Review on Air Distribution in Air Conditioned Spaces and Its Role on Human Comfort

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Abstract - Air distribution has major role in increasing the effectiveness of air conditioning. For better air conditioning, not only thermal comfort is satisfactory, but indoor air quality is also very important on considering better human comfort. Human comfort has substantial role in living standard also. In this review paper, author reviewed on different methods of air distribution & their advantage and limitation as well as different parameter which affect indoor air quality & human comfort.The purpose of this paper is to provide the detail of air distribution as well as its various parameters to improve indoor environment and thus enhance human comfort.

Keyword: Air Distribution, Human comfort, indoor air quality, Thermal comfort

I. INTRODUCTION

In the present scenario, the requirement and demand of Air-conditioning is going on increasing due to increase in average temperature of the environment due to greenhouse effect.The large part of time, a typical individual spends indoors, in which majorly commercial and environment. And this indoor environment have influenced directly on that individual's health, spirit and efficiency [1, 2].

Not only just thermal comfort which play role significantly in human comfort, there is indoor air quality is important because of dust and pollution level. And human comfort enhance standard of living as well. Major of time people spend time indoor environment like residential building and commercial building or workplace. This environment has important effects on human health and work efficiency.Mainly the factor affecting indoor environment includes temperature, humidity, ventilation, air exchange rate, air movement, particle pollutant, biological pollutant and gaseous pollutant.

In last few decades, air conditioning technology and manufacturing technique were rapidly developed, so that not only commercial and public buildings, but most residential buildings and houses were also equipped with air conditioning installations .Because of air conditioning facilities enabled human being to make not only dependence on natural environment, therefore there is great improvement in occupant's standard of living.

Where air conditioning provides a comfortable, affordable and healthy indoor environment which improve living standard but in the same time, it will also related to energy consumption and environmental pollution. Here we need human comfort with care of environment issue also. And there is requirement of sustainable technology of air conditioning and human comfort, here ASHRAE play an important role. ASHRAE makes some standard for thermal comfort with sustainable technology.

II. AIR DISTRIBUTION

Air distribution is the method to how conditioned air is diffused in the space. For better air conditioning, not only removing heat as thermal comfort and removing contaminated air as better indoor air quality is required, but also there is importance of distribution and control of air movement in space so that comfort is obtained in occupied space. [3]Having knowledge indoor air distribution is essential to the design of ventilation systems and control of indoor thermal and air quality conditions. The thermal comfort of person is directly affected by indoor air velocity. As a result, more and more buildings are being equipped with mechanical ventilation or air-conditioning systems.

Without sufficient air distribution, excessive air draft can occur in some spaces, whereas stagnation of air may occur in other areas. Indoor environment can be affected by poor air distribution and degrade the air quality. With different diffusers and different locations of supply inlets and outlets, the distribution of the thermal comfort characteristics is different. It is necessary to study quantitatively the local thermal comfort under different kinds of air diffusion types.

An air distribution system is the system that provides thermal comfort for the occupant which can be complicated system to predict and analyse.An air distribution can be designed successfully by knowing that what makes us comfortable and selecting the proper air distribution method and its layout.

1.1 METHODS OF AIR DISTRIBUTION

Different method includes overhead fully mixed, as well as fully stratified and partially mixed system from below and even personal air delivery system.HVAC airflow delivery system in spaces generally has been classified by different types under constant and variable volume airflow.

1.1.1 Mixing(or dilution) type

In mixing type, supply air mixes with room air so that is at the room design temperature and humidity. The high velocity air supply stream cause turbulence due to which the room air mix with supply air.

