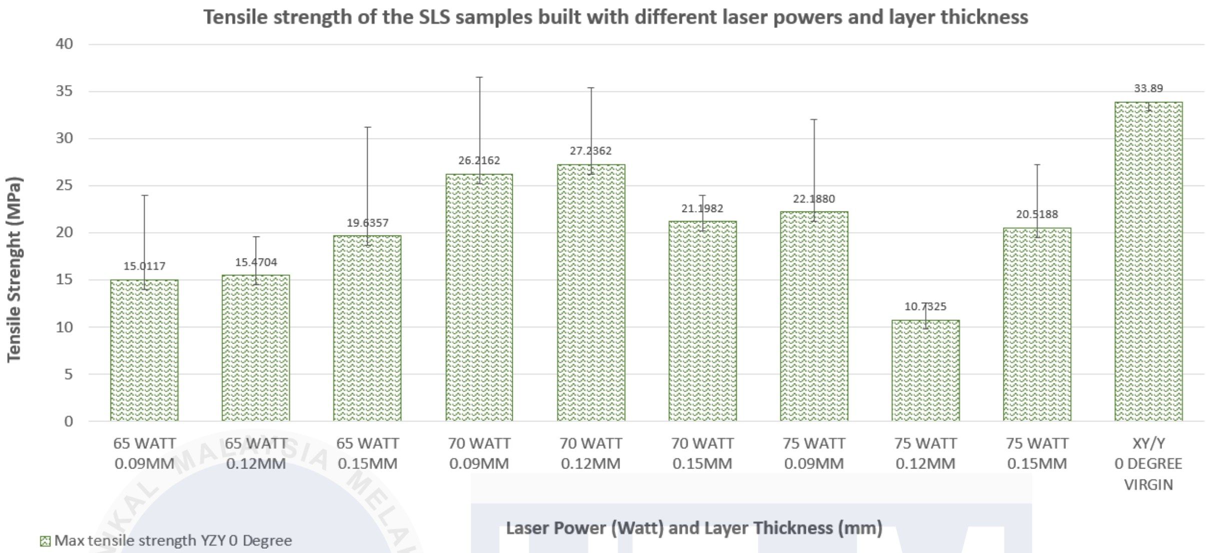


Figure 24: Tensile strength graph

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 65, 70, and75 watts and laser thickness at 0.09, 0.12, 0.15 and YZY 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 27.2362 MPa indicates that the material, when treated with a 75-watt laser, 0.12mm laser thickness at a YZY 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 39.60 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.

