Development of Sonic air flow meter

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ABSTRAK

. Untuk mengurangkan penggunaan kuasa sistem penyaman udara, kita boleh mengoptimumkan kadar aliran dalam sistem penyaman udara. Oleh itu, kita perlu membuat peranti untuk mengukur kadar aliran supaya kita boleh mengoptimumkan kadar aliran dan meningkatkan kecekapan sistem penyaman udara. Halangan yang sedia ada akan simulasi dan akan dibandingkan dengan model sebenar untuk mengesahkan persediaan eksperimen. Dalam eksperimen, halangan yang optimum akan diuji untuk menentukan pembolehubah tahap kuasa bunyi seperti Db, kadar aliran isipadu dan Air halaju eksperimen, dari keamatan bunyi mikrofon dijana dalam mikrofon, akan menggunakan jelmaan Fourier (FFT) untuk mengubah intensiti terhadap frekuensi gelombang bunyi graf. Puncak intensiti akan wujud pada frekuensi. kadar aliran yang berbeza akan memberi keamatan puncak yang berbeza bunyi pada frekuensi yang sama. Selepas eksperimen dan mendapat penentukuran graf keamatan bunyi (dB) terhadap kadar aliran pada frekuensi tertentu, ia boleh menjadi rujukan kita apabila menggunakan bunyi akustik untuk menentukan halaju / kadar aliran dalam penghawa dingin dengan cara yang lebih menjimatkan

ABSTRACT

To reduce the power consumption of air conditioning system, we can optimize the flow rate in air conditioning system. Thus, a device created to measure the flow rate to optimize the flow rate and increase the efficiency of the air conditioning system. The triangular obstacle will be simulated and will be compared with actual model to verify the setup of the experiment . In experiment, the optimum obstacle will be tested to determine variable such Sound power level (Db), Volumetric flow rate and Air velocity experiment, from microphone sound intensity generated in microphone and Fast Fourier Transform (FFT) used to transform intensity against frequency of sound wave graph. A peak of intensity exists at a certain frequency. Different flow rate gave different peak intensity of sound at same frequency of 2194Hz. After the experiment calibration graph of intensity of sound (dB) against flow rate at a specified frequency obtained as reference when using the sound acoustic to determine the velocity /flow rate in air conditioner in a more economical way

CHAPTER 1

INTRODUCTION

1.1 A Brief Introduction

. The frequency of sound waves is measured in hertz, which has the symbol Hz. The bigger the number, the greater the frequency, the higher the pitch of the sound. Human beings can generally hear sounds as low as 20 Hz and as high as 20,000 Hz (20 kHz). Sound waves passing through the air cause air molecules to move back and forth parallel to the direction that the wave is travelling. This back and forth motion of the air molecules results in alternating regions of high pressure and low pressure. A region of high pressure is called a "compression," and a region of low pressure is called a "rarefaction" (node). The number of times that a region is compressed and rarefied in one second is called the frequency (f). These compressions and rarefactions, when interacting with the diaphragm of a microphone, will produce an electrical signal which may be interpreted by a computer.

In fluid dynamics, **laminar flow** is characterized by **smooth or in regular paths** of particles of the fluid, in contrast to **turbulent flow**, that is characterized by the irregular movement of particles of the fluid.

The principle of operation of the experiment in this thesis is almost same as the operation of vortex flowmeter. The basic principle of vortex flowmeter is based on von Kármán effect. According to this principle, when passing a bluff body, flow will generate vortices. Bluff body acts as an obstacle in the air flow. Flow velocity is proportional to the frequency of the vortices. Volumetric flow rate is calculated by multiplying the area of the pipe times the velocity of the flow.($Q = AV$).

