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Design and Analysis of Clothes Dryer

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Abstract

This project is to study the clothes dryer machine by using heat and air. There are many cabinet dryer is widely used today as an alternative to natural clothes drying, especially for those who are busy working from morning until evening, having limited time and for the residents in urban areas. Now a day's cabinet dryer already offered in the market, but its use electrical power as a heat. Therefore in this project, using less heat and axial fan waste will be used as an alternative to electrical heat source. The objective of the project is to design and analyze cloth drying machine by using heat and axial fan and to analyze performance of the drying machine. The heat is taken from heater and use the axial fan as a drying effect. Detail drawing will developed from all concepts. In this project, Pugh Concept has been used to make evaluation of all concepts to decide final concept for further development. In order to obtain a good performance for the chosen concept, performance of drying machine using the concept has been analyzed in air flow simulation using Computational Fluid Dynamic analysis by using ansys Flow Simulation. The result was tested and compared with outdoor natural drying and heater. The result from experiments shows that the maximum drying rate is from the heat utilizing from axial fan. While the result from the simulation shows that the chosen as the better performance in the simulation of the distribution of heat and also for the airflow of temperature and velocity. The final design will considered with all the criteria needed. Therefore, utilizing heat and axial fan flow can be used as one of the sustainable energy resources. Anyway, future effort is required to improve the concept and to provide verification using more experimental data example like to improve the simulation by simulating the design with the cloth hanging inside the cabinet to get accurate data for better design.

Keywords:*Aerodynamic heating, Base heating, models, energy, CFD, Numerical simulation.*

1. Introduction

Formerly, drying clothes normally use natural way by using the sun of light energy and the natural wind, but now a days the technology is generously developed upward and the clothes dryers that use the waste heat energy or electric energy and other energy come to use extensively, especially in the urban or area where limited sunlight due to high building and restricted air flow for house types such as high rise condominiums and apartments, natural drying is prohibited in some housing areas for aesthetic reasons and conventional domestic electric dryers are too expensive and inefficient. Decreasing energy losses and heat recovery are important research topics, nowadays. Many cabinet dryers widely use, especially those who are busy working. Besides that, most of laundries today have their own dryer cabinet. It is not just because to run their operation at all the time, but they also can prevent the risk to the cloths that might lose or dirty. Cabinet dryer on the market nowadays is using electrical power as a source in generating heat. The other alternative of heat source that can be used for drying machine is axial fan and less amount of heat. Heat resources may include chillers, heat pumps, steam condensate lines, hot air associated with kitchen exhaust and laundry facilities, power-generation two equipment (such as micro turbines or fuel cells, and waste water drain lines. There are two basic needs for heat 1) Heat waste demand must be great enough to sustain equipment and maintenance costs. 2) The heat waste temperature must be high sufficient to serve as a useful heat source. Large facilities such as military, Industrial and hospitals often have the perfect mix of heat waste and demand for clothes dryer to mostly use heat waste recovery for clothes dryers. Also large quantities of hot flues are generated from boilers, kilns, oven and furnaces.The numerical finite volume method is used to interpret the equations and to construct a numerical mode of different of dryer.

2. Analytical Solutions

2.1 Basic Concept

A clothes cabinet dryer or tumble dryer is house appliances that are used to take away the moisture from a remove the load of clothing, generally after they are removing dirt in a washing machine. One of the cheapest and simple means of drying clothes using the no appliance Synthetic clothes line and clothes pins cost hardly high. Using the heat of the sun and drying power of gentle wind, clothes lines are making a comeback in many big places or not used place. Some homeowners associations and cities, however, have local convenient, codes and restrictions that restrict the use of clotheslines in planning communities. Woodford (Woodford, 2010) had investigated the process cloths dry [1].

The process is evaporation which removing the liquid water in clothes into a vapor and getting purge of it. In the washing machine usually for simplest and short setting with only a half load of washing, the water used is about 20 liters. Most of that water is spin or remove out the water at high speed and then evacuated away, but even the most efficient energy machines leaves a significant amount of wetness gnawing in clothes. The easiest way to form energy to dry wet clothes is to warmth it up. The molecules of liquid are effective and more closely bind together, move more and more slowly, have less energy than the molecules in a gas. So it needs to put a small amount of energy to make the liquid molecules shatter apart, remove from the big amount of the liquid and form a vapor [5].

