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Air Flow Analysis in a Room Circuated by a Ceiling Fan and Studying The Effects of Non-Uniform Velocity in The Room Generated By It.

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Abstract

Ceiling fans are a good way of achieving thermal comfort. It is cheap, and environment friendly unlike its rival air conditioner. It generates non-uniform velocity profiles which results in circulation of air in a room. The air circulated results in forced convection over the bodies in the room resulting in decrease of temperature of the body.

Keywords: Velocity, temperature,air-flow, enclosure, contours, visualization.

I. INTRODUCTION

The growing demand of the thermalcomfort providingappliances has seen a boom in past few years. The cheap and efficient ceiling fan is almost found in every household and also in public gathering places. It is responsible for circulating the air inside the room, concert halls, offices etc.

They circulate the air inside resulting in forced convection over the bodies with slightly higher temperature than the room temperature.Commercial or industrial ceiling fans usually used in offices, factories or industries are designed to be more cost effective and more energy efficient than other cooling alternatives.

Fig 1. shows schematic of ceiling fan.

The key components of a ceiling fan are the following:

- An electric motor.
- Blades (also known as paddles or wings) usually made from wood, plywood, iron, aluminum, MDF or plastic.
- Blade irons (also known as blade brackets, blade arms, blade holders, or flanges), which hold the blades and connect them to the motor.
- Flywheel, a metal or plastic or tough rubber double-torus which is attached to the motor shaft, and to which the blade irons may be attached. The flywheel inner ring is locked to the shaft by a lock-screw, and the blade irons to the outer ring by bolts thatfeed into tapped metal inserts. Rubber or plastic flywheels may become brittle and break, a common cause of fan failure.

II. USES

Unlike air conditioners, fans only move air—they do not directly change its temperature. Therefore, ceiling fans that have a mechanism for reversing the direction in which the blades push air (most commonly an electrical switch on the unit's switch housing, motor housing, or lower canopy) can help in both heating and cooling.

Some ceiling fans,are mechanically reversible (have adjustable blade pitch) instead of an electrically reversible motor. In this case, the blade should be pitched to the right (or left if the motor spins clockwise) for downdraft, and left (or right if the motor spins clockwise) for updraft. Hunter Hotel Original is one example. In very rare case, such as late 1984 Hunter Original, fans are both mechanically reversible and electrically reversible, in which case it can blow air up, or down, in either direction. Some ceiling fans can only blow air in one direction and are not reversible in any way, more often downdraft only, but rarely updraft only.

Figure 1: A ceiling Fan

For cooling, the fan's direction of rotation should be set so that air is blown downward (Usually counter-clockwise from beneath), unless in rare case in which more breeze would be felt when blowing upward, such as when it's installed in hallway where blades would be so close to the walls. The blades should lead with the upturned side as they spin. The breeze created by a ceiling fan speeds the evaporation of perspiration on human skin, which makes the body's natural cooling mechanism much more efficient. Since the fan works directly on the body, rather than by changing the temperature of the air, during the summer it is a waste of electricity to leave a ceiling fan on when no one is in a room unless there's air conditioning, open windows, or anything that can heat up the room (such as oven) and fan is just to move air around.

For heating, ceiling fans should usually be set to turn the opposite direction (usually clockwise; the blades should spin with the downward turned side leading) and on a low speed (or the lowest speed the fan is able to circulate the air down to the floor). Air naturally stratifies—that is, warmer air rises to the ceiling while cooler air sinks. Unfortunately, this means it is colder on or near the floor where human beings spend most of their time. A ceiling fan, with its direction of rotation set so that air is drawn upward, pulls up the colder air below, forcing the warmer air nearer the ceiling to move down to take its place, without blowing a stream of air directly at the occupants of the room. This action works to even out the temperature in the room, making it cooler nearer the ceiling, but warmer nearer the floor. Thus, the thermostat in the area can be set a few degrees lower to save energy, while maintaining the same level of comfort. It is important to run the fan at a low speed (or a lowest speed the fan is able to circulate the air down

5to the floor) to minimize the wind chill effect described above. However, if the ceiling is high enough, or the lowest speed downdraft would not create wind chill effect, it can be left on downdraft year around.

An additional use of ceiling fans is coupling them with anair conditioning unit. Through-the-wall/through-thewindow air conditioning units typically found in rented properties in North America usually have both the tasks of cooling the air inside the room and circulating it. Provided the ceiling fan is properly sized for the room in which it is operating, its efficiency of moving air far exceeds that of an air conditioning unit, therefore, for peak efficiency, the air conditioner should be set to a low fan setting and the ceiling fan should be used to circulate the air.

