UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND ANALYSIS OF DISC TYPE WATER FILTER USING LATTICE MESH STRUCTURES FOR ADDITIVE MANUFACTURING FABRICATION

Submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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DECLARATION

I hereby, declared this report entitled "Design and Analysis of Disc-Type Water Filter Using Lattice Mesh Structures for Additive Manufacturing Fabrication" is the result of my own research except as cited in references.

Signature : .....

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Date : 2020

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for the degree of Bachelor of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

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ABSTRAK

Dengan matlamat mencapai Revolusi Industri (IR) 4.0, struktur kekisi bukan stokastik digunakan secara meluas dalam pelbagai aplikasi termasuk implan bioperubatan dan penukar haba. Walau bagaimanapun, dalam aplikasi penapisan, penggunaan struktur kekisi masih baru. Di samping itu, penggunaan cetakan 3D membolehkan struktur kekisi untuk disesuaikan mengikut jenis penapis dan kegunaannya sebagai penapis cakera dengan lapisan sel unit kekisi berulang sebagai penapis jaringan. Sistem penapisan aliran bendalir kerap digunakan dengan bantuan sistem mengepaman. Bagi membolehkan cecair mengalir sehingga lokasi yang diingini, tekanan cecair yang tinggi diperlukan, dengan itu ianya memberi kesan penggunaan kuasa. Penurunan tekanan berlaku selepas cecair melepasi penapis dan menyebabkan lebih banyak tekanan diperlukan untuk aliran bendalir. Oleh itu, dengan menggunakan struktur jaringan kekisi dalam penapis air jenis cakera, ia dipercayai dapat mengurangkan penurunan tekanan aliran bendalir. Tujuan projek ini adalah untuk merekabentuk penapis air jenis cakera menggunakan teknik kekisi jaringan struktur dan menganalisis kecekapan penapis berbanding penapis cakera semasa berdasarkan simulasi. Sebanyak tiga sel unit dengan bentuk yang berbeza dengan dimensi kurang 3 mm dari tepi ke tepi, lalu diulang cetak menjadi corak hingga mendapat 50 mm diamensi besar cakera penapis. Mewujudkan model 3D untuk penapis cakera semasa, dengan dimensi yang berada dalam jarak struktur kekisi. Computasi Bendalir Dinamik (CFD) digunakan untuk menilai semua penapis dari segi penurunan tekanan dan halaju aliran bendalir. Selain itu, Analisis Elemen Terhingga (FEA) akan dilakukan untuk menganggarkan kekuatan struktur penapis. Berdasarkan kajian ini, keputusan akhir menunjukkan bahawa penapis cakera dengan struktur jaringan kekisi mempunyai lebih rendah nilai penurunan tekanan dan kelajuan berbanding penapis cakera biasa. Di masa hadapan, kajian ini membolehkan Malaysia mencipta penapis lebih baik untuk industri kerana proses penapisan adalah proses yang digunakan secara tidak langsung di dalam industry lain, lantaran itu, ia memberi kebaikan bukan pada satu pihak sahaja.

ABSTRACT

While aiming for Industry Revolution (IR) 4.0, the non-stochastic lattice structure is widely used in a variety of application including biomedical implants and heat exchangers. However, in filtration application, the use of the lattice structure is still new. In addition, the use of additive manufacturing allows the lattice structure to be customized according to the type of filter and is intended to use as a disc filter with a layer of repeated lattice unit cell as a filter mesh. Filtration application for fluid flow frequently uses with the help of the pumping system. In order for the fluid to flow until its destined location, high pressure of the fluid is needed, thus its effect the power consumption use. Pressure drop occurs after fluid passed a filter and resulted in more pressure needed for the fluid flow. Thus, by using a lattice mesh structure in disc type water filter, it is believed that it can minimize the pressure drop of the fluid flow. This project aims to design a disc-type water filter using a lattice mesh structure and to analyse the efficiency of the filter compared to the current disc filter based on computational simulation. A total of three-unit cells with different shape approximately with less than 3 mm edge to edge dimension is designed to be pattern into 50 mm disc-filter. Creating the 3D model for the current disc filter, with a dimension that is within range of the lattice structure. Computational Fluid Dynamic (CFD) is used to evaluate all filters in term of pressure drop and the velocity of the fluid flow. On the other hands, Finite Element Analysis (FEA) will be done to estimate the structural strength of the filter. Based on this study, the outcome shows filter discs with lattice mesh structure provided a lower pressure drop and velocity drop compared to conventional disc filter. In future, this study may help Malaysia in developing better filtration industries as filtration is an indirect process that occurs in other industry, it will not only benefit one side of the industry.

DEDICATION

For

my late father, Mohd Yazid Bin Selamat,

may you rest in peace there,

my mother, Asmunita Binti Musa,

for moral support and encouragement,

my aunt, Masdalina Binti Selamat & Siti Warda Binti Selamat,

for supporting me with my dream,

my sweet and lovely litter brother and sisters,

Alif Syafiee, Nusrah Husna, Siti Aishah, & Allysha Khadijah

for listening to all my complaint and make me smile,

all my girls, Amyliana, Iffah, Salbiyah, Nuraliana, Najiha, Amirah, & Hazera,

for helping each other during the process of making this project,

Thank you and I love you so much

May Allah bless all of us.

