DEVELOPMENT AND ANALYSIS OF LAB SCALED MACHINE FOR 3D CONCRETE PRINTING

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MASTER OF MECHANICAL ENGINEERING

2021

Faculty of Mechanical Engineering

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this thesis entitled "Development And Analysis of Lab Scaled Machine For 3D Concrete Printing" is the result 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.

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Date : 10 / OCTOBER / 2021

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 degree of Master of Mechanical Engineering.

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ABSTRACT

Application of 3D concrete printing can contribute to the future enhancement of construction industries. The fundamental objective of the study is to enable users to print concrete into three-dimensional model constructions by modifying and improving the open-source FDM 3D printer. During the development additional testing of a laboratory-scale 3D concrete paste printer that uses a syringe-type extruder was developed. The structure generated by the newly designed 3D concrete paste printer can be analyzed by applying the Taguchi method. Modification and analysis of open-source software for the 3D printer used for printing purposes with concrete paste produces result appropriate ratio of water concrete and corn flour. This is to produce concrete mixture in 3D Print that allowed for the construction of a concrete structure. The development of a prototype 3D printer for concrete structures was fabricated. Various design was analysed to verify their appropriateness and efficacy for the designed 3D Printer. The 3D printer was modified for concrete materials rather than plastic printing, which requires additional time, expense, and creativity on the user's part to do the post-processing. Analysis on 3D printed material was made and it was found that there is significant changes compared to the CAD. This is may be due to the unsuitable mixture and composition. Modification of the 3D printer requires further study on the optimum composition of the material mixture. Normal composition of concrete used in conventional process may not suitable to be used directly for 3D concrete printing due to the nature of the process.

ABSTRAK

Aplikasi percetakan konkrit 3D dapat menyumbang kepada peningkatan industri pembinaan di masa hadapan. Objektif asas kajian ini adalah untuk membolehkan pengguna mencetak konkrit ke dalam pembinaan model tiga dimensi dengan mengubah dan memperbaiki pencetak 3D FDM sumber terbuka. Semasa pengembangan, ujian tambahan pencetak pes konkrit 3D berskala makmal yang menggunakan ekstruder jenis jarum suntik telah dikembangkan. Struktur yang dihasilkan oleh pencetak pes konkrit 3D yang baru dirancang dapat dianalisis dengan menggunakan kaedah Taguchi. Pengubahsuaian dan analisis perisian sumber terbuka untuk pencetak 3D yang digunakan untuk tujuan percetakan dengan pes konkrit menghasilkan nisbah konkrit air dan tepung jagung yang sesuai. Ini untuk menghasilkan campuran konkrit dalam Cetakan 3D yang memungkinkan untuk pembinaan struktur konkrit. Pengembangan prototaip pencetak 3D untuk struktur konkrit dibuat. Pelbagai reka bentuk dianalisis untuk mengesahkan kesesuaian dan keberkesanannya untuk Printer 3D yang dirancang. Pencetak 3D diubah suai untuk bahan konkrit dan bukannya percetakan plastik, yang memerlukan masa, perbelanjaan, dan kreativiti tambahan dari pihak pengguna untuk melakukan pemprosesan pasca. Analisis pada bahan bercetak 3D dibuat dan didapati terdapat perubahan yang ketara berbanding dengan CAD. Ini mungkin disebabkan oleh campuran dan komposisi yang tidak sesuai. Pengubahsuaian pencetak 3D memerlukan kajian lebih lanjut mengenai komposisi optimum campuran bahan. Komposisi konkrit biasa yang digunakan dalam proses konvensional berkemungkinan tidak sesuai digunakan secara langsung untuk percetakan konkrit 3D kerana sifat prosesnya.

ACKNOWLEDGEMENTS

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

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life. Furthermore, I would like to thank the Universiti Teknikal Malaysia Melaka (UTeM) for providing the taught course platform. Thank you also to the National Higher Education Fund Corporation (PTPTN) for the financial assistance.

