Monitoring and analysis of indoor air quality at different heights in industrial room by using CFD

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ABSTRACT

The aim of this paper is to maintain indoor air quality in industrial buildings as per requirement. In hot and humid climates in industries, indoor humidity levels are usually high and this is a matter of concern from thermal comfort and Indoor Air Quality (IAQ) perspectives. In industrial climates, occupants seal even the smallest air gaps and eliminate outside fresh air circulating inside the buildings. So it is essential to manage dust and airflow inside the building. In whole analysis, for maintaining indoor air quality measurements like Stack monitoring (measuring the suspended particulates in stack), Ambient air monitoring (measuring the suspended particulates in atmosphere) and numerical simulation by using CFD air flow analysis, are incorporated. The effect of the air supply and flow analysis has been done in the industrial turbine room at the Vikram Cement, Neemuch (M.P.) Environmental conditions, local thermal boundary conditions and climate data are collected from the site. Investigation of natural ventilation criteria affected by various factors in the industrial building for finding the flow rate and velocity in the building for comfort of workers and staff.

1. Introduction

Many recent policy intervention have been undertaken to improve ambient air quality but very little is known about Indoor Air Quality (IAQ). People spend the majority of their time indoor, mostly in domestic environment, where their health may be affected mostly by indoor air pollution. Air pollutants measured in the living rooms included CO, CO₂, NOₓ, SO₂ and air velocity, humidity etc. Indoor Air Quality refers to the nature of conditioned air that circulates throughout the space/area where we work and live, that is, the air we breathe during most of our lives. IAQ, refers not only to comfort, which is affected by temperature, humidity and odors, but also to harmful biological contaminants and chemicals present in the conditioned space.

Indoor air quality (IAQ) may be broadly defined as the nature of air that affects the health and well-being of occupants. It differs from industrial indicators of acceptability, such as threshold limit values, as the latter primarily reflect concern for control of potential hazards.

1.1 Main factors affecting Indoor Air Quality (IAQ)

The factors affecting the indoor air quality mainly are the air conditioning system, indoor pollutant and deterioration of outdoor air.
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1.2 Stack monitoring and high volume sampler

Monitoring of Stack and vent emissions is now becoming a routine requirement not only for large but even the medium and small industrial units. There has also been a growing realisation that gaseous pollutants, chemical fumes and fine mists are hazardous as particulate ashes and dusts. The advantages are:

Figure 1: Effect of outdoor particles in the room

Figure 2: Stack sampling wire frame
• Measures total quantity/volume of the emission very conveniently.

• Temperature and pressure at inlet of the Rota meter, in order to normalize volume of the sampled gas.

• Standard accessories like Rota meter, pressure & temperature, metering system & provision for simultaneous sampling.

1.3 Introduction of High volume sampler

With ever-increasing industrial the ambient air quality is in danger of deteriorating, which contribute to ambient air pollution, has also risen exponentially. Various pollution control boards, including Central Pollution Control Board and the state boards have taken cognizance of the potential hazards to public health due to air pollution. One of the measures taken is the mandate for regular monitoring of the ambient air for Suspended Particulate Matter (SPM) and Respirable Particulate Matter (RSPM).

![Figure 3: High Volume Sampler Wire Frame](image)

The advantages are:

• Easy manipulation of Impinges.
• No heating up of absorbing solutions due to heat from the blower.
• Possibility of using ice or cold water bath around the impingers for complete absorption of sparsely soluble gases.
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2. Model and Experimental

First outdoor particles is sampling by the monitoring technique in that we are industries particles in mixing the air like various particles included are the VOC’s ,CO,SO₂, SPM (suspended particulate matter), NOₓ etc. but measuring air particles in the Vikram cement industries making production with effect the atmospheric air is only spm. It is to be the outdoor particles is closely interrelated by the indoor air in this region finally design the room and find the different height by the fluent software help we measure the velocity in the indoor air quality using fluent software measure the velocity is thermal comfort for room human and environment. Indoor air quality is the main effect the ventilation in that problem are investigated volume flow rate and the net air velocity across the ventilation around cooling the thermal comfort room the computational domain (three dimensional-3D).the computational using a commercial program, Fluent 6.3.

The Industrial room dimension length 100 m, height 30 m, depth 30 m, Inlet and Outlet Door (2×3×1), Turbine 1 and 2 (7×3×3), ventilator’s dimension (5×2×1), cooler (2×2×1), exhaust fan(3×1×3). This problem has been solve by the CFD using fluent software.

