CFD SIMULATION FOR TRAY DRYER OPTIMIZATION

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Abstract – The paper presents the design and analysis of tray dryer system. The design was done in Solidwork while the analysis and simulation performed using ANSYS FLUENT. ANSYS FLUENT is a Computational Fluid Dynamic (CFD) software in which flow fields and other physics are calculated in detail for various engineering applications. The analysis was done to analyze heat transfer and temperature distribution, pressure, air flow and turbulence. Before generating the product in 3D modeling, the basic data or information of tray dryer system is required such as dimension of dryer equipment, air and heat source supply range, sizing method and etc. Through this step, the dryer system development and function ability can be clearly understood by the end of analyzing process is accomplished.

Keywords – , *CFD, Tray Dryer, Heat Transfer.*

1.0 INTRODUCTION

Tray dryer is an equipment or machine to dry up products which is very useful in small industrial sector such as food industry or chemical industry. Commonly, a dryer system consists some form air heater and a fan to pass air over the product to reduce moisture or evaporate the moisture into vapor condition. The drying temperature is set around 30 degree Celsius to 80 degree Celsius or above. The air enters the bottom of the chamber below the trays and then rises, through the trays of product being dried, and exits through the ducting system or opening in the top of chamber. Besides that, this system also reduces back pressure and which is means that the dryer can be build in cheaper cost by using smaller fan and others low cost material.

The drying process depends to the moisture content inside the material and it also affected by the time is taking to reduce the product moisture content. Therefore, drying process is important especially for food industrial, it's made the food in dry condition for the storage purpose, management purpose and manufacture process purpose. However, most of the tray dryers are facing the same problem in design level and drying process, which is the heat flow in drying chamber uncontrollable and unstable. Although the development of tray dryer is at low cost, the unbalanced heat flow directly affected to the production process and labor cost. When the heats are supply from the bottom of dryer, the tray which place near by the heat source is dry faster than other trays. If need to dry up all the product in once drying cycle, it is impossible because the product which close to the heat source will damage and may affected to others product quality.

The paper focuses on the analysis of heat flow in the dryer system to improve the tray dryer system function more effectively by allowing the heat flow easy to run through the system and balanced.

2.0 BASIC PRINCIPLE OF TRAY DRYER SYSTEM

Study from Devahastin, S. (2000), drying is a complex operation involving transient transfer of heat and mass along with several rate processes, such as physical or chemical transformations, which, in turn, may cause changes in product quality as well as the mechanisms of heat and mass transfer. Physical changes that may occur include: shrinkage, puffing, crystallization, glass transitions. In some cases, desirable or undesirable chemical or biochemical reactions may occur leading to changes in color, texture, odor or other properties of the solid product. Drying occurs by effecting vaporization of the liquid by supplying heat to the wet feedstock. As noted earlier, heat may be supplied by convection (direct dryers), by conduction (contact or indirect dryers), radiation or volumetrically by placing the wet material in a microwave or radio frequency electromagnetic field. Over 85 percent of industrial dryers are of the convective type with hot air or direct combustion gases as the drying medium. Over 99 percent of the applications involve removal of water. All modes except the dielectric (microwave and radio frequency) supply heat at the boundaries of the drying object so that the heat must diffuse into the solid primarily by conduction (Devahastin, 2000).

The study from Devahastin, S. (2002), the most common dryer for small amount or quantity of product, a batch tray dryer consist stack of tray or several stacks trays placed in a large insulated chamber in which hot air is circulated with appropriately designed fans and guides vanes. Often, heated air is circulated vertically through the column with a circulating fan (Dalfsen, 1999). These dryers require large amount of labor to load and unload the product. Typically, the drying times are long (10-60 hours). The key to successful operation is the uniform air flow distribution over the trays as the slowest drying tray decides the residence time required and hence dryer capacity. Warpage of trays can also cause poor distribution of drying air and hence poor dryer performance (Devahastin, 2000).

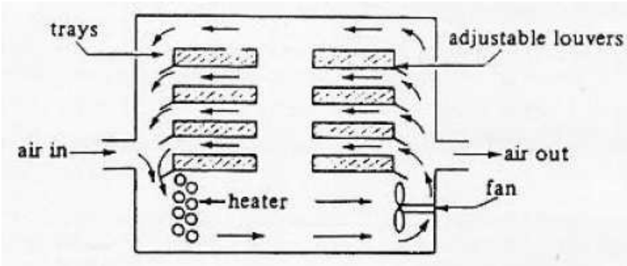

Figure 1. A Batch Tray Dryer (Devahastin, 2000).