My utmost appreciation goes to my main supervisor, Assoc. Prof. Ir. Ts. Dr. Mohd Rizal Bin Alkahari from Universiti Teknikal Malaysia Melaka (UTeM), for all his support, advice, and inspiration. His constant patience for guiding and providing priceless understandings will forever be remembered. Also, to my co-supervisor, Assoc. Prof. Dr. Shajahan Bin Maidin, Universiti Teknikal Malaysia Melaka (UTeM), constantly supported my journey. Finally, my special thanks go to Dr. Muhd Ridzuan Bin Mansor and Dr. Mohd Afzanizam Bin Mohd Rosli for all the help and support I received from them.

Last but not least, from the bottom of my heart, gratitude to my beloved parents, Mr. Mahboob Ali Bin Mohd Kassim and Mrs. Aisha Bee Binti Y.M. Ahmad, for their encouragements and who has been the pillar of strength in all my endeavors, their endless support, love and prayers with priceless. My eternal love also to my friends, Muhd Hamizan, Uvaraaj, Haziq Haikal, Haqim, and Magdelson, for their patience and understanding. I would also like to thank my working colleagues who have supported me and helped take the burden of my work during my study time. Finally, thank you to all the individuals (s) who had provided me with the assistance, support, and inspiration to embark on my study.

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LIST OF SYMBOLS AND ABBREVIATIONS

3D	-	Three-dimension
3DP	-	Three Design Prototype
ABS	-	Acrylonitrile Butadiene Styren
AM	-	Additive Manufacturing
CAD	-	Computer-Aided Design
CNC	-	Computer Numerical Control
CPU	-	Central Processing Unit
COVID-19	-	Coronavirus disease- 2019
DC	-	Direct current
DIY	-	Do It Yourself
DED	-	Directed Energy Deposition
DOE	-	Design Of Experiment
DOD	-	Drop On Demand
DMLS	-	Direct Metal Laser Sintering
EBM	-	Electron Beam Melting
E-steps	-	Extruder steps
FDM	-	Fused Deposition Modelling
G / mL	-	Gram per milli-Litre
G	-	Gram
g / cm^3	-	gram per cubic centimeter
G-code	-	Geometry code
H2O	-	Hydrogen 2 Oxygen 1
JG A5S	-	JG Aurora 5 Special
kJ / m^2	-	kilo Joule per square meter
m	-	meter
mm / s	-	millimeter per second
mba	-	millibarye
mm	-	millimeter
ml	-	milliliter

MPa	-	Mega Pascal
M30	-	Mix grade 30 (N / mm^2)
MCO	-	Movement Controlled Order
N	-	Newton
OBJ	-	Wavefront Object
PLA	-	Polylactic acid
PETG	-	Polyethylene terephthalate glycol
PET	-	Polyethylene terephthalate
PTFE	-	PolyTetraFluoroEthylene
RP	-	Rapid Prototyping
RM	-	Ringgit Malaysia
s/c	-	sand-cement
STL	-	Standard Triangle
SLA	-	Stereolithography
SLM	-	Selective Laser Melting
SHS	-	Selective Heat Sintering
SN	-	Sounds and Noise
SL	-	Stereolithography
UV	-	Ultraviolet
V	-	Volt
w/c	-	water-cement

CHAPTER 1

INTRODUCTION

1.1 Background

The first 3D printing technology appeared in the late 1980s, known as RP (Rapid Prototyping) technology. This is because the process was designed quickly and cost-effectively to prototype for industrial product manufacturing. Interestingly, Dr. Kodama from Japan filed the first patent application for RP technology in May 1980 (Deckard, 1992). On the other hand, 3D printing can be traced back to 1986, when the first stereolithography (SLA) equipment patent was issued. Charles (Chuck) Hull invented his SLA computer in 1983 and held the patent for it. Hull is a co-founder of 3D Systems Corporation, which has become one of the world's largest and most successful 3D printing companies (Herbert, 1981).