4.3.1 Comparison Tensile Strength Between Three Orientation (XYY 0, YZY 0, YZY 90 Degree)

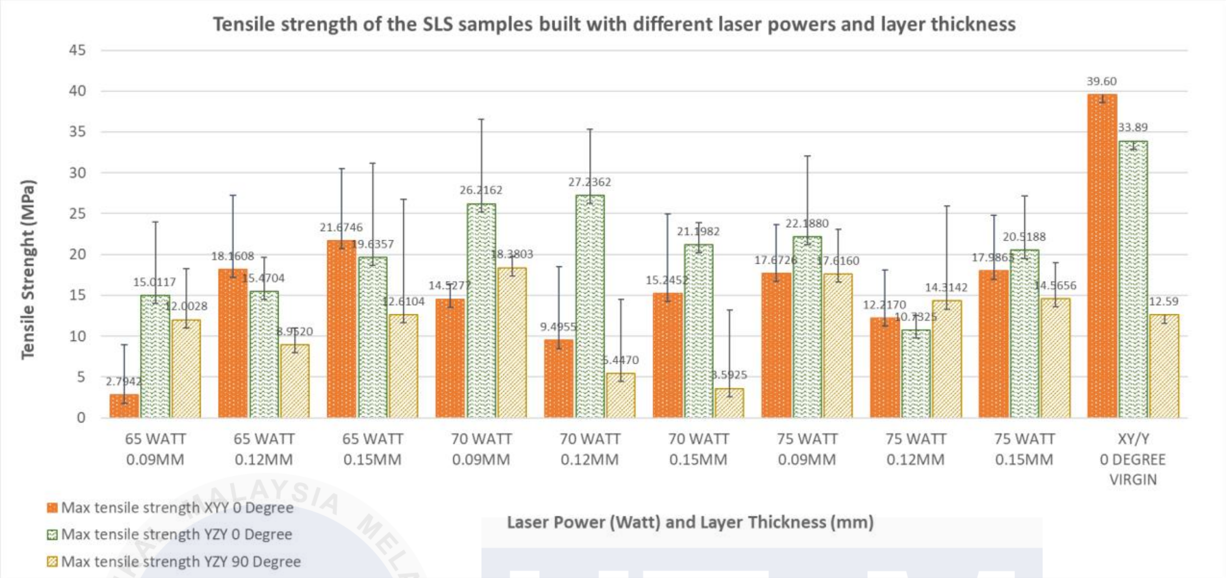


Figure 25 Tensile Strength for XYY 0 Degree, YZY 0 Degree and YZY 90 Degree

The graph for figure 25 compares the tensile strength of FS3300PA PA-12 samples made with Selective Laser Sintering (SLS) at three different build orientations: XYY 0 degree, YZY 0 degree, and YZY 90 degree, under changing laser powers (65 W, 70 W, and 75 W) and layer thicknesses (0.09 mm, 0.12 mm, and 0.15 mm). At 65 W, the tensile strength is highest for the XYY 0-degree orientation at 0.015 mm (21.67 MPa), followed by YZY 0 degree (19.64 MPa) and YZY 90 degree (8.95 MPa). Increasing the layer thickness to 0.12 mm and 0.15 mm lowers the tensile strength in all orientations. At 70 W, where the XYY 0-degree orientation has the highest strength at 0.012 mm (27.23 MPa), followed by XYY 0 degree (9.49 MPa) and YZY 90 degree (5.44 MPa). At 75 W, the results with the YZY 0-degree orientation achieving the highest tensile strength at 0.09 mm (22.18 MPa), followed by XYY 0 degree (17.67 MPa) and YZY 90 degree (17.61 MPa). Thicker layers (0.12 mm and 0.15 mm) lead to reduced tensile strength across all orientations. The unprocessed (virgin) material has the highest tensile strength overall, with a maximum of 39.60 MPa at XYY 0-degree orientation. These results show that tensile strength depends on laser power, layer thickness, build orientation and the UV-exposure process.

The YZY 0-degree orientation consistently gives the highest strength, while the YZY 90-degree orientation used in this study has lower strength but shows noticeable improvement with higher laser power and thinner layers. This highlights the importance of optimizing parameters for FS3300PA PA-12 parts used in seawater environments.