Figure 1 called as a phase diagram which is a best way of indicating that how a particular substance form will be a solid, liquid or gas depending on the temperature and pressure. At high temperatures, the water is going to be gassed (steam) unless the pressure is high. At low temperatures, the water is generally going form ice, unless the pressure is low. So from Figure 1, the solid ice can be heated to make it become a water vapor (gas).

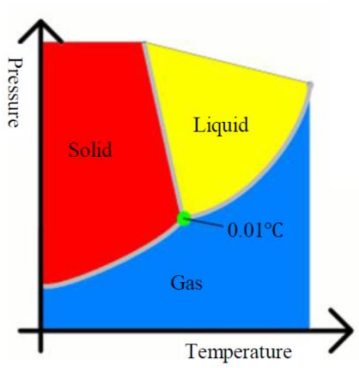


Fig.1 Phase Diagram

Another investigation by Woodford is about the transpiration. The transpiration is when the plants lose the water by the wind blows. For example, when wind flows past trees, the water vaporizes from their leaves and turns into cool water vapor that dissolve in the air. In clothes drying, blowing air past wet objects mean the water will vaporize more quickly and can make the water completely removed from the air around it.

So there are three items favoring the evaporation of water from wetted clothes;

- High temperatures Condition- to increase the number of molecules that can create from liquid to vapor.
- Low humidity Condition- to make the evaporation continue manner and water molecules is not reverting to clothes from the air.
- Air Flow condition - to carry water away and prevent the air near clothes from becoming soaking with vapor.

Moreover for now, there are two types of clothes dryer machine prototype. First, heated wave's clothes dryers which work on the same concepts as a microwave oven. Instead of passing less amount of heat air over the clothes, microwaves directly remove all warm water present in the laundry phase. Microwave clothes dryer devices use about 20 to 25 % less efficient energy and dry clothes devices about 30 % faster than conventional drum or electric air dryers. To avoid the electric problems with metal things, tested prototypes switch to electric resistance heaters when the clothes are nearly dry [6].

Design and analyze the clothes dryer machine using heat waste normally include an exploration on starting and growing a study about the clothes dryer machine and heat waste. The elements that need to be considered are evaluating heat waste, and developing new products and parcel of most designs and analyze clothes dryer machine. The design must be considerate on the economic, ergonomic and environmentally friendly. There are also must be energy efficient and less power consumption [8].

*2.2*Performance parameters

As mentioned above, in the experiments the temperatures, weights, and air velocity in the drying cabinet will be read and recorded by a data acquisition unit. The voltage, electric current, and pressure of the air conditioner will be measured. These measured parameters will be used to analyze performance parameters. The performance parameters used in this study are explained as follows. Non-dimensional wetting moisture ratio (MR) will be used to compare the cabinet or drum drying characteristics. It is calculated using the following equation.

$$MR = m_t - m_e / m_i - m_e$$

Where m_t,m_i, and $m_e$is the mass of the clothes dried at measured time, at initial time, and at equilibrium respectively. The moisture content X [kg/kg db] of the clothes dried is calculated by,

$$X = m_t / m_e$$

The drying rate m[kg/h or g/min] of the clothes dried is calculated by the following equation:

$$m = m_t - m_{t-1} / \Delta t$$

Where Δtis interval measurement in h or min. In the present air-conditioner unit, a vapor compression cycle is utilized as refrigeration cycle. In the cycle, the heat in evaporator (Qe) is drawn from the conditioned space by using compressor power (Wc). The total energy from the cycle will be rejected in condenser (Qcond) and calculated by,

$$Q_{cond} = Q_e + W_c$$

In this study, parameter of performance of specific moisture extraction rate (SMER) will be used. This parameter is defined as number of moisture removed from the clothes divided by energy consumed. Here, the energy used for removing the moist from clothes consists of heat release from condenser and energy to power the auxiliary fan. Since the heat released from condenser is the waste heat, it is considered as free energy. Thus, SMER [kg/kW h] will be calculated using the following equation:

$$SMER = \Delta m_d / P_{fan} \times \Delta_t$$

Dryer efficiency is defined as the ratio of heat of vaporization of water in the dryer load versus the totalelectrical energy used during the drying cycle.

