DESIGN AND PRODUCTION OF A HOT-WIRE ANEMOMETER HOLDER USING ADDITIVE MANUFACTURING METHOD

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DECLARATION

I declare that this thesis entitled "DESIGN AND PRODUCTION OF A HOT-WIRE ANEMOMETER HOLDER USING ADDITIVE MANUFACTURING METHOD" 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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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 and Manufacturing Automotive Engineering Technology (BMMA) with Honours.

Signature :

Supervisor Name : Dr Fadhilah Binti Shikh Anuar

Date : 27.1.2022

DEDICATION

To my beloved parents,

Abu Zaki Bin Romli and Che Liah Binti Ahmad

Thank you for all the support, encouragement, enthusiasm, patient and willingness.

To my honoured supervisor,

Dr Fadhilah Binti Shikh Anuar and all UTeM lecturers and staffs.

To my dearest friends

Thank you for always giving me a guidance and persistent help to complete this project thesis.

ABSTRACT

Hot Wire Anemometers (HWA) are thermal transducers devices that can measure the rate at which thermal energy is transferred from a tiny metallic filament that is submerged in a fluid and is subjected to an electric current. Hot wire anemometer in wind tunnel study about the air stream to determine the velocity and direction of a flow such as aerofoil and car's aerodynamic. In this project, to design the hot wire anemometer holder, need to consider the proper holder because the measurement for taking the result is crucial especially in long run test. The objective of this project is to design a hot-wire anemometer probe holder that is suitable for different probe sizes using AutoCAD software and to analyse the hot-wire anemometer holder design using finite element analysis (FEA) and produce a prototype of the holder using additive manufacturing method. To design a hot-wire anemometer probe holder that is suitable for different probe sizes, first need to sketch different kind of probe holder. After sketching several type of design, the design will be sorted by house of quality to select the best design that meets the research aim and objectives. Next, the selected design from the house of quality will been drawn in AutoCAD 3D design software. After designing in the AutoCAD software, the selected design file will export to .igs type file to undergo the Finite Element Analysis (FEA) test in Ansys software. After undergo the FEA test, the design with the best result in FEA analysis would be selected as the main design that will representing this project and will undergo 3D printing process (Additive Manufacturing method). As for result, the probe holder that able to move the probe vertically with an appropriate scale is embedded on its body to measure the travel distance of the probe were succeeded created. Finally, the holder can be used for different probe sizes from 1mm to 50 mm diameter and the probe holder's overall dimensions must be appropriate for usage in a small-scale wind tunnel with a maximum test section width of 400 mm.

ABSTRAK

Hot-wire Anemometer (HWA) adalah satu alat terma transduser yang boleh mengukur kadar tenaga terma (haba) dimana ianya dipindahkan dari filamen logam kecil yang terendam dalam bendalir dan menukarkannya ke arus elektrik. Hot wire anemometer (HWA) dalam terowong angin mengkaji aliran udara untuk menentukan halaju dan arah aliran seperti aerofoil dan aerodinamik kereta. Objektif projek ini adalah untuk merekabentuk pemegang hot wire anemometer yang sesuai untuk saiz probe yang berbeza dengan menggunakan perisian AutoCAD dan untuk menganalisis reka bentuk pemegang hot wire anemometer menggunakan analisis (FEA) dan menghasilkan prototaip pemegang menggunakan kaedah pembuatan aditif. Untuk mereka bentuk pemegang hot wire anemometer yang sesuai untuk saiz yang berbeza dan menghasilkan prototaip pemegang sesuai, pertama perlu merekabentuk dan melakar pelbagai jenis pemegang (HWA) yang berbeza. Selepas merekabentuk beberapa jenis reka bentuk, reka bentuk yang dipilih akan dibanci mengikut "House of Quality" untuk memilih reka bentuk terbaik yang memenuhi matlamat dan objektif kajian. Seterusnya, reka bentuk yang dipilih dari rumah kualiti (HOQ) akan dilukis dalam perisian reka bentuk AutoCAD 3D. Selepas mereka bentuk dalam perisian AutoCAD, fail reka bentuk yang dipilih akan mengeksport ke fail jenis .igs untuk menjalani ujian Finite Element Analysis (FEA) dalam perisian Ansys. Selepas menjalani ujian FEA, reka bentuk dengan hasil terbaik akan dipilih sebagai reka bentuk utama yang akan mewakili projek ini dan akan menjalani proses cetakan 3D (kaedah Pengilangan Tambahan). Hasil yang diharapkan adalah pemegang probe tersebut boleh bergerak secara secara menegak ataupun lebih tepat 'dapat bergarak keatas dan kebawah' dan mempunyai skala ukuran yang sesuai dilekatkan di badan prototaip untuk mengukur jarak perjalanan probe. Akhir sekali, dimensi keseluruhan prototaip tersebut mesti mengikut dimensi terowong angin berskala kecil yang telah direka sebelum ini dan pemegang probe tersebut boleh memegang probe yang bersaiz 1 mm hingga 50 mm sahaja.