4.4 Young' Modulus

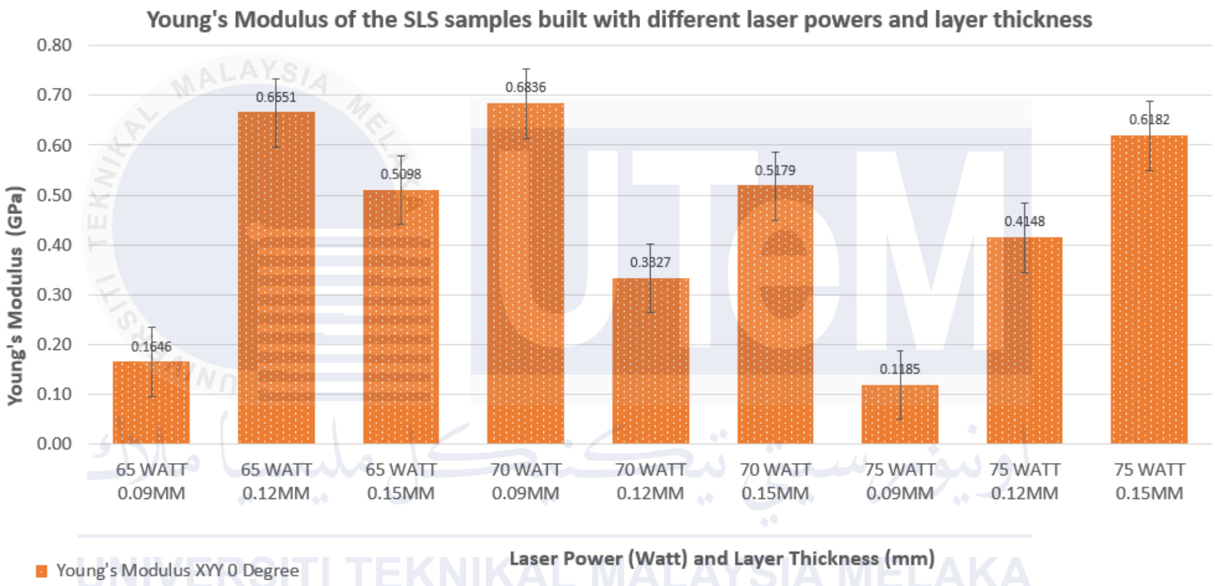


Figure 25 Young's Modulus Graph

The graph for figure 26 shows the Young's modulus (GPa) of FS3300PA PA-12 samples made with Selective Laser Sintering (SLS), measured for different laser powers and layer thickness. Young's modulus reflects the stiffness of the material, or how resistant it is to bending or stretching. At 65 W, the stiffness at 0.09 mm (0.1641 GPa) and increase at thicker layers. The best stiffness overall is achieved with 70 W at 0.09 mm. At 70 W, the stiffness is highest at 0.09 mm thickness (0.6836 GPa for YZY 0-degree orientation) but decreases as the layer thickness increases to 0.12 mm (0.3327 GPa) and 0.15 mm (0.5179 GPa). For 75 W, the stiffness at 0.09 mm is slightly lower (0.1185 GPa), and, like the other settings, it increases with thicker layers. Compared to the virgin material, which has a high stiffness of 0.8088 GPa in the YZY 0-degree orientation, most SLS samples have slightly lower stiffness. However, the virgin material shows poor performance in the XYY 90-degree orientation (0.3604 GPa), indicating that it lacks uniform properties in different directions. In contrast, SLS samples, especially at 70 W and 75 W with 0.09 mm layers, show more balanced stiffness across orientations, making them more reliable for different applications. These results highlight that careful selection of laser power and layer thickness can optimize stiffness and balance mechanical properties for aged FS3300PA PA-12 powder in UV exposure, depending on whether ductility or stiffness is prioritized.

4.4.1 Comparison Young's Modulus Between Three Orientation (XYY 0, YZY 0, YZY 90 Degree)

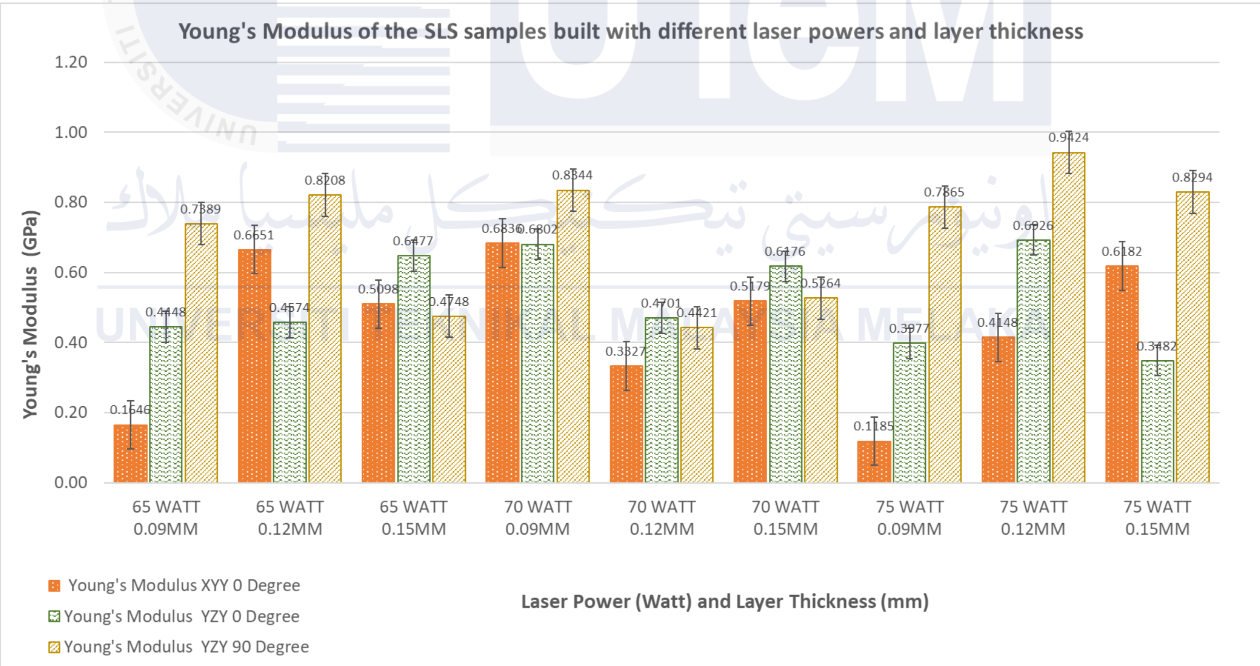


Figure 27 Young's Modulus for XYY 0 Degree, YZY 0 Degree and YZY 90 Degree

The graph for figure 27 shows the Young's modulus (GPa) of FS3300PA PA-12 samples made with Selective Laser Sintering (SLS), measured for different laser powers, layer thicknesses, and orientations. Young's modulus reflects the stiffness of the material, or how resistant it is to bending or stretching. At 65 W, the stiffness is highest at 0.09 mm thickness (0.1646 GPa for XYY 0-degree orientation) but increase as the layer thickness increases to 0.12 mm (0.6651 GPa) and decrease at