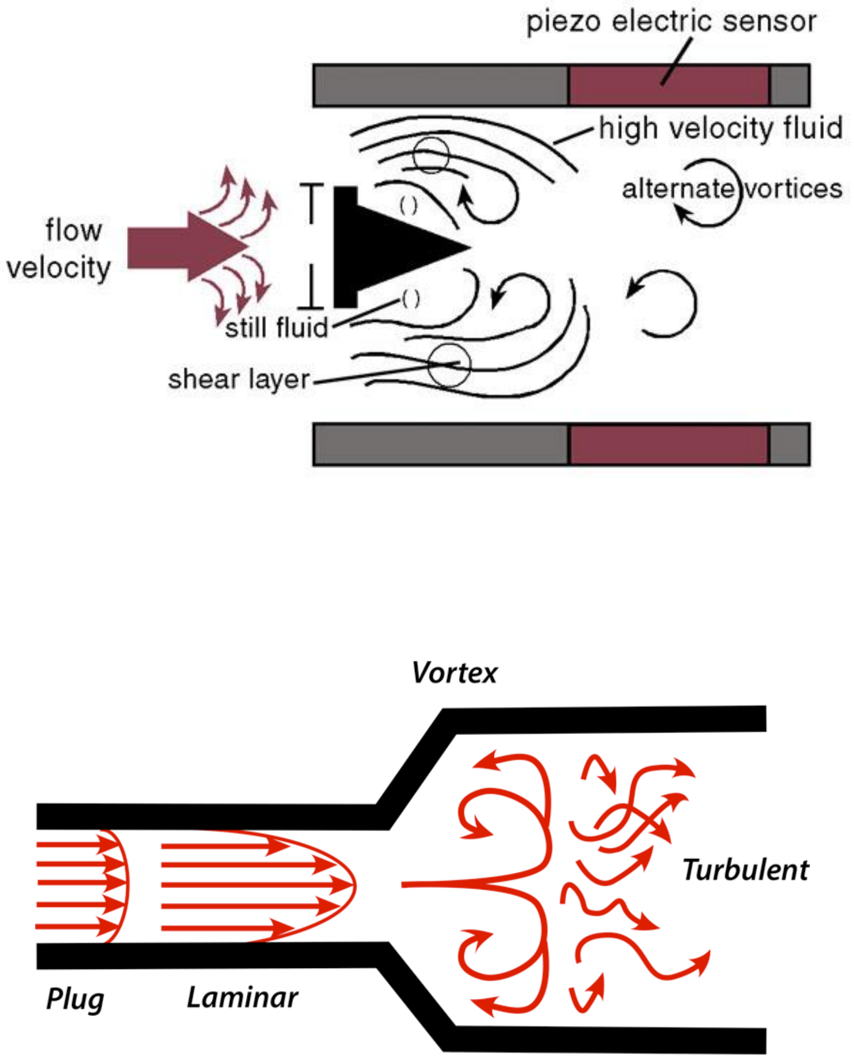

Figure 1.1 Air flow pass through bluff body

Some vortex meters use straight upstream piping to eliminate distorted flow patterns and swirl. Low flow rate gives problem for vortex meters, because they generate vortices irregularly under low flow conditions. In real life, vortex flowmeters are widely used to measure steam flow.

1.2 Project Background

Greenhouse effect is very serious nowadays. This is because human activities are adding a lot of greenhouse gases to the air and causing the average temperature of the Earth to increase. One of the causes of greenhouse effect is combustion of the fossil fuel. The main purpose of combustion of fossil fuel nowadays is to produce electricity. Nowadays, almost all houses and offices have air-conditioner. By using air-conditioner,to much electricity utilized. To reduce the power consumption of air conditioning system, the flow rate must be optimized in air conditioning system. Thus, a device needed to measure the flow rate so the flow rate can be optimized and efficiency of the air conditioning system can be increased. So some equations will be used to predict the flow or streamline such as the Reynolds number. The Reynolds number is the ratio of inertial forces to viscous forces and is a convenient parameter for predicting if a flow condition will be laminar or turbulent. It is defined as:

$$\mathrm{Re}_D = \frac{\rho V D}{\mu} = \frac{V D}{\nu}$$

Equation (1)

Where V is the flow velocity,D is a characteristic linear dimension, (travelled length of the fluid; hydraulic diameter etc.), ρ fluid density (kg/m3), μ dynamic viscosity (Pa.s), ν kinematic viscosity (m2/s); $\nu = \mu / \rho$.

