An Office Room CFD Analysis for winter and Summer Air Conditioning System.

Wael Mokhtar and Ratan Ghosh,

School of Engineering, Grand valley State University,

Grand Rapids, Michigan, USA.

Abstract:

Temperature, Humidity, air velocity and air cleanness are the key factors on which human comfort greatly depends. Those factors widely vary throughout the year and different geometric location. Heating, Ventilation and Air Conditioning (HVAC) system used to achieve the desire comfort level. It is difficult to obtain the uniformity of air quality within the design space without proper simulation. CFD analysis display a clear and real-time airflow, temperature distribution and heat flow in the design space. In this analysis, using STAR CCM+ within an office room temperature distribution, heat flow, air velocity has been analyze in various boundary condition for both summer and winter air conditioning system.

Air inlet velocity, room inside temperature, ambient temperature and air inlet angle considered as testing parameters in this experiment. In case summer air-conditioning system minimum temperature found in high velocity, range (1 m/s) and medium angle (45°). On the other hand, in case of winter air conditioning system desire maximum temperature found in medium velocity (0.9 m/s) and high angle (60°).

Keywords: HVAC, CFD, STAR CCM+

Introduction:

Energy efficient building design become one of the major concern now days. In modern buildings significant amount of energy consumed by Heating Ventilation and Air Conditioning (HVAC) system. HVAC design engineer continuously face the challenge to maintain proper indoor air quality with human comfort and at the same time maintain the energy consumption level low. "In most industrialized countries, energy consumption by the HVAC sector accounts for 33% of the total energy consumption "[1]. "The goal of HVAC design in buildings is to provide good comfort and air quality for occupants during a wide range of outdoor conditions. Sufficient fresh air supply by ventilation is necessary for occupant's health" [2]. To reduce this huge amount of energy, myriad groups of engineer and researcher continuously working to design more and more energy efficient system. Heat recovery system incorporate with various process industry to reduce the heat losses. "Cooling and dehumidifying fresh ventilation air constitutes 20–40% of the total energy load in hot and humid regions" [3]. "HVAC of houses and buildings accounts for 23% of Canada total energy use and 22% of its total GHG emissions" [4].

"Ventilations with stratified air distributions are commonly used to reduce building energy consumption while improving the indoor environment quality. Examples include displacement ventilation and hybrid ventilation. To optimize the design and control of these buildings' HVAC systems, a coupled simulation of the indoor environment and the HVAC system is need. In the past, coupled simulations between building energy simulation tools and computational fluid dynamics (CFD) were proposed to study the energy performance for buildings with stratified air distributions" [5] .

"Many heating, ventilation and air-conditioning (HVAC) design practitioners are already aware of building simulation technologies and its benefits in terms of environmental performance assessment of building designs. However, yet, few practitioners have expertise in using these technologies. This will quickly change due to the introduction of: performance based standards; societies such as the International Building Performance Simulation Association (IBPSA); and appropriate training and continuing education "[6].

"Simulation is a discipline, not a software package; it requires detailed formulation of the problem, careful translation or coding of the system logic into the simulation procedural language (regardless of the interface type), and thorough testing of the resulting model and results. There are at least two different skills required to be successful at simulation. The first skill required is the ability to understand a complex system and its interrelationships. The second skill required is the ability to translate this understanding into an appropriate logical representation recognized by the simulation software" [7]. In the past test camber used to study the air flow pattern , recently CFD simulation is widely use to get the idea about air flow pattern, temperature distribution , velocity profile and many other characteristics. Running the simulation is cost effective and less time-consuming compare with testing in test chamber for various indoor and outdoor environment conditions.

Experimental Setup:

An office room model prepared in SolidWorks. The internal dimension of the room is 6000 mm X 6000mm with 3000 mm height. Three-side wall considered as internal wall, heat transfer through these internal walls are negligible. The remaining wall is consider as outside wall. The outside wall also obtain a glass window the middle position. Fig-1(a) depicts an external view of the office room model with outside wall and glass window.