ACKNOWLEDGEMENT

In the name of Allah, the most merciful, with the highest praise to Allah that I manage to complete this final year project without any difficulty.

First and foremost, in completing this project, I had to take the help and guideline of some respected person, who deserve this greatest gratitude. I would like to show gratitude to En. Hazman Bin Hasib, the supervisors for valuable guidance and advice. He inspired greatly to work in this project. His willingness to motivate me contributed tremendously to this product development. I also would like to thank him for showing some examples related to the topic of this product.

Also, an honourable mention goes to the authors' families and friends for their understanding and support us in completing this project. Without their help for particular, I would face many difficulties and obstacles while doing this project. Lastly, I would like to thank those who directly or indirectly helping us to complete this project.

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LIST OF ABBREVIATIONS

Abbreviations		Definition
3D	-	Three Dimension
ABS	-	Acrylonitrile Butadiene Styrene
AM	-	Additive Manufacturing
CAD	-	Computer-Aided Design
CAE	-	Computer-Aided Engineering
CFD	-	Computational Fluid Dynamic
DFMA	-	Design for Assembly and Manufacturing
DEM	-	Discrete Element System Model
FDM	-	Fused Deposition Modelling
FGM	-	Functionally Graded Material
FEA	-	Finite Element Analysis
EBM	-	Electron Beam Melting
HVAC	-	Heating, Ventilation and Air Conditioning
KD	-	Kagome-lattice Disc
MBD	-	Multibody Dynamic
OD	-	Octet-truss-lattice Disc
PD	-	Perforated Disc
RD	-	Rhombic-lattice Disc
SLM	-	Selective Laser Melting
WD	-	Woven-wire Disc

LIST OF SYMBOLS

Symbols		Definition
μm	:	micrometre
cm	:	centimetre
in	:	inch
L/min	:	Litre per minute
m/s	:	Meter per second
m	:	meter
mm	:	millimetre
MPa	:	Mega Pascal
Pa	:	Pascal
TWh	:	Tera watt-hour

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CHAPTER 1

INTRODUCTION

1.1 Background

According to Oxford Leaner's Dictionaries, the lattice is characterized as a structure made of wood or metal strips that cross over each other with spaces shaped like a diamond between them, used as a fence with any structure or pattern for example, while mesh is a material made of plastic rope or wire strings that are twisted like a net. A filter is characterized as a device that contains paper, sand, chemicals, and much more that passes through a liquid or gas to remove any unwanted materials.

Another study stated filter is a device used to separate one substance from another (Sutherland, 2008). For the filter to function properly, it required placing of filter media in the fluid flow to block the unwanted solid particles. Then, the filter turns into any contrivance that is capable to maintain the filter medium in an exceptional way to attain the function of the filter process.

The filter is put in the fluid flow of any application such as the kitchen countertop water filter to the comprehensive wastewater treatment plants or from the polished ultra-filter membrane to the rough tipping pan filter of a mineral processing job, not to mention the hydraulic control system (Sutherland, 2008). Thus, these shows that filter had many uses not only in human daily life but industries also especially for the process industry, which fluid is pumped under high pressure in the process. As fluid flows through the filter, its velocity is decreasing due to the resistance at the filter medium itself, which also lead to the pressure drop

of the fluid compared from the initial pressure pumped. Therefore more power is needed to ensure the fluid reaches its destination (Vijayakumar et. al, 2013).

There are many types of filter that had to evolve in the industry to satisfy customers need. For disc-type water filter itself, there are perforated and woven-wire filter as shown in Figure 1.1 and Figure 1.2. Traditionally, filter disc is manufactured using perforated plates, mesh and wedge wire cum welding, cutting, rolling, and punching as the subtractive process (Hasib, 2016). Each of these filters has its aperture size, open area and mesh either for perforated filter or woven wire filter in additional of various of diameter for woven-mesh type (Sutherland, 2008).