Reynolds number is dimensionless and if it is less than 2000, the flow is laminar and if it more than 4000 it's called turbulent.In this experiment, turbulent flow is used as inlet air flow.

There are relatively few studies on the experimental measurements of the acoustic velocity field. Different techniques have been used to measure the acoustic particle velocities. It includes, laser Doppler anemometry (LDA), hot-wire anemometry, condenser or piezoelectric microphone, pressure measurements and acoustic sensor. In this experiment, from microphone sound intensity generated in microphone, we use Fast Fourier Transform (FFT) to transform intensity against frequency of sound wave graph. A peak of intensity will exist at a frequency. Different flow rate will give different peak intensity of sound at same frequency. After the experiment and the calibration graph of intensity of sound (dB) against flow rate at a specified frequency obtained, it can be reference when using the sound acoustic to determine the velocity /flow rate in air conditioner in a more economical way by using Sonic Air Flow Meter. Then the flow rate is optimized in order to increase efficiency of air conditioner. Also, other direct velocity measurement components such as hot wire anemometer is used to compare the accuracy of this experiment.

A vortex flowmeter is typically made of 316 stainless steel and includes a bluff body, a vortex sensor assembly and the transmitter electronics. A vortex flowmeter operates based on the vortex shedding principle, where an oscillating vortex occur when a fluid flow past a bluff body. The frequency that the vortexes are shed depends on the size and shape of the body. It is ideal for applications where low maintenance costs are important.

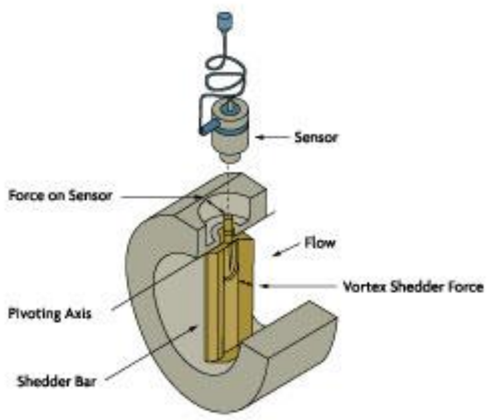

Figure 1.2 Vortex Flowmeter

An anemometer is commonly used to measure wind speed, especially in weather station and wind tunnels. There are several types of velocity anemometer, including cup anemometer, vane anemometer, hot-wire anemometer, laser Doppler anemometer, ultrasonic anemometer, ping pong ball anemometer. The most common anemometer in the market is vane anemometer and hot-wire anemometer.

Figure 1.3: Vane anemometer

The vane anemometer is also called as a windmill/ propeller anemometer. The axis of the vane anemometer must parallel to the direction of the wind. A vane anemometer combines a propeller and a tail on the same axis to obtain accurate and precise wind speed and direction measurements from the same instrument. The speed of the fan is measured by a revolution counter and converted to a wind speed by an electronic chip. Hot-wire anemometer uses a very fine wire (~mm) electrically heated to some temperature above the ambient. Air flowing past the wire cools the wire. The electrical resistance of most metals is dependent upon the temperature of the metal (eg. tungsten), a relationship can be obtained between the resistance of the wire and the flow speed. Hot-wire anemometer has extremely high frequency-response and fine spatial resolution compared to other measurement methods. This make it almost universally employed for the detailed study of turbulent flows, or any flow in which rapid velocity fluctuations are of interest.

Figure 1.3 Hot Air Anemometer

In this Final Year Project experiment, an air velocity measurement system is developed by using flow acoustics. The system requires to be low cost and high efficient that can resemble the classical tomography techniques where the high frequency electronic magnitude waves are replaced by low frequency sound waves. There are also some important settings for the experiment, including blower and a suitable obstacle design. When air passes around a surface, sound waves are generated due to the surface friction and drag. The sound waves magnitude is directly proportional to the drag force and air velocity. The blower should have suitable blow speed to produce turbulent flow through the pipe prepared and the obstacle need to produce significant sound signal that can be detected by the microphone.

The basic component of the system includes the acoustic receivers (microphones), and algorithms (embedded software) to measure the air flow velocity simultaneously. The sound speed in air depends on properties of the air, such as temperature, pressure, humidity, and air velocity.

