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PERFORMANCE OF OPEN-CELL FOAM HEAT EXCHANGER UNDER VARIOUS OPERATING CONDITION

MUHAMMAD ALBAIHAQQI BIN MAIDAN AL HADRI
B091910179

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (MAINTENANCE TECHNOLOGY) WITH HONOURS

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Faculty of Mechanical and Manufacturing Engineering Technology

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MUHAMMAD ALBAIHAQQI BIN MAIDAN AL HADRI

A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

DECLARATION

I declare that this Choose an item. entitled “Performance of Open-Cell Foam Heat Exchanger Under Various Operating Condition” is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

Name : MUHAMMAD ALBAIHAQQI BIN MAIDAN ALHADRI

Date : 11/01/2023

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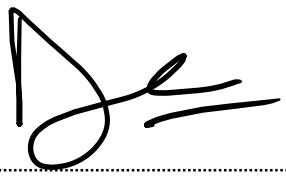
APPROVAL

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 Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.

Signature : 

Supervisor Name : DR. FADHILAH BINTI SHIKH ANUAR

Date : 11/1/23

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DEDICATION

This work is devoted to my institution's mentors, with whose steady help I completed this dissertation. Not only did they provide me with academic knowledge, but they also provided me with invaluable counsel anytime I required it

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ABSTRACT

Metal foam is utilised extensively in the automotive, furniture, and construction industries. In this study, a hybrid radiator with porous foam is studied as an alternative to a present radiator. Radiators are heat exchangers that transmit thermal energy from one medium to the other for cooling and heating. Due to their great heat conductivity, radiators are typically built of aluminium and cooper. Radiators have two type, first downflow type and second is crossflow type. This project objective are design the conventional radiator and hybrid radiator. Another project objective are to simulate temperature characteristics across the open-cell foam radiator and verify the numerical result with experimental data. The radiator design will be exported to CFD software investigate temperature characteristics across open-cell foam heat exchanger (radiator). The temperature of the flow is limited to 313.15 K, 333.15 K and 353.15 K and the porosity, ε of porous foam is 0.90 used for hybrid radiator in the study. The flow rates are in between 1L/min, 1.6 L/min and 2.2 L/min. The design of open-cell foam radiator was done by using Autodesk Inventor software. The design of radiator was follow approximately the dimension of Perodua Kancil 850cc radiator. This study simulates temperature characteristics across the open-cell foam radiator by using ANSYS Fluent software. From this simulation, the results that are obtained the behaviour of temperature characteristics across the open-cell foam radiator. The temperature behavior was discussed in detail by observing the contours color of the simulation data figure. The graph shown the comparison of the outlet temperature and heat transfer rate of experimental and simulation.

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ABSTRAK

Buih logam digunakan secara meluas dalam industri automotif, perabot dan pembinaan. Dalam kajian ini, radiator hibrid dengan buih berliang dikaji sebagai alternatif kepada radiator sedia ada. Radiator adalah penukar haba yang menghantar tenaga haba dari satu medium ke medium lain untuk penyejukan dan pemanasan. Oleh kerana kekonduksian haba yang hebat, radiator biasanya dibina daripada aluminium dan cooper. Radiator mempunyai dua jenis, pertama jenis aliran bawah dan kedua adalah jenis aliran silang. Objektif projek ini adalah mereka bentuk radiator konvensional dan radiator hibrid. Objektif projek lain adalah untuk mensimulasikan ciri suhu merentasi radiator buih sel terbuka dan mengesahkan hasil berangka dengan data eksperimen. Reka bentuk radiator akan dieksport ke perisian CFD yang menyiasat ciri suhu merentas penukar haba buih sel terbuka (radiator). Suhu aliran adalah terhad kepada 313.15 K, 333.15 K dan 353.15 K dan keliangan, ε buih berliang adalah 0.90 digunakan untuk radiator hibrid dalam kajian. Kadar aliran adalah di antara 1L/min, 1.6 L/min dan 2.2 L/min. Reka bentuk radiator foam sel terbuka dilakukan dengan menggunakan perisian Autodesk Inventor. Reka bentuk radiator adalah mengikut kira-kira dimensi radiator Perodua Kancil 850cc. Kajian ini mensimulasikan ciri suhu merentasi radiator buih sel terbuka dengan menggunakan perisian ANSYS Fluent. Daripada simulasi ini, keputusan yang diperolehi kelakuan ciri suhu merentasi radiator buih sel terbuka. Tingkah laku suhu dibincangkan secara terperinci dengan memerhatikan warna kontur rajah data simulasi. Graf menunjukkan perbandingan suhu keluar dan kadar pemindahan haba bagi eksperimen dan simulasi.