PROS

- Cooling and heating commonly accomplished by single system.
- Low cost for reconfigured space.
- Well understood construction details.
- Air diffusion performance index (ADPI) can be predicted to validate stratification. [4]

CONS

- Less efficient.
- Ventilation is shared by all.
- System acoustics should be designed carefully. [4]

1.1.2 Traditional Displacement Ventilation(TDV)

In displacement type, supply air directly to the occupied zone. The velocity of air supplied at low velocity to cause minimal mixing and induction. This type of system is used for large and high space cooling and ventilation. In this type, there is saving of energy, because of treatment on only occupant zone rather than entire space.

This system is preferable when high contamination present in the space like industry, or quiet air is necessary, or specific airflow rate per unit area is high like conference room, or height of space is more than 10 feet.On comparison with mixing ventilation type, it is more advantageous in term of longer time of free cooling, better air quality and less cooling energy and capacity are needed in same required condition.

PROS

- Requirement of less energy for cooling.
- Air quality is better.
- Calculation of energy is not validated.
- Good for classrooms. [4]

CONS

- If ceiling height is less than 10 feet, there are no advantages.
- Requirement of enough space.
- Risk of draft near units.
- Must use of CFD or other method for vertical temperature distribution. [4]

1.1.3 Under Floor Air distribution(UFAD)

The airwhich is supplied in underfloor air distribution (UFAD)is from the bottom up compare to conventional HVAC system which is top down. In this type of air distribution, distribution may be done within the space without ductwork.

PROS

- Silent operation.
- Save energy due to le fan static and higher discharge temperature.
- Simpler control relatively needed. [4]

CONS

- To avoid leakage, requires careful building construction.
- For humid climate, requirement of special considerations.
- No ASHRAE 55 vertical temperature stratification calculation method. [4]

1.1.4 CHILLED BEAMS

The concept introduced and developed in 1980’s and it was adapted to central European markets in middle of the 1990’s and further expanded in other part like southern Europe, US and Australia in 2005. Passive beams are used at that place where more cooling is needed like offices. In this system air flow rate is high and space has high ceilings. However is used where ventilation is also required, normal cooling capacity is needed, air flow rate requirement is less and space is lower than 13 feet.[5]

PROS

- Potential to save energy.
- Silent operation.
- Lower fan energy is required,so smaller ductwork is required.
- Relatively simple controls. [4]

CONS

- It requires a very good building curtain wall construction to control condensation.
- High equipment and installation cost.
- No ASHRAE 55 vertical temperature stratification calculation method. [4]

1.2 DESIGN PARAMETER

For better air distribution and its effectiveness, designing of air conditioning of system and space have great importance. So various design parameters which the air distribution effectiveness are following:

- Space type
- Type of diffuser
- Number of diffuser
- Shape of diffuser
- Diffuser location and its orientation
- Supply of air temperature
- Cooling load
- Secondary heating system
- Overall heat transfer coefficient
- Turbulence
- Return location
- Throw height
- Partition arrangement

From the above designing parameter, there are significant impact parameters are air change rate, supply air velocity, supply air temperature & number of diffusers. Moderate impact parameter are partition location & exhaust location and lastly little impact parameter are diffuser location, occupant location & furniture arrangements.

III. HUMAN COMFORT

Comfort is best describes as absence of discomfort. Besides being aesthetically pleasing, the human environment must provide light, air and thermal comfort. In addition, consideration of proper acoustics and hygiene are also very important.

Uncomfortable condition is formed when there are too hot or too cold, or occupant is feeling uncomfortable when the air is odorous and stale. Good comfort conditions are those conditions by whichpeople do not distract by unpleasant sensations of temperature, draft, humidity or other aspects of the environment. In ideal condition, properly conditioned space is that conditioned space in which people should not be aware of equipment noise, heat, or air movement.The feelingof comfort or better to say feeling of discomfort is based on a network of sensoryorgans like eyes, ears, nose, tactile and heat sensors, and brain.For the better human comfort, it requires some narrow range of condition of environment. There are some factors which affects human comfort, it includes:

- Temperature of air of surrounding
- Humidity of air
- Radiant temperature of the surrounding surfaces
- Air motion
- Odours
- Dust/pollution
- Concentration of carbon dioxide
- Acoustics/noise
- Lighting
- Aesthetics

In these of above, first four factors are related to the thermal interaction of people and their environment. The nest three factors are related to the indoor air quality, and last three related to audible and visual interactions.