Efficiency of dryer = Heat of vaporization/ Electrical energy

*2.3*Calculations for air outlet conditions

Initial assumptions:

- V = 6 m/s
- Diameter of blower outlet = 200 mm
- Moisture removal rate = 10 kg/hr

Inputs:

- Mass flow rate (air) = 0.226 kg/s
- Inlet Temp after Heater (DBT) = 60° C
- RH at inlet = 14 %
- Specific Humidity at inlet = 0.017 kg/kg of dry air

Solution:

Moisture added to air

$$\text{Moisture added to air} = m_w / m_a$$
$$= 0.0125 \text{ kg /kg dry air}$$

Air outlet Conditions

$$\text{Moisture content at outlet} = 0.017 + 0.0125$$
$$= 0.0295 \text{ kg / kg dry air}$$

From Psychometric Chart,

At Outlet:

- DBT = 38°C
- RH = 65 %
- DPT =30°C
- Specific Humidity = 0.0295 kg/ kg dry air

2.4 Dryer Characteristics

TheInternational Electro-technical Commission (IEC) test is method for clothes dryer energy consumption. It's requires clothes dryers to be tested to their asserted the capacity by weight using a cotton laundry load and mixed synthetic cotton load. In other words, the dryer cabinet is tested with an IEC test load that weighs as much as the manufacturer hold the dryer cabinet is capable of drying in one load capacity. If the manufacturer company does not create a capacity claim, the IEC test method provides a formula based on cabinet volume for calculating the weight of the cloths that make up a dryer capacity load (see the sloped lines in Figure 3). As the calculation result, Cabinet dryers with the same cabinet volume are commonly tested with different weights of calculated cloth.
North American manufacturers or Indian company usually rate dryers by drum volume and cabinet volume in cubic feet, without any allusion to capacity by weight. Dryer drum or Cabinet dryer test procedure needs dryers to be tested at either a low type volume of fixed weight of 50/50 synthetic/cotton cloths for "Pressed" volume cabinet dryers, or a higher steady weight of 50/50 synthetic/cotton cloths for "standard" volume dryer (shown as the flat, stepped lines in shown Figure 3). As a analytical result, cabinet or drum dryers with different volumes are usually tested with the same total weight of tested cloths.[4]

Figure 2shows that, same type of clothes cotton weight capacities of the heat dryers that is tested vary with the calculated volumes of each. It is also indicates that same type as above mentioned the clothes volume capacities of the conventional tumbler dryers that were tested vary for the given test weight that has been specified. "HP" indicates that heat pump dryer or tumble dryer and "Conventional" indicate a conventional electric dryer.

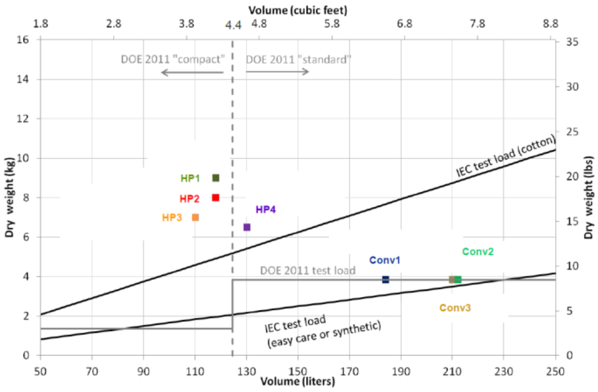


Fig.2 Drying characteristic graph

Dryers reveals that, flammable materials to heat the clothes.Laboratories suggested that, cleaning the dash or lint filter after each cycle for energy efficiency and safety, provision of sufficient ventilation, and preventative the maintains on time at regular intervals. Laboratories also suggested that, dryers not be used for glass fiber, rubber, foam or plastic items, or any item that more flammable substance overturn on it.