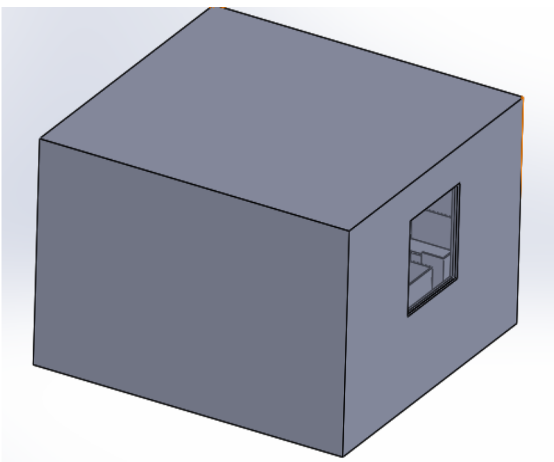

Fig-1(a): Office room model (external)

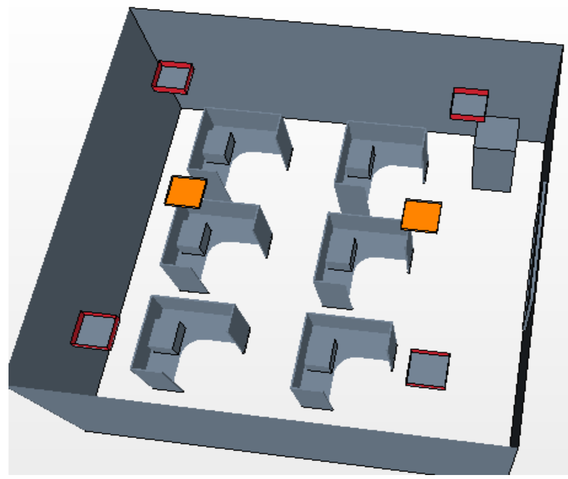

Fig-1(b): Office room model (internal)

Inside the office room model, there are six-office desk each equipped with a computer monitor fig-1(b). A refrigerator also placed in the corner of the room. All computers and refrigerator works as heat source. Four 300mm X 300 mm air supply diffuser are in four corner of the rooftop. These diffuser supply hot air during winter and cold air during summer due to control the inside room temperature. After air, circulating inside the room the temperature gradually changed. Then the hot or cold air depending on the winter or summer go out return grills places in the middle line of the roof.

CFD Study:

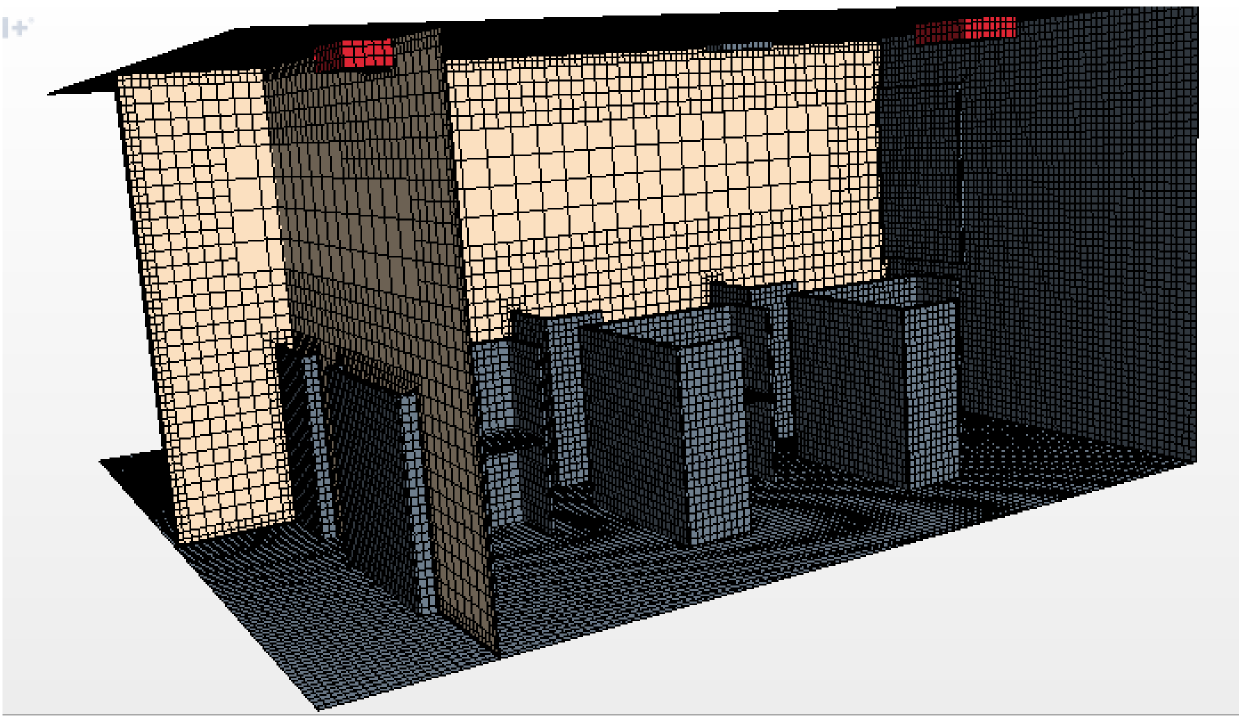

Fig-2: Volume mesh of the office room. No of cell: 916332

Physical Model Used:

Three-dimensional

Steady

SST K-Omega

K-Omega Turbulence

Reynolds Average Navier Stokes

Segregated Flow

Testing Parameter:

1. Air velocity 1.0, 0.9, and 0.8 m/s

2. Flow angle 30°,45°,60° (angle with vertical wall)
3. Inside temperature 60° F (Summer) , 80° F (winter)
4. Outside temperature 95° F (Summer) , 25° F (winter)

Results:

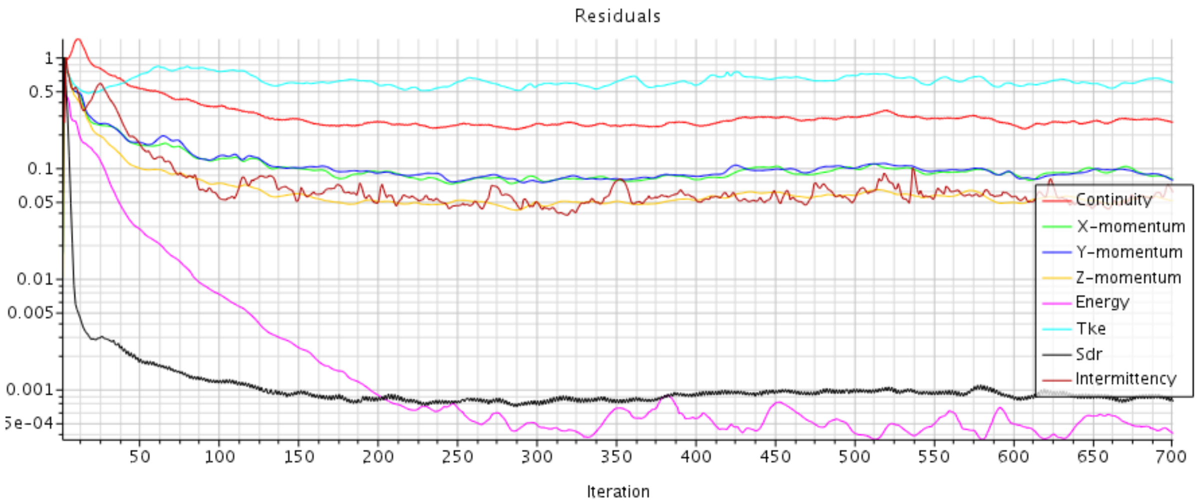

Fig-3: Residual for summer 0.9 m/s 30-degree angle 60 Fahrenheit Temperature

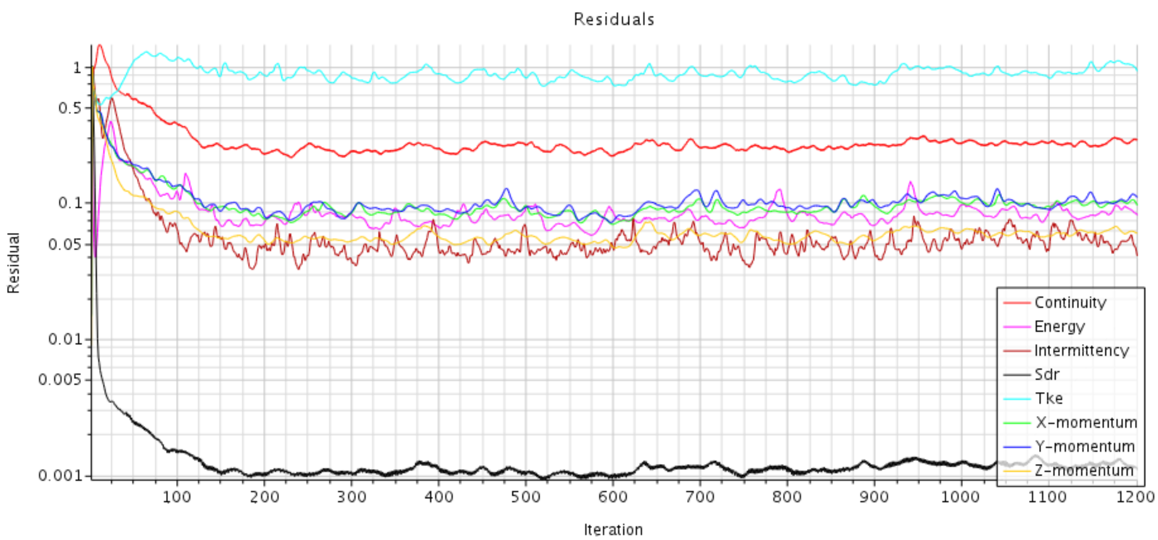

Fig-4: Residual for winter 1.0 m/s 30-degree angle 80° Fahrenheit Temperature

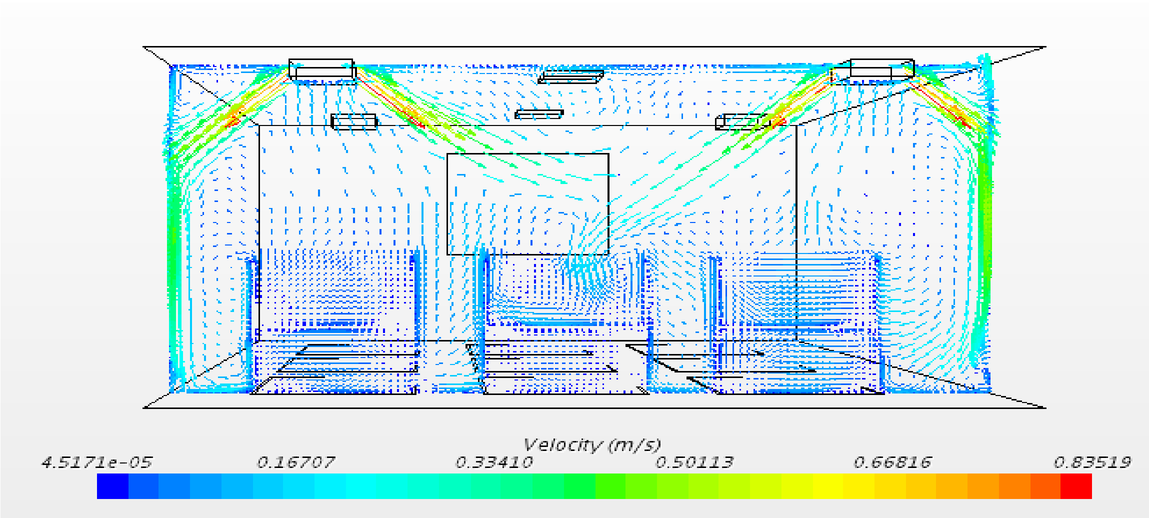

Fig-5: Velocity for summer 0.8 m/s 45-degree angle 60 Fahrenheit Temperature

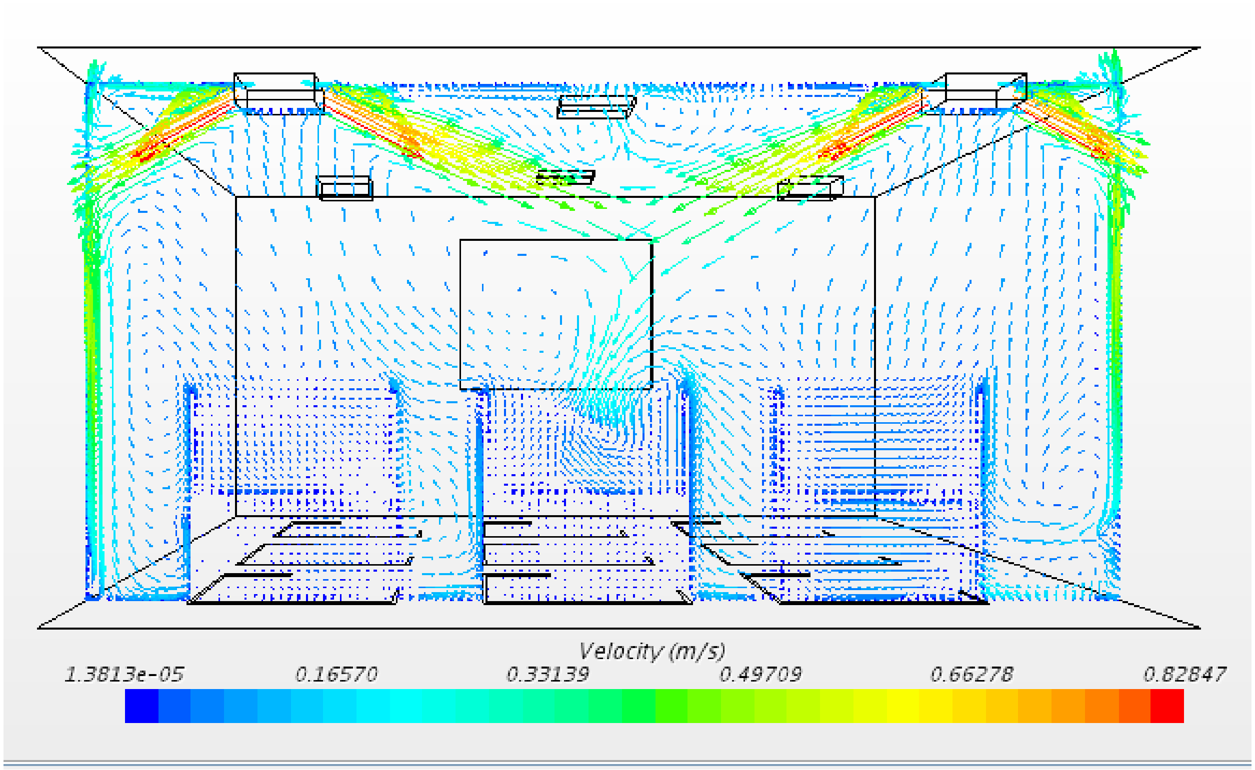

Fig-6: Velocity for summer 0.8 m/s 60-degree angle 60 Fahrenheit Temperature

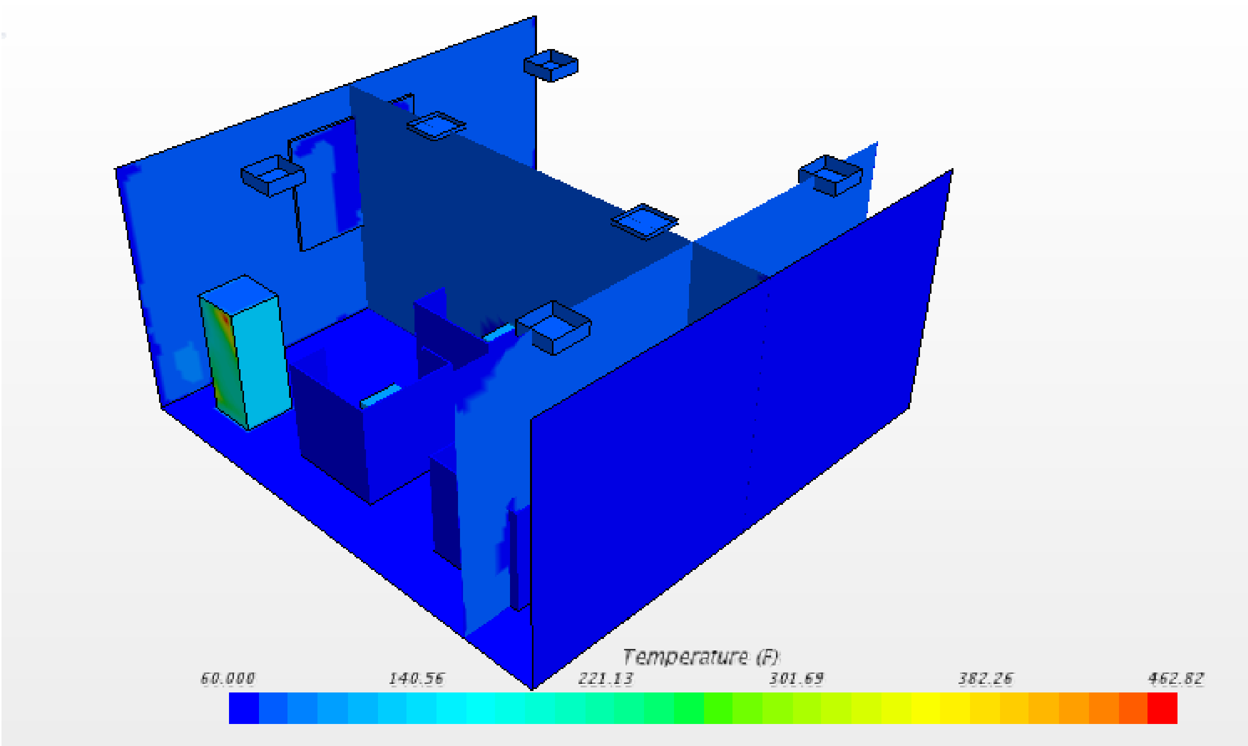

Fig-7: Temperature for winter 0.9 m/s 45-degree angle 80° Fahrenheit Temperature

