Comparative Analysis of Different Evaporator Arrangements in a Cold Storage using CFD

Abhishek Malviya* , Prof. H.S.Sahu**

*M. Tech. Student of Millennium Institute of Technology, Bhopal M.P. India

**H. O. D. of Mechanical Engg. Department

Abstract*-Computational fluid dynamics (CFD) uses powerful computer and applied mathematics to model fluid Flow problems. In the recent years CFD has been applied in the food processing industry. A cold storage is a place where the various items such as vegetables fruits, medicines etc. are stored to protect them from getting spoiled and to prolong their preservation period. Numerical modeling of airflow and temperature distribution in a cold store was performed using the Computational Fluid Dynamics (CFD). The aspects which were investigated include the influence of wind velocity. A mono-scale three-dimensional Computational Fluid Dynamic model was developed for estimating of airflow, heat and mass transfer. A computational Fluid Dynamics model was developed to estimate distribution of temperature and relative humidity. In case 2 the suction temperature is lower i.e. 271.434 K which indicates that the air coming out from the evaporator at 271.15 K is being sucked by the evaporator without circulating properly inside the chamber. The cold air is not coming properly in contact with products hence it is not exchanging heat with the products and hence its temperature is not increasing at the suction point. The temperature of air while travelling from top to bottom (i.e. along the height) of the chamber is also less i.e. 287.35 K in case 1 while the temperature of air in case 2 is 291.064 K. this indicates that there is more heat exchange taking place between cold air and the products in case 1 as compared to case 2.It is seen from table no. 7.6 that in case 1 the velocity of cooling air is nearly 0.242491 m/s at a distance of about 13m along the length from the evaporator whereas in case 2 the velocity of cooling air at the same distance seems nearly 0.105537 m/s which indicates that in case 1 the cooling air is reaching to the farthest point of the chamber whereas in case 2 it is not reaching properly to the farthest point. Hence in this (case 2) arrangement cooling of the product will be less as compared to case 1 because air circulation velocities is low in case 2.Thus considering the above points we can conclude that case 1 evaporator arrangement is better than the case 2 evaporator arrangement.

***KeyWords* – CFD, DUCT, HVAC, EVAPURATOR**

I. INTRODUCTION

Cold storages are the facilities where perishable foodstuffs are stored under controlled temperatures with the purpose of maintaining quality. Preservation of food can be done under frozen or chilled temperatures. For many other products conditions other than temperature might be required. A cold storage is a place where the various items such as vegetables fruits, medicines etc. are stored to protect them from getting spoiled and to prolong their preservation period. This is done by storing the products at their preservation temperature and humidity etc.

Preservation temperature is defined as the temperature at which its respiration rate in Cold storage will not be harm materials as long as the cooling and warming is done in a controlled manner, while keeping the moisture content of the components fixed. Moisture content is an intrinsic property that is influenced by the humidity present in the air, and second, by temperature. In a packed container moisture percentage will not change.

Design of cold storage to be effective and economic is an important criterion in business as ineffective design may lead to financial loss and in some cases may lead to unsafe operation of the system. Beside from the loss of capital due to degradation of quality of the products, there is also power loss and in the country like India, it becomes of greater importance to save as much of power as possible.

Effective temperature management is essential to maintain product quality. The temperature of horticultural produce at harvest is close to that of ambient air. Rapid reduction of produce temperature to the optimum storage condition results in the desired produce quality and prolonged storage life. Rapid cooling after harvest is generally referred to as precooling. Forced-air cooling (pressure cooling) is often adopted for precooling of horticultural produce. Forced-air cooling involves creating a pressure gradient to force cold air through container vents.

Artificial lighting. This is a type of slab where we get hollow holes in the slab when the formwork is removed. Firstly the PVC tray (pods) is placed on shuttering, then reinforcement is provided between the pod and steel mesh and is available at the top of the falls and then concrete is filled. Formwork is removed after concrete and PVC pod is not removed. It creates hollow holes in it, in which the holes on one end are closed. For industrial and commercial buildings Concrete waffle slabs are used, while many other construction sites use wood and metal waffle slabs. It is a type of slab that occurs with the holes below, which is the presence of waffles. It is used where much large span is required to avoid several columns in the middle space (eg, auditorium, cinema hall). Therefore, thick slabs are spread between wide beams. The main purpose of working on this technique is for the strong base characteristics of its crack and engagement resistance. Compared to conventional concrete slab, there is a high amount of load in the waffle slab.