0.15 mm (0.5098 GPa). At 70 W, the stiffness improves, peaking at 0.09 mm (0.6836 GPa) and decrease at 0.12mm (0.3327) and slightly increase at 0.15mm (0.5179). The best stiffness overall is achieved with 70 W at 0.09 mm. For 75 W, the stiffness at 0.09 mm is the lowest (0.1185 GPa), and, like the other settings, it increases with thicker layers. Compared to the virgin material, which has a high stiffness of 0.8294 GPa in the YZY 90-degree orientation, most SLS samples have slightly lower stiffness. However, the virgin material shows poor performance in the YZY 0-degree orientation (0.3482 GPa), indicating that it lacks uniform properties in different directions. In contrast, SLS samples, especially at 70 W and 75 W with 0.09 mm layers at YZY 90-degree, show more balanced stiffness across orientations, making them more reliable for different applications. These results highlight that careful selection of laser power and layer thickness can optimize stiffness and balance mechanical properties for aged FS3300PA PA-12 powder in UV exposure, depending on whether ductility or stiffness is prioritized.

4.4 Elongation to Break

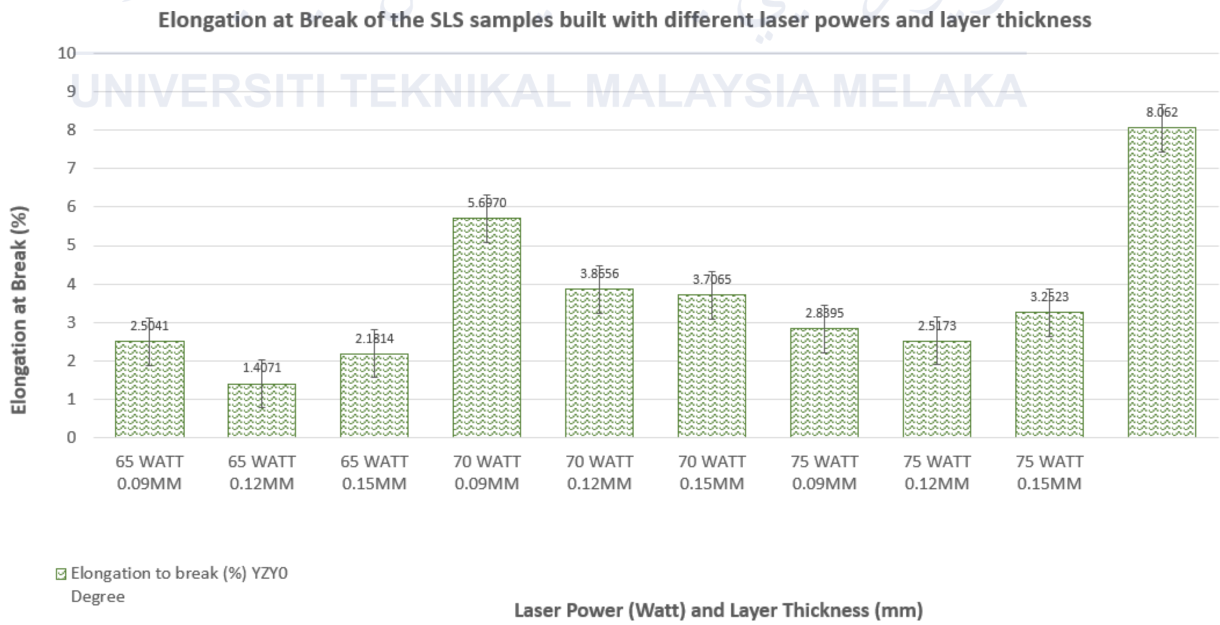


Figure 28 Elongation to Break Graph

The graph for figure 4.5 shows the elongation at break (%) of FS3300PA PA-12 samples made using Selective Laser Sintering (SLS) in the YZY 0-degree orientation. This measures how much the material can stretch before it breaks, which indicates its flexibility or ductility. A trend is seen at 65 W, where the highest elongation is 2.50% at 0.09 mm, decreasing to 1.41% at 0.12 mm and increasing at 2.81% at 0.15 mm. At 70 W, the material stretches the most at a layer thickness of 0.09 mm (5.69%), but the elongation drops significantly as the layers get thicker, with only 3.85% at 0.12 mm and 3.71% at 0.15 mm. At 75 W, the best results are observed, with 3.25% elongation at 0.09 mm, showing that higher laser power and thicker layers produce the most ductile material. In comparison, the virgin material has 8.06% elongation, much higher than the best performing samples, such as 5.69% at 70 W and 0.09 