TRIBOLOGICAL PROPERTIES OF 3D PRINTED ACRYLONITRILE BUTADIENE STYRENE (ABS) UNDER DRY AND WET CONDITIONS

NUR SHAHIRAH BT ALIAS

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NUR SHAHIRAH BINTI ALIAS

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DECLARATION

I declare that this project report entitled "Tribological Properties of 3D Printed Acrylonitrile Butadiene Styrene (ABS) under Dry and Wet Conditions" is the result of my own work except as cited in the references.

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature :. ....

Name of Supervisor : ....

Date : ....

DEDICATION

To my beloved mother and father

ABSTRACT

3D printer was used to fabricate acrylonitrile–butadiene–styrene (ABS) to identify the friction and wear. This new adaptation technology is starting to attract industry especially medical field since it has longer life span and low cost. Previous investigation focuses the influence of hardness, tensile test and temperature effect. However, the understanding regarding tribological properties need more research. It is great to identify application that suitable since ABS is one of biocompatible material. The aim for this study to compare the tribological performance between 3D printer ABS and molded ABS under dry and wet conditions. The result of coefficient of friction of both samples were taken using ball-on-disc machine. Both samples were formed in disc shape for experiment. 3D printer and molded ABS that tested under wet condition were using paraffin oil as lubrication and others parameter were set as constant such as temperature (27℃) and speed (120 rpm). Different load was applied from 20 – 40 N throughout the experiment both sample and conditions. The result shows that molded ABS has the lowest COF than 3D printer ABS under both conditions. However, specific wear rate of the experiment show 3D printer had the lowest wear compared to molded because of it has porosity to retain the fluid in 3D printer sample. As conclusion, 3D printer sample is good wear resistance compared to molded meanwhile COF improvement need further study.

ABSTRAK

Pencetak 3D digunakan untuk membuat Acrylonitrile-Butadiena-Styrene (ABS) untuk mengenal pasti geseran dan pakai. Teknologi penyesuaian baru ini mula menarik minat industri terutama bidang perubatan kerana ia mempunyai jangka hayat yang lebih lama dan kos rendah. Siasatan terdahulu mengkaji lebih banyak kepada kekerasan, ujian tegangan dan kesan suhu. Oleh itu, pemahaman tentang sifat-sifat tribologi memerlukan lebih banyak penyelidikan. Adalah baik untuk mengenal pasti aplikasi yang sesuai kerana ABS adalah salah satu bahan biokompatibel. Tujuan kajian ini untuk membandingkan prestasi tribologi antara ABS pencetak 3D dan acuan ABS di bawah keadaan kering dan basah. Hasil pengkali geseran kedua-dua sampel yang dalam bentuk cakera diambil dengan menggunakan mesin bola-pada-cakera. Pencetak 3D dan acuan ABS yang diuji di bawah keadaan basah menggunakan minyak paraffin sebagai pelinciran dan parameter lain ditetapkan sebagai tetap seperti suhu (27 ℃) dan kelajuan (120 rpm). Beban yang berbeza digunakan dari 20 - 40 N di seluruh eksperimen kedua-dua sampel dan keadaan. Hasilnya menunjukkan bahawa acuan ABS mempunyai COF terendah daripada pencetak 3D ABS di bawah kedua-dua keadaan. Walau bagaimanapun, kadar haus khusus menunjukkan percetakan 3D ABS menunjukkan haus terendah berbanding acuan ABS kerana ia mempunyai keliangan untuk mengekalkan cecair dalam sampel pencetak 3D. Sebagai kesimpulan, sampel pencetak 3D mempunyai penghalang haus yang baik berbanding dengan acuan manakala peningkatan COF memerlukan kajian lanjut.

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LIST OF ABBREVIATIONS

ABS	Acrylonitrile-Butadiene-Styrene
FDM	Fused Deposition Modelling
CAD	Computer Aided Design
3D PRINTER	Three-Dimensional Printer
COF	Coefficient of Friction
DOE	Design of Experiment
ASTM	American Society for Testing and Materials

CHAPTER 1

INTRODUCTION

This introduction chapter provides the background of the study, problem statement, objectives, scope of study and report structure.

