International Journal on Emerging Technologies **5**(2): 130-135(2014)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

Review of factors affecting Indoor Thermal Environment for achieving Thermal Comfort

Shamir Daniel* and Dr. V.N. Bartaria**
**P.G. Scholar, Department of Mechanical Engineering, LNCT Bhopal, (MP), INDIA*
***Professor, Department of Mechanical Engineering, LNCT Bhopal, (MP), INDIA*

(Corresponding author: Shamir Daniel)
(Received 04 July, 2014 Accepted 04 October, 2014)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Indoor thermal environment in air conditioned spaces is most important factor while considering comfort level. We know that air distribution methods are used for comfort purpose which is important for finding the perfect indoor environment condition. If indoor conditions are satisfied, the comfort level has been determined. Some important parameter such as humidity level, air temperature and velocity, noise, indoor air quality can be taking into account for designing a thermal comfort environment. Various methods can be used numerically and experimentally to determine value of these parameter which is important for indoor thermal environment. Here theoretical review has been made for it. Design of a thermally comfortable indoor environment requires detailed information about distribution of air velocity, air temperature, relative humidity, and mean radiant temperature and about heating/cooling load in a space. In this paper we study a review on the indoor environment in a conditioned spaces and parameters which are important for improving the indoor thermal environment. The purpose of this review paper is to understand various theoretical factors which are essential for comfortable indoor environment.

Keywords: Indoor environment, Indoor air quality, Thermal comfort.

I. INTRODUCTION

Time which a person spends indoor, is about more than 80 percent of his whole life, and indoor environment conditions have direct influence on every person's health, spirit and efficiency. Person has to do their physical work in the office, home and other places which require effort from the person, while doing so person liberates lot of heat and this heat needs to be dissipated from the body. Dissipation of heat from the body depends upon environmental conditions and the clothing of a person [2]. With the development of economy and the progress of society, better indoor environment conditions are demanded. Air temperature, relative humidity, air velocity, and environmental radiant temperature are the four most important parameters for indoor thermal comfort. In an indoor conditioned space, with convective, radiation and hybrid heating and cooling systems, the distribution of these parameters is non-uniform and the thermal comfort level varies with location. Many current comfort designs use a single value of air temperature and velocity to represent thermal comfort in a room. A single value is not sufficient because the distributions of air temperature and velocity may not be uniform.

To design an acceptable indoor thermal environment, designers need a tool that can predict the distributions of thermal comfort parameters, such as air velocity and temperature. By using these parameters we can design a conditioned space as per comfort level requirement. These parameters may be analytical or experimental based.

II. THERMAL CONTROL CONCEPTS

Thermal and atmospheric conditions in an enclosed space are usually controlled in order to ensure (1) health and comfort of the occupants and/or (2) proper functioning of sensitive electronic equipment, such as computers, or certain manufacturing processes that have a limited range of temperature and humidity tolerance. The former is referred to as comfort conditioning, and the later is called process air conditioning. The conditions required for optimum operation of machinery may or may not coincide with those conducive to human comfort. Process air conditioning requirements are highly specific to the equipment or operation involved. Specifications are generally available from the producer or manufacturer, and these provide a description of acceptable conditions for a number of generic industrial processes.

