CFD and experimental analysis of solar crop dryer with waste heat recovery system of exhaust gas from diesel engine

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Abstract. Crop drying is the method used to preserve the seasonal food crops during the non-seasonal periods in agricultural sector. In olden days, solar energy was used to dehydrate and preserve the food. Nowadays many new advanced technologies have been introduced. But due to electricity unavailability in rural areas and to utilize the abundantly available solar energy and the waste heat recovery of exhaust gas from the diesel engines used in the agricultural fields for water pumping. Our present work focuses on the CFD and experimental analysis of the solar crop dryer attached with flat plate collector and attached with diesel engine exhaust pipe heat exchanger. A comparison study was made between the crop dryer with and without exhaust pipe heat exchanger and found that when the exhaust pipe was attached there was an improvement in the increase in temperature compared without exhaust pipe. The copper tubes of exhaust pipe were also added with the fins to improve its heat exchanging efficiency.

1. Introduction

Drying of agricultural product is a vital post-harvest operation since it needs high energy consumption. Right smart energy savings are often achieved by victimization alternative energy as energy supply for drying of agriculture product. Ancient sun drying has several disadvantages like insect infestation, catalyst reactions, being growth so drying by solar drier is a choice. Besides standard sun drying takes longer length to succeed in the required wet content. Solar dryers are employed in all elements of globe and intensive analysis has been dole out, aiming at the advance of those systems. From the literature, it's found that the majority of those solar drying systems use flat plate air collectors of assorted styles and solely some of them thought-about a distinct style of collectors, one in every of them being natural and made convection solar tunnel driers. The success of the technology is measured by the numbers of dryers put in throughout the past few years. Few tries are created to boost the technology. The amount of such varieties of dryers put in within the province with regard to amount of paddy to be dried is negligible, solely regarding 0.55% of annual production [1]. The observation within the gift study implies that the temperature of cupboard solar drier is beyond that of open sun drying. Cupboard solar drying is quicker than open sun drying. The performance of solar drying system was extremely captivated with radiation and close temperature [2]. Only a few researchers have done experimental study of hybrid solar dryers, and compared to different dryers,

their numerous style modifications and sweetening techniques. The Hybrid dryers are value effective, and are straight forward to fabricate and use [3]. This shows that drying rate is up in drier integrated with fin sort collector followed by V-type collector and flat plate collector. [4]. A large-scale greenhouse solar drier with LPG burner has been developed and its performance for drying osmotically dehydrated tomato are investigated [5]. A comprehensive review of the varied style details of construction and operational principles of the big variety of much realized styles of alternative energy drying system were given and additionally various styles of solar dryers for drying food materials has been mentioned as well as non- concentrating and concentrating sort [6]. Solar drying system is employed to dry food and save the consumption of the precious standard fuels. Studied that solar dryers not solely save energy compared to different industrial dryers however additionally save plenty of your time, improve quality of the merchandise and create the merchandise a lot of economical and additionally cut back the negative environmental impacts like pollution, ozonosphere depletion [7]. Solar collectors with exhausted tubes [EVT] are a special sort, providing vital benefits compared to flat-plate collectors, like higher efficiencies. EVT collectors, flat-plate ones alike, are classified into 2 broad classes, water and air-collectors, supported their heat transfer fluid. A two-pass solar drier was found to be technically and economically appropriate for drying of bamboo shoots beneath the specific conditions in central Vietnam [8]. The experiments given have shown that a batch of one thousand kilo of paddy are often simply dried to a target megacycle of Bastille Day inside the primary day throughout the time of year, achieving a top quality in terms of head rice yield. However, a second day of drying is usually necessary throughout the time of year [9]. The review state that Passive solar dryers are terribly economical compared with active solar dryers. In keeping with the review of numerous analysis articles the passive sort solar dryers are a lot of appropriate for drying various agricultural products [10]. The target of this study was to dry 2 commercially vital tropical African fish species African sharp tooth cat fish and Nile tilapia victimization completely different improved affordable solar driers. This is often with the aims of evaluating the performance, efficiency, and effectiveness of those improved affordable solar driers in terms of wet loss from the fish samples and testing the organoleptic characteristics of the dried product. [11]. As compared to sun dried product and that they are applicable for production of quality dried fruits, vegetables, spices, herbs and healthful plants, and fish. The potency of solar drying system is full of the properties of drying materials e.g. wet content, size, form and pure mathematics additionally as close conditions, that embrace radiation and temperature, ratio, speed and gas pressure of close air. [12]. The forced convection system has higher air flow through the reflector and drying chamber thus, it's higher drying capabilities compared to the natural convection system.[13]. The solar cupboard drying of Bitter Gourd was found to be quickest drying technique as compared to sun drying resulted in very best quality. Solar drying allows vegetables export worthy processed foods with long time period meeting the healthful standards of the mercantilism countries. Thus solar drying is incredibly viable and valuable one [14]. Here project is targeting decreasing loses in husbandry. Associate experimental study of but this drier fare compared to different dryers [15]. The objective of this paper is to do the CFD and experimental analysis to select the appropriate specification and mass flow rate to get efficient solar crop drier when diesel engine exhaust gas heat is also used for heating in addition to the solar energy as to increase the efficiency of the solar crop drier.

2. Numerical Analysis

The solid models of solar crop drier with exhaust gas pipe are created in SOLIDWORKS and imported to ANSYS –workbench for performing CFD analysis. Figure 1 shows the geometry model of air domain and exhaust gas domain created for analysis and Figure 2 shows the assembly of both the domains.

