A LOW NOISE DUCT VENTILATION USING C-TRANSITION CURVE DESIGN

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"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of
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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

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ABSTRAK

Saluran pengudaraan di dalam bangunan menyumbangkan bunyi yang bising dan tidak menyenangkan. Ini merupakan hasil daripada pertembungan antara udara yang mengalir keluar daripada bangunan dengan struktur sirip saluran pengudaraan tersebut. Bunyi bising tersebut disebabkan oleh pergolakan dalam aliran udara, terutamanya apabila aliran udara mencapai kelajuan yang tinggi. Oleh itu, untuk memastikan kesenangan hidup dan keselesaan tempat bekerja, bunyi bising yang terhasil perlu dikurangkan dengan mengurangkan pergolakan aliran udara. Satu analisa telah dilakukan pada Lengkung Peralihan C dengan menggunakan *Computational Fluid Dynamics* (CFD) untuk mengenal pasti kesan Lengkung Peralihan C terhadap pengurangan pergolakan aliran udara. Lengkung Peralihan C ini dihasilkan daripada pengiraan matematik yang menggunakan persamaan parametrik. Satu model Lengkung Peralihan C yang ringkas pada saluran keluar sistem pengaliran udara telah direka bentuk untuk tujuan tersebut. Analisa juga dilakukan terhadap satu saluran pengaliran udara yang berbentuk separuh bulatan untuk tujuan perbandingan. Akhirnya, Lengkung Peralihan C yang ringkas ini difabrikasi dan diuji dalam terowong angin untuk mengesahkan hasil daripada analisa CFD. Kajian yang dijalankan menunjukkan struktur yang menggunakan Lengkung Peralihan C boleh mengurangkan tahap kebisingan pada frekuensi yang tinggi.

ABSTRACT

In the buildings, ventilation contributes to unwanted noise as the result of the interaction between the outlet air flow and the ventilation fins structure. The noise is caused by turbulence flow especially at high air flow velocity. In order to ensure a comfortable living and working environment, it is important to reduce the radiated noise level by reducing the turbulence flow. An analysis on C-Transition Curve is investigated here by means of Computational Fluid Dynamics (CFD) to identify its effect on reducing the turbulence. The C-Transition Curve is generated from mathematical calculation of parametric equation. A simple C-Transition Curve of outlet duct ventilation model is designed for this purpose. Analysis is also conducted on a semicircle shape of duct ventilation without mathematical calculation as a comparison. Finally, simple C-Transition Curve duct ventilation is fabricated to validate the results from the analysis through experiment in a wind tunnel. It is found that the structure with C-Transition Curve can reduce the output noise level at high frequency.

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LIST OF SYMBOLS

SYMBOL	DESCRIPTION
R_E	The minimum curvature radius of the curve shape of the transition curves.
Q	The planar parametric curve.
P	The control points.
t	The interval of real line.
h, g, k, r_0	The displacement.
C	The center of the circle.
T_0, G, T_1, N_0	The unit vectors.
P	Static pressure.
ρ_0	Density for working fluid.
Q	Flow rate.
A	Cross sectional area.
Re	Reynold's Number.
v	Mean velocity of fluid.
D	Hydraulic diameter of the pipe/characteristic length
μ	Dynamic viscousity of the fluid.
υ	Kinematic viscousity of the fluid.
F	Function
p_0	Total pressure
M	Mach Number

SYMBOL	DESCRIPTION
T_0	Total Temperature
T	Static Temperature
Pa	Pascal
dB	Decibel
K	Kelvin
m	Meter
mm	Millimeter
α	Angle of attack
º	Degree
Zn	Zink
Hz	Hertz

LIST OF ABBREVIATION

ABBREVIATION	DESCRIPTION
ANC	Active Noise Cancellation
CFD	Computational Fluid Dynamic
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
RANS	Reynolds-averaged Navier Stokes
2-D	Two Dimensional
3-D	Three Dimensional
FEA	Finite Element Analysis
FYP	Final Year Project
FLUENT	Fluid Flow
SPL	Sound Pressure Level

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CHAPTER 1

INTRODUCTION

1.0 Introduction

Noise is mainly caused by the vibrating of sound wave or acoustic wave. According to research done by Professor Samir, Guvtav and Wolfgang, industrial machineries and the processes involve in the industries have contributed to the production of noise which includes from the sources such as rotors, stators, gears, fans, vibrating panels, turbulent fluid flow, impact processes, electrical machines, internal combustion engines and many more.

