EFFECT OF TENSILE TEST SPECIMEN GEOMETRY ON MECHANICAL PROPERTY OF 3D PRINTED SINGLE STRUTS

AZIRA BINTI MAT YUSOF

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2019

DECLARATION

I declare that this project report entitled "Effect of Tensile Test Specimen Geometry on Mechanical Property of 3D Printed Single Struts" 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 (with Honours).

Signature : ………………………………..

Name of Supervisor : DR. RAFIDAH BINTI HASAN

Date : …………………………………

DEDICATION

“Nostalgia is like a grammar lesson. You find the present tense and past perfect”

- Orben’s comedy Fillers

I dedicate this thesis to my beloved parents,
Mat Yusof bin Abdul Rahman and Salina binti Mohammed;
to my friends and family members for tremendous supports
and to myself for not giving up on trying.

ACKNOWLEDGEMENT

First, I would like take this opportunity to express my greatest gratitude to my supervisor, Dr. Rafidah binti Hasan, for guiding me throughout this project with patience, encouragement and supports. All the knowledge that I gained enable me complete this final year project successfully.

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Lastly, I would like to thank Universiti Teknikal Malaysia Melaka (UTeM) especially Faculty of Mechanical Engineering (FKM) for giving fully support by allowing me to use their equipment and facilities during conducting my study.

ABSTRACT

The lattice-structure material is a light-weighted material which suitable for lightweight structural application. Elementary unit of lattice structure is single strut which connects two nodes. It is important to know mechanical properties of single strut as they contribute to lattice structure performance. Elastic property is one of the mechanical properties which can be obtained through tensile test. Best elastic property data comes from suitable tensile test specimen geometry. This study is conducted to determine the specimen geometry effect on elastic property of tensile test for acrylonitrile butadiene styrene (ABS) 3D printed single strut specimen. Single struts with geometrical shape (Dogbone) and without geometrical shape (Cylinder) are designed by using a CAD software which is Solidworks. Then, single struts are fabricated by using CubePro 3D printer. Next, tensile test is conducted to single strut specimens. From tensile test, data on Young's modulus is established. Furthermore, hypothesis test is applied on the Young's modulus data to verify the theory made. The engineering conclusions are concluded from hypothesis test on specimen geometry effect on elastic property of tensile test for ABS 3D printed single strut specimen.

ABSTRAK

Kekisi-struktur bahan adalah bahan ringan yang sesuai bagi aplikasi struktur ringan. Unit asas struktur kekisi adalah tupang tunggal yang menghubungkan dua nod. Ia adalah penting untuk mengetahui sifat-sifat mekanik tupang tunggal kerana mereka menyumbang kepada prestasi struktur kekisi. Sifat keanjalan adalah salah satu daripada sifat-sifat mekanikal yang boleh diperolehi melalui ujian tegangan. Data sifat keanjalan yang terbaik datang dari geometri spesimen ujian tegangan yang sesuai. Kajian ini dijalankan untuk menentukan kesan geometri spesimen ke atas sifat keanjalan bagi spesimen ujian tegangan bagi acrylonitrile butadiene styrene (ABS) 3D tupang tunggal bercetak.Tupang tunggal dengan bentuk geometri (Dogbone) dan tanpa bentuk geometri (silinder) direka dengan menggunakan perisian CAD ia itu Solidworks. Kemudian, tupang tunggal dihasilkan dengan menggunakan pencetak 3D CubePro. Seterusnya, ujian tegangan dijalankan ke atas spesimen tupang tunggal. Dari ujian tegangan, data modulus Young akan dihasilkan. Selain itu, ujian hipotesis digunakan kepada data modulus Young bagi mengesahkan teori yang telah dibuat. Kesimpulan kejuruteraan akan dihasilkan daripada ujian hipotesis bagi menguji adakah geometri spesimen memberi kesan ke atas sifat keanjalan bagi spesimen ujian tegangan tupang tunggal ABS 3D bercetak.