Once the necessary conditions for process or machinery operation are established, attention must be paid to providing acceptable comfort, or at least relief from discomfort or physiological stress, for any people who is also occupying the space. Although human beings can be considered very versatile "machines" having the capacity to adapt to wide variations in their working environment while continuing to function, their productivity does vary according to the conditions of their immediate environment. Benefits associated with improvements in thermal environment and lighting quality include: Increased attentiveness and fewer errors, Increased productivity and improved quality of products and services, Lower rates of absenteeism and employee turnover, Fewer accidents, Reduced health hazards such as respiratory illnesses. Indeed, in many cases, air conditioning costs can be justified on the basis of increased profits. The widespread availability of air conditioning has also enabled many U.S. companies to expand into the Sun Belt, which was previously impractical [3]. Air conditioning and electric lights have eliminated the need for large windows, which provided light and ventilation in older commercial and institutional buildings. Although windows are still important for aesthetics, day lighting, and natural ventilation, windowless interior spaces may now be used to a much greater extent. Air conditioning allows for more compact designs with lower ceilings, fewer windows, less exterior wall areas, and less land space for a given enclosed area. Conditioned air, which is cleaner and humidity controlled, contributes to reduced maintenance of the space. As a testament to the importance placed on air conditioning, over one-third of the entire U.S. population presently spends a substantial amount of time in air-conditioned environments. And all of this represents growth since the commercialization of refrigeration cooling in the early 1950s. On the other hand, this improvement in comfort has come about at the expense of greater equipment installation, maintenance, and energy costs. A substantial portion of the energy consumed in buildings [1] is related to the maintenance of comfortable environmental conditions. In fact, approximately 20 percent of the total U.S. energy consumption is directed toward this task. But this doesn't have to continue to be the case. With an understanding of the factors that determine comfort in relation to climate conditions, designers may select design strategies that provide human comfort more economically. Thus, prior to investigating the energy-consuming mechanical systems in buildings, we will begin by discussing the concepts of human comfort. Besides being aesthetically pleasing, the human environment must provide light, air, and thermal comfort. In addition, proper acoustics and hygiene are important. Comfort is best defined as the absence of discomfort. People feel uncomfortable when they are too hot or too cold, or when the air is odorous and stale. Positive comfort conditions are those that do not distract by causing unpleasant sensations of temperature, drafts, humidity, or other aspects of the environment. Ideally, in a properly conditioned space, people should not be aware of equipment noise, heat, or air motion. The feeling of comfort or, more accurately, discomfort is based on a network of sense organs: the eyes, ears, nose, tactile sensors, heat sensors, and brain. Thermal comfort is that state of mind that expresses satisfaction with the thermal environment. (ASHRAE Standard 55). It is thus the condition of minimal stimulation of the skin's heat sensors and of the heat-sensing portion of the brain.

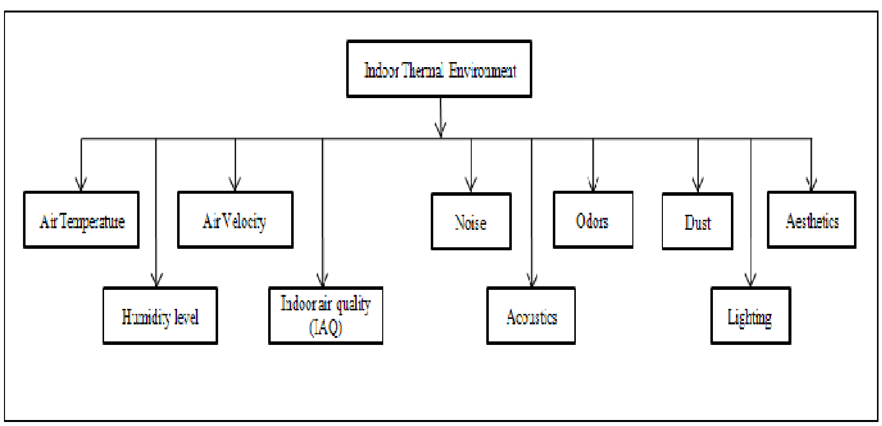

Fig. 1.

The environmental conditions conducive to thermal comfort are not absolute, but rather vary with the individual's metabolism, the nature of the activity engaged in, and the body's ability to adjust to a wider or narrower range of ambient. For comfort and efficiency, the human body requires a fairly narrow range of environmental conditions compared with the full scope of those found in nature. Figure1 shows a few factors that affect humans pleasantly or adversely.

