



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



MUHAMMAD SYAFIQ SYAZWAN BIN ABU ZAKI

B091810218

**BACHELOR OF MECHANICAL AND MANUFACTURING
AUTOMOTIVE ENGINEERING TECHNOLOGY (BMMA) WITH
HONOURS**

2022



Faculty of Mechanical and Manufacturing Engineering Technology

A faded version of the UTeM logo and university name is visible in the background behind the title text.

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

Muhammad Syafiq Syazwan Bin Abu Zaki

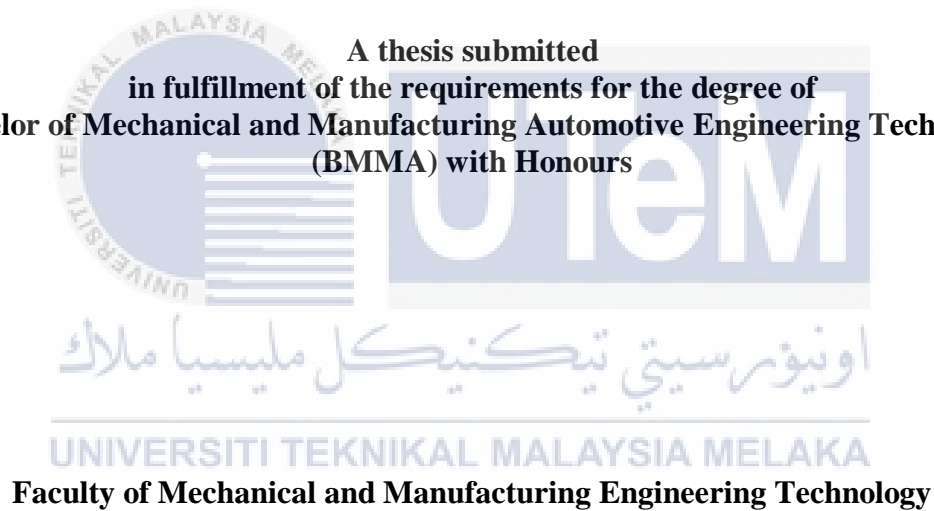
**Bachelor of Mechanical and Manufacturing Automotive Engineering Technology
(BMMA) with Honours**

2022

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

MUHAMMAD SYAFIQ SYAZWAN BIN ABU ZAKI

**A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical and Manufacturing Automotive Engineering Technology
(BMMA) with Honours**



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

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.

Signature



Name

: Muhammad Syafiq Syazwan Bin Abu Zaki

Date

: 18.1.2022

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 be 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.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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.

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, I want to express my gratitude and thanks to Allah the Almighty, my Creator and Sustainer, for everything that I have received from the beginning of my existence. I'd like to express my gratitude to Universiti Teknikal Malaysia Melaka (UTeM) for providing the research environment.

Dr. Fadhilah Binti Shikh Anuar, Faculty of Mechanical and Manufacturing Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM), is my main supervisor, and I am grateful for all of her help, guidance, and inspiration. Her unwavering patience in mentoring and offering invaluable insights will be remembered for the rest of her life. Also, thank you to Mr. Mohd Faez Bin Zainol, my Academic Advisor at Universiti Teknikal Malaysia Melaka (UTeM), for his unwavering support throughout my journey.

Last but not least, I want to express my heartfelt appreciation to both of my loving parents, Abu Zaki Bin Romli and Che Liah Binti Ahmad, for their support and encouragement throughout my life. For their tolerance and understanding, I extend my eternal love to Muhammad Aidil Zuhri Bin Abu Zaki, Muhammad Anas Munawwar Bin Abu Zaki, and Nur Sofea Idzlyani Binti Abu Zaki. I'd want to express my gratitude to my family and closest relatives for their unwavering support, love, and prayers. Finally, I'd want to express my gratitude to everyone who has helped, supported, and inspired me to pursue my studies.

TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATION	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF SYMBOLS AND ABBREVIATIONS	xi
LIST OF APPENDICES	xii
CHAPTER 1 INTRODUCTION	1
1.1 Background of study	1
1.2 Problem Statement	2
1.3 Objective	3
1.4 Scope of Research	3
CHAPTER 2 LITERATURE REVIEW	4
2.1 Introduction	4
2.2 Hot wire anemometer	4
2.2.1 Operation of hot wire anemometer	7
2.2.2 Type of hot wire anemometer outer design	9
2.3 Probe holder	10
2.3.1 Type of device holder	10
2.3.2 Hot wire anemometer holder	11
2.4 Autodesk AutoCAD 2021	12
2.5 Product Development using Finite Element Method	13
2.5.1 Designing the product using FEA	14
2.5.2 Material selection and parameter	14
2.5.3 Geometry	16
2.5.4 Meshing and analysis	16
2.6 Additive Manufacturing Method	16

