AIR FLOW AND TEMPERATURE DISTRIBUTION ANALYSIS IN AN AIR CONDITIONED CAR

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SUPERVISOR DECLARATION

"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 Bachelor of Mechanical Engineering (Thermal-Fluids)"

Signature : ……………………………
Supervisor : ……………………………
Date : ……………………………

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This Technical Report is submitted to
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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."

Signature : …………………….

Author : KHOR MEI YIN

Date : …………………….

For my beloved family and friends

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ABSTRACT

Temperature and velocity are the environmental factors that affect the human comfort level. The purpose of this study is to determine the temperature and velocity distribution inside the passenger compartment of an air-conditioned vehicle. Computational Fluid Dynamics (CFD) simulation is carried out by using ANSYS FLUENT software. The measurements of air velocity and temperature are taken at different location of the passenger seat. The difference in distribution of air flow and temperature with and without human load inside the passenger compartment are being investigated. The results obtained from physical measurement and CFD simulation is analyzed and compared. The actual average temperature increases with number of occupants while the simulation temperature remains constant, where the largest percentage of error is 19.1 %. The simulation velocity shows highest reading at head level and decreases as flows to chest level and knee level of passengers seats. The trend of actual velocity is similar to simulation velocity, except at driver seat where the highest value is at chest level. Based on the result, recommendations and suggestions are made to improve the thermal comfort level inside the passenger compartment.

ABSTRAK

Kadar keselesaan manusia boleh berubah disebabkan oleh faktor-faktor alam sekitar seperti suhu dan aliran udara. Kajian ini dijalankan untuk menentukan taburan suhu dan halaju dalam kenderaan berhawa dingin melalui kaedah eksperimen dan simulasi. Simulasi Pengkomputeran Dinamik Bendalir (CFD) akan dijalankan dengan menggunakan perisian ANSYS FLUENT. Pengukuran halaju dan suhu udara akan diambil pada lokasi tertentu tempat duduk kereta. Perbezaan dalam taburan suhu dan aliran udara di dalam kereta terhadap perubahan bilangan penumpang turut dikaji. Keputusan yang diperolehi daripada pengukuran fizikal dan simulasi CFD dianalisis dan dibandingkan. Purata suhu eksperimen meningkat dengan penambahan penumpang di dalam kenderaan manakala suhu simulasi adalah malar, di mana peratusan kesilapan terbesar adalah 19.1 %. Halaju simulasi menunjukkan bacaan tertinggi di paras kepala dan semakin turun apabila mengalir ke paras dada dan paras lutut penumpang. Trend halaju eksperimen adalah sama dengan halaju simulasi, kecuali di tempat duduk pemandu di mana nilai tertinggi adalah pada tahap dada. Berdasarkan keputusan yang diperolehi, penambahbaikan dicadangkan untuk meningkatkan tahap keselesaan penumpang dalam kenderaan berhawa dingin.

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LIST OF SYMBOLS

°	=	degree
℃	=	degree Celcius
%	=	percentage
atm	=	atmosphere
clo	=	clothing insulation
σ_ε	=	turbulent Prandtl numbers for ε
σ_k		turbulent Prandtl numbers for k
ε	=	turbulent dissipation
G_b	=	turbulence kinetic energy due to buoyancy
G_k	=	turbulence kinetic energy due to the mean velocity gradients
k	=	turbulent kinetic energy
K	=	Kelvin
kg	=	kilogram
m	=	meter
Pa	=	Pascal
s	=	second
T	=	temperature, °C
V	=	air velocity, m/s
W	=	watt
Y_M	=	fluctuating dilatation in compressible turbulence to the overall dissipation rate

LIST OF APPENDICES

LIST OF ABBREVIATIONS

3D	=	three dimensional
ASHRAE	=	American Society of Heating, Refrigeration and Air- Conditioning Engineers
ASM	=	algebraic stress model
CAD	=	Computer Aided Design
CFD	=	Computational Fluid Dynamics
CIL	=	clear insulated laminate tint
DTS	=	Dynamic Thermal Sensation
eqn	=	equation
GIL	=	green insulated laminate tint
HVAC	=	Heating, Ventilation and Air Conditioning
IAQ	=	Indoor Air Quality
PMV	=	Predicted Mean Vote
PPD	=	Predicted Percentage of Dissatisfied
RANS	=	Reynolds Averaged Navier-Stokes
RNG	=	Re-Normalisation Group
TS	=	Thermal Sensation

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Thermal comfort of vehicle passengers has been emphasized due to the increasing in time of people spends inside the vehicles. The passenger compartment is the place which shows significant effect on thermal comfort. It is exposed to internal disturbances such as the speed of vehicle, the number of passengers inside the car cabin and the temperature of engine, and also external disturbances such as air temperature, velocity of wind and solar radiation. (Mezrhab & Bouzidi, 2006) A great temperature control inside the vehicles will provide driver a good physical state of driving and a great visibility by avoiding fogging inside the vehicles. (Alahmer et al., 2010) In order to improve the thermal comfort inside a vehicle, an acceptable range of distribution of air velocity and temperature are to be considered. This project will focus on analyzing the distribution of temperature and velocity inside the vehicle compartment.