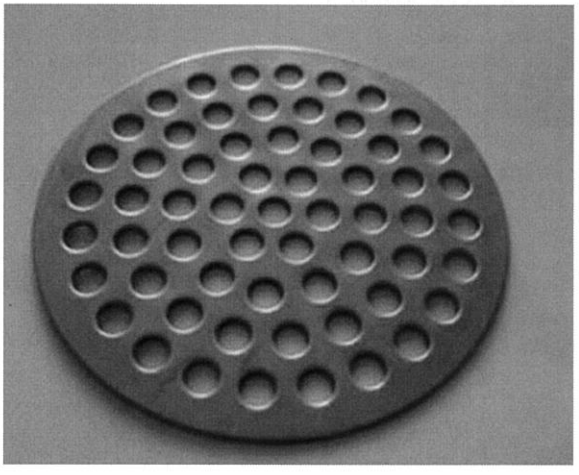

Figure 1.1: Perforated Disc-Type Filter

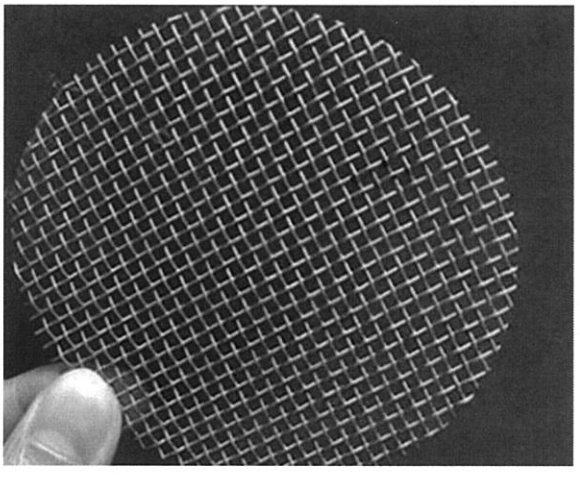

Figure 1.2: Woven Wire Mesh Filter Disc

In order to fabricate a single disc filter, fifteen process steps are needed appropriately which includes designing pattern in Computer-Aided Design (CAD), rolling, welding, flange and many more (Croft Filter, 2014). These steps rather need a lot of time. As the technology reaching to industry 4.0, additive manufacturing or 3D printing also being introduced not only for prototyping but as a final product itself. At the beginning of AM technology, the product is produced by plastic material from cups and saucers to a facial reconstruction for a victim of a road accident. Within years, the development of complex metal component had made metal additive manufacturing to recognise proportionally to the advancement of technology potential (Burns, 2014).

A recent study had run metal additive manufacturing as a process to develop filter by using Selective Laser Melting (SLM) and Electron Beam Melting (EBM). By using SLM, the complex products were produced by fusing metal powder to create the structure depending on the 3D CAD data (Burns et. al, 2019). In the EBM process, the high power electron beam was used in powdered based direct metal fabrication under vacuum inflated temperature (Hasib et. al, 2015). Nonetheless, using additive manufacturing need to consider the use of CAD software as the base for designing the filter either in terms of the strut of structure, open area, or aperture size. The structure of the design needs to be designed accordingly to ensure the filter can work properly.

Generally, Metal foam is a cellular structure of solid metals that forms voids known as pores. The metal form can also be classified into two major categories, stochastic and non-stochastic (Hasib et. al, 2015). Stochastic means random, as in stochastic structure defined as a random and variety of shape and size of a cell. Non-stochastic geometries can be defined as a periodic lattice structure with repeating the shape and size of the cell. The lattice structure or cellular structure consists of a number of connected members or tessellated unit cells forming a complex structural network (Brackett et. al, 2014). Therefore, in this project student will design a disc-type water filter based on the lattice mesh that can be used in additive manufacturing fabrication.

1.2 Problem Statement

As the filter industries are striking for a better improvement to achieve IR 4.0, filtration industries also need to be more innovative. The traditional method used to manufacture a disc-type filter is considered as a time consuming because there are many other processes involved in making a single filter (Croft Filter,2014). AM technology is designed to produce objects with mechanical properties comparable to those of bulk materials and to save considerable time by eliminating or significantly reducing post-processing steps (Yadroitsev et. al, 2009). According to (Vijayakumar et al., 2013) European Commission recorded that pumps in process industries as one of the largest users of electricity which consume 160 Tera Watt hours (TWh), and it also stated that 13% of electrical energy used by pumps and pumping system in the United Kingdom. Based on the data, the filter also plays an important role in industries whereas fluid is pumped under high pressure in filtration process which effect the power consumption in order to let the fluid flow reach its designated place. It is believed that recent developments in the manufacture of additives can also be used to print specific lattice structures from a variety of materials at reasonable cost (Cohen et al., 2019). To reduce the pressure developed, a better design of the filter which can be customised is needed.

1.3 Objective

The objectives of this study are as follows

1. To design the disc-type filter by using SolidWorks

2. To evaluate the fluid characteristics of the disc type water filter using Computational Fluid Dynamic (CFD) using SolidWorks Flow Simulation

3. To analyse structural characteristics of the disc-type water filter by using Finite Element Analysis (FEA) by SolidWorks Simulation

1.4 Scope of Project

The scope of the project is to design a disc-type water filter base on three structure which are rhombic, kagome and octet-truss. The material used for simulation purpose is 316L stainless steel for all design. This project will be not fabricated into a prototype due to Movement Control Order which starts in March 2020. However, to accomplished the design into reality, it can only be done by using Additive Manufacturing, as the design was complex and need extra precision compared to the current disc-type filter.

1.5 Significant of Project

Base on this project, it is believed that designing a customize disc-type filter using lattice structure can help in reducing the pressure used in the pumping system. Furthermore, fabrication of disc-type filter by additive manufacturing will not set a limitation in the designing stage, it will also save time on the process. Therefore, customers satisfaction can be achieved without paying for the non-value-added process.