mm. This shows that selecting the right laser power and layer thickness can greatly improve the flexibility of FS3300PA PA-12, even after being aged in UV exposure. The findings suggest that higher laser power and thinner layers enhance the material's ability to resist cracking or breaking under stress, making it more suitable for harsh environments like UV exposure.

4.4.1 Comparison Elongation at Break Between Three Orientation (XYY 0, YZY 0, YZY 90 Degree)

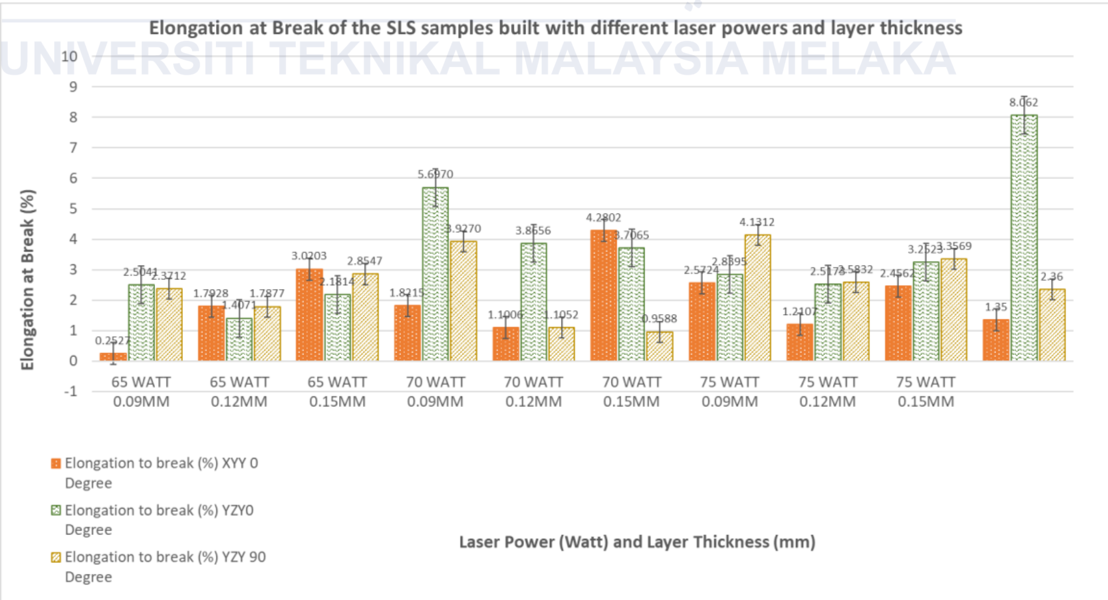


Figure 29 Elongation at Break for XYY 0 Degree, YZY 0 Degree and YZY 90 Degree

The graph for figure 29 shows the elongation at break (%) for SLS samples made with different laser powers and layer thicknesses in three orientations: XYY 0°, YZY 0°, and YZY 90°.

Elongation at break measures how much the material can stretch before breaking, indicating its flexibility. For the YZY 0° orientation, the highest elongation is achieved at 0.09 mm thickness with 70 W laser power (5.6970%). However, as the layer thickness increases to 0.12 mm and 0.15 mm, the elongation drops significantly, showing less flexibility. In comparison, the XYY 0° and YZY 0° orientations consistently show much higher elongation values, with XYY 0° reaching up to 4.8202% at 70 W and 0.15 mm thickness. These results suggest that the orientation and layer thickness greatly affect the material's flexibility. When compared to the virgin material, the SLS built samples perform better in the YZY 0° orientation, as the virgin sample achieves 8.062% elongation in this direction. However, in the XYY 0° and YZY 90° orientations, the virgin material shows decent elongation values of 1.35% and 2.36%, respectively. This highlights that the aging process and UV exposure impact the mechanical properties of FS3300PA PA-12 powder, especially in the YZY 0° orientation. Overall, the study shows that thinner layers (0.09 mm) and laser power (70 W) improve elongation at break, helping to counteract the effects of aging and UV exposure. These findings are important for designing parts with better flexibility and durability in challenging environments.