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3D	3 Dimensional
ABS	Acrylonitrile Butadiene Styrene
AM	Additive Manufacturing
ALM	Additive Layer Manufacturing
ASTM	American Society of Testing for Material
BCC	Body-Centred-Cubic
FCC	Face-Centred-Cubic
FDM	Fused Deposition Modeling
CAD	Computer-Aided Design
HCP	Hexagonal Close Packed
PLA	Polyactic Acid
SLM	Selective Laser Melting
STL	Standard Tessellation Language

LIST OF SYMBOLS

α = significant level

DF = Degree of Freedom

H_0 = Null hypothesis

H_A = Alternative hypothesis

F = Test Statistic for F-test

n = Number of Sets

S = Standard Deviation

t = Test Statistic for t-test

μ = Mean

σ = Variance

CHAPTER 1

INTRODUCTION

1.1 Background

The production of lattice structures by using additive manufacturing (AM) in recent years is increasing as more and more studies have shown the potential of using this material in many application such as energy absorber, acoustic absorber and thermal insulator (Kilinc et al., 2016; Tan et al., 2019; Davami et al., 2019; Mohsenizahed et al., 2017; Guild et al., 2015). Now, studies proved that open-pored cellular lattice structures with more complex geometrical structures are able to be created compared to the starting of the decade where the structures are mostly in regular rectangular forms (Rehme and Emmelmann, 2006).

Lattice structure material is a material which is lightweight, with the properties of high stiffness and strength-to-weight scaling (Doyoyo and Hu, 2006). Many studies have been done to determine the mechanical properties of this material including stainless steel, aluminium, titanium alloy and few other metals. Single strut is the elementary unit of this lattice structure material. The availability of the joint type makes the assembly methods of the strut-based lattice structure to be a flexible configuration which is preferred for complex geometrical designs (Doyoyo and Hu, 2006).

Lattice structure comprises of many struts connected to each other by nodes, in many architectural arrangements such as body-centred-cubic (BCC), face-centred-cubic (FCC) and hexagonal close packed (HCP) (Mines, 2008). A lot of possible architectural arrangements can be proposed within an outlined volume as lattice structure composed of numerous number of nodes and struts. An example of lattice structure with different arrangements is shown in Figure 1.1 (Syam et al., 2017).

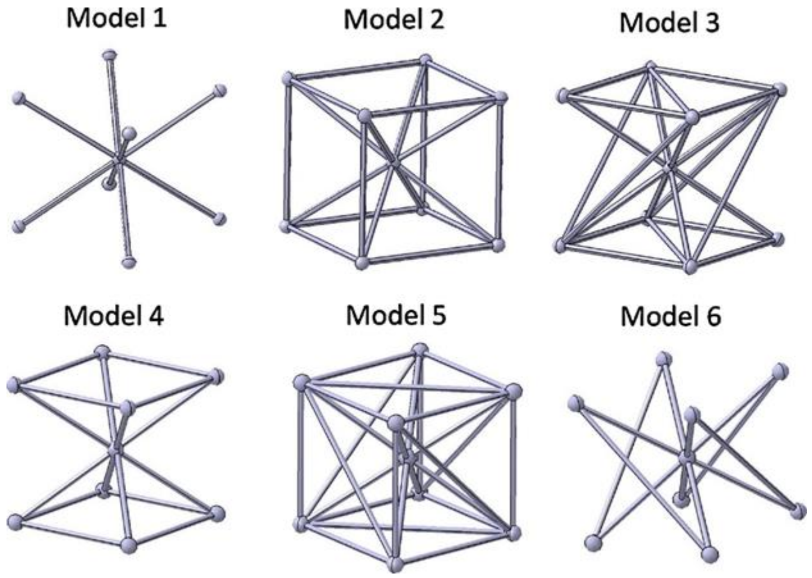

Figure 1.1: Lattice structure with different lattice arrangements

(Source: Syam et al., 2017)

The value for mechanical properties, the performance and the quality of lattice structure can be concluded through examination of struts, thus making struts as fundamental entity for lattice structure (Kessler et al., 2016). Studies have shown that different geometric shapes will affect various mechanical properties, as they are closely related to shear band process and deformation process constrain (Calik et al., 2008). Therefore, this research will observe on struts with and without geometric shape to assist better understanding on how geometric shape affects mechanical properties for lattice structure.

