MECHANICAL PROPERTIES INVESTIGATION ON PLA AND ABS MATERIALS FOR GEOSPATIAL TOPOLOGY PRODUCT PRINTED BY RAPID PROTOTYPING METHOD

ZARIF HASIF BIN TERMITI

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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ZARIF HASIF BIN TERMITI

This report is submitted
in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

DECLARATION

"I hereby declare that this project report entitled "Mechanical Properties Investigation on PLA and ABS Materials for Geospatial Topology Product Printed by Rapid Prototyping Method" is the result of my own work except as cited in the references"

Signature : …….…….

Student Name: …….....

Date : ……

SUPERVISOR DECLARATION

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 : ……

Supervisor's Name : ……

Date : ……

DEDICATION

I would like to dedicate my project to my beloved parents, Mr. Termiti Bin Sidon and Mrs.Siti Azanah Binti Husin, family, my supervisor Dr.Mohd.Azli Bin Salim, lecturers and friends who gave me never ending affection, love, encouragement and pray of day and night throughout this Final Year Project of Bachelor's degree of Mechanical Engineering.

ABSTRACT

Mechanical properties of material is important aspect in designing and producing a high quality product and reliable to user. Geospatial technology is an advance technology that used by human which act as modern tools that provide the geographic mapping and analysis of the earth and human societies. The application of GIS under the geospatial technology is a system that processing and retrieving geospatial reference data which contain geographic attribute information. Rapid prototyping is one of element in the essence of the industrial revolution 4.0 which changes or revolutionize manufacturing industry pattern from mass production to mass customization. For instance, the used of rapid prototyping method have been implemented in the current development of geospatial product from various type of material. Recently, the FDM 3D printing had been widely used including in the development of geospatial product, unfortunately the performance of material after printed is still unknown. This research was done focusing on evaluating the material properties (tensile, flexural, and impact) for ABS and PLA filament for geospatial topology product produce by FDM 3D printing. The previous studies show that the variation or changes in parameter of FDM 3D printing would affect the material properties performance of printed material and product appearance. Other than that, the thesis had fulfilled its objective to investigate the relationship between tensile, flexural and impact data on ABS and PLA filament. The study involving the fabrication of specimen by FDM 3D printing method using same printing parameter of 3D printing geospatial product and finding suitable standard of testing that can be use based on the previous studies. The ASTM standards is used for all testing to study the material properties. For tensile test, ASTM D638 is used as standards guideline which required fabrication of type IV specimen size and 5mm/min testing speed. Meanwhile, ASTM D790 is chosen as guideline in conducting flexural testing that involving specimen preparation of molded type with 51.2mm span length and 1.367mm/min test speed. Impact testing which used izod impact testing method has following ASTM D256 which involving testing the specimen by using 2.75J pendulum energy. The finding of the studies shows that by using proper standard of testing, the material properties of the material used for geospatial product which are ABS and PLA material. For tensile testing, the tensile strength for ABS and PLA material are 3.48 MPa and 37.45 MPa respectively. Meanwhile, the flexural strength of ABS material is 53.15 MPa and 68.52 MPa for PLA material in flexural testing. Last but not least, the result of impact test gives value of impact strength for ABS and PLA material which are 3.33 MPa and 11.63 MPa respectively. The geospatial product which made by PLA material has the ability to withstand high tensile and flexural loading but poor in resisting impact loading compare with ABS material if producing according the reference parameter based on the result in this study.