1.1 Background of study.

In this era of globalization, plastic polymer considers as popular material that are widely used in industry. Acrylonitrile–butadiene–styrene (ABS) is one of the engineering thermoplastic polymer that had been found the applications in many fields like automotive, aerospace, business machines, computers and telephone handsets (Sudeepan et al, 2014). The impact of resistance and toughness on mechanical properties of ABS was the main factor ABS are useful and popular in industry to reduce external or internal friction (Olivera et. al, 2016). Other than that, ABS can be manufactured by two process which is extrusion and molding (Ozcelik et al, 2010; Stansbury & Idacavage, 2016)

According to Ciocca et al (2009), the advantages of ABS that do not easily wear compared to metal makes it became popular even in medical field. The new technologies in medical world where artificial organs or joint made by plastic to replaces the damage organs is also one of the reasons why ABS has been used in medical field. Besides that, the process of manufactured are using one of the modern engineered method which is additive manufacturing or likely known as 3D printer. Additive manufacturing able to transform 3D solid drawing into a physical model without using any additional tools (Berman, 2012;

Huang et al, 2013; Weller et al, 2015). The unique of this process where layer manufactured form the part makes it more suitable for medical because of organ that had their own characteristic and this process doesn't need to be assembled can cut time if the required organs or joint need to be used as soon as possible.

Meanwhile, molded are more conventional where this process required more tools, forms, or punches in process to complete the design. The suitable parameters also played main role in the manufacture process such as compression flow rate, mold wall temperature and tensile modulus of compression molded parts to form the parts. Every parameter is parallel with each other due to the importance of each parameters and how it leads to the performance of the tribological behaviour. It is the aim of any project to know how the input parameters of the process contributes to the performance of the process in order to get an excellent product.

1.2 Problem Statement

ABS is one of the common materials that are widely used in industry. This polymer has starting to attract more industry to use it as part of their material since ABS provide more benefit with low cost and this including medical field. The adaptation of new technology such as 3D printer also attract industry to invest in this area. The fabrication ABS using 3D printed that can printed in the complex shape is one of the important criteria that attract medical field. ABS also prove to be one of the biocompatible materials that can be used as part of medical equipment. However, it has become a huge problem that friction and wear causes high loss for industry. Medical field itself require the material that has lower friction and wear that can be used in long period.

Due to this problem, the demand of research in tribological properties has increase to prove that 3D printer ABS have lower friction and wear. Reduction of friction and wear needed for industry to save cost and have longer lifespan material. Basically, previous research is focusing on the behaviour or strength of ABS instead of tribological properties. This study can help industry to stop doubtful on 3D printer ABS tribological performance.

1.3 Objective

The objective of this study as follow:

- To compare the tribological performance between 3D printer ABS and molded ABS under dry and wet conditions.

1.4 Scopes

This study focuses on tribological properties of acrylonitrile–butadiene–styrene (ABS) under wet and dry conditions. For 3D printer ABS and molded ABS, both of this was prepared in disc form for tribological test. The different load applied to disc were observed within the range of 20 N-40 N to identify the effect of friction. The paraffin oil was used as lubricant when the test for the disc conducted for wet conditions. Other parameters such as speed, ball bearing SKD-11 and temperature will not be covered in this study and these parameters are set to be constant. The tribological test was done at sliding condition according to ASTM G99-95a.

1.5 Report Structure

This report had five chapter to provide more understanding about the flow of this study. This study divided into two phase or two semesters where each semester contain different chapter. In FYP 1, the chapter covered is the primary chapter which is introduction (Chapter 1), literature review (Chapter 2) and methodology (Chapter 3). Meanwhile, FYP 2 covered results and discussion (Chapter 4) and conclusion (Chapter 5). The summarized of this whole chapter combined to achieve the objective of this study. Table 1. 1 shows the report structure for FYP 1 and FYP 2.