3. Designs and Simulation of Cabinet

3.1 Theoretical Calculation

There were four main objectives that the theoretical calculations accomplished: functionality during different seasons, fan size, and condensation (duct sweating). Functionality during different seasons, including harsher conditions in India, key to the design norm of trust; we want our clothes dryer to perform well, even under adverse weather conditions. There are four simulations types to be considered for a season like as summer case, winter case, a Monsoon case. Each simulation elaborated the calculations of Velocity of air, mass flow rates, temperature of the air coming out of the cabinet of dryer chamber, wetted material temperature, incoming velocity of air, and absolute humidity of the velocity air flowing in and out of the dryer chamber. Fig 4 shows that the control volume used for analyzing this system [6].

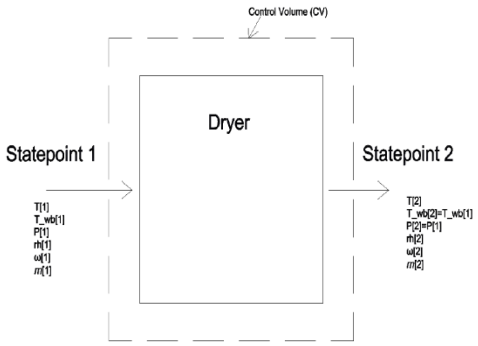
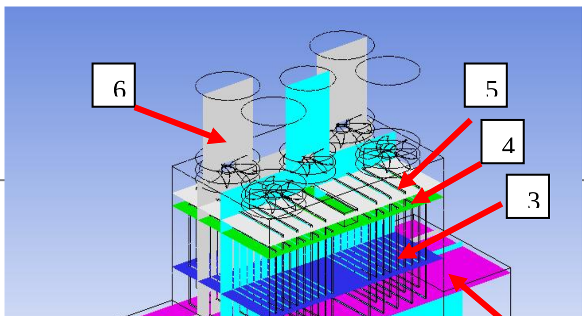


Fig.3 Control Volume and State points for Dryer

3.2 Simulation Inputs

The numerical finite volume method is used to interpret the equations and to construct a numerical model dependent on an unstructured 3D mesh by partial tetrahedral cells. The geometrical layout is like fig. 4 in which control volume and state point for dryer. The design of air stream in the drying chamber is vital role in simulation and since there is no variable condition in this study of simulation, It is carried out in steady state condition. The plane 1 was indicated that (Fig. 4) to learning and analysis the velocity, temperature in the drying cabinet. Plane 1 is situated in below of four axial fans, which considered as the strong zone of air flow and compared to others areas in the drying cabinet.



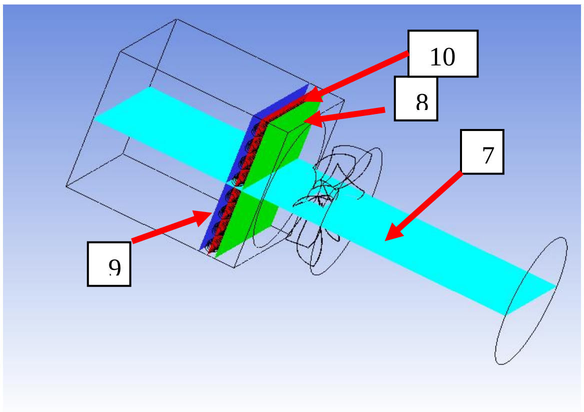


Fig.4 Geometry setup of Model

The set-up of boundary conditions and geometry setup is defined as followings:

- Inlet 1: Let us consider first air mass flow rate 0.5843 kg/s (velocity required for drying clothes of 3 m/s to air inlet) and temperature of air in cabinet required till 7^{0}C.
- Inlet 2: Second mass of air flow rate 0.29215 kg/s (half of the inlet1 and keep same velocity 3 m/s) and air temperature of 65oC.
- Outlets Conditions: Let's assume the gauge pressure =0 at the outlet side.
- Porous media Condition: Trolley cabinet and material consider as porous media with 10% porosity.
- Wall: Heat transfer coefficient of the trolley Cabinet and closed wall surrounding weather temperature condition defined at 33^{o}C. Temperature at the top side of roof is 55^0 C (contact to the heat source from heater coil). No heat loss is assumed at bottom surfaces. Only half of the drying cabinet is analyzed since the shape is considered the same on both sides by defining the symmetry surface to the mid portion of the boundary.

