Thermal Analysis of a Small Room with Its Heating Sources on

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Abstract

Visualization of airflow in an office room with all its heating sources turned on is presented in this paper. The simulations were conducted using SolidWorks flow simulation and the room selected for this study was Savannah State University's (SSU's) Hubert D-414. In a previous analysis, a similar study was conducted without any heat source; this is a continuation of that work. The furniture and the office equipment were created as SolidWorks Part files and then assembled with room's floor, roof, and sidewalls to create an exact replica of the room. One of the pre-defined fans from the software was selected to simulate the airflow. The flow visualization videos show a very clear view of how the airflow from the fan distributes the heat inside the room. The fan created two streams of airflow. The one on the top does not significantly affect the temperature of the room. It just creates an air circulation close to the roof. The heat from the heating sources is actually picked up with the lower air currents and distributed around the room. The flow visualization also shows that the air gets warm while it moves toward the exit.

Keywords: Airflow, thermal, flow visualization, heat source, Computational Fluid Dynamics (CFD).

1. Introduction

It is highly difficult to outline the specific values of the parameters that control human thermal comfort as it varies with individuals [7]. According to ASHRAE (American Society of Heating, Refrigerating, and Air-conditioning Engineers) [6], thermal comfort is defined as 'that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation.' In fact, the combined effect of all environmental and personal factors governs how a person is thermally comfortable in the environment he/she is occupying. Environmental factors include air temperature, radiant temperature (temperature from surfaces surrounding the occupant), air velocity, and relative humidity; and personal factors include metabolic rate (the energy generated from human body) and clothing insulation [7]. In case of an enclosed space, temperature distribution and air movement are two key factors that determine indoor air climate [1]. In addition to these, the position of the heating sources and the airflow that carries the heat generated by the heating sources during the winter season also play a role for the comfort of its occupant. When the position of the air heating sources and the flow velocity are known, it is possible to explore the different temperature zones in a small room to understand where one may sit in order to be the most comfortable. Keeping that in mind, the main purpose of this study is to create flow visualizations and cut plots on different planes to determine the best place to sit inside a room while both the heater and fan are turned on during the winter. The visuals should show the movement of the circulating heated air, which in turn, should suggest its occupant to identify the right location where he/she should sit to feel comfortable. The location selected for this study is Room 414 in SSU's Hubert D building.

2. Analysis Software

The analysis was conducted by SolidWorks Flow Simulation. SolidWorks is a Windows-based three-dimensional Mechanical CAD (Computer Aided Design) program. This software is currently used by over two million engineers and designers at more than 165,000 companies all over the world [8]. SolidWorks Flow Simulation software [2, 3], embedded within SolidWorks, is a powerful a Computational Fluid Dynamics (CFD) tool. This user-friendly section allows the user to quickly and effectively simulate the flow of fluid, and it is able to calculate different aspects of the fluid flow [2, 3].

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3. 3-D Model

The furniture (three desks and three shelves), office equipment (printer, scanner, CPU, and monitor), heater and door of the room were created according to dimensions as SolidWorks Part files [9] and then assembled with the room's floor, roof, and side walls. The exact dimension of the room was maintained; and the furniture and door along with the office equipment and the heater were placed exactly in the same location as they are located in the room in order to build the room virtually. The same 3-D model was used in the precious study [5]. The exploded and assembled views of the room are presented in Figures 1 and 2, respectively.

4. Simulation Details

Since the purpose of this study is to investigate the temperature distribution inside the room, an internal simulation was conducted. The unit system chosen was Meters (m) – Kilograms (Kg) – Seconds (s) – Kelvin (K).

The material for the heater was Steel (mild). The wattage for printer, heater, scanner, monitor, and CPU was 100W, 550W, 75W, 15W, and 30W, respectively [4]. The type fan selected was Axial YS Tech USA YW12038012BS.
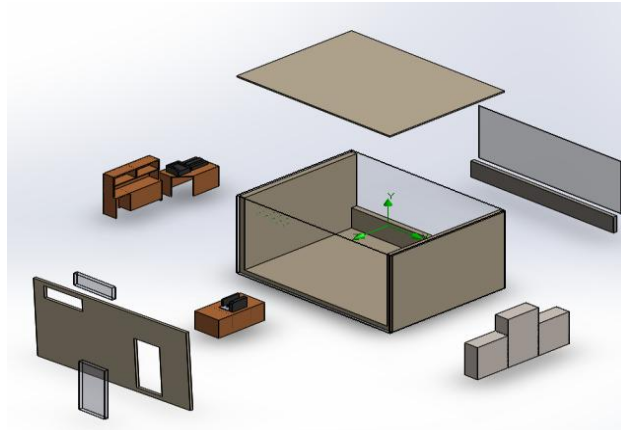