III. HUMAN PHYSIOLOGY

The sense of touch tells whether objects are hot or cold, but it can be misleading in telling just how hot or cold they are. The sense of touch is influenced by how rapidly the objects conduct heat to or from the body than by the actual temperature of the objects. Thus, steel feels colder than wood at the same temperature because heat is conducted away from the fingers more quickly by steel than by wood. Another example, consider the act of removing a pan of biscuits from an oven. Our early childhood training would tell us to avoid touching the hot pan, but at the same time, we would have no trouble picking up the biscuits themselves. The pan and biscuits are at the same temperature, but the metal is a better conductor of heat and may burn us. As this example illustrates, the sensors on our skin are poor gauges of temperature, but rather are designed to sense the degree of heat flow.

Heat. By definition, *heat* is a form of energy that flows from a point at one temperature to another point at a lower temperature. There are two forms of heat of concern in planning for comfort: (1) sensible heat and (2) latent heat. The first is the one we usually have in mind when we speak of heat [16].

Sensible Heat. Sensible heat is an expression of the degree of molecular excitation of a given mass. Such excitation can be caused by a variety of sources, such as exposure to radiation, friction between two objects, chemical reaction, or contact with a hotter object. When the temperature of a substance changes, it is the heat content of the object that is changing. Every material has a property called its specific heat, which identifies how much its temperature changes due to a given input of sensible heat. The three means of transferring sensible heat are radiation, convection, and conduction. All bodies emit thermal radiation. The net exchange of radiant heat between two bodies is a function of the difference in temperature between the two bodies. When radiation encounters one of three things happens: (1) the radiation continues its journey unaffected (in which case it is said to be transmitted), (2) it is deflected from its course (in which case it is said to be reflected), or (3) its journey comes to an end (and it is said to be absorbed). Usually, the response of radiation to a material is some combination of transmission, reflection, and absorption.

The radiation characteristics of a material are determined by its temperature, emissivity (emitting characteristics), absorptive, reflectivity, and transmissivity. Conduction is the process whereby molecular excitation spreads through a substance or from one substance to another by direct contact. Convection occurs in fluids and is the process of carrying heat stored in a particle of the fluid to another location where the heat can conduct away [16].

Latent Heat. The heat transfer mechanisms of radiation, conduction, and convection are elaborated on in Heat that changes the state of matter from solid to liquid or liquid to gas is called latent heat. The latent heat of fusion is that which is needed to melt a solid object into a liquid. A property of the material, it is expressed per unit mass (per pound or per kilogram). The latent heat of vaporization is the heat required to change a liquid to a gas. When a gas liquefies (condenses) or when a liquid solidifies, it releases its latent heat [16].

IV. LITERATURE REVIEW

Yang Ming, Yuan Dongsheng and Ren Xiaoli, simulated the temperature and velocity distribution of air-conditioning office with different air-supply velocity by using a software Airpak. The air -supply velocity less than 0.2m/sec does not causes discomfort to human body, while keeping the inlet temperature constant at 17 deg centigrade. Thus providing the upper limit of the velocity which cause discomfort. The conclusion showed the relationship of air-supply velocity with indoor temperature and airflow field. It's also evaluated the design effect by using the energy utilization coefficient. It provides the theory for designing more reasonable planning working area, and for optimizing the airflow organization [4]. Essam E. Khalil, evaluates the current status, future requirements and expectations to design an optimal HVAC airside system that provides comfort and air quality in the air-conditioned spaces with efficient energy consumption. It proposed that experimental investigations should be considered in the new trend for studies and research work, for validating the numerical tools and also for building a complete database of airflow characteristics in the air-conditioned spaces. But with the vast progress of computers and the advancement in computer technology and associated computer software, the artificial intelligence technique will be a competitor candidate to the experimental and numerical techniques. Hence it reveals that there is greater scope for further research with the advancement of computer technology [5]. Kana Horikiri, Yufeng Yao and Jun Yao, performed the validation study of airflow in an empty room with three convection modes.