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LIST OF SYMBOLS AND ABBREVIATIONS

LIST OF SYMBOLS

T	-	Temperature
K	-	Kelvin
cm	-	Centimeter
m	-	Meter
W	-	Width
L	-	Length
H	-	Height
L/min	-	Liter per minutes
Kg/m^3	-	Kilogram per meter cube
J/(kg k)	-	Joule per kilogram per kelvin
v	-	velocity

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CHAPTER 1

INTRODUCTION

1.1 Background

Metal foams are created by forming a large number of gas-filled bubbles in a metal melt and allowing the liquid to solidify into a solid foam. There are several methods for producing such foams, which differ depending on the type of gas used, the state of the metal used (solid or liquid), how the foam is stabilised, and the procedure used. Aside from standard aluminium alloys, foams can be made from a variety of metals and alloys [1].

Metal foams are available in a variety of forms on the market. Copper foam, aluminium foam, silicon carbide foam, and zirconium oxide foam are a few examples. Closed-cell foam or open-cell foam can be used. The open-cell metal foam is a cellular structure made of solid metal that contains a high volume fraction of gas-filled pores. Each metal foam has unique properties and applications. For example, open-cell metal foams are used as a replacement for conventional fins in aerospace because they provide a higher surface area to volume ratio with marginally higher pressure drop values [1]. In the aerospace industry, metal foam sheets or sandwich panels can replace the costly honeycomb structure [2].

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Metal foams in the automotive sector minimise the number of pieces in the car frame, lowering costs and improving performance [3]. Metal foam's excellent stiffness-to-weight-support ratio makes it ideal for large-area light parts with higher stability needs. Engine hoods and trunk lids are two examples. The metal foam is utilised to reinforce the truck's

interior protection. It is employed as an energy-absorbing component in rear and front automotive bumpers. Metal foams can be utilised in lamps and tables in the furniture and household industries. It can create unique effects in the room when combined with the wood surface. Lightweight furniture can be a huge help when it comes to moving from one location to another for trade shows or exhibitions. Metal foam has outstanding fire resistance and thermal insulation capabilities for the construction and building industry [4]. They can be employed as energy-saving elements because of their thermal insulation capabilities. Because of its sound-absorbing characteristics, they are employed beneath highway bridges, building interiors, and railway tunnels. It's also ideal for ceilings and roofs because it's lightweight and simple to install without the use of mechanical lifting equipment [2].

1.2 Problem Statement

Radiators are heat exchangers that transmit thermal energy from one medium to the other for cooling and heating purposes. The radiator is a mechanism with a vast quantity of cooling surface that contains big quantities of air so that it may efficiently chill water by spreading across it. Due to their great heat conductivity, radiators are typically built of aluminium and cooper. Radiators have two type, downflow type and second is crossflow type.

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The upper and lower tanks of a tubular type of core are connected by a system of tubes through which water flows. The placement of fins around the tubes improves heat transfer. Air circulates around the exterior of the tubes, between the fins, and absorbs heat from the water as it passes. Because water goes through each tube in a tubular radiator, if one tube becomes clogged, the cooling benefit of the entire tube is lost.

Air goes through the tubes and water flows through the spaces between them in a cellular core. The core consists of numerous separate air cells that are surrounded by water. Due to its design, the cellular type is commonly referred to as a honeycomb radiator, particularly when the front cells are hexagonal in shape. The clogging of any route in a cellular radiator result in the loss of only a small portion of the total cooling surface.

To ensure that the porous foam's unique structure is fully utilized, suitable parameters for the foam radiator, such as porosity (ε) of porous foam , must be identified.

1.3 Research Objective

Objectives of this research project are listed as follows:

a) To design open-cell foam heat exchanger (radiator) using CAD software

b) To simulate temperature characteristics across the open-cell foam heat exchanger (radiator)

c) To verify the numerical result with experimental data.

