OPTIMIZATION OF TRIBO-PERFORMANCE OF 3D-PRINTED ABS WITH INTERNAL STRUCTURE FORMATION FOR PRODUCTION OF AUTOMOTIVE BEARING

MUHAMMAD SYAHROL NIZAM BIN MAT AZMAN

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DECLARATION

I declare that this project report entitled “Optimization of Tribo-performance of 3D-printed ABS with internal structure formation for production of automotive bearing” is the result of my work except as cited in 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 Mechanical Engineering

Signature :...................................

Supervisor's Name :...................................

Date :...................................

DEDICATION

This report is dedicated to my beloved parents, family members, lecturers, and friends who’ve been with me throughout a fantastic journey of my academic life. We pray to Allah Almighty for the health and forgiveness of our parents who have given us a lot but claimed nothing.

ABSTRACT

In this paper, the objective to determine the optimized printing parameters of 3D-printed ABS for new automotive bearing formulation using the Taguchi Method. Therefore, the design of experiments was conducted for the analysis of the influence of the printing parameters such as layer height, pattern, and nozzle temperature on the coefficient of friction (COF). The results of the pin-on-disc test were used to characterize the main factors affecting COF by the Analysis of Variance (ANOVA) method Taguchi's parametric design is the effective tool for robust design it offers a simple and systematic qualitative optimal design to a relatively low cost. However, the Design of Experiments (DOE) is the key element for achieving high quality at low cost and COF. The Taguchi method is used to find optimum process parameters in the production process of 3D-printed ABS for new automotive bearings. In the experiment, the value of the layer height is 0.1, 0.2 and 0.3 while the temperature is 225°C, 230°C and 235°C and with three different patterns which is rectilinear, concentric and hilbert was used. Experimental results show that the layer height of the printing parameters is the most significant printing parameter for COF followed by pattern and nozzle temperature in the specified test range.

ABSTRAK

Dalam kajian ini, objektifnya adalah untuk mengenal pasti cara mengoptimumkan penggunaan parameter percetakan tiga dimensibagi bahan Acrylonitrile butadiene styrene (ABS) untuk menghasilkan galas automotif yang baru dengan menggunakan kaedah Taguchi. Oleh itu, reka bentuk experiment ini dilalukan dengan menganalisis printing parameter seperti ketinggian lapisan, corak, suhu muncung pada mesin pencetak tiga dimensi keatas pekali geseran (COF). Keputusan daripada experiment pin-on-disc digunakan untuk mengkategorikan factor-faktor utama yang dipengaruhi oleh pekali geseran melalui Analysis of Variance (ANOVA) di dalam kaedah Taguchi di mana parametric design dalam kaedah ini adalah cara yang efektif untuk mendapatkan reka bentuk yang bagus dan menawarkan cara yang mudah serta sistematik dengan melibatkan kos yang rendah. Reka bentuk experiment adalah elemen yang penting untuk mendapatkan kualiti yang bagus dengan kos dan pekali geseran (COF) yang rendah. Kaedah Taguchi digunakan untuk mencari parameter proses yang optimum dalam penghasilan 3D-printed ABS untuk galas automotif yang baru. Dalam experiment ini, nilai ketinggian lapisan adalah 0.1, 0.2 dan 0.3 manakala suhu muncung pula bersamaan 225°C, 230°C dan 235°C *serta bagi corak mempunyai tiga variasi iaitu rectilinear, concentric dan hilbert telah digunakan. Keputusan experiment menunjukkan bahawa ketinggian lapisan adalah faktor yang paling mempengaruhi pekali geseran (COF) diikuti dengan faktor corak dan suhu muncung.*

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LIST OF ABBREVIATIONS

COF	-	Coefficient of Friction
FDM	-	Fused Deposition Modeling
FFF	-	Fused Filament Manufacturing
FLM	-	Fused Layer Manufacturing
PEI	-	Polyetherimide
PC	-	Polycarbonate
PPSF	-	Polyphenylsulfone
PLA	-	Polylactic Acid
PA	-	Polyammide
PVDF	-	Polyvinylidene Fluoride
HIPS	-	High-Impact Polystyrene
CAD	-	Computer-aided Design
ME	-	Modelling Extrusion
AM	-	Additive Manufacturing
ASTM	-	American Society of Testing and Materials
ABS	-	Acrylonitrile butadiene styrene

LIST OF SYMBOLS

D	-	Distance of slide, m
r	-	Radius wear track, m
N	-	Sliding speed, rpm
t	-	Time, min & sec
F	-	Frictional force, N
W	-	Applied load, N
V_{loss}	-	Volume loss, mm^3
k	-	Specific wear rate, mm^3/N.mm
a	-	Wear scar radius, mm
h	-	Wear depth, mm
L	-	Sliding distance, mm

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Tribology is the concept of the science and engineering of dynamic surfaces in relative motion. The Tribology study includes the application of the principles of lubrication, friction, and wear. It is highly interdisciplinary and has been used in many academic fields such as physics, chemistry, mathematics, biology, material sciences, and engineering. The importance of tribological properties for economic reasons are the same as technological development reason. There is various wear of patterns like erosion, fatigue, and abrasion which caused by damages of contact surfaces (Zmitrowicz, 2006). Ignorance of tribological phenomena and less effectiveness of programs of research to manage this situation cause a tremendous waste of resources.