Numerical simulation of airflow inside an empty room has been carried out for a forced convection, a natural convection and a mixed convection respectively, by using a computational fluid dynamics approach of solving the Reynolds-averaged Navier-Stokes fluid equations. Two-dimensional model was studied first; focusing on the grid refinement, the mesh topology effect, and turbulence model influences. It was found that structured mesh results are in better agreement with available experimental measurements for all three scenarios.

Further study using a three dimensional model has shown very good agreements with test data at measuring points. It also revealed that a 3-dimensional model provides more accurate results that a 2-dimensional model though the time consumed in 3-dimensional model is more, but with the advancement of computer technology, the computational time is constantly reducing thus leading researchers to model more complex situations [6]. Manoj Arya , Rajput. S.P.S, focused on maintaining indoor air quality in industrial buildings. The humidity level inside the industrial building was considered as an important factor affecting the thermal comfort and Indoor Air Quality (IAQ). It analyses how the natural ventilation criteria is affected by various factors in the industrial building for comfort of workers and staff. It was analyzed that for an industrial room of height 22 meters, velocity of 0.5m/sec is required for temperature range from 17 degree centigrade to 26 degree centigrade. It was concluded that for controlling industrial environment, stack monitoring and ambient air monitoring is necessary, and this is done by time to time for controlling pollutant and maintaining the indoor air quality in industrial room [7]. Tsao *et al.*, studied that Indoor air distribution has a great impact on people's thermal sensation. How to remove excessive heat is an important issue to create thermally comfortable indoor environment. To remove extra heat effectively they used dynamic CFD approach to study effect of an air supply guide vane having swinging periodic motion on the indoor air distribution within the model room. Streamline and temperature contours were plotted to analyze the results, it was found that there were two to three vortices formed and the swirling action was able to help the vortices of higher temperature to reduce to the minimum level [8]. Shobha Lata Sinha, used control-volume method to simulate the indoor air flow using Lam-Bermhorst Low-Reynold-number K-epsilon turbulence model. Steady and two dimensional flow was considered. It used Power law scheme to discretise the convective/diffusive terms. It considered two cases with different inlet and outlet conditions. The inlet port position was kept same while the outlet port position was changed. Temperature was found to be almost uniform in the recirculation zones. Sharper temperature gradient were observed near the walls [9].

Shankar, reviewed the application of Computer Fluid dynamics for optimization of air conditioning equipment. CFD simulation can be used as an effective and economical tool to provide valuable guidance for practical improvements to the processing air-conditioning systems in industrial buildings. Outstanding air-conditioning systems help to improve indoor air environment. DOAS and ICTHS realize the independent control of temperature and humidity, and ensure that indoor terminal devices (e.g., FCU, CC) operate in dry condition. The new-style air supply modes either possess prominent potential of energy saving or can provide a comfortable and healthy indoor air environment or both of them. Therefore, it could be concluded that comfort, health and energy saving are recent research topics and provides a new path for air conditioning in future. However, usually there is a contradiction among comfort, health, and energy saving. Current air-conditioning techniques need to be improved further, and new air-conditioning techniques are expected to be proposed soon [10]. Yan Huo, Ye Gao and Wan-Ki Chow, studied the location of diffuser on airflow field in an office. Air conditioning of an office was simulated numerically by Computational Fluid Dynamics (CFD) software - Fire Dynamics simulation (FDS). It used Large Eddy Simulation (LES) model. The results of simulation and experiment were compared. Most of the results agreed well. Supply air rate and exhaust air rate were kept constant and the effect of different locations of diffuser were analyzed, It was found that when the diffuser was at the lower part of the office, the different locations effect on temperature distribution on the office was not apparent. But when the diffuser was placed at an elevated height there was considerable change in temperature distribution in the office. It concluded that influence of diffuser with height is more obvious than with locations at a certain height to the temperature [11]. Zhang *et al.*, studied the performance of under floor air supply ventilation in a typical office environment with a partition wall using Computational fluid dynamics. Assessment was done in terms of thermal comfort and indoor air quality with the use of validated computer model. The results indicate that partitions may significantly affect airflow and performance of under floor air supply ventilation system. Presence of gap above the partition wall improves air distribution owing to less air recirculation in upper zone. Location of the partition and the office layout including headroom are key factors which need further investigation [12]. Alexander *et al.*, assessed the modeling requirements and accuracy of computational fluid dynamics using Reynolds-Averaged Navier-Stokes equations for forced, free and mixed convection flows in a building enclosures.