Food Preservation

The food preservation is the technique by which the foods are stored in the cold area where the food can be withstand or protected for the long period. By this technique the food also controlled for getting damaged during the storage time or period. The food preservation is the important technique to save the food for future use. It is also work for controlling the taste, colour and their nutritive value.

Principal of Food Preservation

The food preservation is one of the best techniques to preserve the food commodities. And it prevented to the getting ruined and saves for the long period. Also, the food should not be damaged during the food preservation for all achieving to these conditions, certain basic methods were applied, and using the knowledge gained from the some observations of the effects of the natural conditions on different type of foods.

Method of Food Preservation

Dehydration The variety of food items is protected by the dehydration method. Dehydration means that the remove the moisture or water from the preserving food items. There is the one method that most usable in the society that is the drying the food items in the sun light. Now this method is elaborated in detailed the some food items are dried in the sun light such as Potatoes, grapes, onion, raw mangos and green leafy vegetables like cauliflower etc. And some preserving foods are firstly boiled and then it dried in the sun light. . For example, banana, chips, potato chips, grapes, coconuts, ground nuts etc. for the dehydration process first we have to do the wash and soak to the food items for the sometimes in the water. And then the washed foods are dehydrated. The potatoes are preserved by the using of this method.

Lowering Temperature Lowering temperature method is also one of the most important methods to save the foods. The enzyme and micro organism are in-activated of the food items by the decreasing the temperature of the preserving food agents. And then the foods are protected for the long time. This is the method that are used mostly in the home and as well as in the food preserving industries. The refrigerators are working on this method. Foods can be sealed at low temperature, the low temperature format is given below:–

Refrigeration 40 C to 70 C

Cold storage – 10 C to – 40 C

Freezing –180 C or below

Increasing Temperature

This method is generally used in home to preserve the food stuff. By increasing the temperature

Of the food stuffs, the enzymes and micro organism get destroyed. But all the micro organism

Pasteurization Pasteurization is one of the methods of preservation of the food stuff, where the food stuffs are heated up to the high temperature and then cooled suddenly. Due to sudden decrease in temperature harmful micro organism are not able withstand the sudden changed in temperature and then it get destroyed to the micro organism. However, some organism still remains in the food stuffs. This method mainly used for the liquid product. But now days this process broadly used in dairy industry.

II. LITERATURE REVIEW

M.K. Chourasia,et, al. [2005]"Steady state CFD modeling of airflow, heat transfer and moisture loss in a commercial potato cold store" They Conducted a Steady state CFD modeling of airflow pattern, transfer of heat and loss of moisture in a commercial potato cold store. The losses in the stored potatoes have a direct relation to the intricate coupled transport phenomena of heat, mass and momentum transfer therein. Therefore, airflow, heat transfer and moisture loss.

Dr. Manoj Kumar Chourasia [2006]"Efficient design, operation, maintenance and management of cold storage" This paper deals with different aspects of design of cold storage and its improvement over the existing ones. Cold air flow being one of the key components in establishing the performance of a cold storage, a CFD analysis has been done and the results have been discussed in this paper. The problems generally encountered in running a cold storage have also been high-lighted and their probable solutions have also been suggested in this paper.

M.K. Chourasia,et, al. [2007] "Three dimensional modeling on airflow, heat and mass transferin partially impermeable enclosure containing agriculturalproduce during natural convective cooling"A three dimensional model was developed to simulate the transport phenomena in heat and mass generating porous medium cooled under natural convective environment. Unlike the previous works on this aspect, the present model was aimed for bulk stored agricultural produce contained in a permeable package placed on a hard surface. This situation made the bottom of the package impermeable to fluid flow as well as moisture transfer and adiabatic to heat transfer. The velocity vectors, isotherms and contours of rate of moisture loss were presented during transient cooling as well as at steady state using the commercially available computational fluid dynamics (CFD) code based on the finite volume technique. The CFD model was validated using the experimental data on the time–temperature history as well as weight loss obtained from a bag of potatoes kept in a cold store. The simulated and experimental values on temperature and moisture loss of the product were found to be in good agreement.

G. Murali , G. Vikram (2016) CFD models having solid field, fluid field and solid-fluid field coalesce are generated for different heat exchangers profile to stimulate turbulence andtemperature contours operating at same condition. Comparing four different heat exchangers,the serial plate has high rate of heat transfer compared with other heat exchangers.

