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CFD simulation for airflow pattern and temperature behavior in the cold storehouse for different stacking arrangements

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***Abstract*— Cold storehouses have larger cold chain throughout in India. But effective performance of these storehouses is biggest challenge for storing vegetables and food products. In the given paper the effective performance of the cold storehouse was checked on the basis of different stacking arrangement with the numerical simulation (CFD) for the cold room. This study gives a more optimum position for stacking arrangement which tells about the more uniform distribution of airflow and temperature of the air within the cold storehouse. The room temperature is kept at 50C and it will check at different points in the cold room. For this 3D model was established to perform the activity, while the K-e model was used for turbulence flow. This experiment was done to maintain homogeneous the temperature in the cold room. Also, these results convince us that CFD has a better tool to analyze and design cold rooms for effective performance of cold storehouses.**

***Index Terms:* CFD, experimental, temperature, airflow, stacking arrangement, numerical simulation.**

I.INTRODUCTION

In India production of fruits and vegetables are more, on this positive side, we have trouble with the performance of cold storage for storing product for a long time. Along with these the temperature and velocity airflow distribution was mostly affected for better performance of the cold storage. But every time designing a cold rooms and taking experimental readings for these parameters and checking whether these will give better performance for cooling or not is time - consuming and required more money. So, to overcome these problems computational fluid dynamics (CFD) technique was used to analyze the proper distribution of temperature and velocity airflow to get a better evaluation of airflow and heat transfer in the cold room within less time and even gives more accuracy rather than numerical analysis.

The distribution of temperature and velocity airflow in the cold room for different stacking arrangements was checked by with CFD technique. It was used to simulate the temperature and velocity field in a cold room and also helps to recognize better stacking arrangements patterns in the cold storehouses. According to this, the cold store was designed for the two different patterns then compare on basis of uniform distribution. The product they kept in the cold storage was raisins whose required a temperature range is -2 to 8℃ with airflow rate of 2m/s for these input parameters the cold storage was going under the supervision and numerical data was obtained.

II.LITERATURE REVIEW

The homogeneous distribution of the temperature and velocity airflow in the cold storehouse was affected by different stacking arrangements of goods. To analyses the better arrangement of stack for uniform distribution of the temperature and velocity the computation fluid dynamics (CFD) tool was used which help to analysis the result in less time with better accuracy[1]. To see the better performance of stacking arrangements cold store is running for 14hours with three different stacking arrangement in which racks of good kept apart from each other at distance 10cm, 20cm, and 30cm respectively[2]. CFD simulation shows the optimum position for the inlets, a number of inlets and stacking methodology was required to achieve the uniform temperature and velocity distribution within the cold storehouse. These analyses give optimum solution to design and optimize the airflow field in the cold store[3]. The performance a cold store is analyzed based on different cooling coil arrangement for three dimensional models of cold storage having dimensions [10m(l)×8m(w)×9m(h)] was create. During the experimental analysis it seen to have mixed flow arrangement of the cooling coil that is more effective than the axial flow arrangement, in this arrangement average temperature of the cold store was analyzed[4-5].

The CFD simulation was used to evaluate temperature gradient with the following steps are pre-processing, geometry setup and design of descretization scheme, processing afterward boundary and inlet condition will insert and after calculation post processing was done the visualization of temperature and velocity field was happened[6]. Currently CFD has mostly been used to recognize temperature field and local thermal comfort sensation in non- residential by setting outside conditions accordingly[7].The cold storage performance mostly depends on cooling capacity of the refrigeration unit installed in the cold room. The cold store was used to store an apple as product under study to the recognize the uniform distribution of the temperature and velocity in the cold store. To analyze these parameters CFD technique was used for better accuracy[8]. To get a better evaluation of airflow and heat transfer rate in the cold room, CFD model of the cold store was developed. The computational fluid dynamics (CFD) technique was required to define physical- mathematical model depend on equation of momentum, energy and continuity[9-10]. The CFD simulation is done for the cold store under the k-e model for steady state airflow and turbulence flow[11].

III.EXPERIMENTAL

The experimental analysis was done for the cold store for two different stacking arrangements as shown in the following figure1&2. The cold room have dimension [1.14m(l)×0.45m(w)×2m(h)] was create.