Fused deposition modeling (FDM), also known as fused filament manufacturing (FFF), fused layer manufacturing (FLM), extrusion modeling (ME) or 3D printing is one of the most popular additive manufacturing (AM) processes used in the manufacture of prototypes and functional parts in common extrusion-based engineering plastics, the material being "selectively dispensed via a nozzle or orifice" (Iso, 2015).

The study of printing parameters and tribological properties of 3D-printed ABS material is most important because different parameters and tribological properties provide different types of properties in the materials ' mechanical behavior, friction, and wear due to different combinations of factors. This project will focus on investigating the optimum printing parameters that affect the coefficient of friction (COF) and wear of 3D-printed ABS material by varying three different factors: layer height, printing pattern, and temperature of the nozzle. The outcome of this project will provide ABS material with better and suitable printing parameters for the lowest coefficient of friction and wear.

1.2 Problem Statement

A bearing is a moving device that supports the movement of rotation between a stationary part and a rotating part. In the automotive industry, carbon steel, stainless steel, chrome steel, brass, aluminum, tungsten carbide, and plastic are used in many types of bearing materials. Compared to acrylonitrile butadiene styrene (ABS) material, these common material bearings are more expensive, a higher coefficient of friction and wear. It is part of the category of thermoplastic polymer made by polymerizing styrene and acrylonitrile with polybutadiene. This is a material commonly used in 3D printing for personal, industrial, and household uses primarily fused deposition modeling (FDM) or 3D printers for fused filament manufacturing (FFF). These ABS materials have great, lightweight plastic properties, good impact strength, resistance to abrasion, and affordable.

Therefore, this project focuses on optimized printing parameters of 3D-printed ABS material for a new automotive bearing to design a lower cost, friction coefficient, and wear bearing using ABS materials.

1.3 Objective

The objective of this study is to determine the optimized printing parameters of 3D-printed ABS for new automotive bearing formulation using the Taguchi Method.

1.4 Scope

The study covers the development of specimen of 3D-printed ABS with internal structure formation for production of automotive bearing with different parameters using fused deposition modelling (FDM), also known as fused layer manufacturing (FLM), modelling extrusion (ME), fused filament fabrication or 3D printing. This study focuses on friction and wears properties using the ASTM standard ball-on-disk tribometer with fixed temperature, speed, and time parameters. In this study, which is layer height, pattern, and nozzle temperature, three independent factors that have been considered.

1.5 General Methodology

1.5.1 Flowchart

This section explains how to carry out this project to achieve the goals of this project, such as correctly processing, identifying, analyzing data, and information. The project methodology is summarized in the flowchart below in Figure 1.1.

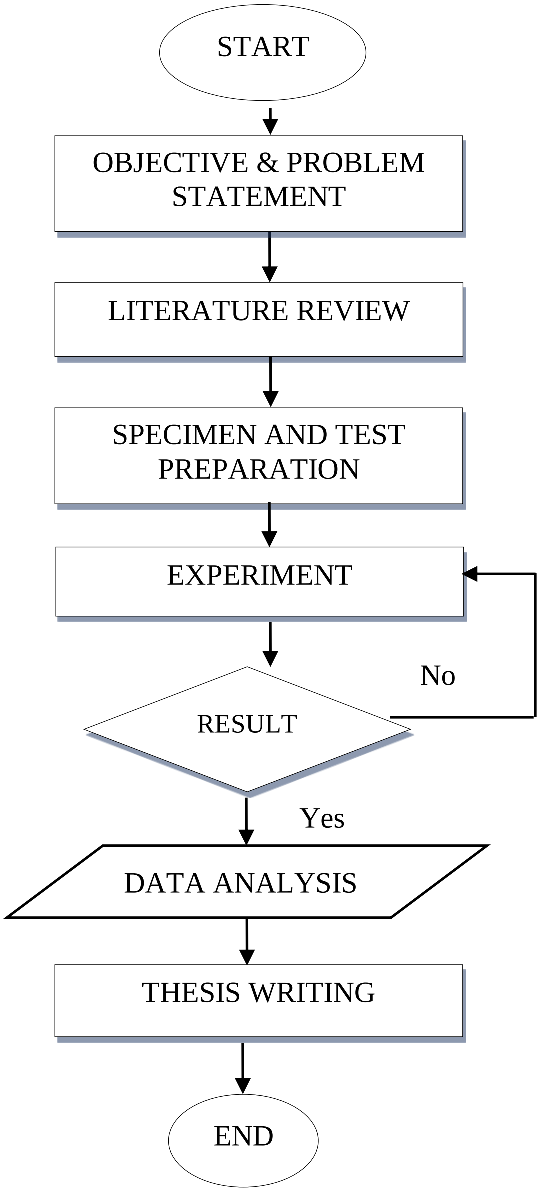


Figure 1.1: Flowchart of the methodology

Based on Figure 1.1, the first process is the selection of the project title followed by the identification of the problem statement and title-based objectives, which is to optimize the printing parameters for friction and wear analysis of fused deposition modeling (FDM) 3D-printed ABS.

