Introduction
Chapter 1

Introduction

1.1 Introduction

In the modern technological society, people spend more than 90% of their time in air-conditioned dwellings, workplaces and transport vehicles (Chung and Lee, 1996; Kaynakli and Kilic, 2005). These artificially created indoor environments have contributed both their advantages and disadvantages to the human beings. Improper uses of artificial devices have lead to the deterioration of Indoor Air Quality (IAQ) in air-conditioned buildings. The degradation of IAQ in particular, arises due to poor plant maintenance, high concentration of internally generated pollutants and low outdoor air supply rates. Hence, it can be referred that optimization of parameters associated with air-conditioning would enhance human comfort. Also, further researches in this direction have shown that the optimization of air-conditioning parameters would result in significant energy and cost savings (Warren and Harper, 1991). Due to this reason, in the recent years, there has been a flux of published information on thermal comfort and air quality. These findings in contemporary research motivated the researcher to pursue the doctoral work reported in this thesis.

Air-conditioning is defined as simultaneous control of temperature, humidity, cleanliness and air motion. The widely used terms in air-conditioning systems are discussed here. According to American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) standards, the thermal comfort is “the condition of mind which expresses satisfaction with the thermal environment”. As per ASHRAE
standards 62, acceptable IAQ is “air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% more) of people exposed do not express dissatisfaction”. Addition of moisture to the air, without change in its dry bulb temperature is known as humidification. Better comfort conditions and IAQ can be maintained through optimum design, appropriate location of supply diffusers and optimum ventilations supply rates using CO₂ based Demand Control Ventilation (DCV). According to International Energy Agency (IEA), DCV is defined as a ventilation system where the air flow rate is governed by a sensor detecting humidity or airborne pollutants, in order to keep the concentration levels of the detected substances below a preset value (Soleimani-Mohseni, 2003). This doctoral work was begun by setting appropriate objectives in such a way that certain studies conducted would be useful to both research and practicing communities.

1.2 Problem Definition

Various factors such as high demand for comfortable living and equipments requiring air-conditioned environments necessitate a better thermal comfort. The enhancement of thermal comfort has been effective due to the installation of artificial air-conditioning devices. The increased installations of these devices lead to high cost of their operation and maintenance. In this direction, research studies are necessary to enhance thermal comfort through three avenues namely diffuser optimization, CO₂ based DCV and humidification using aerodynamic principles for better IAQ and thermal comfort. These avenues have an immense potential of
enhancing thermal comfort and also saving the energy and hence, cost. Scant research studies have been carried out in these specific avenues.

1.3 Objectives

In order to solve the problem defined in the previous section, the following primary objectives were set in the beginning stage of this doctoral work:

1. To study and compare the room air distribution for thermal comfort, before and after optimizing the diffuser location.
2. To study the minimization of ventilation rates to room using CO2 based DCV.
3. To study and develop a non-conventional humidification system using aerodynamic principles.

1.4 Scope of the Doctoral Work

As hinted in the earlier section, this doctoral work was carried out in three modules. The background of the theory of these modules is briefly described here.

The purpose of most air conditioning systems is to provide thermal comfort and an acceptable IAQ for human occupants with minimum energy consumption. Successful predictions of room air flow yield information such as distributions of velocity, temperature, Predicted Mean Vote (PMV) and contaminant distributions which are useful in Heating Ventilating and Air-conditioning (HVAC) system design and analysis of better thermal comfort. These parameters could be optimized by appropriately selecting the number of diffusers and identifying these locations in air-conditioned rooms. This forms the basis of diffuser optimization technique.

The CO2 based DCV technique describes the proper procedure for using CO2 concentration as a reference index and modulating the ventilation based on actual
occupancy. This way, the energy can be conserved and at the same time, the acceptable IAQ can also be maintained in accordance with the American National Standard Institute (ANSI) /ASHRAE standard.