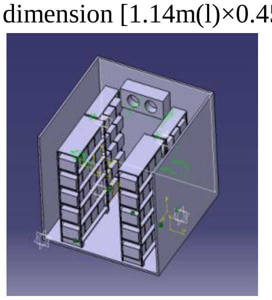


Figure 1

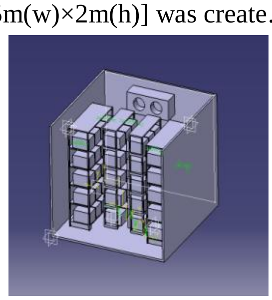


Figure 2

series stacking arrangement parallel stacking arrangement

IV.EXPERIMENTAL FACILITY

On the resin product, experimental study was carried out. The cold store was loaded with 50 boxes (4cases/ column, 5x5 rows) of 1.14m length, 0.45m width and 2m height. The temperature of air and velocity was checked at different 50 points in 5 different planes. It can be seen in Figure3&4 at measurement points temperature and velocity were located. Computation data was found by using Ansys Fluent Software from CFD simulation models. The temperature and velocity models were created for X-Z planes, Y-Z and X-Y planes by using Ansys Fluent Software.

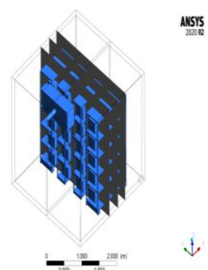


Figure 3

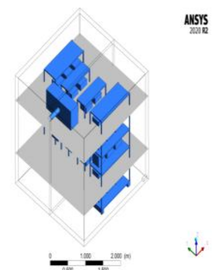


Figure 4

Plane 1,2&3 Plane 4&5

In the cold store to perform the measurements of air velocity, a turbine anemometer used, (accuracy: 0.2m/s). K- type thermocouples was also used to check the temperature with, (accuracy:1.5℃). At the measuring points, the testing procedure consisted of consecutive measurements until thermal equilibrium was achieved.

V.BOUNDARY CONDITIONS

The computation of the cold storage was done by putting the boundary conditions as follows:

- Inlet: Within the cold portion analysis the velocity rate at 2m/s. The water temperature is fastened at 278 K.
- Outlet:The airflow inside the cold storage which facilitates relative pressure is about zero.
- Racks:Heat generated due to respiration of raisins hold on inside the racks for different stacking arrangements
- Outside wall:Heat transfer rate is constant and out of doors temperature was given zero. Which

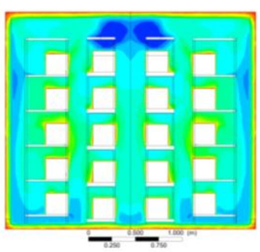
is 027 Wm^2/K and 298K respectively. For the computation 2 domains were thought about like air and solid wall, each domain is stationary.

- K-e model was employed for computation for the turbulence and the air may be a fluid domain. Reference Pressure is taken into account as 1 atm.
- Solid wall may be a solid domain that was given the properties of polyurethane foam.

VI.RESULTS AND DISCUSSION

A. *Temperature Distribution For Parallel Arrangement :*

The Distribution of the temperature in the planes is given below. The temperature for the parallel stacking arrangement was mostly decreased in a particular portion of the room due to strong airflow from the inlet of the draft fan.The temperature of air in the cold room varies from 4.51 °C to 4.83 °C near the front portion of draft fan and this value was again lowered to the range of 4.52-4.82 °C near the middle portion of the rack. Air temperature distribution along the cold storehouse upward height changes from 4.51 °C (a few centimetres above cold storehouse ground and close to the airflow outlets) to 4.57 °C at portion on the ground of the cold store and in the room corners randomly at which unaffected by air velocities.



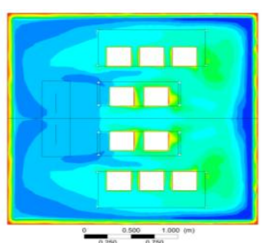
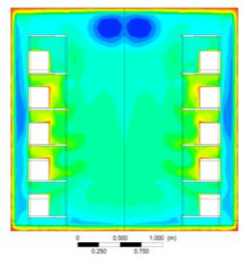


Figure 5 Figure 6

CFD simulation of temperature for parallel stacking arrangement

B. *Temperature distribution for series Arrangement :*

The temperature of the cold room for series stacking arrangement gets more changes in flow pattern in between the middle of the cold room. Also near to the draft fan temperature changed from 4.39 °C to 4.65 °C and this range was again decreased to the 4.39-4.65°C near the middle of the rack. In the planes air temperature distribution has been given in following Figure. The temperature distribution was more uniform along the length of the cold storehouse. The cold store air temperature was changes from 4.52 °C to 4.56 °C near the ground and the wall. Air temperature raised and its ranged from 4.44 °C to 4.76 °C near the door of the cold storehouse because of decreased air velocities.



