UNIVERSITI TEKNIKAL MALAYSIA MELAKA

SIMULATIONS ON FLOW CHARACTERISTICS FOR NON-STOCHASTIC LATTICE STRUCTURE MESHES DESIGNED FOR WATER FILTRATION APPLICATION

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

by

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I hereby, declared this report entitled "Simulations on Flow Characteristics for Non-Stochastic Lattice Structure Meshes Designed for Water Filtration Application" is the result of my own research except as cited in references.

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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

Penapisan bukan hanya digunakan dalam kegunaan domestik, malahan turut digunakan di industri secara meluas. Walau bagaimanapun, industri menghadapi beberapa cabaran apabila tekanan dan halaju bendalir tidak stabil dan tidak konsisten di sepanjang saluran paip terutamanya semasa bendalir melewati penapis, menyebabkan penggunaan kuasa tinggi untuk menyediakan tekanan yang lebih tinggi. Hal ini mempengaruhi prestasi penapisan, serta memerlukan lebih banyak tenaga untuk penyelenggaraan, kos yang lebih tinggi, dan menunda waktu pengeluaran. Oleh itu, penapis yang lebih berkesan diperlukan dan reka bentuk struktur yang lebih baik adalah salah satu bahagian yang paling penting. Pendekatan baru yang akan dilaksanakan adalah dengan menggunakan struktur kekisi bukan stokastik sebagai media berpori. Oleh hal demikian, kajian ini akan menumpukan pada prestasi struktur kekisi bukan stokastik dalam media penapis sebagai mesh penapis. Prestasi yang diperhatikan meliputi halaju, ciri aliran, dan penurunan tekanan pada saluran keluar penapis. Pemerhatian ini dilakukan pada tiga struktur yang berbeza, heksagon, dodecahedron rhombik, dan kagome menggunakan perisian SolidWorks Flow Simulation pada lima halaju masuk yang berbeza (1 m/s, 3 m/s, 6 m/s, 9 m/ s, dan 12 m/s). Hasil yang diperoleh dibandingkan di antara struktur tiga kekisi dan mendapati bahawa kekisi Dodecahedron Rhombic mempunyai penurunan tekanan minimum. Finite Element Analysis (FEA) juga dikaji untuk memerhatikan sifat mekanikal struktur seperti tekanan Von Mises, regangan, dan Faktor Keselamatannya. Dari analisis tersebut, ditunjukkan bahawa heksagon mempunyai Faktor Keselamatan tertinggi walaupun pada peningkatan halaju masuk.

ABSTRACT

Filtration is not only applied in domestic used, it also being applied in industry widely. However, the industry facing few challenges when pressure and velocity of the fluid are unstable and inconsistent throughout the pipeline especially during fluid passes through the filter, causing high power consumption to provide higher pressure. Thus, affect the performance of the filter, as well as require more manpower for maintenance, higher cost, and delay the production. Therefore, more effective filter is required and the designing of the better structure is one of the most crucial parts. A new approach to be implemented is by using non-stochastic lattice structure as the porous media. Hence, this study will focus on the performance of the non-stochastic lattice structure in filters media as the filter mesh. The performances observed are include velocity, flow characteristics, and pressure drop at the outlet of the filter. These observations were carried out on three different structures, hexagon, rhombic dodecahedron, and kagome using SolidWorks Flow Simulation software at five different inlet velocity (1 m/s, 3 m/s, 6 m/s, 9 m/s, and 12 m/s). The results obtained are compared among the three lattice structure and find out that Rhombic Dodecahedron lattice has the minimum pressure drop. Finite Element Analysis (FEA) is also investigated to observe the mechanical properties of the structure such as Von Mises stress, strain, and its Factor of Safety. From the analysis, it is shown that hexagon has highest Factor of Safety even though at increasing inlet velocity.

DEDICATION

This study is dedicated to everyone who directly and indirectly involved with this study,
especially both my parents,
Zakaria Bin Ismail and Nur Azidah Binti Che Soh,
my brothers and sister,
for the endless moral support,
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LIST OF ABBREVIATIONS

2D	-	2 Dimensional
3D	-	3 Dimensional
ABS	-	Acrylonitrile Butadiene Styrene
AM	-	Additive Manufacturing
CAD	-	Computer Aided Design
CFD	-	Computational Fluid Dynamics
FDM	-	Fused Deposition Modeling
FEA	-	Finite Element Analysis
FEM	-	Finite Element Method
FFF	-	Fused Filament Fabrication
RD	-	Rhombic Dodecahedron
SLM	-	Selective Laser Melting