1.2 Problem statement

Tension, compression and flexure are important aspects that need to be fully characterized in lattice- structure material study to know its optimum functionality and mechanical properties. Based on previous research (Wahi, 2018), compression test was done for 3D printed polymer lattice structure; acrylonitrile butadiene styrene (ABS) material specimen, with and without enhancement of lattice structure unit, to get the compression stress versus compression strain diagram in providing information on mechanical properties particularly on young modulus, yield strength and maximum strength of lattice structure materials. However, this compression test is unable to give data on failure strength or failure strain which can be attained through tensile test. When it comes to obtain failure data, tensile test is preferable. To simplify this, it is suggested that tensile test on single strut specimen for ABS material to be performed in providing information related to basic failure of lattice structure material. Best elastic property data comes from suitable tensile test specimen geometry. In order to get precise information from the tensile test, it is important to study the proper handling of single strut specimen which is affected by the geometric shape of the specimen. Thus, this study is to determine the specimen geometry effect on elastic property of tensile test for ABS 3D printed single strut specimen.

1.3 Objective

The objective of this study is to investigate the effect of geometric shape on elastic property of tensile test for 3D printed single strut with selected parameter.

1.4 Scope of Project

The scopes of this project are:

i. Design single strut with and without geometrical shape by using acrylonitrile butadiene styrene (ABS) material for tensile test specimen referring to ASTM (E8/E8M-13a) for the specimen design ratio.

ii. Use a CAD software which is Solidworks to design and CubePro 3D printer to fabricate both type of single struts.

iii. Use Shimadzu EZ Test (EZ-LX) machine to conduct tensile test for both type of single struts.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The background of this chapter is based on relevant journal articles and academic books that are related to this study. It is needed for this chapter to be studied for better understanding for the next progress as this chapter describes on previous studies that related to this study.

2.2 Lattice-structure and strut

Lattice structure material is a material which is lightweight structure with the properties of high stiffness and strength-to-weight scaling (Doyoyo and Hu, 2006). Many studies have been done to determine the mechanical properties of this material including stainless steel, aluminium, titanium alloy and few other metals. Single strut is the elementary unit of this lattice structure material. The availability of the joint type makes the assembly methods of the strut-based lattice structure to be a flexible configuration which is preferred for complex geometrical designs (Doyoyo and Hu, 2006).

Lattice structure comprises of many strut connected to each other by nodes, in many architectural arrangements such as body-centred-cubic (BCC), face-centred-cubic (FCC) and hexagonal close packed (HCP) (Mines, 2008). A lot of possible architectural arrangements can be proposed within an outlined volume as lattice structure composed of numerous number of nodes and struts. An example of lattice structure with its nodes (n) and struts (p) is shown in Figure 2.2 (Syam et al., 2017).