2.1 INDOOR ENVIRONMENT

From the indoor environment we mean that what are the different conditions of space where the occupant lies, what are the measurements of different parameters which affect human comfort.From the above factor, there are few other factors, more precisely, environmental factor are following

- Air(Dry bulb) temperature
- Humidity
- Mean radiant temperature
- Air movement
- Clothing insulation
- Activity level
- Rate of change of any of above

Indoor environment is depend on types of parameters which are thermal parameter based on indices PMV (Predictive Mean Vote) and PPD (Predicted Percentage Dissatisfied), noise parameter based on index NPD (Noise-caused Percentage Dissatisfaction), indoor air quality parameter based on QPD (Quality-caused Percentage Dissatisfaction) and visual parameter such as lighting quality and level. [6, 7]Indoor air environments must meet the requirement of thermal comfort andindoor air quality (IAQ).

3.1.1THERMAL COMFORT

Thermal comfort is affected by many factors, which mainly include air temperature, air humidity, air velocity,

mean radiant temperature, human clothing, and activity levels.The six factors affecting thermal comfort are both environmental and personal. These factors may be independent of each other, but together contribute to a worker's thermal comfort.[8]

Environmental factors:

- Air temperature
- Radiant temperature
- Air velocity
- Humidity

Personal factors:

- Clothing Insulation
- Metabolic heat

3.1.2INDOOR AIR QUALITY (IAQ)

Indoor air quality means the nature of the air which is circulated in the space where occupant live or work. Besides all the thermal comfort of an environment, health is also dependent content and composition of the air. Let take an example,it feels uncomfortable for occupant in odorous or stale air. From the study and research, it have been seen that indoor air quality plays an important role in intellectual efficiency as well as health of occupant.[9]

There is wide use of air conditioning which improve thermal comfort but simultaneously due to recognition of importance of energy saving, fresh air is reduced which leads to lower indoor air quality. Therefore there is much importance of indoor air quality sothat occupant will respires well for better health and having higher productivity. For better indoor air quality, proper ventilation is required.

The quality of air can even more serious in heavy occupancy spaces, where concentration level can rises to deleterious level. And at same place, excessive accumulations of some air contamination become hazardous. With increase in concentration of excessive accumulation or inlet pollution, there decrease in reaction rate.[10]Many researcher and expert believe, in near future IAQ will be the most important and relatively overlooked requirement due to environmental issue and pollution level. Indoor pollutants include particle pollutant, gaseous pollutant, biological pollutant and chemical pollutant also.

3.2THE COMFORT CHART

The comfort chart correlates the perception of comfort with the various environmental factors known to influence it. The dry-bulb temperature represents on the bottom. The right side of the chart contains a dew point scale (DBT) and the left side a wet-bulb temperature (WBT) scale indicating guide marks for imaginary lines sloping diagonally down from left to right. The lines curving upward from left to right represent relative humidity (RH).

These are the sloping dashed lines that cross the RH lines and are shown in increments of 5 □F. At any any one of these lines, an occupant will feel the same thermal sensation and will have the same amount of skin wetness due to regulatory sweating. At that CLO levels 94 % of occupants will find acceptable comfort are also indicated.[8]Two comfort fieldor zones which are shown as the shaded regions on the comfort chart—one for winter and another for summer. The zones overlap in the 73 □□ to 75 □F range (23□□ to 24□C)