2.1 Fan

Basically, fans can divided in many types and it was depends on the performance and ability of fan that can be use in certain specification and requirements. Besides that, fan can be driven by different type of mechanical instruments, electrical device or both of it to generate energy and air flow which needed to use.

2.2 Electric Heater

Electrical heater is an induction heating method which is using the electromagnetic induction to transfer heat to object. This method of heating is of great interest to materials and manufacturing industries as it is fast, precise and controllable. However, for this type of heating system may be more expensive, and it is usually preferable to other types of processing methods such as open flame heating or chemical processes. In most cases it also is the most efficient and precise heating method in practice today (Butturini, 2002).

2.3 Heat Recovery System

Heat recovery is a system that can give opportunities to increase the quality heating system, productivity of product and also decrease the manufacturing or production cost. Based on the study of Scullion, W. K. (2005), Energy intensive processes such as those associated with the manufacture of tape and label products offer opportunities to reduce operating costs

2.4 Consideration in Sizing Heater and Fan

The main purpose of the dryer system is to dry up the work piece or product which carrying the moisture or liquid internally or externally. Inside the dryer system, it consist two main components which is, heater and fan/blower (Devahastin, 2000). Without one of these components, the dryer system will fail to complete the drying process. Basically, at the beginning of the dryer process, heater will start to generate heat until certain temperature required, and at the same time, the fan/blower also start to operate which is set behind the heater and driven by the air flow which is generated by the fan/blower (Dalfsen, 1999). After that, the heat flow will pass through the work piece or product and convection process will dry up the product and carry out the moisture or fluid content in the product to the ducting system or direct outlet system (Tanthapanichakoon, 2002). The fan/blower will carry in new or fresh air into the heater and cycle back the drying process (Adapa, 2004). Base on the design concept, some of the dryer designs are using reheat system to save energy and cost.

2.5 Insulation of the Drying Chamber

According to Stephen and Emmanuel, (2009), the development of drying chamber with different materials is available for insulation, however, to select a suitable insulating material for installation, it need to consider about the drying temperature, availability and manufacturing costing. Besides that, heat loss from the drying chamber takes place by conduction, convection and radiation. The heat loss is directly proportional to the temperature difference between the indoor and outside ambient temperature (Eltief, 2007). To approximate the thickness of the insulating material, it needs to identify the heat loss from the chamber of the quantity of heat produced (Kaminski, 2005).

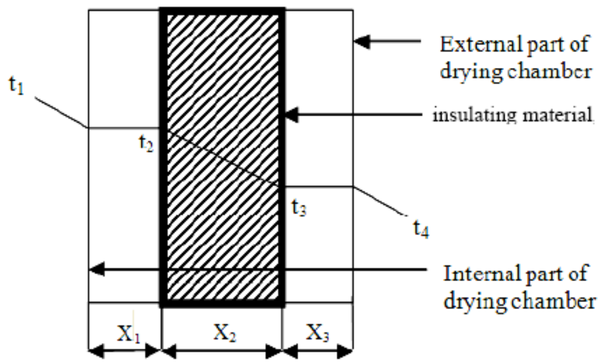

Figure 2. Insulation Diagram of Drying Chamber

2.6 Heat Transfer

Generally, there are three fundamental modes of the heat transfer involved in the dryer system which is convection, conduction and radiation. All three modes of heat transfer are assumed as the steady-state heat transfer and can be expressed as follows:

For conduction process,

$$Q = \frac{kA\,(T1 - T2)}{L} \qquad (1)$$

Where,

Q	= Rate of heat transfer
k	= Thermal conductivity of material
A	= Cross section area
T1	= Temperature before transfer
T2	= Temperature after transfer
L	= Length

For forced convection which occurs on vertical surface and on cold surface exposed to a hot fluid, the convection heat transfer can be expressed as:

$$Q = hA\Delta T \quad (2)$$

Where,

- Q = Rate of heat transfer
- h = Heat transfer coefficient
- A = Surface area exposed to convection
- ΔT = Temperature difference between the solid and fluid

The possible radiation that can be emitted

$$Q = \sigma A\,(T_s^4 - T_{surr}^4) \quad (3)$$

Where,

- T_s = Uniform temperature
- T_{surr} =The absolute temperature of the surrounding surface
- A = The surface area exposed to radiation
- σ = The Stefan-Boltzmann constant

3.0 DESIGN AND MODELING OF TRAY DRYER SYSTEM

Figure 3 and figure 4 show the overall design of the tray dryer system which consists of several components. The design will be analyzed and simulated using ANSYS FLUENT.