For many years, traditional machining techniques like turning, milling, drilling, and grilling have been used to assist humans in building things. Standard machining technology has advanced in recent years, but it still has several disadvantages (Jasveer and Jianbin, 2018). Since non-traditional machining techniques such as electric discharge machining and chemical machining, the manufacturing world has changed. Nearly all industrial operations now involve computers and robot technology (Deckard, 1992). Instead, layers are added to a product through additive manufacturing. This enables three-dimensional production while also reducing scrap (Matias and Rao, 2015). Many people believe that additive manufacturing is a disruptive invention for society because it allows people to create their products (Steenhuis and Pretorius, 2015). This includes both the consumer and the manufacturing perspectives. Any Additive Manufacturing procedure will typically combine the eight processes listed below (Parupelli and Desai, 2019).

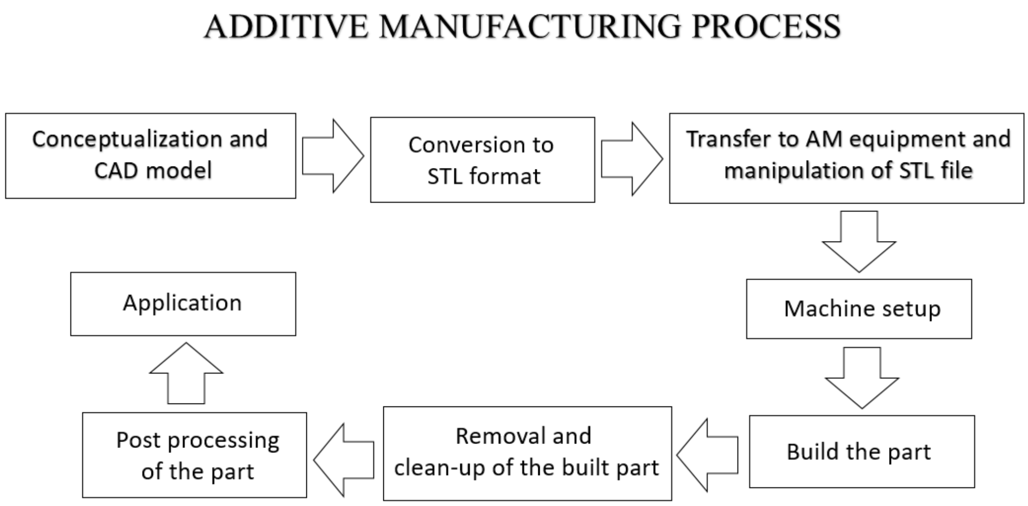

Figure 1.1: Additive Manufacturing processes

In comparison to other sectors, construction and civil engineering have historically been reluctant to adopt new technology. However, these changes have already started as the industry continues to modernize and adapt to the circumstances imposed by the fourth industrial revolution (also known as the digital revolution). Because the industrialization of construction often relies on off-site manufacturing and the shift to prefabricated homes, these technologies may assist in the preservation of essential activities on building sites (Ortega and Madrid, 2020). Additive manufacturing is a new area in the realm of concrete and cement-based products. In the construction sector, additive manufacturing research mainly focuses on two technical advancements: powder-based and extrusion-based (Parupelli and Desai, 2019).

These methods are appropriate for producing complex-shaped construction components with a high print resolution, a high degree of geometric independence, and tolerable manufacturing speeds in line with industrial demand. This will also be beneficial if used in small or medium-sized quantities. The present-day study case for the new development's construction will be used (Parupelli and Desai, 2019). The material used to construct the model is a production-grade thermoplastic, which is melted and then extruded onto the deck using a custom-made head. The platform was lowered to the next layer and pressed against the previous layer as the cross-section solidified quickly (Dudek, 2013).

1.2 Problem Statement

The primary goal of this project is to discover the flaws in prior innovations that led to the completion of this research. For example, the old FDM 3D printer could not print paste or other materials, just polymers in roll or filament spools. Another reason for the existence of FDM 3D printers is that they have size and printing configuration limits. So the open-source 3D Printer will be modified and analyzed to be used for printing purposes with concrete paste, which will lead to this study in this project with the appropriate ratio of water mixture and other substances such as corn flour for better concrete mix in 3D Print that to be able to build a concrete model using FDM 3D printer. However, this helps prevent the user or an organization from constructing a structure with adequate materials at a low cost with fewer workers in a site area, resulting in too much traffic in a site area. Furthermore, it may be used for prototypes that require actual concrete materials rather than plastic printing, which requires more time, money, and ingenuity on the user's part to perform post-processing. If concrete buildings can be printed in various patterns, Malaysia will have an excellent supply of low-cost facilities in the future.