4.5 Comparison Weights of Virgin and Extremely Aged Powder with Different Watt and Layer Thickness

Parts Name	No	Weight before immersed (	Weight after immersed (	Difference (%	Average difference (
65 WATT 0.15MI (VIRGIN)	1	18.643	18.134	2.73	2.364
	2	18.451	18.041	2.22	
	3	19.134	18.725	2.14	
	4	18.423	18.017	2.2	
	5	18.018	17.562	2.53	
75 WATT 0.15MI	1	19.073	18.751	1.69	2.02
	2	18.205	17.734	2.59	
	3	18.613	18.192	2.26	
	4	18.598	18.236	1.95	
	5	18.831	18.527	1.61	
75 WATT 0.12MI	1	18.376	17.983	2.14	2.582
	2	18.37	17.892	2.6	
	3	18.121	17.734	2.14	
	4	18.402	17.841	3.05	
	5	18.415	17.865	2.98	
75 WATT 0.09M	1	17.491	16.972	2.96	2.906
	2	16.889	16.318	3.38	
	3	16.314	15.871	2.72	
	4	16.596	16.214	2.3	
	5	16.39	15.871	3.17	
70 WATT 0.15MI	1	16.476	16.124	2.14	2.032
	2	16.412	16.067	2.1	
	3	17.42	17.085	1.92	
	4	17.031	16.738	1.72	
	5	16.921	16.536	2.28	
70 WATT 0.12MI	1	18.412	18.115	1.61	2.052
	2	18.231	17.953	1.52	
	3	18.304	17.963	1.86	
	4	18.687	18.156	2.84	
	5	18.462	18.013	2.43	
70 WATT 0.09M	1	18.254	17.789	2.55	2.342
	2	17.183	16.798	2.24	
	3	17.47	17.031	2.51	
	4	17.921	17.593	1.83	
	5	17.187	16.743	2.58	
65 WATT 0.15MI	1	16.054	15.768	1.78	2.222
	2	17.156	16.738	2.44	
	3	17.302	16.912	2.25	
	4	16.175	15.754	2.6	
	5	16.203	15.872	2.04	
65 WATT 0.12MI	1	16.912	16.431	2.84	2.3
	2	17.934	17.476	2.55	
	3	17.956	17.561	2.2	
	4	17.057	16.742	1.85	
	5	17.325	16.968	2.06	
65 WATT 0.09M	1	18.498	18.038	2.48	2.458
	2	17.853	17.278	3.22	
	3	18.76	18.538	1.18	
	4	17.895	17.307	3.3	
	5	18.503	18.113	2.11	

Table 27 Weights of Virgin and Extremely Aged Powder

The table shows how much the weight of FS3300PA PA-12 powder samples changed before and after undergoing UV exposure. This test helps us understand how UV exposed affects the material's properties. The samples were made using different laser power settings (65 W, 70 W, and

75 W) and layer thicknesses (0.09 mm, 0.12 mm, and 0.15 mm). All the samples were created in the YZY 0-degree orientation. For example, the virgin sample processed with 65 W laser power and a 0.15 mm layer thickness had a weight change of 2.364%, which shows moderate UV exposure.

The sample processed with the highest laser power, 75 W, and the thickest layer, 0.15 mm, had the smallest weight change of 2.02%. In contrast, the sample made with the same laser power 75 W but with a thinner layer of 0.12 mm, with a weight change of 2.582%. This indicates that thicker layers are more resistant to UV exposure, possibly due to lower material density.

Similar patterns were seen with samples processed using 70 W laser power. Samples with a 0.15 mm thick layer absorbed UV exposure compared to those with thinner layers like 0.09 mm. This shows that thicker layers, regardless of the laser power, perform better in resisting UV exposure. Thicker layers may have better structural integrity and are less porous, which limits UV exposure.

Overall, the results show that both higher laser power and thicker layers are important for reducing water absorption in FS3300PA PA-12 powder samples. This is useful for applications where the material is exposed to UV sunlight or other harsh environments. By using the right settings during the manufacturing process, the material's durability and performance can be significantly improved, making it more suitable for marine applications. These findings are critical for designing strong, reliable materials that can handle long-term UV exposure.

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 Hydro QS 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 YZY 0-degee, has shown consistently positive results.

By comparing the YZY 0-degree orientation print cycle with virgin powder using the SLS machine, the experiment achieves its goal. The YZY 0-degree orientation cycle has the best surface roughness and has a beneficial effect on PA-12.

