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Operational Augmentation of Forced Circulation Type Solar Dryer System Using CFD Analysis

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ABSTRACT
Solar drying is basically heat and mass transfer process in which the liquid water from the surface and the vapour removed by draft. The efficiency of a solar drying system is affected by the properties of drying materials.e.g. size, shape and geometry as well as ambient conditions. In this research article, the authors have done the CFD analysis of a Forced Circulation type Solar Dryer used conventionally for dehydrating vegetables and fruits. Using CFD analysis, the limiting values of pressure and velocity could be obtained using which the modifications can be implemented in the existing system in order to gain operational augmentation. Later on, the validation of the simulated results was achieved by associating them with the experimental outcomes.
Keywords – CFD Analysis, Drying chamber, Forced Circulation, Pressure-drop analysis, Solar Dryer

I. INTRODUCTION

Seasonal crops like grains, vegetables and fruits are rich sources of vitamins, minerals and low fats but contain high concentration of moisture. Hence, they demand for favorable storage conditions, efficient handling, transportation, adequate post-harvest infrastructure, etc. Sun drying is still the most common method used to preserve agricultural products in most tropical and subtropical countries. The main advantages being its low capital and operating costs and the fact that little expertise is required. But, Sun drying is only possible in areas where, in an average year, the weather allows food to be dried immediately after harvest. [1]

Hence, Dryers have been developed and used to dry agricultural products in order to improve shelf life, product variety and large volume reduction. Most of these either use an expensive source of energy such as electricity or a combination of solar energy and some other form of energy. [2] In Forced Circulation type Solar Dryers, hot air is continuously blown over the food products which is loaded or unload continuously or periodically. Such dryers are comparatively thermodynamically efficient, faster and can be used for drying in bulk.[3] But, the major criteria to be considered in such dryers is the operational efficiency.

In the present work, the CFD analysis of the drying chamber of a conventional Forced Circulation type Solar Dryer is done in order to obtain the cause for reduction in efficiency.

The pressure loss was found to be playing a major role for reducing the efficiency. Thus, a modified design is proposed to gain maximum output by minimizing the pressure drop. The validation of the simulated results is achieved through experimental analysis with the adapted design which has proven up to the mark.

II. RESEARCH METHODOLOGY

2.1 Modelling of Dryer

A solar dryer consists of drying chamber, blower, and air heating unit, dumping, ducting and drying trays. [4] For CFD analysis, the modelling of drying chamber is considered since the flow through the ducts remains constant.

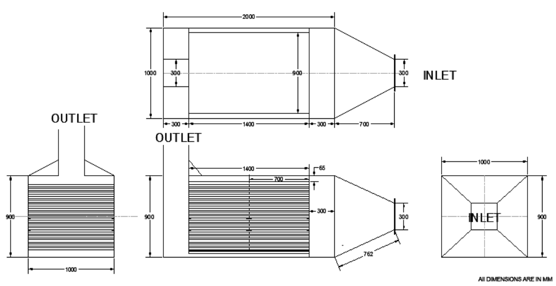

Fig 1. 2D drawing of Drying Chamber

The modelling of drying chamber is done in modeling software as per the dimensions prescribe in Fig 1 & as per specifications as mentioned in succeeding topic.

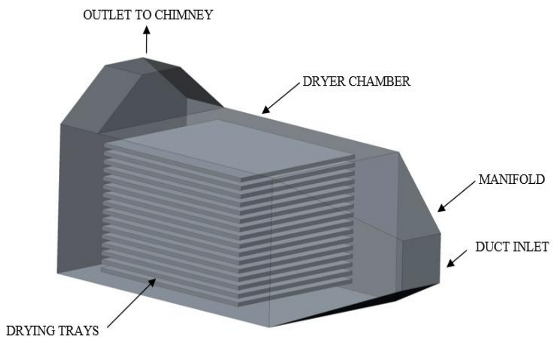

Fig 2. 3D Model of Drying Chamber

2.2 Drying Chamber Specifications

The indorsed specifications of drying chamber are as follows:

Table 1. Drying Chamber Specifications

Material	Outer Body	Aluminum Iron Sheet (26 SWG)
	Inner Body	SS 304 (1.5 mm)
	Tray	SS 304 (0.6 mm)
	Chamber Door	SS 304 (2.0 mm)
	Insulator	Rockwool Slabs (Two layers of 50 mm thick, 48 kg / cu. meter density)
Consecutive Tray Spacing		25 mm
No: of Trays		16
Size of each tray		600 x 1000 x 20 mm

2.3 CFD Modelling

Inner volume is also created in the modeling software as shown in fig.3 for CFD analysis.