3.3 Geometry setup

The results were obtained after carrying out simulations on several concepts and configurations varying the boundary conditions for the same concept and also changing their geometry so as to obtain to suitable for theirconfiguration. Planes have been taken at different places to record, study and interpret the physical phenomena occurring at different points within the machine. The 2 outlets provided at the adjacent sides have a length which is 5 times their hydraulic diameter. This typically allows the instabilities of the solution to settle down and prevents incorrect results.Figures 1 and 2 indicate different planes on which the results of the pressure, velocity and temperature contours have been plotted. Figure 1 indicates the actual drier model with 5 fans on the top surface and 2 bottom cut-outs. Figure 2 indicates the heater and the duct assembly with the fan just placed after the heater.

Table 1 Position of planes

Table 1 indicates the planes along with their position in the actual 3d model as well as the final working machine

*3.4*Case setup - Boundary conditions

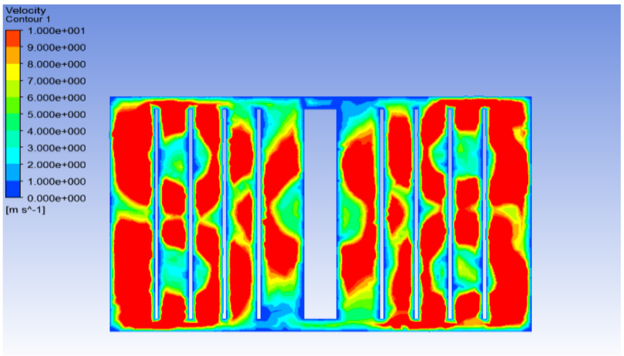
The problem is initialized at atmospheric pressure or zero gauge pressure to simulate the actual conditions of the surroundings. The fans were given different rotational speeds with the central fan spinning at a lower rpm as compared to the other fans. Therefore a required pressure difference at the suction and the discharge was obtained in order to propel the air into the machine and overcome the pressure drop of the heater coils as well as of the clothes inside the machine. The 4 fans located at the corners were rotated by a speed of 1500rpm and the central fan was rotated at 1000rpm in the clockwise direction. For the heater duct the smaller fan was rotated with a speed of 1000rpm in the clockwise direction and the similar conditions of atm. pressure at the inlet and outlet were applied. The additional input here was the temperature. An ambient temperature of 300K was applied at the inlet and the heater coil surface was kept at a temperature of 673K.

Sr. No.	Plane Number	Position
1	1	Center of the cabinet
2	2	470 mm from the bottom surface
3	3	230 mm from plane 2
4	4	365 mm from plane 3
5	5	75 mm from plane 4
6	6	212.5mm from plane 1
7	7	Center of the heater duct
8	8	25mm on the rhs of plane 9
9	9	25mm on the lhs of plane 9
10	10	Center of the heater coils

3.5 Case Setup - Cell zone conditions

Moving reference plane indicates a frame of reference wherein the observer is placed at the hub of the fan and tends to rotate with the speed of the fan. This is different from the condition wherein the observer is observing the fan from the outside which is a case of dynamic mesh. Since there is no relative motion between the observer and the fan the fan does not seem to rotate in the actual case setup.

3.6 Interpretation of results



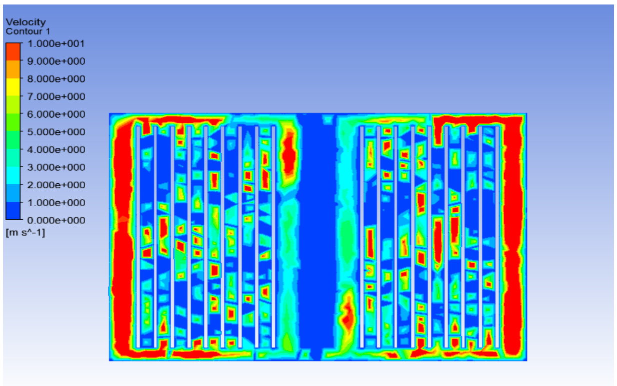


Fig.5 Velocity Contour at Plane 4 and Plane 5

Figure 5 indicates plane no 5 which is 50mm below the fans. It is observed that the red circular patches below the fan indicate the regions below the blades where the air is thrown with a higher velocity. There is no velocity at the hub or the central region of the fan. It is seen that most of the cabinet is covered by the fans and the air spreads out more or less evenly throughout the chamber.

