Major project report

On

VENTILATION STUDIES ON OPEN WINDOW BUS

Submitted by

PAWAN KUMAR PANT
2007MET2567

Under the Guidance of

Dr. SUNIL R. KALE
Dr. S. V. VEERAVALLI

DEPARTMENT OF MECHANICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
HAUZ KHAS, NEW DELHI, 110016
CERTIFICATE

This is to certify that dissertation entitled, "Ventilation studies on open window bus", submitted by Pawan Kumar Pant to the Mechanical Engineering Department, Indian Institute of Technology, Delhi, in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of bonafide work carried out by him under our supervision and guidance. The work has not been submitted in parts or full to any other University or Institute for the award of any degree or diploma or for any other purpose.

Prof. S.R. Kale
Professor
Mechanical Engineering Department
Indian Institute of Technology, Delhi
New Delhi-110016

Prof. S.V. Veeravalli
Professor
Applied Mechanics Department
Indian Institute of Technology, Delhi
New Delhi-110016
ACKNOWLEDGEMENT

The tenure of human in this world is supported by many others. Acknowledgement for a few might be just a trifle thing written on a piece of paper. But in the true essence it gives us an opportunity to remember and express our feelings to those, whom we love, revere and share our secrets. Here I get a great chance to express my token of thanks to people who in a way helped and supported me to complete this record.

First of all, I express profound sense of obligations to almighty God for showing immense blessings upon me due to which I could accomplish this academic task. Words fail to express noble sacrifice of my parents who brought me to this position.

This work provided me an opportunity to work with two guides (Prof Sunil R Kale and Prof Srinivas V Veeravalli) whose guidance has taken the work to this level. I am thankful for Prof Veeravalli's immaculate guidance, prudent suggestions, sincere exhortation, abundant interest and above all cooperative attitude during the course of my M. Tech. research work. Prof Kale is very dynamic person, his ideas are always different. I am thankful for his keen interest, sustained support (both academically and financially) and encouragement in absence of which the work would not have seen the light of the day. Both of my guides always entertained me when ever I was there for discussion even when they were occupied by important work. I was very grateful to both the guides in putting confidence in me and spending 6 lakhs for the experiments at National Wind Tunnel Facility and giving me such an opportunity to get acquainted with such latest techniques of NWTF.

My experimental work at IIT Kanpur would have not been possible without the help and cooperation of Prof. Kamal Poddar, Head of National Wind Tunnel Facility, IIT Kanpur. I am very thankful to him for allowing me to use the facility. I am highly thankful to National Wind Tunnel Facility team at IIT Kanpur

Dr. Brajesh Chandra (Project Research Engineer)
Dr. Chaturi Singh (Senior Research Engineer)
Mr. Sharad Sharma (Technical Advisor)
Mr. Jay Narayan (Technician)
Mr. Rajesh Shukla (Technician)
Mr. Munesh Kumar (Mechanic)
Mr. Rajesh Pal (Mechanic)
Mr. Shiv Balak (Mechanic)
who worked day and night to get the experiments done and made the experiments a success. Without their effort the work could have not been done.

I would like to express my gratitude to all the teachers of thermal engineering department for helping us out in all kind of difficult situations.

The author is also grateful for Mr. Sunil Bhogal and Mr. Vineet Kumar( Ph. D student, Mechanical department IIT Delhi) for their support.

The author extends his undying respects and unperceived depth of reverence to his parents who have constantly showered blessings and stood by him steadfastly thick and thin since last twenty four years to this date. Words will definitely fall short to express the gravity of feelings for my brother Anil for his cooperation and support.

It is with grateful appreciation that the author acknowledges the worthy contribution of his colleague Amit Arora and friends like Arun Chhabra, Nitin Piplani, Dikendra Verma, Rakesh Burfal, Amit Dev, Chandraveer Singh Kanawat, Akshay Pandey, Vivek Pant, Mishu and Nitesh Singh.

This list is obviously incomplete, but let me submit that the omissions are inadvertent and once again I record my deep felt gratitude to all those who have cooperated, either directly or indirectly, with me in this endeavor. Any omission in this brief acknowledgement does not imply ingratitude.

\[Signature\]

Pawan Kumar Pant
ABSTRACT

In India non air conditioning buses are the major modes of transport in urban areas. In hot and humid climates the journey becomes very uncomfortable. The existing designs have little scientific basis. All the designs are based on reducing drag. No one has focused on thermal comfort. In the present work interaction of outside and inside air of the bus has been studied with a twin aim of reducing drag and increasing thermal comfort.