RH plays a major role in many areas, especially in climatically geographical dry locations and also in industrial sectors like textile, where the quality of the yarn depends largely on RH, which is the ratio of amount of water vapour actually present in the air to the amount of air needed to saturate the air at the same conditions. Instead of setting up a conventional air washer for humidification, an attempt was made in this doctoral work to set up an alternative type of humidifier, which works based on aerodynamic principles. The doctoral work pursued in this direction is presented in the following three subsections.

1.4.1 Thermal Comfort through Diffuser Optimization

In this module of the work, certain studies were conducted in an air-conditioned hall of a three star hotel. During the study, the existing layout of the diffusers installed in the conference hall for supplying conditioned air was studied. The conference hall was simulated using Computational Fluid Dynamics (CFD) software. Boundary conditions like wall thickness, coefficient of thermal conductivity of the wall, air velocity etc., were fed into the software as input. The software gives the output information such as velocity, temperature, and PMV and Predicted Percentage of Dissatisfied (PPD) distributions.

The simulated results were in good agreement with the measured results. Hence, different modified diffuser layouts were analyzed using CFD and from the results obtained, the optimized diffuser layout was determined. This final modified
diffuser layout provides better thermal comfort at a lesser time, which results in reduction of the air-conditioning unit running time.

1.4.2 CO₂ based Demand Control Ventilation

DCV is a method used to minimize the energy wastage associated with over ventilation. In this method, the amount of ventilation is adjusted according to the occupancy level. Typically, CO₂ is used as a passive tracer gas to determine human occupancy in the space. The best potential applications for DCV are spaces with highly variable occupancy, such as movie theatres, restaurants, stores, auditorium etc.

In this doctoral work, a movie theatre was taken up for study. Based on the data collected for a period of one year with varying occupancy levels, energy conservation was calculated theoretically by applying CO₂ based DCV technique. To study the energy conservation through this method, simulation using Programmable Logic Controller (PLC) was carried out in the researcher's place. The results of the study indicated that the CO₂ sensor can be installed in the air stream of the return duct to monitor the concentration of the CO₂ in the return air. Also, the position of the damper opening can be regulated according to the number of occupants inside the hall. The PLC simulated the position of the damper for a varying airflow rate (V₁₀A), which would depend upon occupants’ activity level, CO₂ generation rate (e₀) and indoor CO₂ concentration (Cᵣ).

1.4.3 Humidification using Aerodynamic Principles

The non-conventional humidifier setup requires selection of an airfoil, design venturi section and suction tube. So a suitable airfoil was selected using Foilsim
software. The coordinates and the profile of the airfoil were obtained using Winfoil software. The generated coordinates were used to model the airfoil in the setup using Gambit software. By assuming a pressure at the throat and fixing available blower speed as the input air velocity, the velocity of air and the diameter of the throat of the venturi section were determined. The suction tube, which connects the reservoir to the venturi section's throat, was designed. Next, the discharge of the water was also determined. After knowing the amount of water needed to saturate the air at room conditions, the addition of RH was found out. The designed setup was modeled in Gambit and analyzed in Fluent.

1.5 Chapter Organisation

This thesis is organized under six chapters. After this introduction chapter, the literature survey conducted during this doctoral work is presented in chapter two. In this chapter the research work that are being carried out on thermal comfort are described. Further the research gaps noticed in this direction are pointed out. In chapter three, the work carried out on conservation of energy through the diffuser optimization is presented. In chapter four, the module of the doctoral work carried out on CO₂ base DCV for energy conservation is described. In chapter six, the module of the doctoral work on non-conventional humidification system using aerodynamic principles is explained. This thesis is concluded in chapter six, in which the contributions of this doctoral work are enumerated and their role in thermal comfort and energy conservation is appraised. The scope for the future work is also indicated in this chapter.
1.6 Conclusion

With the aim of energy conservation in an air conditioning system, during this doctoral work,

- An optimal diffuser layout was simulated using CFD software for the air-conditioned conference hall located in Coimbatore city of India.
- The significance of CO₂ based DCV technique in achieving energy savings was studied by considering an air-conditioned movie theatre as the reference model.
- A non-conventional humidifier, which could work based on aerodynamic principles, is proposed, as it is energy efficient.

The detailed of these modules are discussed in the forthcoming chapters.