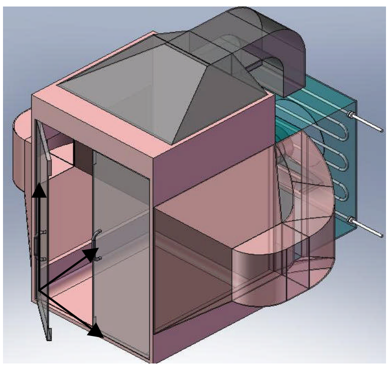

Figure 3 Design of Dryer System

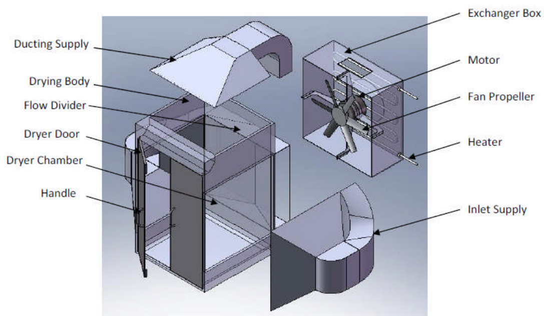

Figure 4 Exploded View of Dryer System

3.1 Modeling

The actual model was designed in Solidwork and imported into ANSYS FLUENT as a half model to reduce the memory space and time required to perform the analysis.

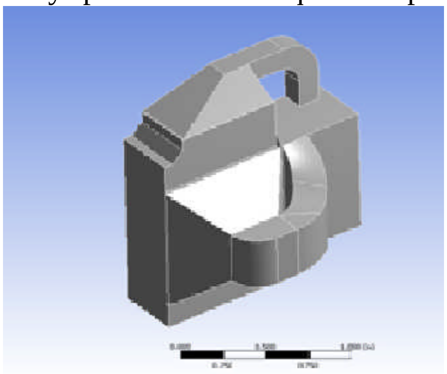

Figure 5 Half Model of the Dryer System

3.2 Meshing and Boundary Condition

The model was meshed by using several types of FE model or topology due to the complexity of the model i.e. tetrahedral, pyramid and prism elements, as shown in table 1.

The boundary condition for the model was applied at the air soured inlet surface as shown in figure 7.

Table 1: Volume Mesh Generation Statistics

Mesh Statistics	
Total number of nodes	69327
Total number of tetrahedral	176056
Total number of pyramids	1108
Total number of prisms	69456
Total number of elements	246620

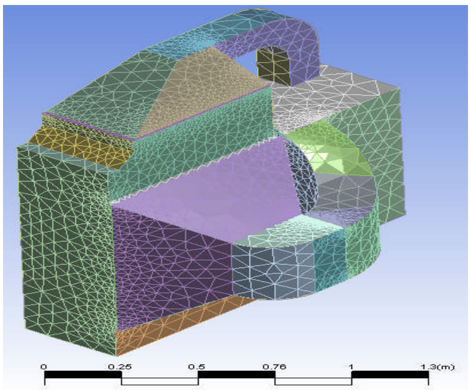

Figure 6 Meshing of the Dryer System

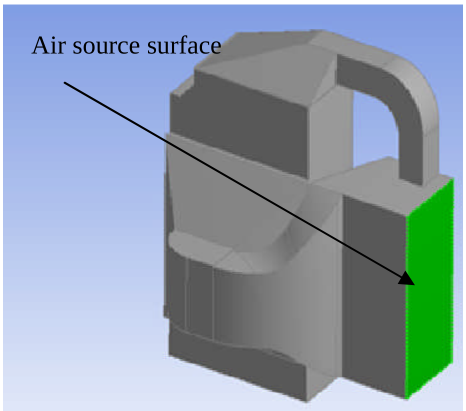

Figure 7 Boundary Condition

3.3 Meshing and Boundary Condition

Some parameters and properties which are required during analysis are shown in table 2.

Table 2: Physical Parameter and Properties

No	Physical Parameter	Remarks
1	Fluid	Air
2	Density of air	1.127 kg/m^3
3	Specific heat (Cp)	4182 j/kg.k
4	Thermal conductivity	0.0242 w/m-k
5	Viscosity	1.7894e-05 kg/m-s
6	Velocity magnitude (Inlet)	2 m/s
7	Temperature (Inlet)	313.15 K
8	Gauge Pressure (Room Pressure)	101325 Pa
9	Temperature (Room Temperature)	300 K

4.0 RESULT AND ANALYSIS

4.1 Air FLow

As shown in figure 8, the flow velocity is evenly distributed in each direction and the representative flow variables and energy show that the residuals have stagnated and do not change with further iteration. Therefore, the convergence in model is consistent and balance in time consuming.