Problem Statement

Based on the problem field experience it is observed that the design & mounting of cooling coil play an important role to achieve the fast cooling.

There are two types of cooling coil arrangements are available in the field.

In the other arrangement the air coming out of the fan strikes over the plate & distribute it in the cold storage

III. OBJECTIVE OF STUDY

The basic objective of the present study is to see the performance of these two above said cooling coil arrangements.

IV. METHODOLOGY

After studying the basic steps in CFD to be followed to analyze the flow inside a chamber. Now we can start the analysis of the cold storage with actual data. Following three steps are required to run the simulation.

Pre-processing

1. CAD Modeling

2. Meshing

3. Type of Solver:

4. Physical model

5. Material Property.

6. Boundary Condition

V. ANALYSIS AND RESULT

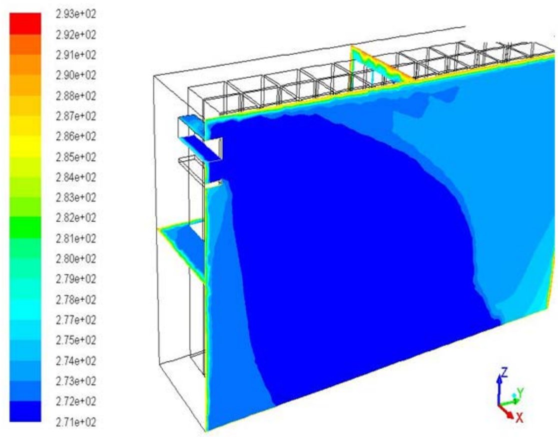
CAD Modeling

Three-dimensional Model Description A 3-dimensional model of a room in the shape of a rectangular prism is developed for Type 1 & Type 2 evaporator arrangements. The physical dimensions set to be 14 m length, 7 m width, and 8 m height. The model geometry will be created using pre-processor ANSYS DESIGN MODELER. On the basis of this data, two geometry and mesh as per project is discussed.

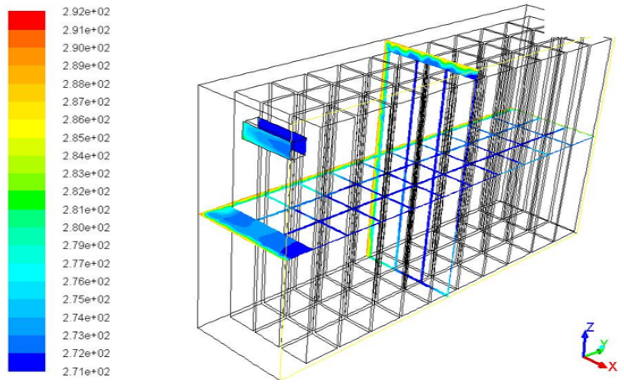
Case 1:-The cooling unit is located at the top centre of the storage and consisted axial fans for air circulation and a finned tube heat exchanger at a height of 6.5 m from bottom wall or floor and 0.1 m from back wall. The inlet was given to the front of the fan and the outlet was given to the bottom of the heat exchanger as shown in figure further.

Case 2:-The cooling unit with same capacity is located at a height of 4 ft from the floor and 0.1 m from back wall and consisted axial fans for air circulation and a finned tube heat exchanger. The inlet was given at the bottom of the fan and the outlet was given on the top of the heat exchanger as shown in figure below.

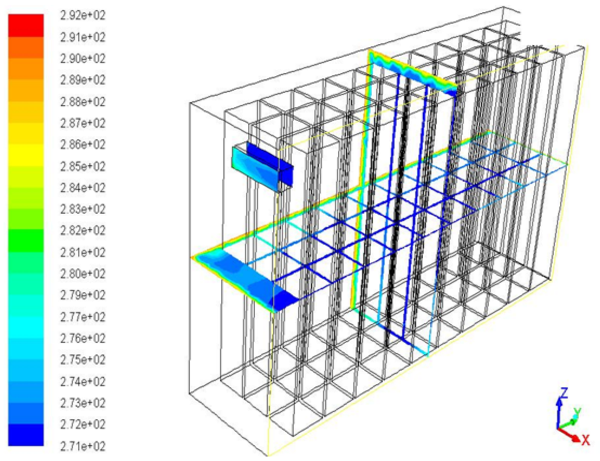
The data collected using ANSYS FLUENT 14.5 included the temperature data, pressure data and airflow velocity at the monitor point and the temperature distribution , pressure distribution and airflow velocity at all node points in the model room.