Malaysia**.**

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REFERENCES

A. Awad, F. Fina, A. Goyanes, S. Gaisford, and A. W. Basit, "3D printing: Principles and pharmaceutical applications of selective laser sintering," International Journal of Pharmaceutics, vol. 586, Aug. 2020, doi: 10.1016/j.ijpharm.2020.119594.

A. el Magri, S. E. Bencaid, H. R. Vanaei, and S. Vaudreuil, "Effects of Laser Power and Hatch Orientation on Final Properties of PA12 Parts Produced by Selective Laser Sintering," Polymers, vol. 14, no. 17, Sep. 2022, doi: 10.3390/polym14173674.

H. J. O'Connor, A. N. Dickson, and D. P. Dowling, "Evaluation of the mechanical performance of polymer parts fabricated using a production scale multi jet fusion printing process," Additive Manufacturing, vol. 22, pp. 381–387, Aug. 2018, doi: 10.1016/j.addma.2018.05.035.

M. K. Razaviye, R. A. Tafti, and M. Khajehmohammadi, "An investigation on mechanical properties of PA12 parts produced by a SLS 3D printer: An experimental approach," CIRP Journal of Manufacturing Science and Technology, vol. 38, pp. 760–768, Aug. 2022, doi: 10.1016/j.cirpj.2022.06.016.

F. Yang, N. Zobeiry, R. Mamidala, and X. Chen, "A review of aging, degradation, and reusability of PA12 powders in selective laser sintering additive manufacturing," Materials Today Communications, vol. 34. Elsevier Ltd, Mar. 01, 2023. doi: 10.1016/j.mtcomm.2022.105279.

P. du Maire, M. Deckert, M. Johlitz, and A. Öchsner, "Characterisation of the mechanical properties of polyamide 12 powder when using titanium dioxide as antimicrobial additive," Materialwissenschaft und Werkstofftechnik, vol. 54, no. 4, pp. 385–390, Apr. 2023, doi: 10.1002/mawe.202200329.

M. Petousis, N. Vidakis, N. Mountakis, V. Papadakis, and L. Tzounis, "ThreeDimensional Printed Polyamide 12 (PA12) and Polylactic Acid (PLA) Alumina (Al2O3) Nanocomposites with Significantly Enhanced Tensile, Flexural, and Impact Properties," Nanomaterials, vol. 12, no. 23, Dec. 2022, doi: 10.3390/nano12234292.

I. Malashin, D. Martysyuk, V. Tynchenko, V. Nelyub, A. Borodulin, and A. Galinovsky, "Mechanical Testing of Selective-Laser-Sintered Polyamide PA2200 Details: Analysis of Tensile Properties via Finite Element Method and Machine Learning Approaches," Polymers, vol. 16, no. 6, Mar. 2024, doi: 10.3390/polym16060737. 42

F. Lupone, E. Padovano, F. Casamento, and C. Badini, "Process phenomena and material properties in selective laser sintering of polymers: A review," Materials, vol. 15, no. 1. MDPI, Jan. 01, 2022. doi: 10.3390/ma15010183.

N. Vidakis et al., "Sustainable additive manufacturing: Mechanical response of polyamide 12 over multiple recycling processes," Materials, vol. 14, no. 2, pp. 1–15, Jan. 2021, doi: 10.3390/ma14020466.

M. Picard, A. K. Mohanty, and M. Misra, "Recent advances in additive manufacturing of engineering thermoplastics: Challenges and opportunities," RSC Advances, vol. 10, no. 59. Royal Society of Chemistry, pp. 36058–36089, Oct. 01, 2020. doi: 10.1039/d0ra04857g.

S. Lv, Y. Li, S. Zhao, and Z. Shao, "Biodegradation of Typical Plastics: From Microbial Diversity to Metabolic Mechanisms," International Journal of Molecular Sciences, vol. 25, no. 1. Multidisciplinary Digital Publishing Institute (MDPI), Jan. 01, 2024. doi: 10.3390/ijms25010593.

R. Puglisi et al., "Photo- and Water-Degradation Phenomena of ZnO Bio-Blend Based on Poly (lactic acid) and Polyamide 11," Polymers, vol. 15, no. 6, Mar. 2023, doi: 10.3390/polym15061434.

X. Zhang and Z. Deng, "Effects of Seawater Environment on the Degradation of GFRP Composites by Molecular Dynamics Method," Polymers, vol. 14, no. 14, Jul. 2022, doi:

10.3390/polym14142804.