Research has been done by Fukano, Kodoma and Senoo (1977a) on low pressure axial flow fans to find the solution to the noise in ventilations system. In the ventilation system, the component such as exhaust fans and cooling tower fans are the most common sources of noise or undesired sound. From their (1977b) observation, the noise generated by the axial flow fan is divided into turbulence noise and discrete frequency noise. Discrete frequency noise is created by the high pressurize compressor tank. However, discrete frequency noise can be reduced by implement suitable arrangement of impeller and struts (Senoo and Kodama, 1977c). This will eventually reduced or decreased the noise level in the duct to low level. As a result, if the low pressure axial fan is observed from a far distance, the noise generated is mostly due to turbulence noise.

Air turbulence will created noise especially at high air flow velocities. Turbulence can be generated in many ways. One of the methods to generated turbulence flow is by moving or rotating a solid object, for example the rotation of the blade tip of a fan in the ventilation system. Besides that, the turbulent flow also can be initiated by changing the high pressurize discharge fluid to low pressure, for example by introducing an obstacle object into a high speed fluid flow (Gerges *et al.*). Any obstruction or solid body in a flow of air stream will result in turbulent stream which contributed to aerodynamic noise generation or acts as a sound generator (Bies *et al.* 1997).

Moreover, turbulence flow also can be influence by the surface of the pipe where the fluid is flowing through. If the surface of the pipe is rough or uneven, friction between the wall of the pipe and the fluid will occurred. This will happen as a result from the viscousity of the fluid.

The design of air duct geometries is crucial in order to decrease the noise level in ventilation systems. From the study by Garrison and Byers (1980) on the static pressure, velocity, and noise characteristics of rectangular nozzles, they found out that flanges shape have significant effects on the nozzle performance. Next, in another study with different geometry of nozzle, Garrison and Byers (1980) also found out that variations in nozzle shape and size had significant effects upon noise levels propagated into the environment.

According to Veld and Passlack-Zwaans (1998a), the selection of ventilation systems is mainly determined by the perceived indoor air quality, thermal comfort and noise. They (1998b) divided the noise in ventilation systems into three main categories, which are outdoor noise, noise generated by components or parts of ventilation system and the impact of ventilation systems on sound reduction of partitions such as between rooms. Outdoor noise can be caused by ventilation openings, cracks, mechanical supply and exhaust openings.

Besides, Veld and Passlack-Zwaans (1998c) also categorized the noise in ventilation systems into direct noise and indirect noise. Direct noise is noise generated by the ventilation system such as noise generated by ventilation fans, vibration of air ducts which is structure born noise, control valves and grilles or fins structure which is aerodynamic noise. Next, indirect noise is noise from the outside of system such as traffic noise, industrial plants and aircraft.

As for Waddington and Oldham (2000), they mentioned that buildings located in noisy areas such as big cities require better sound insulation. The solution is implemented mechanical ventilation system in order to make sure the building virtually airtight. However, mechanical ventilation system involved with ducts discontinuities. The higher degree or conditions of discontinuities in ducts will result in greater loss of static pressure and sound power generated.

In addition, the example of noise created in the living neighbourhood of human is the ventilation system on top of the building or houses especially for large ventilation system which created noisy and uncomfortable sound. So, because of their wide application in the human neighbourhood, there is a need for decreasing the noise level (Somek *et al.* 2001). Besides, many researches and experiments have been done to achieve the low noise level which is very essential and important feature nowadays when installing ventilation systems.