1.3 Research Objective

The objectives of this study are

a. To develop a 3D Printer that can print concrete paste structure through modification and improvement of open-source FDM 3D printer.
b. To test and develop a lab-scaled 3D concrete paste printer using a syringe-type extruder.
c. To analyze using Taguchi method for the structure produced by the newly developed 3D concrete paste printer.

1.4 Scope of Research

The study's scope is focused on producing a review on 3D printing for Construction that can aid in the future improvement of construction buildings. The concrete Construction with the concrete mixture may be created using an FDM 3D printer. The primary goal of FDM 3D print modification is to allow users to print concrete into 3D model structures. The intended consumers of this FDM 3D printer for building purposes, which will aid in determining the prototype before moving on to the actual scale. The features include the extruder modification and extruder stepper motor installed to support the printing development. Solidwork Design may be used for simulation running testing. Therefore, the design was developed using the same CAD program, explaining the printed concrete structure's thermal stresses and mechanical strength. The approach is used from the inception of the concept to the completion. The material selection took several types of prototype materials and actual products for process manufacturing. The lab-scale model is tiny and may be made up to a maximum of (10 cm (length) x 10 cm (width) x 10 cm (height)) based on a concrete syringe of 60 ml.

1.5 Contribution of Research

The cement paste mixture will assist the Printer in printing the concrete in 3D shape. A modification accomplishes this to the existing FDM 3D printer, which will aid in reading Geometric code (G-Code) or Stereolithographic (STL) file models for printing. As a result, this modification 3D printer will help identify difficulties in the Construction of concrete using an FDM 3D printer, which will offer a low-cost and quick prototype. In addition, this study may assist the user to enhance the building site by utilizing a lab-size FDM 3D printer, which may help decrease the cost, time, creativity, and energy of a person with quick mobility in the working area.

1.6 Research Question

The lab-scale 3D printer concrete is used to help improve the structure or pattern in the Cement when printing by observing and further the investigation. This reduces the porosity and gets used with the mixed material to build concrete without harming the environment. The lab-scale 3D Printer help to print the concrete on a small scale for the study purpose. In addition to learning with the new structure and pattern for the concrete model.

1. What type of 3D Printer was used to develop 3D concrete printing through modification and improvement.

2. How the laboratory-scaled three-dimensional concrete paste was tested and created.

3. Which method was used to analyze the newly created structure created by 3D concrete paste printing.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Additive Manufacturing (AM), also known as Rapid Prototyping (RP), is primarily a manufacturing process that uses 3D computer-aided design (CAD) files to cut it into various thicknesses (Espera and Dizon, 2019). The cut file determines the geometry of each layer, and the manufacturing settings are instructed to deposit layers based on that geometry (Manju and Deepika, 2019). To make a complete 3D object, layer-by-layer deposition continues until the last layer (Yushchenko, Magizov, and Gumerova, 2021). Many deposition methods can operate according to different principles (Dehghanghadikolaei, Namdari and Mohammadian, 2018). For example, fused Deposition Modeling (FDM) is a method of manufacturing additive polymers that do not require the use of lasers (Panagiotis Kazanas, 2012). This configuration includes a computer-controlled nozzle head to deposit semi-solid material on the surface to form a layer. This method is generally used since the complex polymers are semi-solid before deposition (Dehghanghadikolaei, Namdari, and Mohammadian, 2018).

There are no specialized studies in building materials, and various courtiers are attempting to manufacture filaments for the construction industry (Nair, 2020). This technology is intended to complement existing technologies and construction methods (Bos and Wolfs, 2016). 3D printing can alter how resources are used, such as workforce, which machines can replace (Jiménez, Romero and L, 2019). This printing technology development phase is situated somewhere between automation and robotics (Paudyal, 2015). Implementation is the product of the information revolution, and it allows for improvements in construction project structure and management. The effect of 3D printing technology on the construction site is examined, with automation and robotics and work and organization playing a role (Sobotka and Pacewicz, 2016).