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LIST OF SYMBOLS AND ABBREVIATIONS

2D	-	2-dimension
3D	-	3-dimension
AM	-	Additive Manufacturing
CAD	-	Computer-Aided-Design
CC	-	Constant Current
CT	-	Constant Temperature
FDM		Fused Deposition Modelling
HOQ	-	House of Quality
HWA	-	Hot-wire-Anemometer
OEM	-	Original Equipment Manufacturer
PA66	-	Polyamide 66
QFD	-	Quality Function Deployment
SLS	-	Selective Laser Sintering
TCR	-	Temperature Coefficient of Resistance
mA	-	Current, I
mm	-	Diameter, d
kHz	-	Frequency, f
mm	-	Length, l
%	-	Percentage
Ω	-	Resistance, R
°C	-	Temperature, T
µm	-	Width, s

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Hot Wire Anemometer is a device for determining and analyses both velocity and direction of a fluid. This may be assessed by looking at the wire's heat loss in the fluid stream. The wire or filament is heated by electrical current. When a heated wire is immersed in a fluid stream, heat is transferred from the wire to the fluid, lowering the wire's temperature. The wire resistance is used to determine the fluid flow rate. The hot wire anemometer is a research device used in fluid mechanics. It works on the principle of heat transfer from a hot to a cold environment. According to (Charlie c, 1994), typically, the electrical arrangements are in either a constant current (CC) mode or a constant temperature (CT) mode.

The wire is often made of platinum, tungsten or some special alloy. The reason why the wire made from these material because of the material are had many kind of resistance that made the wires last longer. The size of the wire is about 5 µm in diameter and 1mm in length. It can have a resistance ranging from 10 Ω to 30 Ω and a temperature coefficient of resistance (TCR) about 0.1%/°C at room temperature. Such a wire would normally need a current from 10 to 40 mA to operate and a cut-off frequency of the anemometer in the tens of kHz range is obtainable using high speed electronics according to ((Charlie c, 1994), (Nagano and Tsuji, 1994) and (Bruun, 1996)).

1.2 Problem Statement

According to Dr Fadhilah, when taking a measurement using a hot-wire anemometer, it is usually necessary to hold it manually. This approach may be inefficient for a long-hour experiment since one person must hold the hot-wire anemometer and ensure that it is steady and correctly face the flow direction. Furthermore, the depth of a measurement location, such as within a wind tunnel, is not always known and is generally approximated using the naked eye. However, when measuring near a surface or when one precise place is the point of interest, the flow velocity measurement might be incorrect. To achieve the most accurate result during a fluid dynamic experiment, it is critical to ensure that the hot-wire-anemometer (probe) can stay stationary and travel vertically without difficulty within the wind tunnel. It should be created a flexible probe holder for several types of hot-wire anemometers with various probe diameters. The material utilized in the holder design must be carefully examined so that it can securely grab the probe and provide a stable position outside of the wind tunnel. Improper designs can be caused by a variety of reasons, according to (Xie, Lu and Li, 2017). The frequency with which environmental and computational variables cause errors. As a result, the probe holder must be exact in both scientific and environmental terms.

