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CFD SIMULATION OF COLD AIR SYSTEM IN ENCLOSED SPACES

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Ain Shams University

A Thesis

Submitted in Partial Fulfillment of the Degree of Master

of Science in Mechanical Power Engineering

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STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Mechanical Power Engineering.

The work included in this thesis has been carried out by the author at the Department of Mechanical Power Engineering, Ain Shams University, during the period from 2010 to 2014.

No part of this thesis has been submitted for a degree or a qualification at any other university or institution.

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ACKNOWLEDGMENTS

First and foremost, praise and thanks to Almighty Allah, the Most Gracious, the Most Merciful, and peace be upon His Prophet.

I would like to express my deepest gratitude to Prof. Dr. Raouf Nassif AbedlMessih and Prof. Dr. Ahmed Reda Elbaz, for their invaluable guidance, support, and encouragement.

I also greatly appreciate the help and guidance provided by Dr. Ehab Mouris Mina throughout all stages of the research.

Finally, I would like to express my appreciation to my father, my beloved mother, my lovely sister, and my brother for their tremendous support in all aspects of my life.

Ahmed Ali Youssef

ABSTRACT

Cold air systems have proven to offer economical and environmental benefits, and are found suitable for many applications. However, these systems did not spread because of the fear from cold draft formation leading to unaccepted indoor air conditions. The current study aims to evaluate the performance of cold air systems when used in enclosed spaces using Computational Fluid Dynamics (CFD).

A brief introduction is presented explaining theory, advantages, and disadvantages of cold air systems. Also, different factors and design considerations affecting human comfort are explained. A brief literature review of previous work in the field of cold air distribution systems and indoor flow simulations is presented as well.

The basic theory and governing equations of CFD are explained, and different turbulence modeling techniques are presented. The CFD code used in the current study is validated by comparing its results with experimental results found in the literature. Three validation cases are conducted to assess the accuracy of the CFD model and to evaluate several turbulence models when used for indoor simulations.

The flow of cold air was studied in a 2D room at different supply temperatures and velocities and at different sensible heat loads. The velocity field and the temperature distribution were analyzed and used to calculate the effective draft temperature. And hence, the comfort level was assessed using the air diffusion performance index, ADPI. The effect of each factor was studied independently and it was found that the supply temperature and velocity have minimum effect on the room conditions. The room thermal environment was uniform and satisfactory even at low supply temperature due to the good mixing of air inside the room. Reduction in supply temperature and reduction in supply velocity each causes limited enhancement on the ADPI. The main source of drafts inside the room was the heat flux from the floor. The velocities induced

by the floor heat flux were much higher than those caused by the air jet. At lower thermal loads, the induced air velocity was weaker, and hence the ADPI values increased.

It was observed that air circulates in the room under the effect of natural convection with no air supplied to the room. As the rate of heat transferred by air increased, the air circulation and velocity increased as well. Air circulation and velocity were also enhanced when the percent of the thermal load concentrated in the floor was increased in the air conditioned room. Also, it was found that separating the air jet from the ceiling does not affect the jet attachment to the ceiling. Air jet when supplied far from the ceiling was still pushed upwards by the air circulating in the room causing it to attach to the ceiling.

Cold air system was also studied in a 3D room similar to a typical office room with a standard vertical supply diffuser. A comparison was made between the performance of a conventional air conditioning system (supply air at 14ºC) and a cold air system (supply air at 10ºC) in the same room space. The performance of the conventional system was convenient since air velocities and temperatures throughout the room were within acceptable limits. The cold air system on the other hand had a poor performance due to high-velocity low-temperature air falling directly to room space which reduced comfort level in the room. It was found that changing the air supply angle from the diffuser from 45° to 30° has noticeably improved the performance of the cold air system and increased the room's comfort level. This improvement was due to the nearly horizontal supply air which caused the air jet to attach to the room's ceiling and hence eliminating the direct effect of cold air on the room.

Finally, a summary of the work carried out in this thesis along with general conclusions obtained from the study and recommendations for future studies in the same field are presented.

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