Next is the research and journal literature review, which is data from the literature review of existing projects, journals, articles, and other resources on this project. Another step is the sample preparation and testing, the materials used acrylonitrile butadiene styrene (ABS) material and the testing uses a pin-on-disk device at room temperature under the dry sliding condition.

After that, the results of the testing process were obtained. The result will be recorded in writing and figure. Analyses how to optimize printing parameters for the lowest friction coefficient (COF) and wear of ABS material for the result analysis. Finally, the report writing process includes relevant information and data on the work of the project based on the format

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

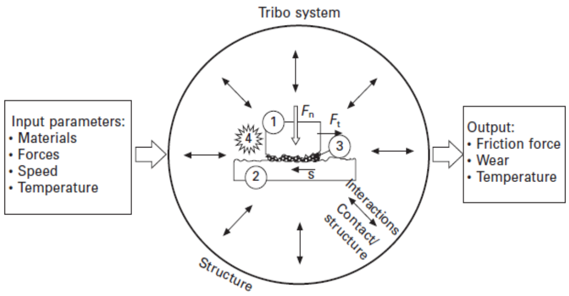
Previous research and sources from journals, reports, articles, books, and websites will be evaluated in this chapter to discover the information related to this study. The purpose of this chapter is to generate a guideline to complete this project from previous knowledge and ideas. Besides, all the information is selected under this study's objectives. Some information on tribological studies, 3D printing technologies, and materials, the Taguchi method of optimization, and pin-on-disk testing is required to achieve the objectives of this study.

For this chapter, the entire section is arranged as follows, which is the second section on tribological studies explains Section 2.2. Section 2.3 will continue to discuss 3D printing technology while Section 2.4 will explain 3D printing materials. The following section 2.5 describes the method of optimization and Section 2.6 clarifies the potential applications in this study of the 3D-printed ABS materials.

2.2 Tribology study

Tribology is the study of the science and engineering of interacting surfaces in relative motion, a phenomenon that affects our lives in various ways every day. It includes the study and application of the principles of friction, lubrication, and wear. The term tribology is based on the Greek word for rubbing which is introduced by Peter Jost in 1966 and it was officially published in Jost Report. Generally, the tribological study includes three main components which are friction, wear, and lubrication. Friction is the resistance to relative motion while wear is the loss of material due to that motion and lubrication is the use of a fluid to reduce friction and wear of materials.

The industrial growth rapidly because of the growth of technology led to the needed for a better understanding of tribology. (Lyon, 2011) stated that the study of mechanisms of tribology needs to be done to understand this field and improves the technology. The mechanisms mostly machine elements such as bearings, clutches, gears, cables, and human joints. The mechanisms are operated which require forces, speeds, temperature, etc., act on the moving object form the output of friction force, wear, and temperature. The important objective of tribology is to optimize moving systems functionally, economically as well as ecologically.



4.1 The various components of the tribosystem: 1 and 2 are the two first bodies; 3 is the interfacial body or third body; 4 represents the environment (Fn: normal force, Ft: tangential force, S: sliding speed) (Czichos, 1978).

Figure 2.1: The key elements of a tribology system from Lyon, (2011)

2.3 3D Printing Technologies

Additive manufacturing, also known as 3D printing, is a group of processes that create items by applying the material in layers that correspond to successive 3D model cross-sections unlike traditional processes of machining, casting and forging, where the material is extracted from a stock product (subtractive manufacturing) or poured into a mold and formed by dies, presses, and hammers. Rapid prototyping was the first method developed in the 1980s to create a three-dimensional layer-by-layer object using computer-aided design (CAD) to produce models and prototype parts. Plastics and metal alloys are the most commonly used materials for 3D printing, but they can work on almost anything from concrete to living tissue.

There are some advantages of 3D printing, which is capable of creating any shape that can fit within the volume of its construction. For example, in other manufacturing processes such as milling, each new part or part design change requires the manufacture of a new mold, tool, die, or jig to create a new part. The design can be fed into slicer software with 3D printing, any necessary supports can be added and then printed with less or no change in the physical machinery or equipment compared to conventional production. Besides, 3D printing is faster than injection molding and subtractive production. Faster design and prototype production, longer time to iterate the prototype, and find the product-market fit before competitors. The costs of machine operation, materials, and manufacturing for 3D printing are significantly cheaper than other alternative production methods, such as injection molding.

Many of the existing fast prototyping or 3D printing technologies on the market (Wang and Zhang 2012) are based on a similar layer manufacturing approach. First, a 3D computer-aided design (CAD) file is sliced into a stack of two-dimensional flat layers. These layers are made by a 3D printing machine and stacked one after the other