Faculty of Mechanical and Manufacturing Engineering Technology

AN EXPERIMENTAL INVESTIGATION ON THE SURFACE FINISH OF MELAKA HISTORICAL ARTIFACT FABRICATED USING ADDITIVE MANUFACTURING SYSTEM

Low Kah Lai

Bachelor of Manufacturing Engineering Technology (Product Design) with Honours

2019

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LOW KAH LAI

A thesis submitted
in fulfillment of the requirements for the degree of Bachelor in Manufacturing Engineering Technology (Product Design) with Honours

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

DECLARATION

I declare that this thesis entitled “An Experimental Investigation on the Surface Finish of Melaka Historical Artifact Fabricated Using Additive Manufacturing System” is the results of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : …….

Author’s Name : LOW KAH LAI

Date : ……

APPROVAL

This report is submitted to the Faculty of Mechanical and Manufacturing Engineering Technology of UTeM as a partial fulfillment of the requirements for the Bachelor of Manufacturing Engineering Technology (Product Design) with Honours. The member of the supervisory is as follow:

Signature :……

Supervisor Name : TS.Dr. Syahibudil Ikhwan bin Abdul Kudus

Date :…….

DEDICATION

This work is wholeheartedly dedicated to all my valuable treasures:

For my beloved parents:

Mr. Low Yan Nyin

Mrs. Lee Kim Lan

For my supportive siblings:

Low Kuan Yee

Low Mei Yan

Low Siew Keong

Thank you always provide me moral, emotional, financial support and gave me strength when I thought of giving up.

For my beloved supervisor and co-supervisor:

TS. Dr. Syahibudil Ikhwan bin Abdul Kudus & TS. Dr. Hambali bin Boejang

For all UTeM lecturers, The Stadthuys Museum and my treasured friends.

Who shared their words of advice and encouragement to finish this study.

ABSTRACT

Additive Manufacturing (AM) is the one technology that can fabricate or build a part in more efficiency way and lower costs compared to other manufacturing technologies. It built the 3D objects by adding material layer upon layer through the machines. To build 3D objects with AM, Reverse Engineering (RE), Computer-Aided-Design (CAD) data and AM system such as Fusion Deposition Modelling (FDM), Stereolithography (SLA) and Selective Laser Sintering (SLS) are needed. In this study, it was found there have various countries such as Germany have used AM technology to restore and preserve historical artifacts from the museums. There have a few museums in Melaka have kept the historical artifacts. Thus, the purpose of this study is to investigate the surface finish Melaka historical artifacts fabricated using Additive Manufacturing system. This is to compare the surface finish of prototype and the original historical artefact based on the measurement of surface. The measurement on the surface finish will be determined by using the surface roughness tester.

ABSTRAK

"Additive Manufacturing" (AM) merupakan salah satu teknologi yang dapat membina dalam kaedah yang lebih cekap dan kos rendah berbanding dengan teknologi pembuatan lain. Ia membina objek 3D dengan menambah bahan lapisan ke lapisan melalui mesin. Untuk membina objeck 3D, "Reverse Engieering" (RE), "Computer-Aided-Design" (CAD) data dan system "Additive Manufacturing" seperti "Fusion Deposition Modelling (FDM)", "Stereolithography (SLA)" and "Selective Laser Sintering (SLS)" adalah diperlukan. Dalam kajian ini, terdapat beberapa negara seperti Jerman telah menggunakan teknologi AM untuk memulihkan dan memeliharakan artifak-artifak sejarah dari muzium. Selain itu, terdapat beberapa muzium di Melaka menyimpan artifak-artifak sejarah. Oleh sebab itu, tujuan kajian ini adalah untuk menyelidik permukaan artifak sejarah yang dibinakan dengan sistem "Additive Manufacturing". Hal ini adalah untuk mambandingkan permukaan prototaip dengan artifak sejarah berdasarkan pengukuran permukaan. Mesin "surface roughness tester" akan digunakan untuk mengukurkan permukaan.

ACKNOWLEDGEMENTS

First and foremost, I appreciate to my brilliant and outstanding supervisor, TS. Dr. Syahibudil Ikhwan bin Abdul Kudus who encouragement, guidance and support from the initial to the final level. Besides, I also appreciate to TS. Dr. Hambali bin Boejang, without his guidance and persistent help this project would not have been possible. Moreover, a special thanks to Madam Azimah binti Md. Ali, the curator of Stadthuys museum for giving information of the historical artifact to me.

Lastly, I would like to thanks to all UTeM lecturers and my fellow friends that involved direct and indirectly who provided their time, efforts and support for this project. Also, I would like to thanks to my course mate who under the same supervisor with me.