Table 1. 1: Report Structure

Chapter	**Content**	**Division**
1	Introduction • Consists of title, problem statement, objectives, scopes of the project and report structure.	**FYP 1**
2	Literature Review • The research based on journal which related to the scope of the study that focus on books, and journal.	
3	Methodology • The method used to conduct the experiment	
4	Result and Discussion • Collecting the data that has been gathered during conducted research and discuss the result.	**FYP 2**
5	Conclusion • Conclude the overall project and improvement can be done.	

CHAPTER 2

LITERATURE REVIEW

Literature review will be discussed in this chapter. The outline of this chapter is the theory that need to emphasized stage by stage for this study and every related topic will be discussed before starting any project analysis or study. Relevant sources like journals, articles, websites and books had been utilized well in order to script this chapter.

2.1 Additive Manufacturing

Additive manufacturing or known as 3D printer is one of the new era or revolutions that currently had potential uses in industry. The popularity of this technologies is dramatically increased in past a decade. According to Wohler's report (2014), the percentage of world sales 2014 increased up to 33% annually in past three years and this combine the sales from devices, material and services for industrial scale to consumer-based printers.

This technology that have their own uniqueness where doesn't need any mold or tools to customized product. The abilities to direct manufacturing process where 3D drawing transform into physical part is one of the factors this technology seen as one of the prospective future development. In future prospect, this technology seen as one of the big steps for every company in world to compete toward Fourth Industrial Revolutions. Thus, development of this technology is one of the successful strategic to solve the problem that currently faced by industry.

There are seven process of additive manufacturing which is binder jetting, directed energy deposition, material extrusion, material jetting, powder ped fusion, sheet lamination and vat photo-polymerization (Lee et al, 2017). Each of this process had their own characteristic that significantly helps the manufacturing fields. However, the focus on this study is material extrusion or known as fused deposition modelling where this process used to fabricate material for this study.

2.1.1 Fused Deposition Modelling (FDM)

Fused Deposition Modelling (FDM) was one of the process involve in additive manufacturing. The printed process was done layer by layer to build the object draw in CAD and transform into physical parts. This process provides a lot of benefit such as complex design part printed according to real part structure, short cycle time and save cost compared to conventional manufacturing process. Plus, engineering and industry such as aircraft, dental restorations, medical implants and automotive products still searching on its application for this technology (Mohamed, Masood, & Bhowmik, 2015). Figure 2. 1 shows the actual diagram of 3D printer that used in this study.

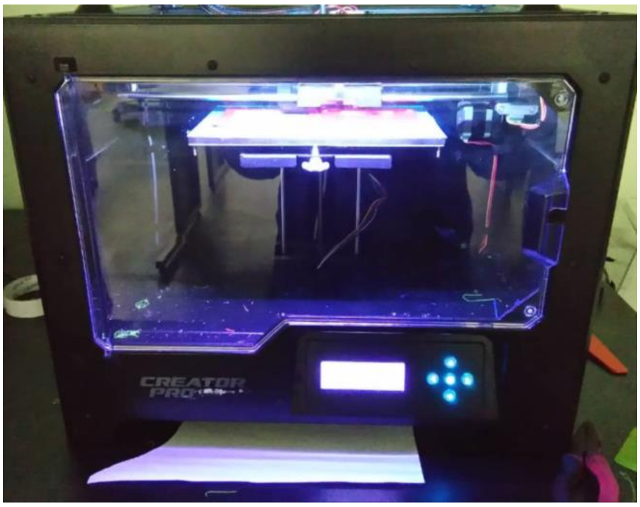

Figure 2. 1: The actual diagram of 3D printer

According to (J. Y. Lee et al., 2017), 3D printer consider as new journey on revolutions towards advanced technology. This is the beginning of technology that helps most of industry on producing the impossible part such as body part or organs. This shows the future of 3D printer in future generation to create unimaginable solutions on undefined problems. The better future in industries can be seen with the expansion on 3D printer since this technology seen as one of the easier ways to save cost and times. Figure 2. 2 shows the AM producing material that can create opportunity on advance technologies.

Figure 2. 2: Additive Manufacturing Material (J. Y. Lee et al., 2017).