Above fig shows the temperature distribution of cold chamber having an evaporator in which the direction of flow of air is vertically downward and after reflecting with the plate, flow along the length of the chamber air is not reaching up to the end wall of the cold chamber. Temperature distribution is also not uniform. Hence heat transfer will be less which results in poor performance of the machine.



Above fig is showing the temperature distribution for case 1 at the middle section of chamber. It is clear from the fig that there is uniformity of temperature in the above case along both height and length of the chamber.



Above fig is showing the temperature distribution for case 2 at the middle section of chamber. It is clear from the fig that there is less uniformity of temperature in the above case along both height and length of the chamber.

VI. RESULTS AND DISCUSSION

Results obtained after the simulation

Table No. -Final air properties after the simulation

Evaporator arrangement Type	Air-inlet temp in K	Air outlet temp in K	Inlet vel. in m/s	air-outlet-temp-max	Pressure-drop in Pa
Top(Case 1)	271.15	273.694	3	276.41	60.7054
Bottom(Case 2)	271.15	272.999	3	275.5	19.795

From the above results it is clear that the rate of heat transfer and pressure drop is more in case 1 as compared to case 2 and as per the simulations of temperature distribution, case 1 has more even distribution as compared to case 2.

VII. SUMMARY AND CONCLUSION

A three-dimensional CFD simulation was developed to compare airflow and heat transfer models in different airflow patterns in a fully loaded cool storage Dynamic behavior of the fan, and heat exchanger were considered in the model. In this project work two different evaporator arrangements compared and analyzed.

The calculation domains were discretised with a tetrahedral meshing for the entire domain was selected. Using ANSYS FLUENT 14.5 software a finite volume code was used for the numerical implementation of the models.

Standard k - turbulence model was enabled based on the previous studies (Nahor, et al., 2008).

The overall accuracy of the model was selected as second order upwind. The pressure–velocity coupling was ensured using SIMPLE algorithm; the model was solved for velocity field. Initial conditions i.e. inlet air temperature, room temperature, cooling capacity were kept same for all the three cases.

After getting all the results based on CFD and analyzing them now we can conclude that the Case 1 i.e. evaporator located at the top center and air flowing horizontally is a better arrangement than Case 2 type i.e. evaporator with air flowing vertically downward on the basis of following points.

1) In case 2 the suction temperature is lower i.e. 271.434 K which indicates that the air coming out from the evaporator at 271.15 K is being sucked by the evaporator without circulating properly inside the chamber. The cold air is not coming properly in contact with products hence it is not exchanging heat with the products and hence its temperature is not increasing at the suction point.

Whereas in case 1 the suction temperature is higher i.e. 273.271 K which indicates that air is reaching to the evaporator after circulating properly throughout the chamber.

2) The temperature of air while travelling from top to bottom (i.e. along the height) of the chamber is also less i.e. 287.35 K in case 1 while the temperature of air in case 2 is 291.064 K. this indicates that there is more heat

exchange taking place between cold air and the products in case 1 as compared to case 2.

3) The temperature of air while travelling along length of the chamber is again less in case 1 as compared to case 2. The end temperatures are 272.87 K in case 1 and 274.165 K. this is again an indication of proper heat exchange between cold air and products.

4) All the readings regarding pressure distribution shows that pressure drop is more in case 1 as compared to case 2. This is may be due to the fact that in case 1 the air coming out from the evaporator is circulating properly throughout the chamber therefore the pressure drop is more whereas in case 2 the air coming out from the evaporator is not reaching to all the corners of the chamber hence the pressure drop is less compared to case 1.

5) It is seen from table no. 7.6 that in case 1 the velocity of cooling air is nearly 0.242491 m/s at a distance of about 13m along the length from the evaporator whereas in case 2 the velocity of cooling air at the same distance seems nearly 0.105537 m/s which indicates that in case 1 the cooling air is reaching to the farthest point of the chamber whereas in case 2 it is not reaching properly to the farthest point. Hence in this (case 2) arrangement cooling of the product will be less as compared to case 1 because air circulation velocities is low in case 2.

Thus considering the above points we can conclude that case 1 evaporator arrangement is better than the case 2 evaporator arrangement.

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