1.3 Problem Statement

For air ducts flow measurement in air conditioning system, the digital flow Having an affordable online digital measurement connected directly with a central control by using variable air speed system that reduces the power consumption of the air conditioning system significantly. Even when using constant air speed system, the in-line air speed measurement can improve and reduce the cost of regular system calibration and maintenance cost.

1.4 Objectives of the study

The current research revolves around three prime objectives listed below:

- To design and construct a simple and efficient flow meter based on acoustic responses of the flowing medium i.e., air.
- To evaluate the sound waves generated for different airflows from different geometries of obstacle placed in a circular tube and determine the optimum geometry using ANSYS-Fluent Software for high efficient flow measurements.
- To experimentally test and verify the optimum obstacle geometry obtained from simulation results in order to determine the measurable working range of the velocity of flow.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Working with the right pieces of equipment is of the utmost importance for the smooth performance and completion of all tasks, and of obtaining the maximum results. Particularly when it comes to industrial processes, when precise and accurate work is a must. Each industry requires an apparel of industrial tools and equipment for processing the work tasks successfully. The truth is, many of these tools are frequently used in various industries, thanks to their exceptional versatility and optimum performance they provide. One of such tools is the flow meter. A flow meter is a device used to measure a gas or liquid's volume or mass. Depending on the particular industry, flow meters are referred to by many names, such as flow gage, flow indicator, liquid meter, flow rate sensor, etc. All of them, however, measure flow. With flow meters, open channels, such as rivers or streams, can be measured. Improving fluid measurement precision, accuracy, and resolution are the greatest advantages of the best flow meters.[1].

2.2 Applications of flow meters

In many industries, the flow meter is well-known for many applications such as Building Automation, Chemical, Food & Beverage, Power & Utilities, Marine, Metals & Mining, Oil & Gas, Pharmaceutical, Pulp & Paper and Water & Wastewater.[2]

a) For building automation, water and energy measurements have been used to optimize chillers, monitor hot water consumption and monitor the flow of primary and secondary heat exchangers The flow meters also used to optimize energy balancing and also for chemical addition optimization and other applications for water & energy control. For example to effectively manage and conserve Heat Ventilation and Air Conditioning resources in buildings, a comprehensive metering program is essential and with integrated display and multiple outputs flow meters can provide wide range of flow,temperature and energy consumption.Another application for building automation is managing the flow of heating and cooling water which non-intrusive energy flow meter used without interrupting the flow into buildings. This saves considerable installation and operating costs .

b) For chemical application, using flow meters to measure acids and other corrosive material,mass balacing and also for mixing and batching application for gases and liquids.For example for Sulphuric acid measurement a non-instrusive flowmeter has the ability to measure the liquid flows containing up to 30 percent particulates or bubbles provides excellent solution for measuring Sulphuric acid to the evoporators while minimizing the wear of the pumps. For the second application for chemical is Hydrofluoric acid measurement.The flow meter allow the measure of not only volumetric flow rate but also the sonic velocity of the hydrofluoric acid . A PLC(Programmable Logic Controller) or DSC(Differential Scanning Calorimetery) can be programmed to correlate acid concentration with sonic fluid velocity measurements as there is a direct relationship between sonic velocity and changes in hydrofluoric acid concentration.

c) For Food and Beverage, the flow meter are used to measure accurately the amount of steam before reaching the kettle for the saturated steam flows through a control valve from the steam header . The flowmeter also measures and calculates steam mass flow rates to control heat to boil the wort.For the second application the flow meter used in measurement of soft drink. CO_2 measurement is a unique challenge for soft drink producers. Manufacturers often use old technology gas flow meters to measure CO_2 flow so process engineers can control a valve and supply the right amount of gas to their soft drink production.

d) For Oil and Gas , the flow meter are used to measure the wellhead crude oil which able to develop measuring solutions that perform reliably in the toughest onshore environments.For the second applcation of Oil and Gas is drilling muds. The flow meters are used in online mixing and mixing of expensive mud (WBM and OBM) as well as in custody transfer measurement with 0.1 percent accuracy at the point of transfer for on-site delivery of ships and mud tanks. Online density and viscosity measurement keeps the parameters of mud constant.