From figure above, it shows the opportunity for local industries to expand with this technology in several areas. For example, in electronic material where FDM used to print the organic field transistor, LED and circuit that had special and sensitive characteristic in terms of application (Murr, 2016). The development of FDM seen as successful due to the ability to print the surface that flexible and transparent polymer sheets. Moreover, FDM is not only advanced technologies that suitable with current trend of 4.0 Industrial Revolutions but this technology also played major role on increasing the production that lead to more profit in company or organizations.

There are huge different between 3D printer and compression molding in terms of cost and speed. Compression molding required more time since their need the traditional process such as assemble that take times and expensive tooling involved. In addition, 3D printer might not suitable for small production but it can reduce the material waste during production (Berman, 2012). According to Petrovic et al. (2011), the material waste from production also proved that it can be recycled and reused to creating other product. This is one of the advantages to industry and one of the big reasons to choose 3D printer as part of production line.

2.1.2 FDM Applications for Biomaterial

Biomaterial is the process that involved the biological or synthetic substance that used as implant an organ, medical device and produce tissue to help body functions (Araujo Borges, Choudhury, & Zou, 2018; Ciocca et al., 2009; Daly et al., 2017; Puetzer & Bonassar, 2016). The development of 3D printer is one of benefit to medical institutes to solve problems on difficulties to find suitable donor. The advancements in biocompatible materials have empowered 3D bio-printing for useful living tissues, which can be connected regenerative medication to address the requirement for organs transplantation (Stansbury & Idacavage, 2016; Suntornnond, An, & Chua, 2017; Tack et al., 2016).

The beginning process of this technologies starts with CAD drawing in three dimensional forms before converted to stereolithography (STL) format. STL format support the CAD drawing and helping on reducing the geometry shape to keep the basic components. According to Wright (2001), the basic triangle that can be shows instead of true arcs and spline was one of the handicaps for drawn part. However, 3D printer is as yet the best decisions to embed an organ or tissue in human body to over since it can directly insert cells inside a hydrogel for fabricate, however most lithography methods require a couple of ventures to make an example of cells (Suntornnond et al., 2017)

3D printing method or FDM is used to create solid tissue engineering scaffolds (Bellini & Güçeri, 2003). Other than that, the uniqueness of 3D printer that can fabricated the tissue that had complex geometry makes this technology had a high possibility to expand in medical field since the organ and tissue itself have their own geometry. Even some of the geometry only consist of triangle but most of the characteristic still available. This combination of medical and 3D printing shows the rapid growth on research related to medical fields to create the impossible treatment and reduce the percentage of unsuccessful surgery.

2.1.3 Advantage of FDM for Biomaterials

The advantages of FDM in Biomaterials had been summarized below:

1. Daly et al, (2017) stated that the benefit of FDM is that scaffolds with coordinate pore geometries and channels size can be produce in short times. By shifting procedure parameters such as the extrusion pressure, nozzle diameter and deposition speed it had potential to print scaffolds with extensive variety of filament diameter and porosities.
2. Banis et al., (2014) found that the capacity of the framework to precisely deliver the customized platform design which is programmed scaffold architecture that will be characterized by how much the extruded framework compares to the first model.
3. Cui et al., (2017) confirmed that the FDM process in tissue engineering accomplishment is easy employment, fast printing capacity diverse biomaterial availability and good mechanical properties makes hard tissue seem possible.
4. Suntornnond, An and Chua, (2017) concluded that bioprinting has great repeatability, high accuracy, and satisfactory adaptability, which are imperative for tissue substitute manufacture and may possibly lead to organ printing.

5. (M. Lee & Wu, 2012) the lead of FDM due to high porosity because of complex design and high mechanical strength.

2.1.4 Limitation of FDM for Biomaterial

There are limitations of FDM for Biomaterial listed below to shows the discussion:

1) Geometric limitation

- Stated that FDM able to identify the complex geometries but this technology in the beginning state to identify the correct of design. This effect the geometries of object and the printer item might not have the same surface roughness.

2) Limitation to material

- Thermoplastic materials with good melt viscosity properties that are high enough to build viscosity but low enough for extrusion viscosity

3) High temperature.

- Due to high processing temperature, the inability to incorporate living cells or temperature sensitive biological agents during extrusion.