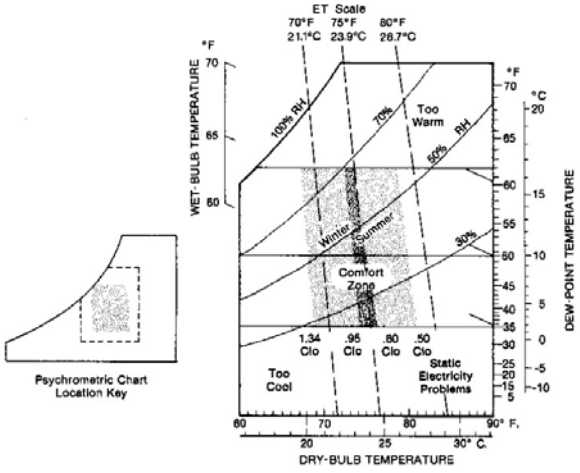

Figure 1:The comfort chart

3.3ASHRAE's Thermal Comfort Standard

ASHRAE makes some standards for human well-being (human comfort) through sustainable technology for build environment which focus on many areas like building system, energy efficiency, indoor air qualityrefrigeration and sustainability within the industry.ANSI/ASHRAE Standard 55-2013, "Thermal Environment Conditions for Human Occupancy", specifies conditions for acceptable thermal environments and is intended for use in design, operation and commissioning of building and other occupied space. These standards are focus on Adaptive and Predicted Mean Vote (PMV). [11]

By using this standard, specification of thermal environmental conditions can be achieved by the combinations of indoor thermal environmental factors and personal factors that will acceptable to a majority of the occupants within the space. The standard addresses four primary factors (i.e. temperature, thermal radiation, humidity and air speed) and two personal factors (I.e. activity and clothing).

3.4METHOD TO IMPROVE INDOOR ENVIRONMENT

In the recent past years, there are many research has been done that how to improve indoor environment and enhance human comfort. The main factor is how to diffuse the air i.e. air distribution.Following are some basic factor, on changing/manipulating will lead to improved indoor environment of conditioned space.[10]

- Air distribution method
- Humidity level
- Comfort condition
- Air temperature & velocity distribution
- Indoor air quality
- Lighting condition
- Ventilation system

As much as environmental issue is concern, indoor air quality(IAQ) will become a very important factor. Therefore for improving IAQ following are some steps:

- Filtering outdoor air to prevent pollutant entering the room
- Isolating the sits that may pollution source
- Maintaining bacteria prone component and changing with time
- Clean the air filter in proper time so that air is free from dust.
- Proper ventilation, so that fresh air is to be circulated

There are various methods to analyse different strategies and results which is mentioned above to achieve human comfort in the conditioned space. There were some common methods are:

- CFD analysis or simulation tool
- Field survey method
- Experimental investigation
- CPD(comprehensive percentage dissatisfied) method

IV. CONCLUSION

There are various air distribution methods like mixing type, TDV, UFAD & chilled beam, so the selection of method depends as per requirement. The authors also studied the influence of differentparameters which affect the air distribution as well as human comfort. The parameters are temperature of air surrounding, humidity of air, radiant temperature of surrounding, air motion, odour, dust and pollution, concentration of carbon dioxide, acoustics or noise, lighting and aesthetics.

In these factor air temperature, radiant air temperature, air velocity and humidity of air are environmental factors&they may vary place to place in different time, however clothing factors & metabolic heat are personal factors which may vary with respect to person(Gender & age) and their culture. From the designing parameters of air conditioning the parameter which have major impact on air distribution effectiveness are throw height from diffuser, number of diffuser, supply air temperature, total flow rate, cooling load and cooling mode.

In this paper author has also uses ASHRAE standard 55-2013 for standardisation of thermal factors(temperature, thermal radiation, humidity & air speed) to maintain better thermal environment condition which based on predictive mean vote (PMV). From this standard, the two zone of summer and winter overlaps in 23 □ range 24□

From the literature reviewed it is found that the air distribution plays important role in the air conditioning for better comfort, energy conservation and it needs to be fully analysed and optimised for a particular requirement of air distribution system design.

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