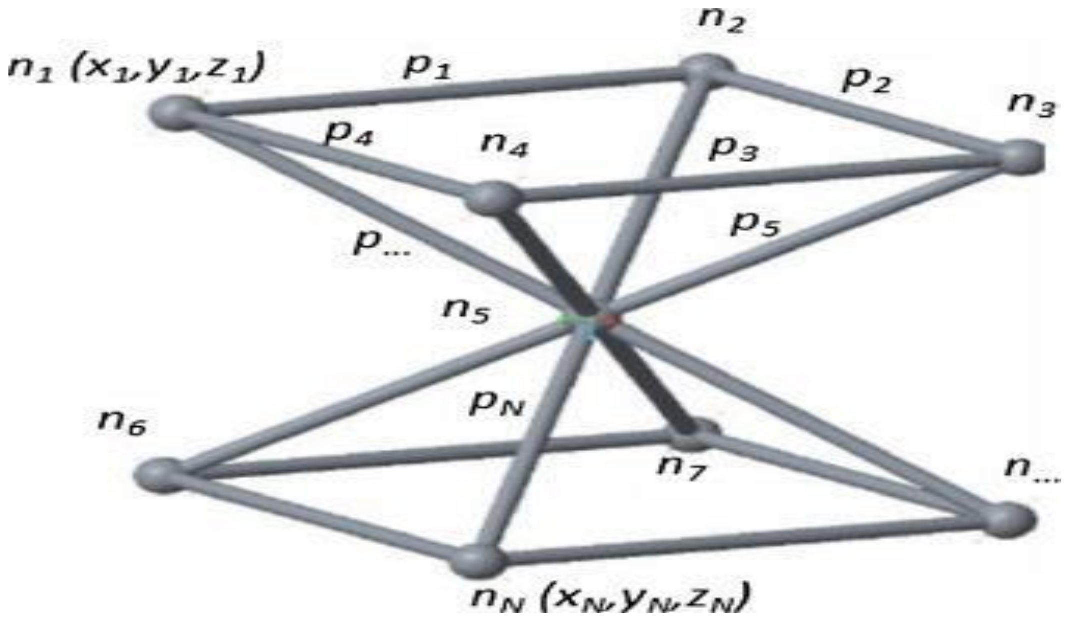

Figure 2.2: Struts and nodes based lattice arrangement, n=9 and p=16

(Source: Syam et al., 2017)

2.3 Methods in Producing Lattice Structure

There are conventional and advanced method in manufacturing lattice-structures. Conventionally, latice-structures are manufactured through casting, sheet metal forming or wire bonding process. These traditional manufacturing process are time-consuming and limiting lattice structure with complex designs to be built (Rashed et al., 2016).

For investment casting process (Rashed et al., 2016), a volatile wax or polymer is injected from an injection molding or a rapid prototyping to manifacture the truss pattern. This is where the system of gating and risers will be used to coat pattern by ceramic casting slurry.The wax or polymer is then detached by melting or vaporization process, followed by contenting metal liquid into the empty mold. The weakness of this method is that this method is pricey and taking more time to be manufactured. The structures manufactured also contained considerable porosity. Figure 2.3.1 shows the example of lattice material that is manufacted through investment casting process and has been assembled to be 3D Kagome core sandwich panel.