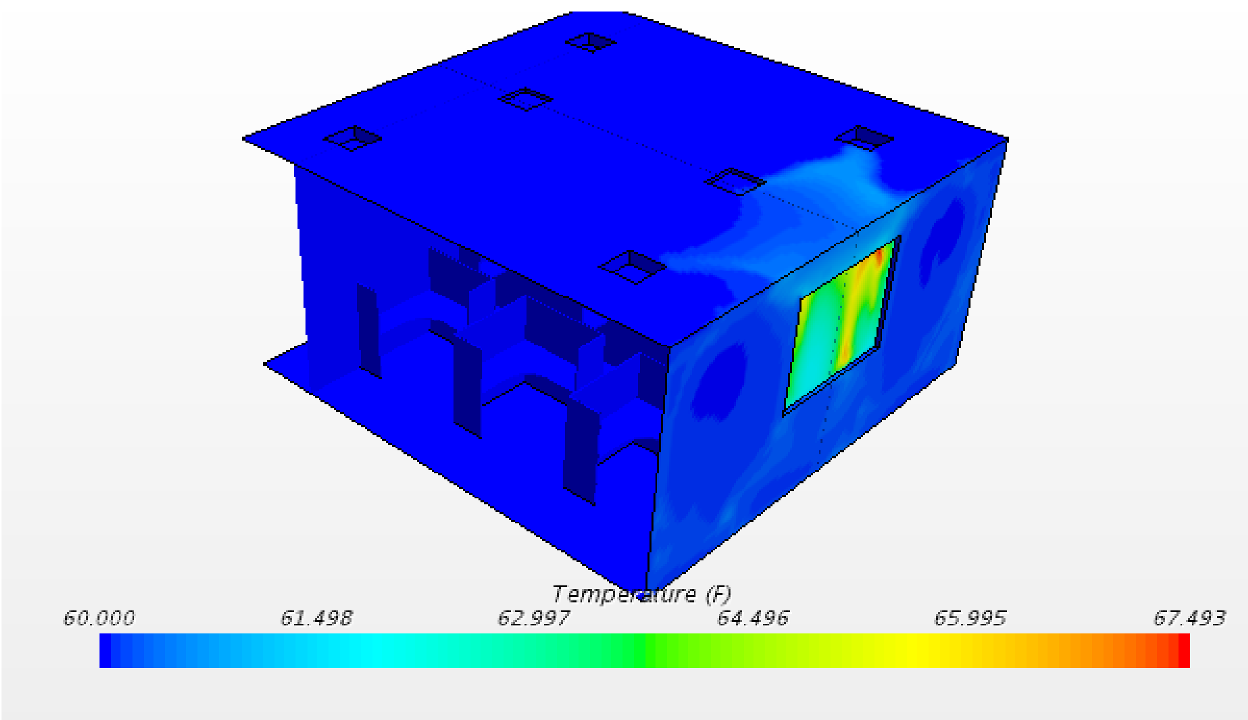

Fig-8: Temperature for summer 0.8 m/s 45-degree angle 60° Fahrenheit Temperature

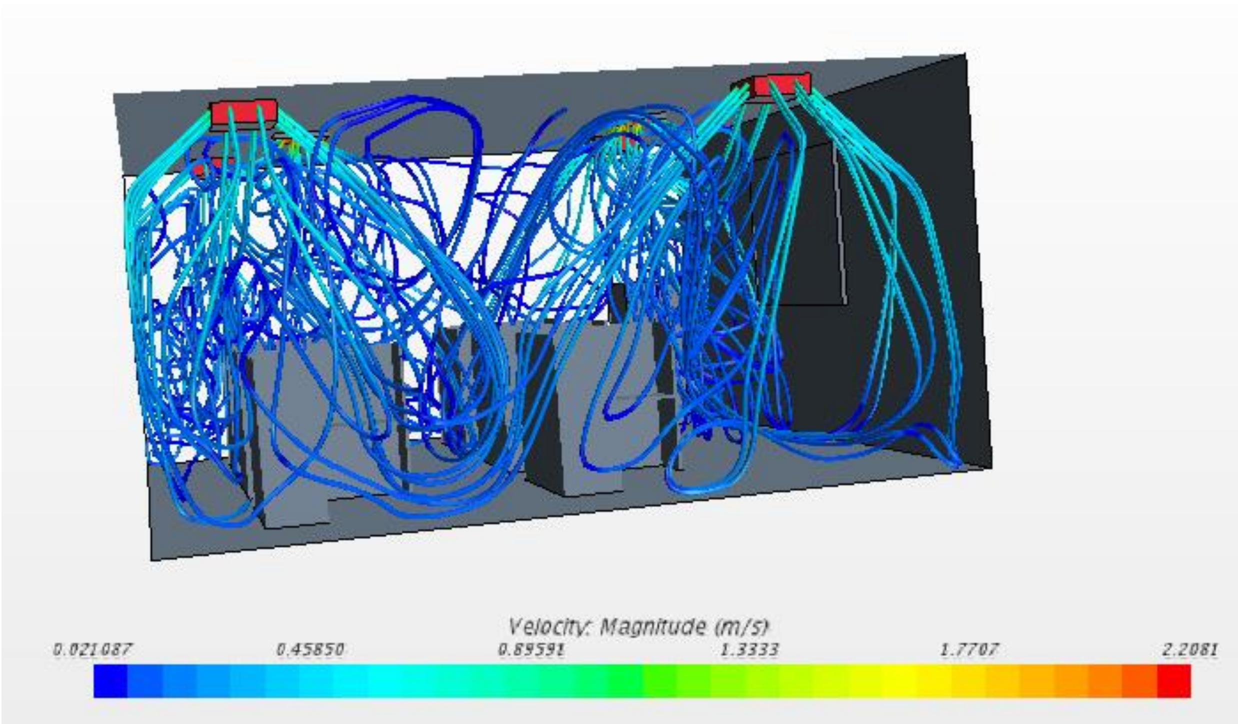

Fig-9: Streamline for winter 1.0 m/s 45-degree angle 80° Fahrenheit Temperature

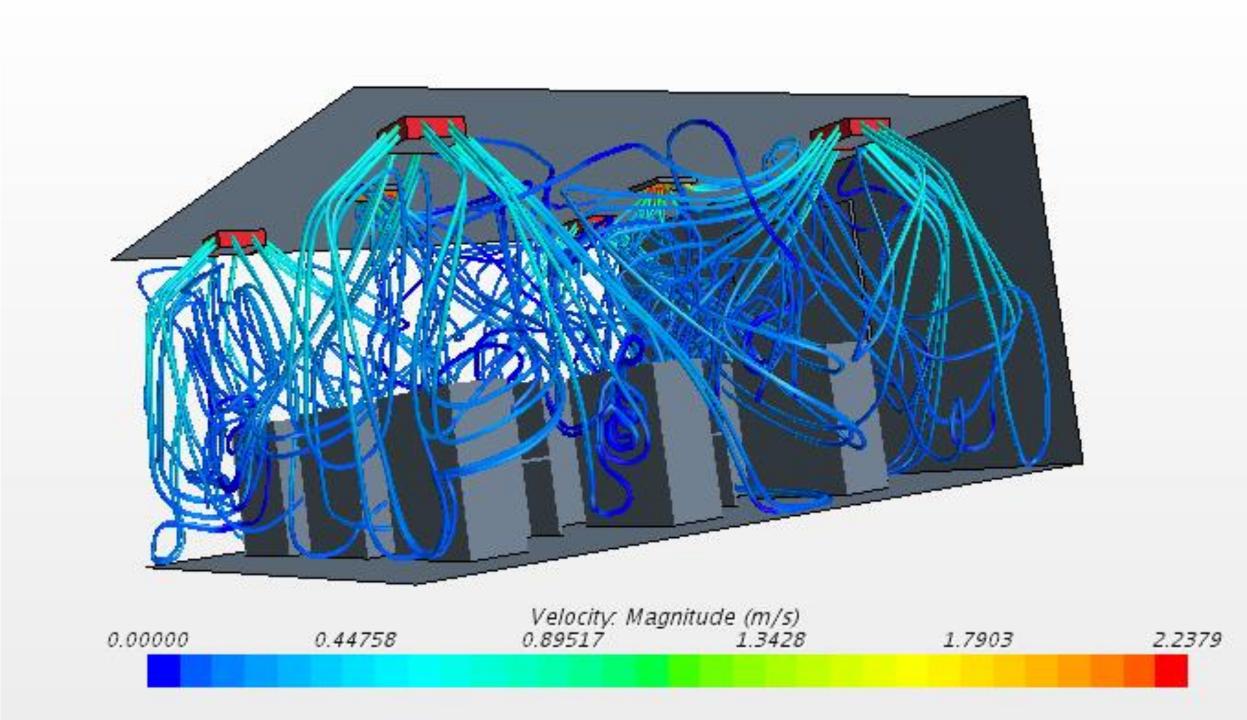

Fig-10: Streamline for summer 0.9 m/s 45-degree angle 60 Fahrenheit Temperature

Result Summary:

Table-1: Maximum temperature in the summer inside the room (°F)

Angle and Velocity	1 m/s	0.9 m/s	0.8 m/s
30°	587.43	474.55	443.39
45°	361.16	443.7	372.67