2.6.1	3D printing technique	17
2.6.2	Materials used in 3D-printing process	20
CHAPTER 3 METHODOLOGY		22
3.1	Introduction	22
3.2	Procedure	25
3.2.1	Sketch design	25
3.2.2	Produce HOQ	25
3.2.3	Selection of design	25
3.3	Morphological Chart	27
3.4	House of Quality	29
3.5	Concept selection	30
3.6	Main features Of Design	34
3.7	CAD and Finite Element Method (FEM)	37
3.7.1	AutoCAD software	37
3.7.2	Ansys software	42
3.7.3	FEA parameter	46
3.7.4	Load distribution	47
3.8	3D printing and Material	51
3.8.1	SLS (SS402P)	51
3.8.2	Crealty Ender CR-6	54
3.9	Bill of material	56
CHAPTER 4 RESULTS AND DISCUSSION		59
4.1	Introduction	59
4.2	House of quality evaluation	60
4.3	Schematic drawing and FEA analysis result	63
4.4	Orthographic Drawing	64
4.5	Explosive drawing	67
4.6	Load distribution calculation	69
4.6.1	Load distribution of design A	70
4.6.2	Load distribution of design B	71
4.6.3	Load distribution of design C	72
4.7	FEA analysis result	73
4.8	3D printing hours	81
4.9	Prototype result	87
4.9.1	Testing and adjustment	87
4.9.2	Project finishing process	90
4.9.3	Prototype assembly process	93
4.9.4	Final result product	95
CHAPTER 5 CONCLUSION AND RECOMMENDATIONS		97
5.1	Conclusion	97
5.2	Recommendation	98
REFERENCES		100



LIST OF TABLES

TABLE	TITLE	PAGE
Table 1	Technical data of Testo 405-i	10
Table 2	FEA parameter for nylon (PA 66)	46
Table 3	FEA parameter for hardware components (Stainless steel)	46
Table 4	Design parameter of Design A	48
Table 5	Design parameter of Design B	49
Table 6	Design parameter of Design C	50
Table 7	Bill of material	56
Table 8	The pro and cons of selected design	68
Table 9	Mass of all component in design A	70
Table 10	Mass of all component in design B	71
Table 11	Mass of all component in design C	72
Table 12	Result of FEA analysis of all part of selected design	73
Table 13	Procedure of assembly the prototype	93

LIST OF FIGURES

FIGURE	TITLE	PAGE
Figure 2.1	Type of HWA system	5
Figure 2.2	Work principle of probe	7
Figure 2.3	Testo 405-i	9
Figure 2.4	Hot wire anemometer holder	12
Figure 2.5	AutoCAD 2021 3D drawing home page	13
Figure 2.6	Mind map/chart of material selection and parameter	15
Figure 2.7	Schematic of SLS 3D printing setup	18
Figure 2.8	Schematic FDM 3D printing system setup	19
Figure 3.1	Top view drawing of small scale wind tunnel (Nazri, 2020)	23
Figure 3.2	Test section drawing of small scale wind tunnel (Nazri, 2020)	23
Figure 3.3	Test section 3D design of Small scale wind tunnel (Nazri, 2020)	24
Figure 3.4	Whole 3D design of small scale wind tunnel (Nazri, 2020)	24
Figure 3.5	Design A	34
Figure 3.6	Design B	35
Figure 3.7	Design C	36
Figure 3.8	Newton Second law and Moment diagram	47
Figure 3.9	Distribution force of Design A	48
Figure 3.10	Distribution force of Design B	49
Figure 3.11	Distribution force of Design C	50
Figure 4.1	Flow chart of working process of chapter 4	59

Figure 4.2	The method of how to fill in costumers importance rating value	60
Figure 4.3	Method of how to fill in the interrelationship matrix value	61
Figure 4.4	The relationship of selected design and costumer requirement	62
Figure 4.5	Orthographic drawing of design A,B and C	64
Figure 4.6	Type of assemble technique of design A,B and C	65
Figure 4.7	The condition of design B pole when assemble with holder	66
Figure 4.8	Explosive drawing of design A,B and C	67
Figure 4.9	Printing hours of holder	81
Figure 4.10	Printing hours of base	82
Figure 4.11	Printing hours of tips	82
Figure 4.12	Printing hours of pole A	83
Figure 4.13	Printing hours of pole B	83
Figure 4.14	Printing hours of pole C	84
Figure 4.15	Printing hours of post	84
Figure 4.16	Custom-made tips	88
Figure 4.17	The condition of testo405-i after attached on the probe holder	88
Figure 4.18	M10 Helicoil plug coil thread	89
Figure 4.19	New tips create using FDM 3D printing method	90
Figure 4.20	Process scraping the prototype surface using sandpaper	90
Figure 4.21	Process of painting the product	91
Figure 4.22	The application of self-adhesive cushion protector on the holder and tips	92
Figure 4.23	The application of self-adhesive cushion protector on the base	92
Figure 4.24	The application of sticker ruler on the pole	92

Figure 4.25 Front view of full assemble HWA holder	95
Figure 4.26 Back view of full assemble HWA holder	96
Figure 5.1 The direction that needed to expand of HWA holder	98
Figure 5.2 The holder part that needed to make adjustment	99
Figure 5.3 The mechanism that needed to make adjustment	99



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
$^{\circ}\text{C}$	-	Temperature, T
μm	-	Width, s

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
APPENDIX A	SCHEMATIC VIEW OF DESIGN A	102
APPENDIX B	EXPERIMENT SITE USING HOT WIRE ANEMOMETER HOLDER	108



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 disassemble.
- Farsoon FS3300 PA 10k (Nylon powder) and nylon filament 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 μm 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