A research has been done by Öhrström and Skånberg (2004) to compare the sleep disturbance of human from road traffic and ventilation noise. The reference for the experiments was quiet night. From the research, they found out that the sleep quality was decreased by 22% when human are exposed to road traffic noise while decreased by 12% when human are exposed to ventilation noise. The combined noise from ventilation and road traffic caused more awakenings which result in decrease of 25%. This shows that the disturbance of sleep not only comes from outdoor noise such as road traffic, it may also come from the ventilation system.

Next, according to Mak (2002), flow-generated noise generated in a ventilation system is the result of interaction between air flow and the duct discontinuities. Thus, it is essential to predict the flow-generated noise caused by air duct elements in ventilation systems at the beginning of the design stage. Mak (2005) also mentioned that the current design of air ducts ventilation has underestimated the levels of aerodynamic sound production in practical systems. Thus, he suggested that engineers should accurately predict aerodynamic sound produced by components in air ducts such as dampers and bends.

The cause of flow-generated noise problem by in-duct elements is complicated acoustic and turbulent interactions of multiple in-duct flow noise sources. Noise resulting from airflow through the ductwork has caused many problems to engineers since it is almost impossible to apply remedial treatment after installation of ventilation systems. Thus, in order to reduce the cost of research which used expensive special combined acoustic and aerodynamic experimental facility, conducting a large-scale data collection is needed in development of accurate prediction methods for flow-generated noise created by in-duct elements (Han and Mak 2008).

The combustion of fossil fuels technology is the main source of energy in many end-user industries. The combustion technology is accompanied by unwanted effects such as pollution and noise (Ihme *et al.* 2009a). In aircraft, the source of cabin noise is structure borne noise caused by imbalance forces within the engines which result in vibrations. Then, the radiate noise created by the vibrations is transfer into the interior cabin. Thus, acoustic treatment or reduction of the noise at the source is necessary for future noise reduction improvements (Griffin 2006a).

The trailing edges of airfoils which consist of elastic materials and other flow surfaces which exposed to moving fluids are known to be one of the sources of high frequency sound. The turbulent flow will excite structural modes of vibration which will create structure-borne noise especially in aircraft and submarine (Howe 1993). Thus, noise produced by elastic materials moving through low Mach number turbulent flows has become one of the interesting subjects in engineering applications. The noise that has been generated is treated as sound radiation of elastic structural elements in the acoustic medium (Borisyuk and Grinchenko 1997). Besides, noise generated by turbulent flow passing or crossing a sharp edge is important in the design of high-end applications such as aircraft and wind turbines. Therefore, it is important to develop some methods in order to capture the effects of the design changes on the flow and the resulting radiated noise. (Albarracin Gonzalez *et al.* 2012).

The turbulent in the internal flows is known to be the one of the causes of intense noise besides the surface pressure fluctuations in ducts. Thus, the main objective of modern aircraft design is the reduction of noise. The increase of noise and environmental regulations has encouraged the design and development of new designs of devices and components which are more accurate models of noise generation (Marretta and Tassone 2003).

According to Lozovskiy, (2011), the acoustic noise generated by a turbulent flow in transport technologies such as airplanes and trains is increasing every year. He mentioned that the next generations of fighter jets that are being designed are expected to produce 147 dB of noise. This will be dangerous as 150dB of sound level will result in damage of internal organs.

Besides that, the interaction between a rotating system such as moving rotor and a turbulent boundary layer has been the spotlight of many studies since it is the source of noise and vibration in aircraft engines. The rotor which has direct contact with the non-uniform turbulent flow will generates unsteady forces on the surfaces of blade. The unsteady or imbalance forces will propagated into mechanical vibration. Thus, reduction of the noise and vibration is preferred to ensure the engines drive system can operated effectively as well as to increase the life of the engine (Morton 2012).

In a jet-powered aircraft industry, the interior noise level in aircraft is mainly caused by noise generated by turbulent boundary layers, ventilation systems, fans and