Stack monitoring

\[ V = K \sqrt{(H \times T_S)} \] first velocity determine the calculation

\[ Q_s = V \times A \times 60 \times 1000 \] Nozzle cross rate sampling

\[ Q_s' = Q_s \times \frac{25+273}{T_s} \] Rate of sampling as per gas law,

\[ Q_m = Q_s' \times \left( P_m - P_m \right) \times 273 + 25/T_a \times P_{atm} \] Sampled gases at the point of flow measurement

\[ W/Q_m \] Suspended particulate matter

Ambient air monitoring

\[ Q = (Q_1 + Q_2)/2 \] Orifice meter reading

\[ T = T_2 - T_1 \] Total time
Volume of air sampled \[ V = Q \times T \]
suspended particulate matter: \[ W/V \]

Analysis for Room

1. Area (A) = L \times H
2. Volume flow rate: \[ V_1 = \frac{C_d A}{3} v gH(T_i - T_o)/T_o \]
3. Velocity of air flow in room: \[ v = V_1/A \]

Figure 5: Left side view

Figure 6: Right side view
2.1 **Boundary conditions used in the room**

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>Room condition</th>
<th>Boundary condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Room Wall</td>
<td>Insulated wall</td>
</tr>
<tr>
<td>2.</td>
<td>Inlet door</td>
<td>velocity inlet</td>
</tr>
<tr>
<td>3.</td>
<td>Outlet door</td>
<td>pressure outlet</td>
</tr>
<tr>
<td>4.</td>
<td>Turbine 1</td>
<td>wall with certain temperature</td>
</tr>
<tr>
<td>5.</td>
<td>Turbine 2</td>
<td>wall with certain temperature</td>
</tr>
<tr>
<td>6.</td>
<td>Fluid</td>
<td>air</td>
</tr>
<tr>
<td>7.</td>
<td>Ventilation</td>
<td>outflow</td>
</tr>
<tr>
<td>8.</td>
<td>Cooler</td>
<td>velocity inlet medium velocity with fresh air</td>
</tr>
<tr>
<td>9.</td>
<td>Exhaust section</td>
<td>exhaust fan</td>
</tr>
</tbody>
</table>

*Figure 7: Perfect picture*
3. Results & Discussions

First we analyse the Environment condition of the industries and collect the climate data of industrial site.

0. Stack emits dust 250 mg/nm$^3$
Maximum limits of Air pollution are:
1. Dust (SPM) 500 µg/m$^3$
2. SO$_2$ (Sulphur di oxide) 120 µg/m$^3$
3. NO$_2$ (Nitrogen di oxide) 120 µg/m$^3$
4. CO$_2$ (Carbon di oxide) 5000 µg/m$^3$

Doing the stack monitoring measure the SPM(suspended particulate matter) from the stack of thermal power plant. Find that height of stack supply the particulate to upper atmosphere this is safe for industrial environment and also unsafe particulate filter in the stack for controlling pollutant technique. In Ambient air monitoring measure the amount SPM, this test doing for
controlling the dust particles in the atmosphere and maintaining the safe SPM for human health. This SPM is controlled by the production department of the industry. Indoor air quality is analysed by the software using fluent 6.3.26 solver at different heights by measuring the air velocity. The velocity is mainly affected by the temperature of room and equipment used in the turbine room. Circulation of air in the room is maintained by using ventilation and cooler at minimum electricity consumption.

**Table 5.1**: Range of velocity according to different height (AT 20m ROOM LENGTH)

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Volume flow rate (m³/s)</th>
<th>velocity (m/s)</th>
<th>Height (m)</th>
<th>Area (m²)</th>
<th>Inlet temperature (k)</th>
<th>Average Outlet temperature (k)</th>
<th>Coefficient of Discharge (C_d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.70</td>
<td>.27</td>
<td>28</td>
<td>20</td>
<td>290</td>
<td>293</td>
<td>0.6</td>
</tr>
<tr>
<td>2</td>
<td>8.31</td>
<td>.41</td>
<td>26</td>
<td>20</td>
<td>290</td>
<td>295</td>
<td>0.6</td>
</tr>
<tr>
<td>3</td>
<td>9.42</td>
<td>.47</td>
<td>24</td>
<td>20</td>
<td>290</td>
<td>297</td>
<td>0.6</td>
</tr>
<tr>
<td>4</td>
<td>10.19</td>
<td>.50</td>
<td>22</td>
<td>20</td>
<td>290</td>
<td>299</td>
<td>0.6</td>
</tr>
<tr>
<td>5</td>
<td>10.71</td>
<td>.53</td>
<td>20</td>
<td>20</td>
<td>290</td>
<td>301</td>
<td>0.6</td>
</tr>
</tbody>
</table>

**Figure 10**: Velocity profiles at different heights

4. Conclusions

Thermal comfort is very important to many work-related factors. It can affect the distraction levels of the workers, and in turn affect their performance and productivity of their work. Study found that higher indoor temperatures, even within the recommended thermal comfort range, increased worker symptoms. The occurrence of symptoms increased much more with raised indoor temperatures in the winter than in the summer due to the larger difference created between indoor and outdoor temperatures. During the stack monitoring analysis, calculated level of SPM (suspended particulate matter) is 244 mg/nm³. During the ambient air monitoring, calculated SPM is 251 µg/m³, which safe for industrial environment within range 500 µg/m³. In numerical simulation done by the fluent 6.3.26 solver, this gives the visualization flow in the turbine room. This is very helpful for control the thermal comfort in the turbine room. Graph shows that range of velocity at different height of room at different position at the particular length (20, 40, 60, 80) is measured the velocity for thermal comfort one of the value obtained optimum range at 22 meter room height this is 0.50 m/s, this is for temperature range 290 K to 299 K. Finally, conclude that 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.

5. References


6. Martin w. Liddament, air quality in commercial building, air filtration and ventilation, great Britain WREC, 1996.