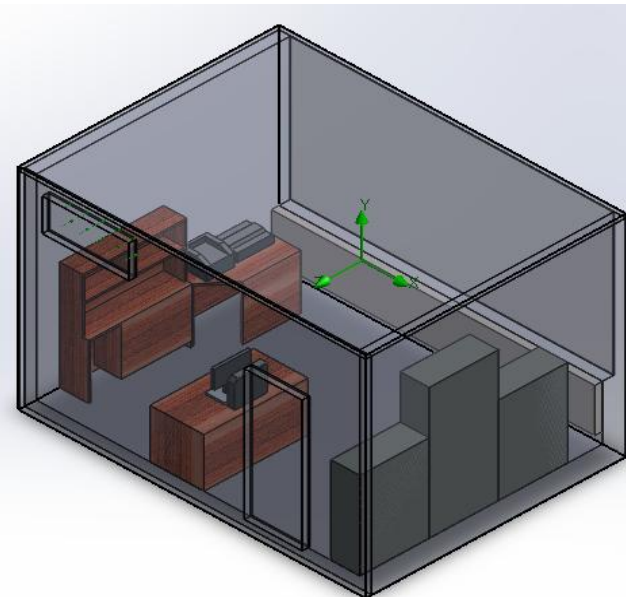**Figure 1: Exploded view of the 3-D model**

Figure 2: Assembled view of the 3-D model

The boundary condition for simulation was outlet pressure = environmental pressure and the simulation goal was to achieve the maximum average room temperature. The air flows from the fan on the upper left corner of the room, which then circulates inside room, takes the heat from the heater and the office equipment and distributes the heat.

5. Results

Two types of post-simulation results were produced for this study, temperature distribution videos and cut plots of top and font views. The top view of temperature distribution plots at four different elevations are shown in Figure 3.
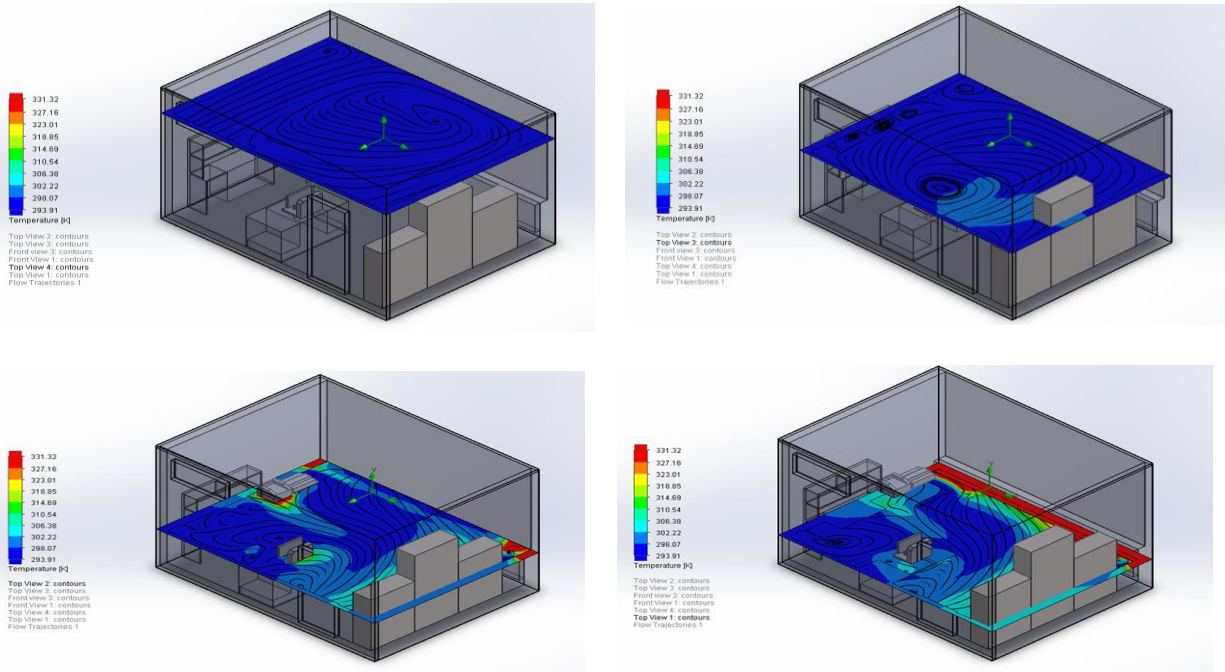

Figure 3: Top View - Temperature distribution at different elevations

The set of these four plot reveals that there is not a significant variation in temperature at higher elevation. The higher the elevation is the cooler the air got. However, at lower elevations, the temperature of the room is significantly affected by the heating sources and the flow of air.