III. Simulation Setup

The environment is simulated in Ansys Fluent. A room of 4m x 4m x 3m is made which holds the fluid i.e the air, shown in Fig. 2. A fan is attached in centre of the ceiling with the rotating unit being 0.2m from the ceiling. The rotating blades of the fan are given a domain as shownin the Fig. 3

- Properties of surrounding Air

1.Density(ρ)= 1.225 kg/m^3
2.Temperature(T_1) =300K
3.specific heat(C_p)=1.006 kJ/Kg.K

4.Conductivity(k) =0.0225W/m.K

- Properties of Body subjected to the analysis

1.Density=985 kg/m^3
2.Temperature= 310K
3.Specific heat=3.8 kJ/Kg.K
4.Conductivity=1.6 W/m.K
5.Heat generation=92 W/m^3

The properties provided for the body subjected to the analysis resembles human body. In this analysis relations regarding temperature changes occurring in the enclosure(room) with rotational motion/circulation provided to the air in the room. A fan is attached at the centre of the ceiling and is given rotational velocity of 31.42 rad/sec.

A cylindrical body resembling human body is kept inside the room. The body is at 310 K. The human body gives away heat which goes to the surrounding air. The air acts as a sink as the volume is very large as compared to the volume of body. The heat given out by the body does not bring any significant change in the room temperature.

$$\rho\frac{Dk}{Dt}=\tau_{ij}\frac{\partial\bar{u}_i}{\partial x_j}-\rho\beta^* f_{\beta^*} k\omega+\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial k}{\partial x_j}\right]$$

$$\mu_t=\alpha^*\rho\frac{k}{\omega}$$

$$\rho\frac{D\omega}{Dt}=\alpha\frac{\omega}{k}\tau_{ij}\frac{\partial\bar{u}_i}{\partial x_j}-\rho\beta f_\beta\omega^2+\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_\omega}\right)\frac{\partial\omega}{\partial x_j}\right]$$

For this particular case we have used k-ω turbulence model. The equation is given as follows:

Where,
ρ = density of air
k = turbulent kinetic energy,
μ_t = turbulent viscosity,
ω = angular velocity induced in surrounding air,
τ_{ij} = Reynold's stress,
u_i= velocity component in x-direction,
f_β= friction factor,
α = thermal diffusivity.

IV. Procedure for Ansys Fluent.

Modelling fan in Solidworks.Modelling a cylinder (resembling human body) and the surrounding fluid in AnsysDesign Modeler of Fluent.Specifying the material for each geometry from the material library.

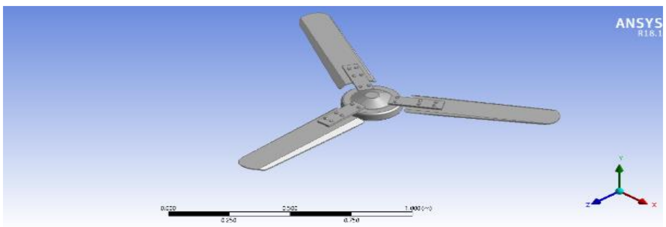

Figure: 2 Fan

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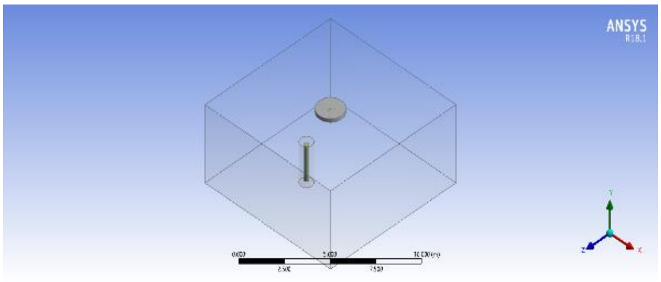

Figure 3: Model of enclosure (room)

- Meshing the geometry according to its shape and structure

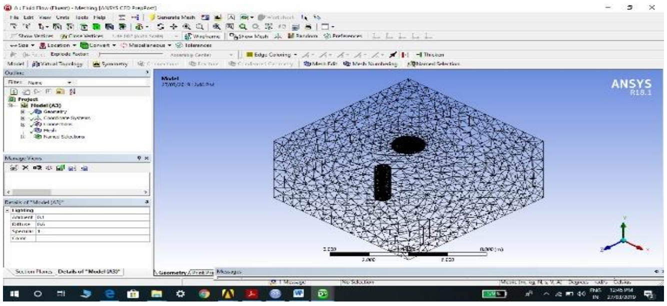

Figure 4: Mesh Modeler

- Setting up the geometry i.e providing the conditions in CFD-Pre- processing.