1.3 Objective

- To design a hot-wire anemometer probe holder that is suitable for different probe sizes using AutoCAD software.
- To analyze the hot-wire anemometer holder design using finite element analysis (FEA) and produce a prototype of the holder using additive manufacturing method

1.4 Scope of Research

- Probe holder should be easy to assemble and dissemble.
- Farsoon FS3300 PA 10k (Nylon powder) and nylon filement is the material for the probe holder prototype.
- The probe holder should be able to move the probe vertically with an appropriate scale is embedded on its body to measure the travel distance of the probe.
- The holder can be used for different probe hot wire anemometer sizes from 1mm to 50 mm diameter.
- The probe holder whole dimension size must be suitable to be used for a small-scale in-house manufactured wind tunnel with maximum test section width up to 400 mm. The holder should be able to position the probe in any horizontal position (400 mm flexible distance) before inserting the probe into a hole on the top of the test section.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this IR 4.0 era, there are many kinds of technological tools that have been developed to ease the research and development process in the wide industries. Good instrumentation and tools are required so that more accurate data can be collected during experiments and laboratory works. For instance, medical fields that involving surgical practices in today's technology and even in the distant past of Chinese traditional medical practitioner. Meanwhile, in the engineering industries, measurement probes such as thermocouple, hot-wire anemometer, tachometer etc. have been widely used.

2.2 Hot wire anemometer

With relative free stream turbulence levels about 25%, hot wire anemometers (HWA) have been available for over a generation and are still a valuable instrument for simulation and practical fluid flow study. According to (Eguti and Vieira, 2004), when compared to alternative approaches for measuring the speed of fluid flows, hot wire anemometry (HWA) has several benefits, the most notable of which is a lower relative acquisition cost when compared to unlike LDA, which has a frequency response of just 30 kHz, HWA has a frequency response of 20 to 50 kHz in most cases. Some hot wire anemometers can even operate at frequencies above 100 kHz. Low maintenance costs and simplicity of use are other key characteristics that make HWA for use in research laboratories the preferred technique of determining fluid flow speed, making it engineers and researchers should make a sensible effort searching for rapid and practical results in fluid dynamics studies.

Figure 2.1 Type of HWA system

Figure 1 depicts a typical Dantec Inc. laboratorial probe, model 55P11, and a HWA industrial sensor, type 430, from Kurtz Instruments Inc. The first probe contains a tungsten wire with a diameter of 4 mm and a length of 1.2 mm, while the second probe has a wire that is totally insulated with ceramic and mechanically protected by a stainless tube with a diameter of 10 mm. A tiny platinum temperature sensor is integrated within the Kurtz's probe for automated temperature adjustment of the output signal.

In the industrial environment, hot-wire anemometers can be used to detect fluid velocities and volumetric or mass flow. Because of the low cost, ease of signal conditioning, electrical linear output signal, all solid state components, low loss pressure in the flow, automated fluid temperature compensation, absence of rotating parts, and ability to work in aggressive environments with chemical reactions or the presence of solid particles in the fluid, this equipment is heavily used during in.

According to (Horváth, 2000), the cost of a buying hot wire anemometer is affordable. The frequency responsiveness of HWA is strong, and can give the best result when undergo the experiment. Plus, it has a compact measuring volume, good spatial and temporal resolution, and can readily monitor turbulent flows. In addition, the multi-sensor probe allows for simultaneous thermal analysis and inter measurement. Then it can measure two-phase flow with the same precision and low signal-to-noise ratio as a Laser Doppler anemometer. Probe and analysis selection: Finding an appropriate measuring system is straightforward for most measurements and signal analysis. Contractually period and wavelength sampling is possible with analogue output. Finally, with wall sensors placed flush to the surface, the HWA may collect measurements in gases, transparent, opaque, electrically conducting liquids, and instantaneous wall shear stresses.

However, hot wire anemometer has a difficulty with high turbulence intensity. It's only good for low and moderate turbulence flows, and flow disturbance from beyond the measuring plane skews the findings. Aside from the hot wire anemometer, may contaminate the probe more easily because of the liquid flow probe, and temperature fluctuations in the fluid had a greater impact on the results owing to the smaller overheat ratio employed in liquids. Furthermore, HWA struggles with high turbulence intensity. It works best for low to moderate turbulence flows, and flow disturbance beyond the measuring plane skews the results. Aside from the HWA, there was a liquid flow probe that could be contaminated more readily, and temperature variations in the fluid had a bigger influence on the results since liquids have a lower over heat ratio. Finally, the HWA had aerodynamic problems. Probes are insensitive to flow direction (reverse flow), and probe supports interfere with flow into