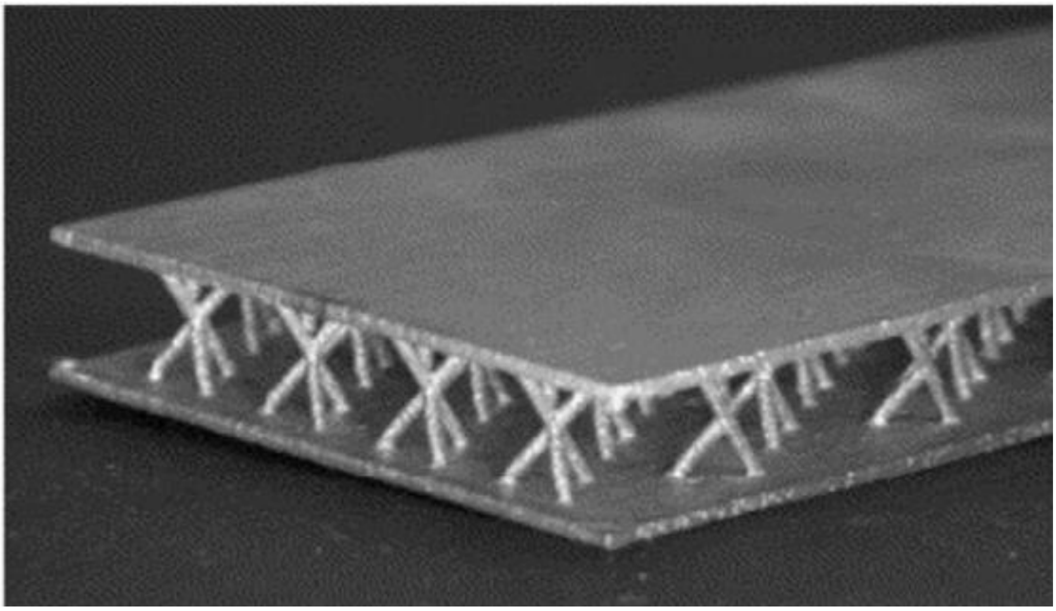

Figure 2.3.1: Lattice structure assembled to be 3D Kagome core sandwich panel

(Source: Rashed et al., 2016)

For sheet metal forming method (Rashed et al., 2016), press forming operation is used to produce lattice structure. This method enable cell sizes of millimeter to several centimeters to be obtained as it utilizes the usage of sheet perforation and shaping techniques. The perforated metal sheets are deformed with hexagonal or diamond shaped holes at the nodes and assembled to produce different sheets of structure such as tetrahedrons or pyramidal. Figure 2.3.2 shows deformation of sheet metal forming process.

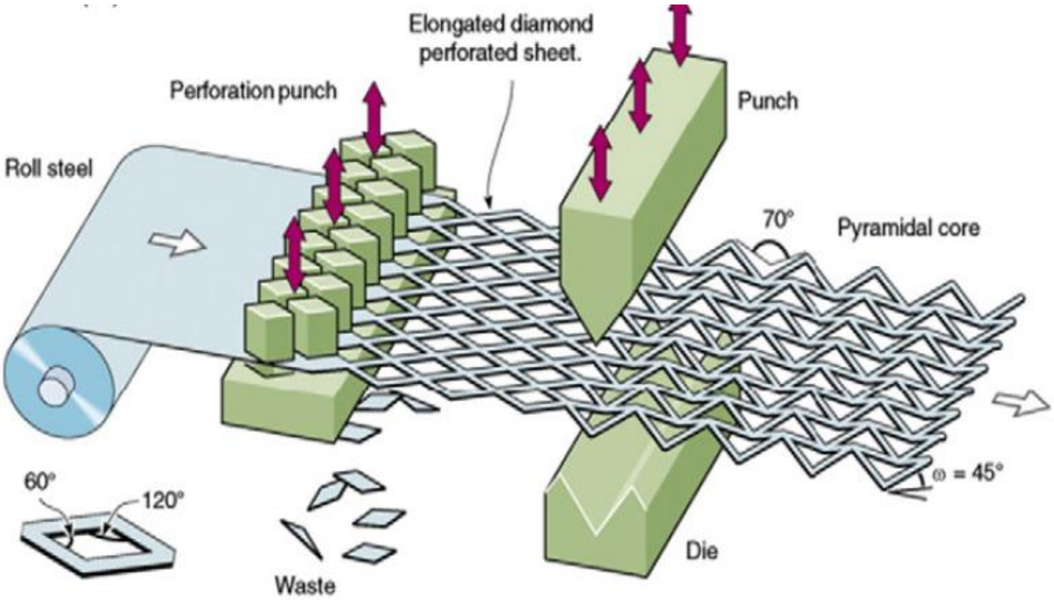

Figure 2.3.2: Deformation of sheet metal forming process

(Source: Rashed et al., 2016)

For wire bonding process (Rashed et al., 2016), the method is limited to produce metal latice structures. This method is relatively faster compared to other method but it is not effective as it caused wastage of material throughout the making process. This method promises a good surface quality.

The intoduction of additive manufacturing (AM) technologies in advance manufacturing is a very helpful discovery. Producing lattice structures by using AM technologies had reduced many limitations that is countered in conventional manufacturing process. Highly complex components with inside-lying structures and functional areas can be manufactured through one process step. This has made AM technologies less time consuming as compared to conventional manufaturing technologies (Kessler et al., 2016).