60°	365.5	385.85	680.5

Table-2: Maximum temperature in the winter inside the room (°F)

Angle and Velocity	1 m/s	0.9 m/s	0.8 m/s
30°	523.42	595.88	596.07
45°	383.74	462.82	433.66
60°	345.66	746.64	539.35

Discussion:

In case summer HVAC system maximum temperature found at 60 degree angle of attack and 0.8 m/s velocity and value of maximum temperature 680.5° F and the minimum temperature 361.16° found at 45 degree angle of attack and velocity 1 m/s. On the other hand in case winter HVAC system maximum temperature found at 60 degree angle of attack and 0.9 m/s velocity and value of maximum temperature 746.64° F and the minimum temperature 345.66° found at 60 degree angle of attack and velocity 1 m/s. In summer system, at 30° angle of attack temperature decreases as air velocity decreases but at 60° angle of attack temperature increases as air velocity decreases . At 45° angle of attack maximum temperature at 0.9 m/s, temperature decreases for both at 1 m/s and 0.8 m/s air velocity. In winter air conditioning system maximum temperature found at 0.9 m/s velocity at 45° and 60° angle of attack but at 30° angle of attack temperature increases as velocity decreases.

Conclusions:

1. In both case summer and winter maximum heat flow and heat, loss occurred through external wall window. Double glass vacuum windows may reduce the heat loss and that will save the heat loss.
2. Refrigerator placed inside the room works as a heat source that supply heat inside the room ambient and room temperature raises.
3. The further study, will be done by adding some other appliances and in presences of human occupancy consideration.

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