2.3 Types of Flowmeters

Depending on the application, nature and type of fluid and the flow meter construction, including materials, there are numerous types of flow meters. The five basic flow meter classification includes,Differential Pressure Flow Meters,Positive Displacement Flow meters,Velocity Flow Meters,Mass flow Meters and finally Open Channel Flow Meters.[3]

The Differential Pressure Flow Meters measure the differential pressure across an orifice where the flow is directly linked to the square root of the produced differential pressure.In differential flow meters there are also primary and secondary elements.Using either flow nozzle,Pitot tube,Orifice plate or Venturi Flowmeters, the primary element produce change in kinectic energy.Differential Flow Meters commonly used in oil & gas industry, water and chemical application. While the positive displacement flow meters measure the volume filled with fluid,deliver it forward and fill it again, calculating the amount of fluid transferred.The positive displacement commonly used in transfer of oils and fluids,hydraulics and also home-use for water and gas application.The Velocity meters measure stream velocity to calculate volumetric flow rate, which is less sensitive when the Reynolds fluid number is higher than 10000. Velocity flow meters include turbine, paddle wheel, vortex shedding, electromagnetic and sonic / ultrasonic flow meters. In mass-related processes, mass flow meters are more effective in measuring the force resulting from the acceleration of mass.Finally the Open Channel Flow meter allows the measurement of v-notch, weirs and flumes in open channels. These dam-like structures, or overflows, permit a limited or concentrated free flow of liquids based on the structure's unique shape and size

2.3.1 Liquid flow meters and application

A number of different industries, including power, oil, water, and waste treatment, are important for using liquid flow measurement. These industries need to know the exact amount of liquid flowing through a point. Liquid flow meters are used to determine the volume of liquid that flows through to determine the quantity to be billed or the quantity to be produced. A liquid flow meter is an instrument used to measure a liquid flow rate linearly, nonlinear, mass or volumetric. It is used in a variety of applications, including natural sources, pipelines, chambers, tanks, usable chambers of industry, etc. The particular application, which is available with various technical features and mechanisms, defines the capacity and type of the liquid flow meter. It is used in a variety of applications such as natural sources, pipelines, chambers, tanks, usable chambers of industry, etc.[4].For example in petroleum pipelines, turbine flow meters are used. Leaks along the pipeline are detected. Turbine meters are also used in rail cars and road tankers to load light hydrocarbon products. They also measure chemicals, fuel and water used in processes of oil drilling.

2.3.2 Gas and steam flow meters

Gas is a measure of mass flow due to the unique properties of gas compared to liquids. Although some volumetric technologies can measure gas flow rates, totalized flow problems can occur. Generally, when measuring air or other gasses, the best choice is mass-flow sensing technology — especially in critical applications.

2.3.2(a) Types and applications

1) **Coriolis Flow Meter.** The operating principle for Coriolis flowmeters is based on a vibrating tube where the fluid flow causes frequency, phase shift or amplitude changes that are proportional to the mass flow rate. Coriolis meters are highly accurate and are often used in transfer applications for custody, but they are on the costly side and require labor-intensive inline applications.

2) **Optical flow meter**. Optical. Laser technology and photo detectors are used for flowmeters designed with optical sensing. This technology requires particles in the gas stream to be present. These particles disperse the light beam and it can be used to calculate the gas velocity and volumetric flow rate for these particles to travel from one laser beam to the other laser beam. These meters are precise and accurate

3) **Thermal Dispersion**. Thermal dispersion sensor flow meters provide direct measurement of the mass flow. In the process stream are placed two thermowell-protected platinum temperature detector (RTD) sensors. One RTD is heated while the other senses the temperature of the actual

process. The difference in temperature between these sensors results in a voltage output proportional to the media