The increasing use of computational fluid dynamics to model the air circulation and temperature environment inside rooms of residential and office buildings to gain insight into the relative energy consumption of various HVAC systems for cooling/heating for climate control and thermal comfort. To analyze an accurate simulation of turbulent flow and heat transfer is required. It clearly stated that large eddy simulation or Direct Numerical simulation of Navier-stokes equation is computationally intensive and expensive for simulation of this kind.

Vast majority of computational fluid dynamics simulations employ RANS equations in conjunction with a turbulence model. To access modeling requirements, mesh, numerical algorithm, turbulence model etc. for accurate simulation. It performed simulations on a number of meshes of different density. In particulate two cases were considered for which experimental data were available, first airflow and heat transfer in naturally ventilated room and second airflow and temperature distribution in an atrium. a good agreement with experimental data and computations of other investigators is obtained. In summary, it is demonstrated that computational fluid dynamics can model the flow field and heat transfer in building enclosure quite accurately with proper choice of mesh density and turbulence model [13]. Buratti *et al.*, investigated the wind forced natural ventilation rates of an office as observed with tracer decay method both with an experimental and numerical procedure. Experimental data were used to validate numerical method. Tracer gas concentration decay method was employed to evaluate age of air in an office room. Natural ventilation was created by opening the window and door of the office. Four different conditions of natural ventilation were considered for door and window opening. It calculated the mean age of air linking to ventilation efficiency. CO_2 was used as a tracer gas. Measurements were done in two campaigns, in January and October. The decay method was employed to evaluate variation of tracer gas concentrations with time. The local mean age of air was calculated through tracer gas measurements and numerical simulations, then the uncertainty of local mean age of air was estimated [14]. David *et al.*, studied the numerical and experimental analysis for an air-conditioning energy saving mechanism. It studied how Regional air conditioning mechanism can control the airflow in a room for the purpose of achieving individual thermal comfort zone. Thus each staff in a different area of location can satisfy with his/her local environment and also significantly contribute to energy saving issue of the cooling load. A symmetrical two dimensional standard model was applied. The experimental data were used to validate the computational fluid dynamics model . It was found that CFD simulation results were in good agreement with experimental data. It concluded that the regional air-conditioning mechanism can be successfully established contributing to reduced energy consumption while satisfying the occupant's demand for thermal comfort [15].

Thermal Comfort: Energy saving remains a vital issue amid the increasing environmental problems. Heating, ventilation and air conditioning (HVAC) system has one of the major contributions to the global energy consumption. For hot-climate countries, the application of cooling systems is important for occupants to fulfill their desired indoor thermal comfort. Human comfort temperature is at 22 ~26ºC and the air speed is 0.2m/s at its highest level [2]. Passive cooling and active cooling are the two main types of cooling systems. Passive cooling includes the application of natural processes and passive technologies without the usage of a conventional cooling system. Natural processes involve convection, evaporation and radiation in removing heat while passive technologies utilize building envelops design. Conversely, active cooling requires energy or a power source to provide the cooling effect. The efficiency of cooling systems needs to be emphasized, especially when energy consumption is taken into consideration. Therefore, effective cooling techniques should be studied to improve the current cooling systems. The popularity of air conditioning systems has grown works. The conclusion of this review is presented in due to increased demand for better indoor. Air conditioning is becoming essential in many types of buildings such as offices, airports, factories, halls, auditoriums, libraries, shopping malls, houses etc.