Figure 5 indicates plane no 4. It is seen that there is no air in the central portion of the cabinet just below the C channel to support the trolleys. This is because the smaller fan throws air right on top of the channel. Also the air has higher velocity values at the peripheries where there is a larger gap between the clothes and the wall of the cabinet. The average value of velocity on the clothes is 5m/s thought it is not uniform in all the gaps.

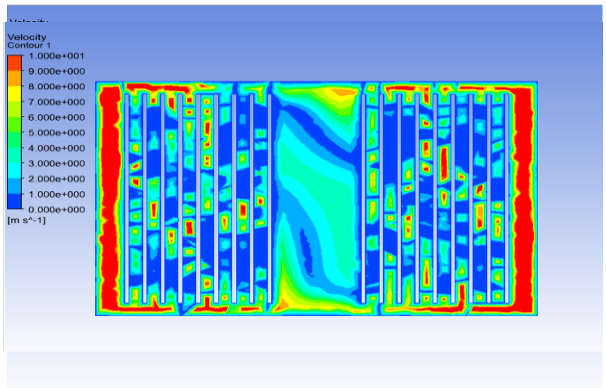


Fig.6 Velocity Contour at Plane 3 and Plane 2

Figure 6 indicates plane no 3. The velocity distribution is more or less similar to that of the previous figure. This indicates that there is not a larger velocity drop across the height of the cabinet. The velocity values tend to increase in the region below the c channel. The air streams regain momentum and tend to converge in the lower portion of the cabinet.

Figure 6 indicates plane no 2. The air has a higher concentration towards the outlet peripheries. At the outlets there is a localized pressure difference which forces the outside air to come inside the cabinet and increase the overall recirculation of air inside the chamber. Thus the velocity values are higher as compared to the previous planes. The average velocity is 7m/s at the bottom.

Figure 7 indicates plane no 1. In this plane the central fan which is smaller in diameter is seen. The velocity distribution remains more or less uniform throughout the area of the cabinet. The red patches in the middle indicate that that there are small eddies which may be formed in between the clothes. There is no motion that is transferred to the clothes due to the air flow as in case of fluid structure interaction. The air has a higher velocity as observed initially in the left and right hand side margins because of a higher gap there.

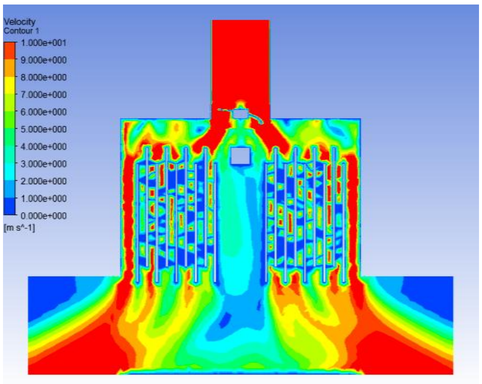


Fig.7 Velocity Contour at Plane 1

Figure 8 indicates plane no 6. A more or less similar velocity distribution is observed here. Only the difference being that the air stagnates to a greater extent in between the clothes. The results indicate that if the gap at the 2 sides is reduced then it will help in shifting the momentum of air towards the center and therefore more air will be able to flow from between the clothes.