The front view of temperature distribution plots at three different positions are shown in Figure 4. These three plots demonstrate that the temperature is higher close to the heater and the office equipment.
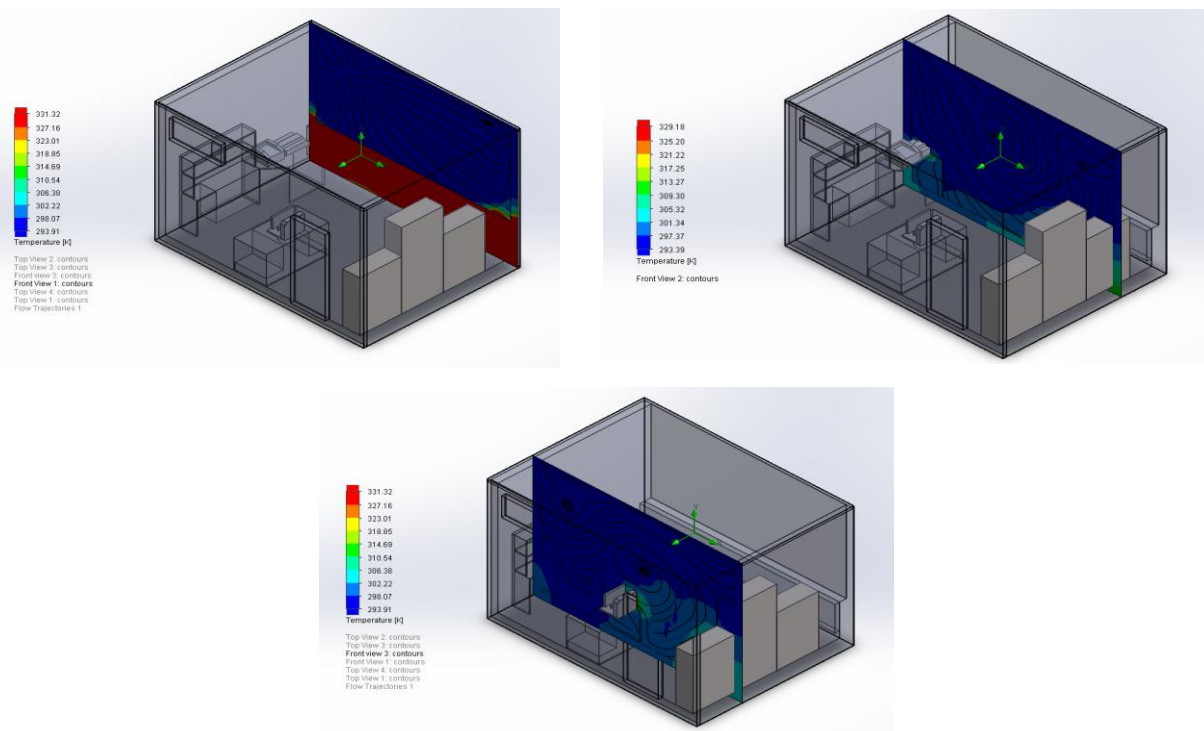
The flow trajectory video shows a very clear view how the airflow from the fan distributes the heat inside the room. It is evident that the fan creates two streams of airflow. The one on the top does not significantly affect the temperature of the room. It just creates an air circulation close to the roof. The heat from the heating sources is actually picked up with the lower air currents and distributed around the room. It also shows that the air gets warm while it moves toward the exit.

Based on all these three visualizations, an occupant can decide where he/she should sit inside the room during the winter to feel comfortable for this specific room setting.

6. Conclusions

In this study, airflow from a fan was simulated using SolidWorks flow simulation to visualize the movement of hot circulating air in a small office room when all the heating sources were turned on during the winter. An exact replica of the room was created with its furniture, office equipment and heater located in the same position as they were located in the room. The flow visualization videos show a very clear view of how the airflow from the fan distributes the heat inside the room. The fan created two streams of airflow. The one on the top does not significantly affect the temperature of the room. It just creates an air circulation close to the roof. The heat from the heating sources is actually picked up with the lower air currents and distributed around the room. It also shows that the air is gets warm while it moves toward the exit. Flow visualizations like these are very helpful for the occupant of the room to decide where he/she should sit to feel comfortable for a specific room setting.

7. Acknowledgement

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