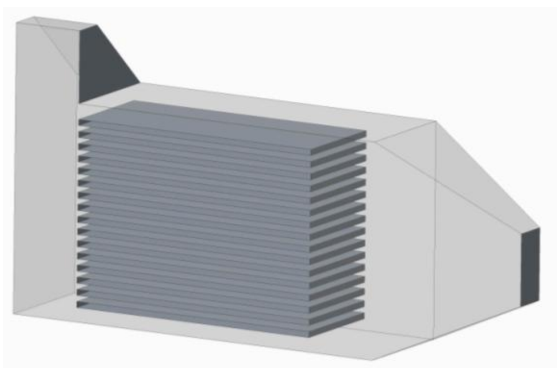

Fig 3. Inner volume of drying chamber

As the volume is symmetrical, only half volume is considered for analysis. After creation of inner volume, boundary conditions are applied as shown in fig 4. [5]

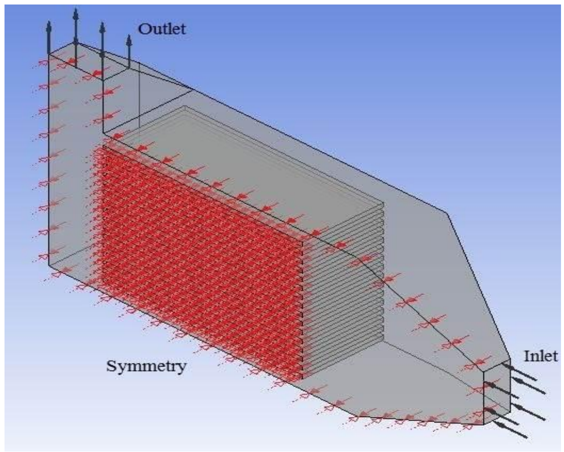

Fig 4. Boundary conditions

After applying boundary conditions, meshing of the inner volume is carried out by Finite Volume Method.

2.4 Meshing

Herein, ANSYS GAMBIT 2.3.16 is used for the meshing. The meshing parameters are taken as per the following:

Table 2. Mesh Specifications

Entity	
Mesh type	Unmapped
Type of elements	Tetrahedral
No of Nodes	4367
No of Tetrahedral Cells	15041
Interior faces	26262
Wall Faces	6770
Velocity Inlet Faces	14
Outflow Faces	14

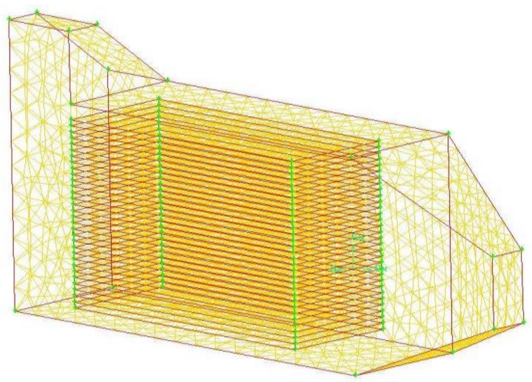

Fig 5. Meshing of drying chamber

After the mesh generation, CFD analysis is performed as per the different specifications mentioned in previous topic.

2.5 CFD Analysis

In CFD analysis, following criteria is considered for simulation:

Table 3. CFD Specifications

Model Specifications	
Design	
Simulation Type	3 – D, Steady
Solver Type	Density based
Gradient Type	Green – Gauss Node based
Fluid Specifications	
Type	Air (fluid)
Density	1.225 Kg / m3
Sp. Heat (Cp)	1.006 KJ / kg K
Dynamic Viscosity	1.78e-05 Kg / m s
Thermal Conductivity	0.0242 w / m K
Operating Parameters Specifications	
Operating pressure	253.27 Pascal (25.82 mm of water)
Operating temperature	333 K (60 □C)
Inlet velocity	32.22 m / s

After performing the simulations as per the prescribed condition of air flow through dryer chamber, the characteristics of flow-fields are analyzed.

III. EXPERIMENTATION

In order to carry out experimental work forced convection solar dryer is constructed and fabricated by using the material described in Table 1.

The construction of drying chamber is shown in the figure given below.