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1.4 Scope of Research

This study will conduct simulation temperature characteristics across of conventional radiator and temperature characteristics across the open-cell foam of hybrid radiator. Hybrid radiator is the radiator with open-cell foam. The design of the radiator will be done by using Autodesk Inventor. The size of the radiator will follow approximately the dimension of Perodua Kancil 850 model radiator as a bench marking case. The radiator design will be exported to CFD software investigate temperature characteristics across open-cell foam heat exchanger (radiator). The temperature of the flow is limited to 313.15 K, 333.15 K and 353.15 K and the porosity, ε of porous foam is 0.90. The flow rates are in 1 L/min, 1.6 L/min, and 2.2 L/min.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The idea, knowledge and discoveries of past research that are relevant to the objective of this study will be discussed in this chapter. This chapter includes flow and temperature characteristics across the open-cell foam and the properties of open-cell metal foam are discussed in Section 2.3.

2.2 Radiator

A radiator is a type of heat exchanger that draws heat away from an engine. In this case, heat is transferred from the coolant medium to the air. It is made up of three tanks: the core, the top, and the bottom. The core is made up of two sets of means: a set of tubes and a set of fins. Coolant flows inside the blade when air passes through the outer surface of the blade. The coolant transfers the heat generated in the engine and transports it through the radiator before exchanging it with the atmosphere [5].

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This coolant mixture is heated by the combustion reaction of fuel and oxygen in the air and is pumped through the engine by a water pump. The fluid then flows to the radiator, where it circulates through a tube clamped between metal honeycomb honeycombs to provide a large surface cooling zone. The vehicle's discovered air blows through a network of straits, absorbing some of the heat as it progresses. The circulating air cools the liquid in the tube, which is then recycled through the engine to generate more heat. Furthermore, heat is generated by the movement of the inside of the motor. The cooling system, specifically the radiator, dissipates this heat.

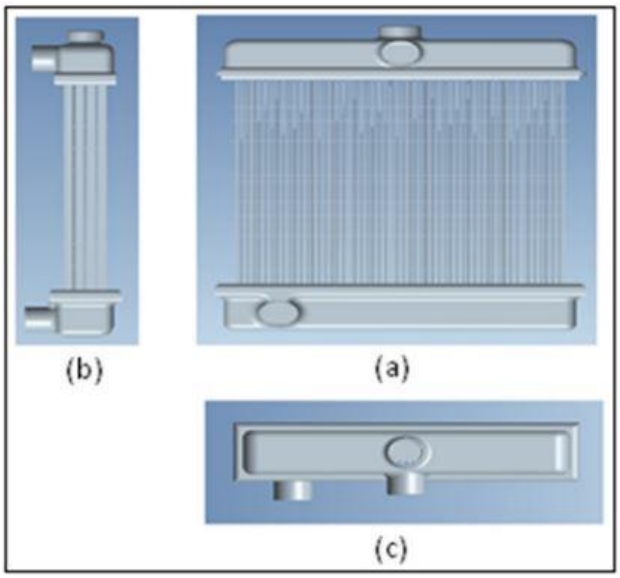

Figure 2.1CAD modeling of the radiator (a) front (b) side and (c) top views [5]

2.3 Metal Foam

Open cell foam is a permeable material with metallic properties. They have a highly homogeneous structure that ensures consistent properties over a wide temperature range. The pore size and density of the open cell metal foam can be adjusted. The pore size can be adjusted from 0.3 to 5 mm, and the relative density can range from 5% to 30%. Functional properties such as mechanical strength, sound absorption, fluidity, and heat transfer can be adjusted precisely due to the high structural variability. As a result, functional materials with a variety of applications have emerged [6].

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Metal foam is a metal with a large number of pores. Metal foam is a naturally inspired lightweight cellular material. Wood, bone, and sea sponge are some well-known examples of similar structure of porous media. Solid metal foam is, in fact, a preserved image of their liquid metal foam counterparts. Some of its distinguishing characteristics include a high specific strength to weight ratio, high gas permeability, high thermal conductivity, and good energy and sound absorption properties [6].