ABSTRAK

Sifat mekanikal bahan adalah aspek penting dalam merekabentuk dan menghasilkan produk berkualiti tinggi dan boleh dipercayai kepada pengguna. Teknologi geospatial adalah teknologi maju yang digunakan oleh manusia yang bertindak sebagai alat moden yang menyediakan pemetaan dan analisis geografi bumi dan masyarakat. Aplikasi GIS di bawah teknologi geospatial adalah sistem yang memproses dan mengambil data rujukan geospasial yang mengandungi maklumat sifat geografi. Prototaip pantas merupakan element dalam intipati revolusi industri 4.0 yang mengubah atau merevolusikan corak industri pembuatan dari pengeluaran besar-besaran ke penyesuaian besar-besaran. Sebagai contoh, penggunaan kaedah prototaip pantas digunakan dalam pembangunan produk geospatial menggunakan pelbagai jenis bahan. Pada masa kini, percetakan 3D FDM telah digunakan secara meluas termasuk dalam pembangunan produk geospatial, malangnya prestasi bahan selepas dicetak masih tidak diketahui. Kajian ini dilakukan dengan berfokus kepada penilaian sifat bahan (tegangan, lenturan, dan impak) untuk filamen ABS dan PLA untuk menghasilkan produk topologi geospatial menggunakan percetakan FDM 3D. Kajian terdahulu menunjukkan bahawa variasi atau perubahan dalam parameter percetakan FDM 3D akan mempengaruhi prestasi sifat mekanikal bahan dan penampilan produk. Selain itu, tesis in telah memenuhi objektifnya untuk menyiasat hubungan antara data tegangan, lenturan dan impak pada filamen ABS dan PLA. Kajian yang melibatkan fabrikasi spesimen menggunakan kaedah percetakan 3D FDM menggunakan parameter percetakan yang sama dengan produk geospatial percetakan 3D dan mencari standard ujian yang sesuai yang boleh digunakan berdasarkan kajian terdahulu. Piawaian ASTM digunakan untuk semua ujian untuk mengkaji sifat bahan. Untuk ujian tegangan, ASTM D638 digunakan sebagai panduan piawaian yang memerlukan fabrikasi saiz spesimen jenis IV dan kelajuan ujian 5mm / min. Sementara itu, ASTM D790 dipilih sebagai garis panduan dalam menjalankan ujian lenturan yang melibatkan penyediaan spesimen berjangka dengan panjang span 51.2mm dan kelajuan ujian 1.367mm / min. Ujian impak yang menggunakan kaedah ujian impak izod telah mengikuti ASTM D256 yang melibatkan ujian spesimen dengan menggunakan tenaga pendulum 2.75J. Kajian menunjukkan bahawa dengan standard ujian yang tepat, sifat bahan bahan yang digunakan untuk produk geospatial yang merupakan bahan ABS dan PLA dikenal pasti. Untuk ujian tegangan, kekuatan tegangan untuk bahan ABS dan PLA masing-masing ialah 3.48 MPa dan 37.45 MPa. Sementara itu, kekuatan lenturan bahan ABS ialah 53.15 MPa dan 68.52 MPa untuk bahan PLA dalam ujian lenturan. Akhir sekali, keputusan ujian impak memberikan nilai kekuatan impak bagi bahan ABS dan PLA iaitu masing-masing 3.33 MPa dan 11.63 MPa. Produk geospatial yang dibuat oleh bahan PLA mempunyai keupayaan untuk menahan pemuatan tegangan dan lenturan yang tinggi tetapi miskin untuk menahan impak beban berbanding dengan bahan ABS jika menghasilkan mengikut parameter rujukan berdasarkan hasil kajian ini.

ACKNOWLEDGEMENT

Praise to Allah SWT almighty for giving me the opportunity and strength to finish up my project. I am grateful and would like to express my sincere appreciation to my supervisor Dr.Mohd Azli Bin Salim from the Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka for providing tremendous technical guidance, advices, continuous encouragement, constructive criticisms, suggestions and glorious knowledge throughout the completion of this project. Sincerely, a great appreciation indicates to Dr. Mohd Nur Azmi Bin Nordin And En. Wan Mohd Farid Bin Wan Mohamad for evaluating my final year project

I would also like to express my greatest gratitude to my mentor for this project, Adhwa Atira Binti Zainal Abidin which help me in accomplishing my project especially in laboratory work. I also want to thank to laboratory assistant engineer En.Faizol Bin Kamarul Zahari and Azizul Ikhwan Bin Mohd. which assist and guide me through all the laboratory work.

A special thank for my loving mother, Siti Azanah Binti Husin and my father, Termiti Bin Sidon for never endless support and stunning advice. I also would like to express my special thanks of gratitude to thank my friends and classmates who involve helping me a lot finalizing this project successfully.

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LIST OF ABBEREVATIONS

ABS	Acrylonitrile butadiene styrene
AM	Additive Manufacturing
ASTM	American Society for Testing and Materials
BS	British Standard
CAC	Computer Assisted Cartography
CAD	Computer Aided Design
DEM	Digital Elevation Model
DLP	Digital Light Processing
EBM	Electron Beam Melting
FDM	Fused Deposition Modelling
GIS	Geographic Information System
GPS	Global Positioning System
ISO	International Organization for Standardization
LOM	Laminated Object Manufacturing
LCD	Liquid Crystal Display
PLA	Polylactic Acid
RP	Rapid Prototyping
SLA	Stereolithography
SLM	Selective Laser Melting
SLS	Selective Laser Sintering
STL	Standard Triangulation Language
USGS	National Mapping Website
UTM	Universal Testing Machine
VR	Visual Reality
VRML	Virtual Reality Modeling Language