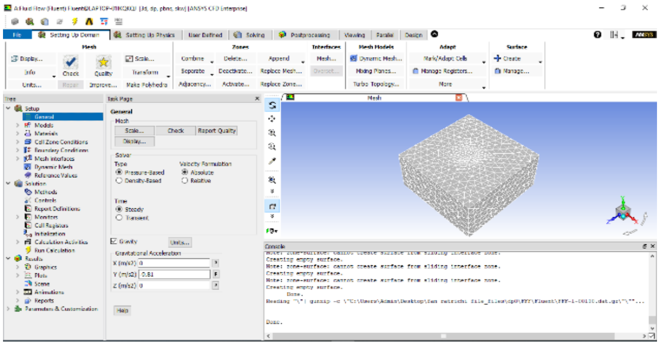

Figure 5: Setup module

- Acquiring required solutions from Result module.

V. Results

Following results are obtained for this particular analysis.

a) Fig.6 shows flow pattern across the room.

b) As shown in figure 8. Velocity contour across the enclosure is visualized.

Velocity	Min.	Max.
m/s	0	24.99

c) As shown in Fig. 9 We can see the temperature contour across the enclosure.

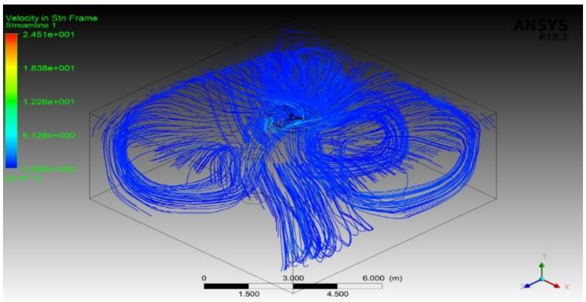

Figure 6: Flow Pattern in the room

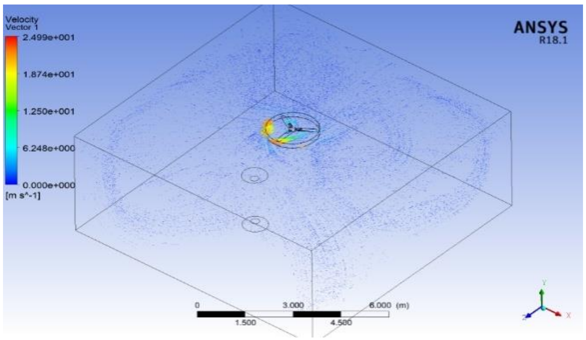

Figure 7: Volume Rendering of Velocity profile

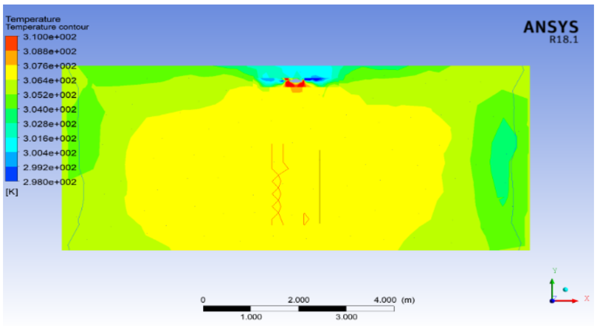

Figure 8: Velocity Contour

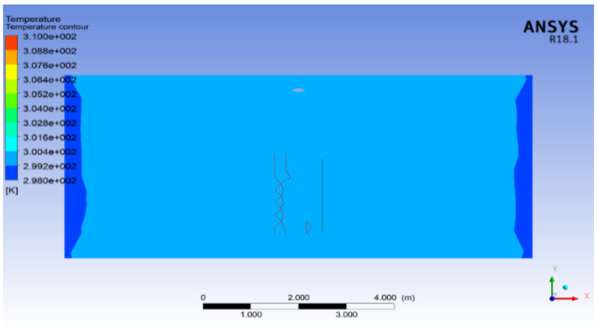

Figure 9: Temperature Contour

VI. Conclusion

a) In this analysis the flow pattern of air is distributed across the room non-uniformly. The velocity of air at the boundary of the enclosure is reduced as shown in Fig. 8.

b) The heat generated by the body is not sufficient to raise the temperature of the air surrounding it. Hence, the air acts as a sink and the temperature gradient is negligible.

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