2.4 Sonic air flow meters- A new generation flow measurement application

Throughout the century, many methods have been developed and studied to design and fabricate sonic air flow meter . In 2015, in-duct ultrasonic airflow measurement device has been designed, developed and tested. The airflow measurement results for a small range of airflow velocities and temperatures show that the accuracy was better than 3.5% root mean square (RMS) when it was tested within a round or square duct compared to the in-line Venturi tube airflow meter used for reference, which developed by [5] Andrew B. Raine, Nauman Aslam *, Christopher P. Underwood and Sean Danaher from Northumbria University. In 2013, Karten Tawackolian [6] had conduct research on flow instrument performance to date has tend to focus on flow profile effects more than temperature effects, mainly because precision flow calibration facilities for high temperature are expensive to operate and therefore scarce. One common aspect shared by these studies is that their focus is on the effectiveness and the accuracy that can be achieved by their method in designing air flow meter

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the existing obstacle will be simulated and will be compared with actual model to verify the setup of the experiment. In experiment, the optimum obstacle will be tested to determine variable such Sound power level Db, Volumetric Air velocity

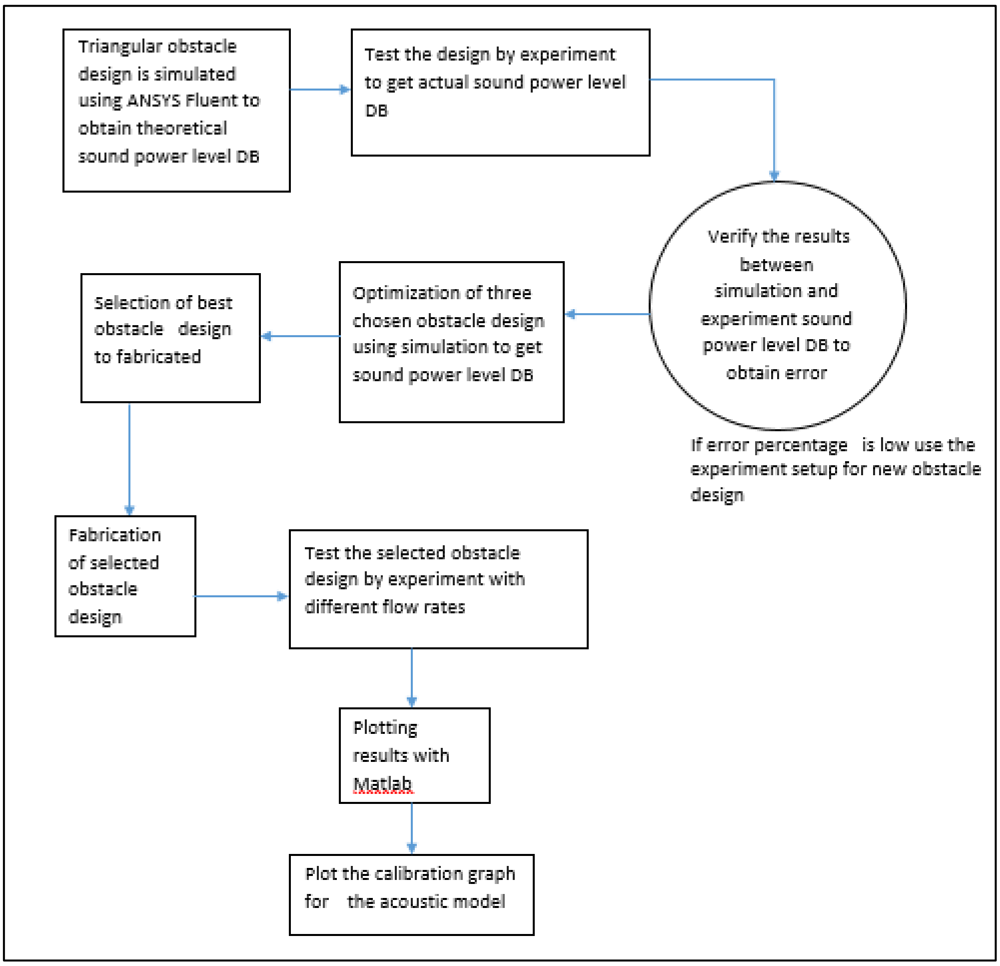

Figure 3.1 Flow chart of methodology