M. M. Brette, A. H. Holm, A. D. Drozdov, and J. de C. Christiansen, “Pure Hydrolysis of Polyamides: A Comparative Study,” Chemistry (Switzerland), vol. 6, no. 1. Multidisciplinary Digital Publishing Institute (MDPI), pp. 13–50, Feb. 01, 2024. doi: 10.3390/chemistry6010002.

C. Amstutz, B. Weisse, S. Valet, A. Haeberlin, J. Burger, and A. Zurbuchen, “Temperaturedependent tensile properties of polyamide 12 for the use in percutaneous transluminal coronary angioplasty balloon catheters,” BioMedical Engineering Online, vol. 20, no. 1, Dec. 2021, doi: 10.1186/s12938-021-00947-8.

K. Wudy, D. Drummer, F. Kühnlein, and M. Drexler, “Influence of degradation behavior of polyamide 12 powders in laser sintering process on produced parts,” in AIP Conference Proceedings, American Institute of Physics Inc., 2014, pp. 691–695. doi: 10.1063/1.4873873.

43

L. Zheng, M. Wang, Y. Li, Y. Xiong, and C. Wu, “Recycling and Degradation of Polyamides,” Molecules, vol. 29, no. 8, p. 1742, Apr. 2024, doi: 10.3390/molecules29081742.

K. Wudy and D. Drummer, “AGING BEHAVIOR OF POLYAMIDE 12: INTERRELATION BETWEEN BULK CHARACTERISTICS AND PART PROPERTIES.”

B. Sanders, E. Cant, H. Amel, and M. Jenkins, “The Effect of Physical Aging and Degradation on the Re-Use of Polyamide 12 in Powder Bed Fusion,” Polymers, vol. 14, no. 13, Jul. 2022, doi: 10.3390/polym14132682.

D. S. Nakonieczny et al., “Cenospheres-Reinforced PA-12 Composite: Preparation, Physicochemical Properties, and Soaking Tests,” Polymers, vol. 14, no. 12, Jun. 2022, doi: 10.3390/polym14122332.

M. Bahrami, J. Abenojar, and M. A. Martínez, “Comparative characterization of hotpressed polyamide 11 and 12: Mechanical, thermal and durability properties,” Polymers, vol. 13, no. 20, Oct. 2021, doi: 10.3390/polym13203553.

J. Bai, J. Song, and J. Wei, "Tribological and mechanical properties of MoS2 enhanced polyamide 12 for selective laser sintering," Journal of Materials Processing Technology, vol. 264, pp. 382–388, Feb. 2019, doi: 10.1016/j.jmatprotec.2018.09.026.

M. Kadkhodaei, M. Pawlikowski, R. Drobnicki, and J. Domański, "Modeling of hyperelasticity in polyamide 12 produced by selective laser sintering," Continuum Mechanics and Thermodynamics, vol. 35, no. 4, pp. 1735–1744, Jul. 2023, doi: 10.1007/s00161-023- 01199-8.

R. D. Goodridge, C. J. Tuck, and R. J. M. Hague, "Laser sintering of polyamides and other polymers," Progress in Materials Science, vol. 57, no. 2. pp. 229–267, Feb. 2012. doi: 10.1016/j.pmatsci.2011.04.001.

M. Y. Kondo et al., "Recent advances in the use of Polyamide-based materials for the automotive industry," Polimeros, vol. 32, no. 2, 2022, doi: 10.1590/0104-1428.20220042.

M. Rafi Omar et al., "Effect of Polyamide-12 Material Compositions on Mechanical Properties and Surface Morphology of SLS 3D Printed Part," 2022.

"TITLE: FABRICATION OF HOUSING FOR HYDRO QUALITY SURVEY SYSTEM (HydroQS) OF SUNGAI MELAKA USING RECYCLED AGING POLYAMIDE PA-12 POWDER."

No.	Task	Implementation	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1	PSM 1 online briefing	Plan														
		Actual														
2	Meeting with supervisor	Plan														
		Actual														
3	Preparation report	Plan														
		Actual														
4	Chapter 1 writing	Plan														
		Actual														
5	PSM 1 Module 2 Briefing	Plan														
		Actual														
6	Chapter 2 writing	Plan														
		Actual														
7	Chapter 3 writing	Plan														
		Actual														
8	Design planning	Plan														
		Actual														
9	Design development (PSM 2)	Plan														
		Actual														
10	Preliminary results	Plan														
		Actual														
11	Report writing	Plan														
		Actual														
12	Slide presentation preparation	Plan														
		Actual														
13	Presentation	Plan														
		Actual														

Appendix B Gantt Chart

Plan (P)	
Actual (A)	