In this work numerical simulation, k-ε and LES, was done for the best configuration proposed by Gupta. First, standard k-ε simulation was done. This simulation was used as an initial flow field and Les simulation was done. The heat and humidity analysis was also included. The results from k-ε were in accordance with the flow visualizations experiments but the drag forces calculated were not in accordance with the experimental results. Les simulation showed results were in good accordance with the flow visualization and drag forces also were very near. Therefore it was concluded that the configuration having one front slot, two rear slots, one deflector and first three windows closed was the best configuration both experimentally and numerically.

Further, flow pattern in Low Floor Bus, manufactured by Tata Motors, has been studied both numerically and experimentally. k-ε simulation was done for getting an idea of the flow pattern inside the Low Floor Bus having one front slot, two rear slots, two deflectors and first three windows closed. Based on the findings a 0.11 scaled model was made for Flow Visualization experiments at IIT Kanpur. Different configurations of Low Floor Bus were used based on different locations of Deflectors. The flow visualization experiments at the National Wind Tunnel Facility (NWTF) at IIT Kanpur concluded improvement in the flow pattern inside the bus and changed the direction and increased the magnitude of the flow of air in the bus from the normal non-ac bus being used nowadays. The Coefficient of drag reduction was found to be reduced by approximately 10% from the normal bus having no deflector and slots. The test repeatability of dynamic analysis was also done for all the configurations.

Keywords: Flow visualization, NWTF, k-ε, LES, Humidity
# TABLE OF CONTENTS

CERTIFICATE .............................................................. ii
ACKNOWLEDGEMENT ...................................................... iii
ABSTRACT ..................................................................... v
TABLE OF CONTENTS ...................................................... vi
LIST OF FIGURES ........................................................... vii
CHAPTER 1 INTRODUCTION ............................................... 1
  1.1 MOTIVATION ............................................................ 1
  1.2 OBJECTIVES ............................................................ 2
  1.3 OVERVIEW OF THE PROJECT ....................................... 2
  1.4 ORGANIZATION OF THE REPORT ................................. 3
CHAPTER 2 LITERATURE SURVEY ...................................... 4
  2.1 AT IIT DELHI .......................................................... 4
  2.2 OUTSIDE INDIA ....................................................... 5
  2.3 LOW FLOOR BUS ...................................................... 6
CHAPTER 3 NUMERICAL SIMULATIONS ............................... 7
  3.1 SIMULATION FOR THE OPTIMUM CONFIGURATION OF GUPTA [1] 7
  3.2 SIMULATION FOR LOW FLOOR BUS .............................. 19
CHAPTER 4 EXPERIMENTAL WORK ON LOW FLOOR BUS ........ 24
  4.1 THE MODEL OF THE BUS ............................................ 24
  4.2 ASSUMPTIONS MADE IN THE MODEL ............................. 24
  4.3 MODELLING OF PASSENGER COMPARTMENT .................. 25
  4.4 FRAME OF THE BUS ................................................. 25
  4.5 FINAL ASSEMBLY OF THE BUS ..................................... 26
  4.6 NATIONAL WIND TUNNEL FACILITY AT IIT KANPUR .......... 26
  4.7 EXPERIMENTAL SETUP ............................................. 28
  4.8 CONFIGURATIONS USED IN EXPERIMENTS ..................... 29
  4.9 DRAG FORCE CALCULATION ...................................... 30
  4.10 FLOW VISUALIZATION ............................................ 36
CHAPTER FIVE CONCLUSION AND FUTURE WORK .................. 42
  5.1 CONCLUSION ......................................................... 42
  5.2 FUTURE WORK ....................................................... 42
REFERENCES ................................................................. 44
APPENDIX 1 EXPERIMENTAL REPEATABILITY GRAPHS ............ 45
APPENDIX 2 UDF FOR HUMIDITY ......................................... 48
APPENDIX 3 SETTINGS USED IN FLUENT ............................. 49
APPENDIX 4 CONFIGURATION USED BY GUPTA [1] IN HIS WORK ... 52
APPENDIX 5 THERMAL BOUNDARY CONDITIONS .................... 53
APPENDIX 6 VARIATION OF TEMPERATURE FOR DIFFERENT PASSENGERS IN CONFIGURATION 3 OF GUPTA [1] ....................... 53
APPENDIX 7 VARIATION OF WATER VAPOR SPECIES MASS CONCENTRATION 55
APPENDIX 8 DETAILS OF CD/DVD ...................................... 56