1.2 PROBLEM STATEMENT

Air flow and temperature distribution in an air conditioned car will change according to the various human loads. Based on the proposed simulation, this project is aimed to investigate the velocity and temperature distribution inside an air conditioned car which relate to human comfort level. Measuring points of air velocity and temperature can be taken at different location of the passenger seat by physical measurements and Computational Fluid Dynamics (CFD) simulation. CFD simulation can predict the airflow numerically without creating a prototype, thus save cost, time and manpower. Hence, an optimum environment should be able to simulate by using CFD software in analyzing the temperature and air flow inside passenger compartment, in order to improve the thermal comfort level. Thermal comfort of passengers inside vehicle can be evaluated by Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD).

1.3 OBJECTIVES

i. To investigate the temperature and air flow distribution with and without human loads inside the passenger compartment.
ii. To perform thermal comfort analysis inside vehicle.

1.4 SCOPES

i. Evaluate the air flow and temperature distribution by experimental method (measurement) and CFD simulation.
ii. Only indoor environmental condition of the car is taken into consideration.
iii. Boundary parameters are determined for valid CFD modelling to be applied in the car.

1.5 EXPECTED OUTCOMES

i. Physical measurement of distribution of temperature and air velocity in an air conditioned vehicle.
ii. CFD simulation of distribution of temperature and air velocity in an air conditioned vehicle.
iii. Compare results between physical measurement and numerical simulation.
iv. Thermal comfort analysis inside the air conditioned vehicle.
v. Recommendations to improve the thermal comfort level inside the passenger compartments.

CHAPTER 2

THEORY

2.1 OVERVIEW

All the principles and definitions related to the case study should be included in this chapter. The theories such as thermal comfort, Heating, Ventilation and Air Conditioning (HVAC) system in vehicles, CFD and turbulence modelling are studied and compiled in this chapter for better understanding.

2.2 ENVIRONMENTAL PARAMETERS OF VEHICLE

A vehicle is exposed to both internal disturbances such as car speed, engine temperature and passengers inside car cabin, and also external disturbances such as temperature, sun and wind. This project will focus on environmental parameters that are temperature and air velocity distribution inside the air conditioning car. Figure 2.1 shows the relationship between air velocity and temperature. The air velocity will increase with temperature.

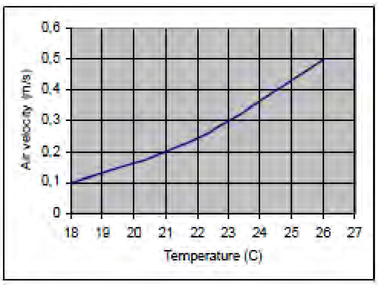

Figure 2.1: Air Flow Sensation Curve (Musat and Helerea, 2009)

When the air conditioning system is switched on, the temperature will drop slightly as the cooled air is suddenly directed into the passenger compartment and will rise steadily as time passed. Due to the small space inside passenger compartment, the temperature will be affected by the heat exchange in the space (Zhou, 2013). When there are occupants inside the vehicle cabin, the temperature will increase due to the sensible heat transferred from human body. (Mohamed Kamar et. al., 2013)

The air flow inside the vehicle is directed to a small section due to the limited space of car. The air flows from air conditioning vents will increase the air velocity. It will be blocked by the front seats and rear seats and formed recirculating flow patterns. This flow pattern is well mixed with the cold air from air conditioning inlets and the surrounding heated air inside vehicle cabin, and then directed back to the air conditioning outlets (Jalal and Haider, 2007). Hence, the air velocity will decrease as human loads will occupy certain spaces inside the passenger compartment.

2.3 THERMAL COMFORT

American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 55 defines thermal comfort as “that condition of mind which expresses satisfaction with the thermal environment”. However, different people have different sensations towards the thermal environment. Hence, six factors are used as an indicator of thermal comfort:

i. Air temperature
ii. Air velocity
iii. Radiant temperature
iv. Humidity level
v. Clothing insulation
vi. Activity level