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Ra	-	Surface roughness reading

LIST OF ABBREVIATIONS

AM	-	Additive Manufacturing
RE	-	Reverse Engineering
CAD	-	Computer Aided Design
SLS	-	Selective Laser Sintering
PSM	-	Project Sarjana Muda
STL	-	Standard Triangulation Language
3D	-	3-Dimensional
LS	-	Laser Sintering
TCT	-	Time Compression Technology
CH	-	Cultural Heritage
FDM	-	Fused Deposition Modeling
LOM	-	Laminated Objective Manufacturing
3DP	-	Three Dimensional Printing
LMD	-	Laser Metal Deposition
SLA	-	Stereolithography

CHAPTER 1

INTRODUCTION

1.1 Project Background

Additive Manufacturing (AM) and Reverse Engineering (RE) is playing an important role in reducing the product development time, now it becomes the critical to the product design and development. In recent years, the last 3D scanning and reverse engineering (RE) technologies improved significantly, and it became a viable option in capturing the geometry of complicated design models (Lee & Woo, 1998). Despite of the advantages of the technology, the surface roughness has become the main issue (Kaji & Barari, 2015). There have many attempts are made to control, monitor and predict the surface roughness of the printed part surface.

Campbell et al. (Campbell, Martorelli, & Lee, 2002) presented surface roughness visualisation for additive manufacturing models. In this research, the values of surface roughness were obtained and used as the database for a visualisation algorithm that represents varying surface roughness of the AM model. Kaji and Barari (Kaji & Barari, 2015) have presented the evaluation of the surface roughness of AM parts based on the modelling of cusp geometry. An experimental method for describing surface roughness distribution is provided on the basis of actual observation and simulation of the cusp geometry under various setups and manufacturing conditions(Kaji & Barari, 2015).

Thus, this project is conducted to investigate surface finish on parts printed using an Additive Manufacturing (AM) printing system that are currently available in Fakulti

Teknologi Kejuruteraan Mekanikal & Pembuatan (FTKMP), UTeM. The development of the additive manufacturing technologies are expanded and widely used in various application fields included archaeology field. A certain country used AM technologies to restore or preserve the historical artifacts. This study is conducted to investigate the surface finish of the produced part whether it is similar to the original product. Also, this technology might be used for restoring and preserving the Malaysia's historical artifacts in the future. Furthermore, the experiment will be conducted using non-contact reverse engineering and Laser Sintering Machine, based on the local historical artifact object. Non-contact RE which is 3D scanner will be used to duplicate the geometry of object and the part will be built by using Laser Sintering machine. Last but not least, the expectation result of this project is the surface finish of the produced part is similar to the surface of the original part.

1.2 Problem Statement

The historical artifact is very important to human because it imposes the structure on people's live and provides information about the past. Meanwhile, there are a lot of historical artifacts are damaged or lost due to the occurrence of the natural disaster. For example, a fragmented artifact, The Madonna of Pietranico is damaged after the earthquake (Arbace et al., 2013). There have many methods of reconstruction or restoration, but the method used need to consider the material used of the artifacts. Moreover, some of the artifacts are in complex shape or structure and it would cause inconvenient to the conservators when they restored the artifacts. Also, the more complex the structure of the artifacts, the longest the time is taken to complete the restoration of the artifacts. Nowadays Reverse Engineering (RE), Computer Aided Design (CAD) and Additive Manufacturing (AM) technologies has been used extensively in the reproduction of damaged historical artifacts. With the assistance of those technologies, conservators are able to restore the artifacts in low cost and more

efficiency ways. The minimal time and costs demands of the prototype production via AM leads to improve product quality because more times are available for design iteration and optimization. Even the AM have brought benefits in application of artifact restoration, the surface finish of built part commonly different to the historical artifact. Zhang et al (Zhang, Campbell, & Graham, 2016) have presented the digital restoration of archaeological artifact, they have carried out various finishing technique for external effect to improve the surface finish of the built part. Thus, the surface roughness of historical artifact which have fabricated using AM will be studied in this project.

1.3 Objective of Project

The objectives of this research work can be concluded as followed;

1. To duplicate the geometric data of the historical artifact object by using non-contact reverse engineering (RE) and Laser Sintering Machine.
2. To measure surface roughness of the original object and prototype with Portable Surface Roughness Tester.
3. To do a comparison analysis between the original object and prototypes based on surface roughness measurement result of prototypes produced by Laser Sintering machine.

1.4 Project Scope

The scopes of this project are:

1. To do a literature search and reviews.
2. To identify the potential scanned object to be studied (17^{th} century Dutch Flintlock Pistol).