Fig 6. Drying chamber unit

Fig 7. Power Control Unit of Solar Dryer

As shown in the above figure a control panel is provided for the solar dryer which consists of 6 channel temperature scanner to indicate temperature sequentially and to monitor it, an ammeter to measure current and a voltmeter to measure voltage for each blower. Auto / Manual selector switch is available to select the blower operation mode. RH sensor & controller with memory (we can indicate the RH on panel as well as record in memory) are also provided. A temperature controller, load cell to indicate the weight, air flow measurement and its indication and pressure gauges for different locations to check pressure drop are provided in control system.[6]

During experimentation, the pressure drop is measured at different flow rates which are achieved by controlling the speed of the blower.

IV. RESULTS AND DISCUSSION

The results obtained by simulation are compared with those obtained during experimentation.

4.1 Pressure Distribution

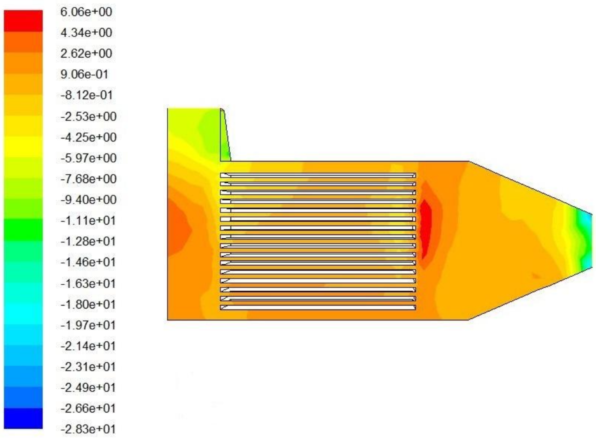

Fig 8. Pressure Distributions of Design

From the pressure distribution, it is clear that high pressure prevails at the forward-facing edges of all the upper trays. Whereas low pressure region is obtained at the entrance of the drying chamber.

4.2 Velocity Distribution

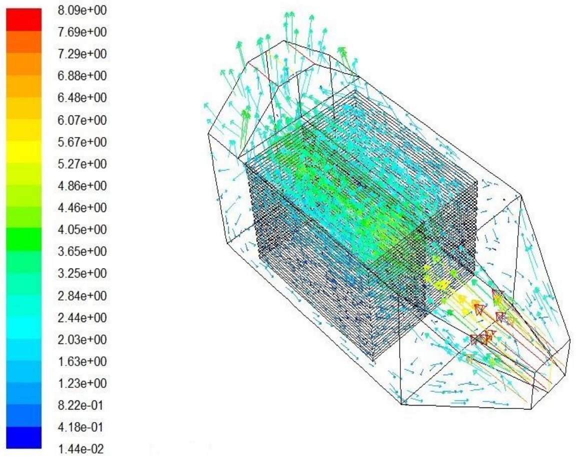

Fig 9. Velocity Distributions of Design

The high gradient of air velocity appears at the inlet of the drying chamber. The reduction in velocity is due to the hindrance provided by the trays as well as the outlet part of the drying chamber.as a result the backward flow is observed within in the manifold portion of the solar dryer which causes the inlet flow to be restricted. [7]

4.3 Comparison of Results

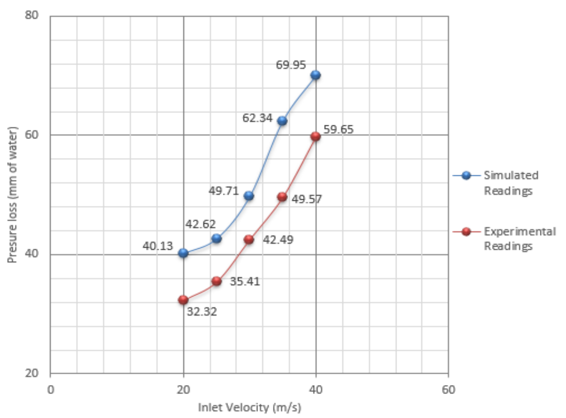

Fig 10. Comparison between Simulated results and Experimental results

From the above figure, it is clearly observed that the values of pressure drop seem to be almost similar for simulated as well as experimental work.

V. CONCLUSION

Investigating the simulation results by visualizing the flow pattern of fluid and pressure drop in specific region, appropriate physical modifications are implemented such that overall system efficiency is improved by about 3% over the existing system, and this is really found to be effective as overall cost of the system is very high. Hence, payback period of the system can be covered early.

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