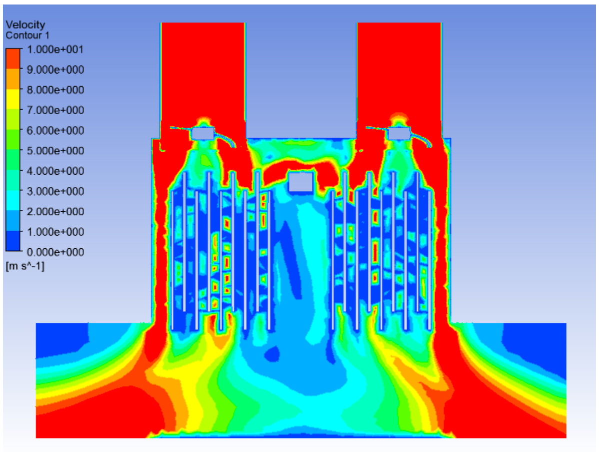


Fig.8 Velocity Contour at Plane 6

Figure 9 indicates plane no 7. It represents the contours of static temperature. As observed there is a significant rise in the temperature of air near the heater coils. The temperature rise is about 10^0 C. This temperature goes on dropping along the length of the cabinet due to the momentum of the air inside the duct. A higher mass flow of air facilitates forhigher heat transfer and causes a greater loss in the enthalpy. Therefore a net temperature rise of 6^0 C to 7^0 C Celsius is obtained inside the duct. To keep the rate of mass flow air is lower so that air can retain more amount of heat the fan is rotated at a lower speed.

Figure 10 indicates plane no 7 representing the velocity contours. The velocity of air rises drastically after the heater coils as per the Bernoulli's principle.

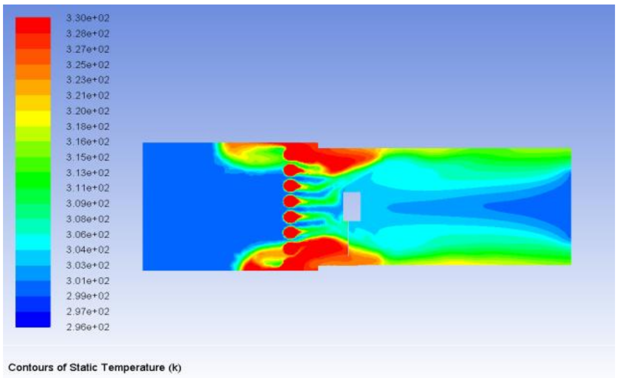


Fig.9 Static Temperature at Plane 7

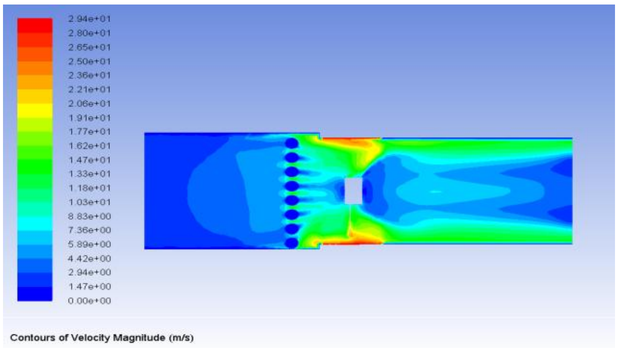


Fig.10 Velocity Contour at Plane 7

There is a wake region produced throughout the duct just below the hub of the fan. The air tends to stick to the boundaries of the duct as expected. This also is partly due to the conical spread of the fan and the blade geometry. Simulation result and summary as per below.

1) Side outlets provide good air flow distribution.
2) Temperature rise of 7 to 10º C is obtained.
3) Using 5 fans instead of 2 bigger fans improves the distribution and reduces the static pressure.
4) Optimum Distance of 150 mm between the Fan and Clothes.
5) Optimum Distance of 150 mm between the heater and the fan.

Conclusion

Design and analysis is carried out to show that the ventilation is essential for drying process wherein the heating at ambient temperature is help to greatly accelerate the cloth drying process. In this process, drying clothes is mostly used in monsoon season and in that season more humidity in the ambient air. Due to humidity in the air, required sufficient heat and air for dry the clothes. On simulation results, side outlets provide good air flow distribution and temperature should be 7^0C - 10^0C for dry the clothes for few minutes then air flow distribution to dry the clothes.

During the design of cabinet, that should be optimum design of 1500 between fan and clothes and Fan distance required optimum distance 150mm. The result from experiments shows that the maximum drying rate is from the heat utilizing from axial fan. Result from the simulation shows that the chosen as the better performance in the simulation of the distribution of heat and also for the airflow of temperature and velocity. Therefore, utilizing heat and axial fan flow can be used as one of the sustainable energy resources.

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