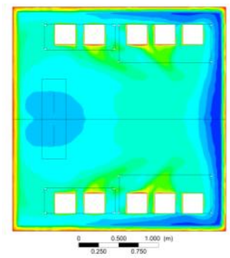
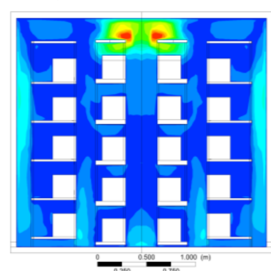


Figure 7 Figure 8

CFD simulation of temperature for series stacking arrangement

C. *Velocity distribution for parallel arrangement :*

In the cold room the velocity was getting more near the draft fan afterward this will varies towards the door of the cold room from 1.38 to 2.54 m/s. Then at the middle plane its decreases from 2.13 to 1.05 m/s at the door side its again varies from 2.65 to 1.14 m/s along with it at the top near to floor it increases up to 2.87 m/s.From above values of velocity the range it seems that velocity didn't much affect for parallel arrangement.



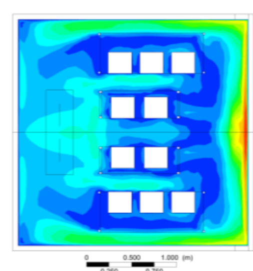


Figure 9 Figure 10

CFD simulation of velocity for parallel stacking arrangement

D. *Velocity Distribution for Series Arrangement :*

In the cold room velocity in the 1^{st} plane is higher and it varies from 1.08to 2.83 m/s afterward in the middle plane it decreases from 2.67to 1.07 m/s at door side it again varies from 2.63 to 1.14 m/s along with it at the top near to floor it increases up to 2.72 m/s.

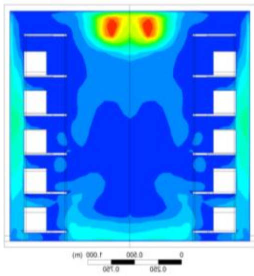


Figure 11

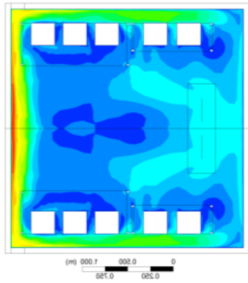


Figure 12

CFD simulation of velocity for series stacking arrangement

Data found from CFD simulation models and experimental statistics was given in following Table1 for parallel stacking arrangement And Table2 for series stacking arrangement of cold stores.

Sr.No	Mean	Mini-mum	Maxi-mum	Standard Deviation
Temperature by Experimental	4.832	4.78	4.87	0.0196
Velocity by Experimental	2.039	1.09	2.98	0.5644
Temperature by CFD simulation	4.567	4.51	4.67	0.0392
Velocity by CFD simulation	1.559	0.76	2.87	0.6021
Temperature Difference	0.264	0.17	0.33	0.0416
Velocity Difference	0.479	0.08	0.87	0.2019

Table 1

Sr.No	Mean	Mini-mum	Maxi-mum	Standard Deviation
Temperature By Experimental	4.846	4.79	4.91	0.02788
Velocity by Experimental	2.336	1.42	2.98	0.5091
Temperature by CFD simulation	4.502	4.27	4.73	0.1134
Velocity by CFD simulation	2.042	1.01	2.93	0.6004
Temperature Difference	0.344	0.11	0.57	0.1108
Velocity Difference	0.294	0.04	0.97	0.2169

Table 2

VII. CONCLUSIONS

In this current work, the cold storehouse was prepared with a simulation model. The unstructured mesh is used, to improve the accuracy of the calculation. Equations of Energy, continuity, momentum, and k-e were solved. Also to accurately predict the performance of the airflow patterns in the cold store Under Relaxation techniques were applied. It was found that CFD is a powerful tool that can simulate air patterns inside the cold store. Temperature and velocity gradients were affected by the flow field due to the different stacking arrangements. It was found that using of parallel stacking arrangement design gives better flow patterns (velocity and Temperature distributions) and minimizes the dead zones. It was found that using of proper arrangement of stacking at the particular distance would give a better flow field (velocity and Temperature distributions) and would minimize dead zones. It is not recommended to use a series stacking pattern for that the cold store because it will create large dead zones with high temperature and low air stream velocities.

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