LIST OF SYMBOLS

α	-	Darcy coefficient
β	-	Non-Darcy coefficient
v	-	Inlet velocity
μ	-	Dynamic viscosity
K	-	Specific permeability
ρ	-	Density
C_f	-	Inertia coeeficient
ΔP	-	Total Pressure
Pa	-	Pascal, SI unit of pressure
L	-	Length
m/s	-	metre per second
mm	-	millimeter
S	-	Surface are
N/m^2	-	Newton per meter

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Filtration is detached into few types; separation of solid from solid, solid from liquid, liquid from liquid, and gas from liquid, every types of filtration are carried out by different processes. The filtration in this project is only focusing on filtration of solid from liquid. According to Sutherland (2008), filtration is an act of separating particle with different size and shape, which the larger particles are trapped at the obstacles, while particles that is below the specification can pass through the filter.

Traditionally, the filters are fabricated by either by wire mesh method or perforated sheet metal. The structures of these two types of filters are different but its mechanical properties are quite similar. According to Hendrick Manufacturing (2018), perforated sheet metal is a metal that can be fabricated by applying CNC punching or laser cutting to make holes that punched through the metal. Meanwhile, wire mesh is a strands of metal wire that is fastened together by woven or welding. However, in terms of filtration, wire mesh for filter sheet is fabricated by layers of metal mesh that is layered onto each other (Wang, 2018).

On the other hand, lattice structure is a three dimensionally cell structures which is formed by repeating more than one unit cells. It is different both in physically and mechanical properties as well as method of fabrication. The parameter of the lattice structure can also be controlled depending to its application. Lattice structures are categorized into two classifications, stochastic and non-stochastic geometries. Shapes and sizes of the cells in stochastic foams are random, meanwhile, non-stochastic foams have uniform, repeating, and categorized shapes and sizes (Hasib, 2015). Fabrication of non-stochastic metal foams

by Additive Manufacturing, AM has been widely applied in industry such as for silencers, heat exchangers, impact energy absorber, and biomedical implants.

As the technology in fabrication evolves, the technology of AM is also shows advancements in industry. While AM is used to fabricate products correlated with plastics, nowadays it has widen its potential by establishing more complex metal components and enable the designer to design a customized product with more efficient and optimum rate of performance (Burns, 2014). AM is such a practical technology in the industry as it reduces the additional process required for the fabricating the product such as cutting, rolling, and welding. Moreover, AM also reduce waste of materials by recycle the excess materials and lessen cost of additional materials without neglecting customers' specifications.

1.2 Problem Statement

The existing filter involves higher power consumption to pump the water due to pressure drop during filtration. The pressure drop reduced the efficiency of the filtration as well as require more manpower for maintenance, higher cost, and delay the production. According to Jha (2015), perforated plates which widely used for water filtration in industry cause pressure drop by 200 Pa with flow rate of 250 m^3/hr and its velocity gradually decreases. In addition, the turbulence occurred are reduced by using polyurethane foams as porous media. It is also involved the separation of filter into three stages with the purpose to remove different sizes of the impurities in the water. Thus, non-stochastic lattice structure manufactured by additive manufacturing is a new approach that to be attempted to solve the problem as it can customize the design of the filter's structure as well as minimize the filter component by eliminate the stages of filter.

1.3 Objectives

Following are the objectives that need to be achieved throughout the project:

1) To design the structure using SolidWorks software.

2) To analyse the flow characteristics for every different structure using SolidWorks Flow Simulation.

3) To determine most suitable non-stochastic lattice structures among hexagon, rhombic dodecahedron, and kagome for filtration application

1.4 Scope

Scope of the project is mainly to describe the range of studies involved in the researches including type of approach used and type of result expected from the method. Therefore, this study will only cover several non-stochastic lattice structures including hexagon, rhombic dodecahedron, and kagome structure. The simulation will be performed using SolidWorks Simulation and the parameters observed are pressure drop, flow characteristics, and velocity of the water. The simulation will be carried out at five different flow rates at the inlet of the filter, 1m/s, 3 m/s, 6 m/s, 9 m/s, and 12 m/s (Carton, 2014). Analysis on the finite element of the structure will also be conducted to analyse the strength of the structures.

1.5 Significance of Study

The aim of this study is to analyse the feasibility and influences of non-stochastic lattice structure in water filtration application. The structure is developed by repeating the lattice unit cells by using CAD software, SolidWorks 2020. The study is carried out to

determine the efficiency of the non-stochastic lattice structures in minimizing the pressure drop as well as its effects on the velocity and water flow characteristics at the outlet of the filter by carry out CFD simulation using SolidWorks Simulation software. To ensure that the structures are suitable to go through simulation, research and understanding the properties and parameters of each structure is a must. Thereafter, the ultimate tensile load of the structures is determined by conducting Finite Element Analysis (FEA).