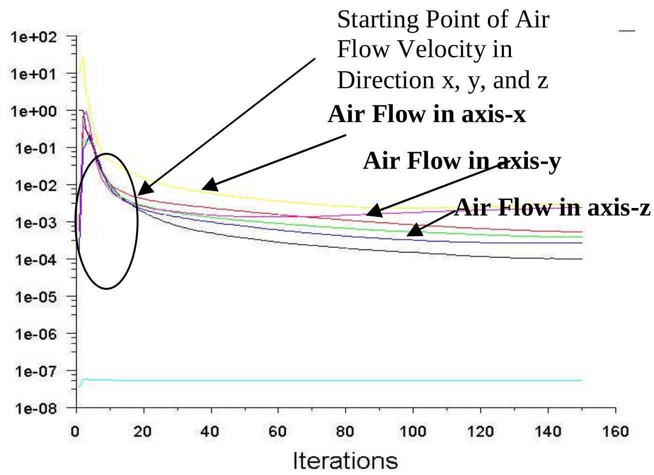

Figure 8 Air Flow Rate Result

4.2 Turbulence Kinetic Energy

The turbulence kinetic energy is characterized by measured root means square of velocity fluctuations. The lesser the magnitude of the turbulence kinetic energy the more stable of the flow. The maximum value obtained during simulation is 9.00e+01 m^2/s^2 which indicate that the flow is in stable condition.

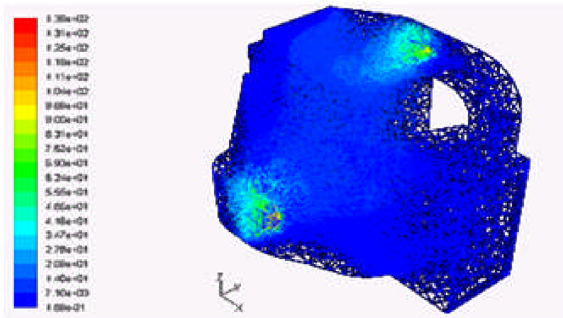

Figure 9 Turbulence Kinetic Energy

4.3 Static Temperature

Static temperature shows that the maximum temperature spreads and distributes evenly in the drying chamber which means that the drying process is efficient.

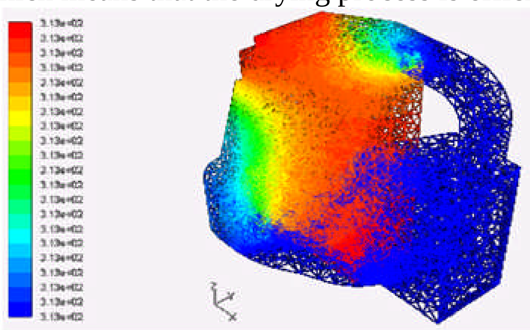

Figure 10 Static Temperature

4.3 Static Pressure

As shown in figure 11, the static pressure of the drying system is concentrated on exchanger box and the maximum pressure is 4.24e+01 Pa, which is considered very low. The low static pressure indicates that the humidity of air flow is easily carried in and out to the drying chamber.

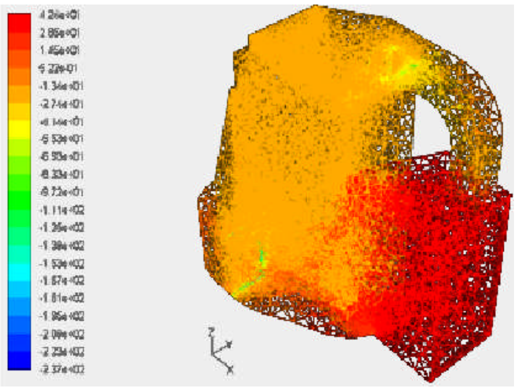

Figure 11 Static Pressure

5.0 CONCLUSION

The design and analysis .for the tray dryer system is presented and computational fluid dynamic (CFD) for the dryer has been carried out by simulating the realistic condition to analyze the air flow distribution /convergence, turbulence, temperature distribution and pressure to predict the efficiency of the tray dryer. The result shows that the tray dryer system is sufficiently efficient according the measured parameter.

6.0 REFERENCES

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