3. To familiarize Reverse Engineering (RE), Computer Aided Design (CAD) and Laser Sintering Machine.
4. To scan a physical object and manipulate the data (point cloud).
5. To convert the RE data directly to Standard Triangulation Language (STL).
6. To verify both of the STL data and fabricate a prototype by using Laser Sintering Machine
7. To carry out a comparison of surface roughness analysis between the historical artifact object and prototypes.

1.5 Summary

In this chapter, the project background is discussed, the purpose of this project is to investigate the surface finish, quality file and built time of the prototype. The objectives and project scopes are determined to easier understanding the needs of this project. A historical artifact will be used as the experiment object to fulfil the project objectives. Also, a comparison between the historical artefact and prototype on the surface finish will be conducted based on the surface finish analysis. The literature research to the Additive Manufacturing (AM), Reverse Engineering (RE), background of historical artifact and Computer Aided Design data will be conducted in chapter 2.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Historical Artifact

An artifact is a something which is made by human, such as a work of art, especially an objects of archaeological interest. In simplest sense, an artifact is anything made or modified by conscious human action (Orser, 2016). A modem dictionary of anthropology defines an artifact as "an object of any type made by human hands. Tools, weapons, and sculptured and engraved objects are representative artefacts (Author, Reviewed, Review, Geographical, & Stable, 2012)." This definition seems to exclude deliberately mental objects such as legends and myths and to include only objects that are made by human hands, that can survive the erosion of time, and that can be accommodated in a museum (Author et al., 2012).

The artifacts are the physical objects that created and used by a human, and the artifacts may include such objects as utensils, tools and coins. The existing of historical artifacts is very important to human. What is important about artifacts is that they require interpretation. Artifacts require interpretation because they are not passive creations. Artifacts impose structure on people's lives in the same way people impose structure on an artifacts in the process of fashioning it. The relationship between humans and things may best be considered by thinking about a small farmhouse (Orser, 2016). Other than that, all of archaeology is based on the simple premise that artifacts have past knowledge. Some archaeologist have treat artifacts as the source of historical documents for more than a century. The idea that artifacts can be read as the historical text has a great deal to do with

the artifact production technology of. Historical archaeologists use artifacts as historical documents in many ways (Orser, 2016).

In global, every country has its own historical artifacts as the representative of the country. For the example, the religious medallions is representative historical artifact to St.Catherine's Island (see Figure 2.1). Since artifacts have considered as the historical documents, the history, religions, political and philosophy from a certain country can be displayed or assumed from the artifacts.

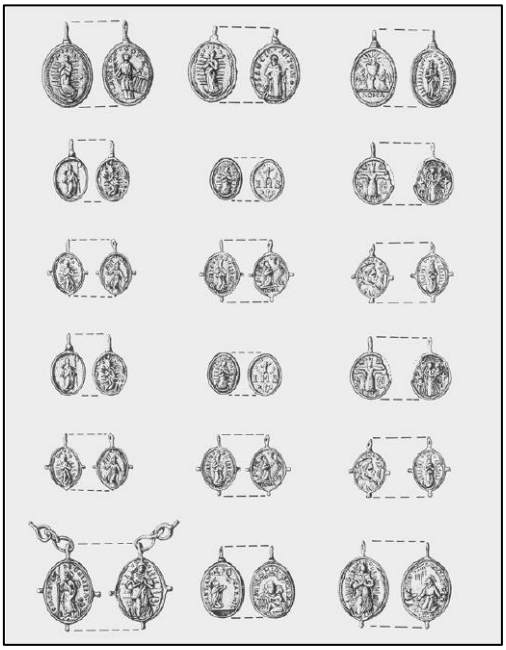

Figure 2.1: Example historical artifact of Religious medallions from St. Catherine's Island (Orser, 2016)

2.1.1 Restoration Method of Historical Artifact

There are several methods to restore or reconstruct historical artifacts in long ago, and the methods used to restore artefact basically was based on the material of the artefact. Meanwhile, the introduction of new technologies in the context of cultural heritage (CH) and Archaeology has often been a difficult issue. However, in the last few years both 3D modelling and 3D scanning have become a valued way to present and analyse CH artifact. While a lot of those rescued artifacts had been damaged, they have been able to be partially restored in digitally and physically with the used of 3D technology.

3D technology have been widely used by the artifact conservators to restore the damaged ancient or history artifacts. The lost partial decoration of architecture component in the Fu Wang Ge, the main architecture of Qianlong Garden have been restored by using the 3D technologies. The lost part decoration as described in Figure 2.2 and the printed part as described in Figure 2.3.

Figure 2.2: Missing region Chisel copper and gilding decoration (Shui, Qu, Gao, & Wu, 2016)

Figure 2.3: Top figure shows the painted model and the bottom figure shows the printed model (Shui et al., 2016)