V. CONCLUSION

If comfort is the control target, the main goal is to maintain fixed conditions. Present review research works focuses mainly on the relationship between energy saving and changes in environmental conditions, including temperature, air velocity and humidity. Locations of air intake and exhaust ports greatly affect indoor air distribution. The efficiency of the air-conditioning system also has a significant impact. Therefore, understanding the relationship between the locations of the intake and exhaust ports and thermal comfort will provide a useful system to design a comfortable indoor thermal environment. Experimental setups requires huge amount of cost and time, though the results are accurate within the boundary conditions involved, the simulation technique helps in evaluating and analyzing the indoor environment condition on a virtual platform, thus reducing the time, cost and effort involved while using experimental setup. Thus Thermal simulation is crucial to minimize energy costs as simulation creates a “virtual” data and provides detailed 3D visualization of airflow and temperature at every point throughout the room.

Armed with this vital information, we can quickly and easily minimize cooling power requirements and energy costs; optimize cooling effectiveness; ensure that the room temperatures are within specifications and eliminate hot spots thus avoiding potential discomfort.

REFERENCES

[1]. Van Dike, D. and Khalil, E.E., 2009, Energy Efficiency in Buildings, ISO Focus, September 2009, page.16-20, 2009.

[2]. ASHRAE (American Society of Heating, Ventilating and Refrigerating Engineers) ASHRAE Handbook, Fundamentals, Atlanta, USA, ASHARE 2009.

[3]. Henderson, HI Jr., Rengarajan, K., "The Impact of Comfort Control on Air Conditioner Energy Use in Humid Climated", *ASHRAE Transactions: Research*: 423-430, 1992.

[4]. Yang Ming, Yuan Dongsheng and Ren Xiaoli, Numerical simulation on the influence of air-supply velocity in air-conditioning office, *IPCSIT* vol. **47**, 2012.

[5]. Essam E. Khalil, Energy-Efficiency in Air Conditioned Buildings: The Green Buildings Dream, *Int. J. of Thermal & Environmental Engineering*, Volume **2**, No. 1, 2011.

[6]. Kana Horikiri, Yufeng Yao and Jun Yao, Numerical Simulation of Convective Airflow in an Empty Room, *International Journal of Energy and Environment*, Volume **5**(4): 2011

[7]. Manoj Arya, Rajput. S.P.S, Monitoring and analysis of indoor air quality at different heights in industrial room by using CFD, *International Journal of Environmental Sciences*, Vol. **1**, No 6, 2011.

[8]. CC Tsao, SW Nien, WH Chen, YC Shih, The Impact of an air supply guide vane on the Indoor air distribution, World Academy of Science, Engineering and Technology, 2013.

[9]. Shobha Lata Sinha, Numerical Simulation of Hot Buoyant Supply Air Jet in a Room with different outlets, IJRRAS 5 November 2010.

[10]. Shankar, Application of Computer Fluid dynamics for optimization of air conditioning equipment: A review of research work done, *International Journal of Latest Research in Science and Technology*, Vol. **2** Issue 1,pp 499-501, 2013.

[11]. Yan Huo, Ye Gao and Wan-Ki Chow, Locations of Diffusers in Air Flow Field in an Office, 2009.

[12]. Zhang Lin, T.T. Chow, C.F. Tsang, K.F. Fong, L.S. Chan, W.S. Shum, Luther Tsai, Effect of internal partitions on the performance of under floor air supply ventilation in a typical office environment, Elsevier 2008.

[13]. Alexander Kayne, Ramesh K. Agarwal, Computational Fluid dynamics modeling of mixed convection flows in building enclosures, *International Journal of Energy and Environment*, 2013.

[14]. C Buratti, R Mariani, E Morett, Mean age of air in a naturally ventilated office: Experimental data and Simulations, ELSEVIER - Energy & Building, 2011.

[15]. K David Huang, Nguyen Anh Tuan, Numerical and Experimental analysis of an Air conditioning energy saving mechanism, Asian Symposium on Computational Heat Transfer and Fluid Flow, 2009.

[16]. Fanger, P., Thermal comfort, McGraw-Hill book company, 1972.