LIST OF SYMBOL

σ_T	=	Tensile Stress
F_t	=	Tensile Force
E	=	Modulus Elasticity
ε	=	Strain
Gc	=	Impact Strength of Material
Uc	=	Energy of Impact
Ac	=	Cross-Sectional Area of the Specimen
R	=	Rate of Crosshead Motion
L	=	Length of Support Span
Z	=	Rate Of Straining Outer Fibre
D	=	Mid-Span Deflection
σ_f	=	Flexural Stress, MPa
P	=	Force, N
E_f	=	Modulus Elasticity in Bending, MPa
m	=	Slope of The Tangent Curve

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CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter will brief the introduction of the research that include background information about relationship between geospatial technology and additive manufacturing 3D printing. In addition, the mechanical properties of 3D printing material use in 3D printing will be brief which focusing on tensile, flexural and impact loading. This chapter also cover the problem statement, objective and scopes of the research.

1.2 Background Study

Geospatial technology is a technology that related to the collection or processing of data that is associated with location. It also can be describe as the range of modern tools contributing to the geographic mapping and analysis of the earth and human societies. This technology has existed since the first maps were drawn in the early age, and it have been evolving to other form of technologies which is related to geographic or positioning information. The collection of modern geographic data information has begun since 19th century. It begins when this technology collaborated with aerial photography technology to collect the data by using camera which use balloons and pigeons as aerial transportation medium. In 20th century, the collection of data becomes more reliable when the aerial vehicle which is airplanes used in process of collecting geospatial data. The science and art of photographic

interpretation and map making was increased rapidly during the Second World War and during the Cold War it took on new upgrades with the advent of satellites and computers. Nowadays, the geospatial technology has been widely used in our daily life such as Global Positioning System (GPS), Geographic Information System (GIS) and Remote Sensing. GIS is a system which has been designed to capture, store, manipulate, analyse, manage, and present spatial or geographic data. The aspect of GIS which important in term of geospatial is GIS has capability to gather and manage geospatial data into layered set of maps. This layers enable the geospatial data which contains various spatial information that includes information regarding precise location on the earth surface to be analysed and shared to audiences.

Additive manufacturing technology has become a phenomenon that contribute in industrial revolution recently. This manufacturing technology is declared as focused area of element in the 4^{th} industrial revolution focus area. For the past few years, the development of AM technology has been rapidly increase which change and revolutionized the industrial fabrication process towards efficient product or part making. AM technology use the method of building parts layer-by-layer through depositing the build material such as thermoplastic, metal, and concrete. Basically, AM required three basics things to operate which are build material, machine and 3D file format such as STL and VRML. The 3D file format can be generated by using Computer Aided Design (CAD) software and image scanning. When the 3D file format is link with the machine, it will start deposit or lay down successive layer of build material in layer by layer pattern to generate the 3D model. The term of AM is related with Rapid Prototyping (RP) and 3D printing. In other words, AM and 3D printing are the process, and rapid prototyping is the end result of the AM and 3D

printing. Rapid prototyping can be classified as one of many applications under the 3D printing and additive manufacturing process.

Currently, the 3D geospatial model is used for the visualization purpose such as for project presentation tool and public display. It enhances the human understanding on physical environment which consist of many spatial aspects. The traditional method to produce the 3D geospatial model require a lot of effort and time to produce a model that has accurate parameter and exactly same as the real geospatial image. The implementation of 3D printing AM for producing a 3D geospatial model has overcome the problem and limitation to produce a precise 3D model exactly as the real geospatial image. The 3D printing process of geospatial model require a GIS data that contain all the geospatial image parameter. The data can be access from the valid mapping source and need to be convert into 3D file format for the 3D printer to generate the G-Code for the fabrication process. This printing method can provide a better visualisation due to the model is generated according to the GIS data compared to the traditional method that inaccurate which can cause measuring and estimation error such as distance and contour height measurement.

A good product or services can be define as a product or services that made or invented for fulling the requirement and needs of the customer. The important aspect which become the priority and concern by the customer is the quality aspects. The aspects of producing goods which has high quality is essential for the manufacturer to ensure reliability of the product that manufactured for customer use. For every manufacturing process, mechanical properties of the material become the essential of making high quality goods. The properties are referring to the ability of the material to get through any stress or deflection which can affect the product physically. Every material that undergo manufacturing process which exposed too many types of