2.1 Modeling

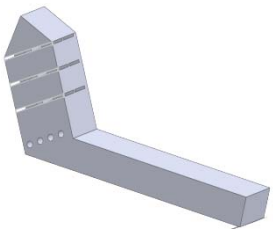
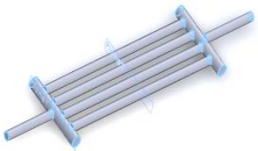

Figure1. Part Model

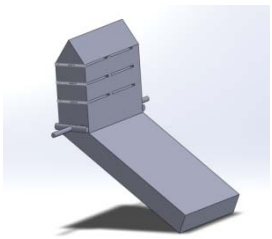

Figure2. Assembly

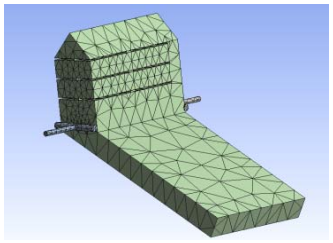

Figure 3. Meshed Model

2.2 Meshing

The solid model was meshed in **I**CEM-**C**FD using tetrahedral volume mesh. Figure 3 shows the meshed model of the assembled domains.

2.3 Boundary Conditions

Figure 4 shows the boundary condition of the meshed model which is imported to **C**FX-Pre. Air inlet is applied with air mass flow rate of 2 kg/s at temperature of 30 ^{0}C and out let at average static pressure of 1 bar. Exhaust gas inlet is applied with 2 kg/sec mass flow rate at inlet temperature of about 50 ^{0}C and outlet with static pressure of 1 bar. Heat flux was also applied on the glass top. Mass and momentum is selected with free slip wall. CFD analysis was performed to compute the air flow temperature by taking the inlet mass flow rate of about 2 kg/s.

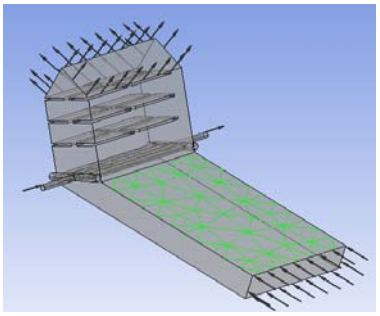

Figure 4. Boundary conditions

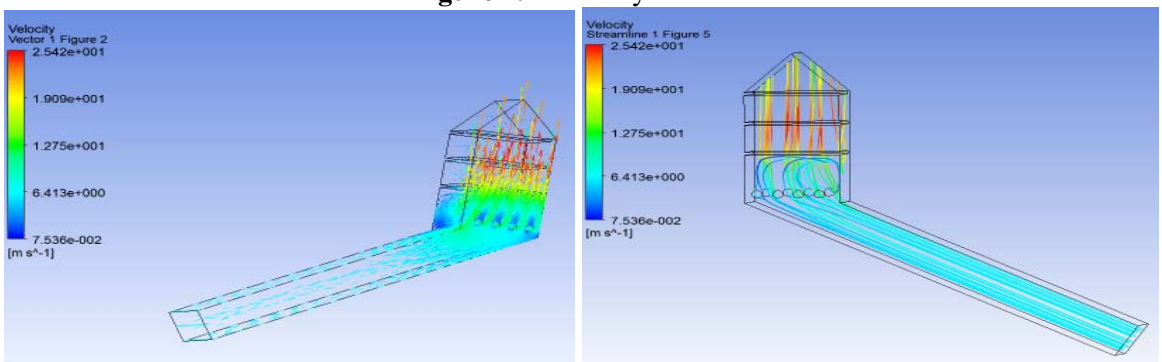

Figure 5. Velocity vector and streamline

2.4 CFD results

Figure 5 shows the velocity vector and streamline flow of air. Figure 6 represents the temperature distribution in solar drier without exhaust gas heat exchanger. The figure shows that the temperature at the food plate collector is very less. Figure 7 shows the temperature distribution when exhaust gas heat exchanger was inserted and it proves that there is a valuable increase in the temperature flow at the food plates.

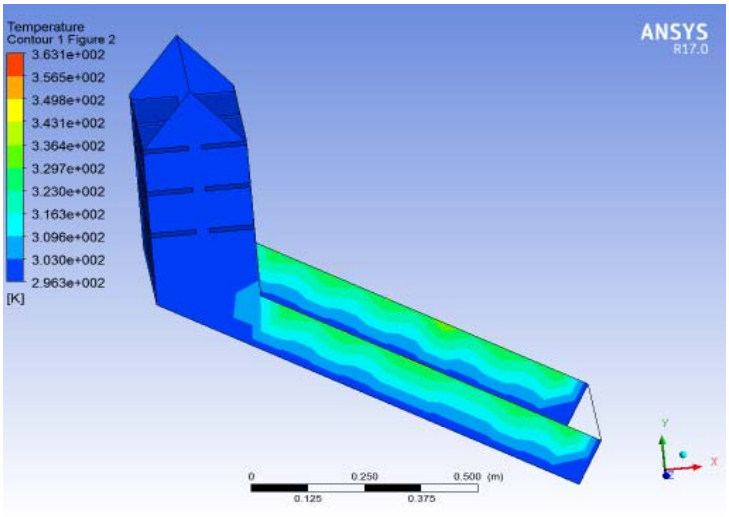

Figure 6. Temperature distribution

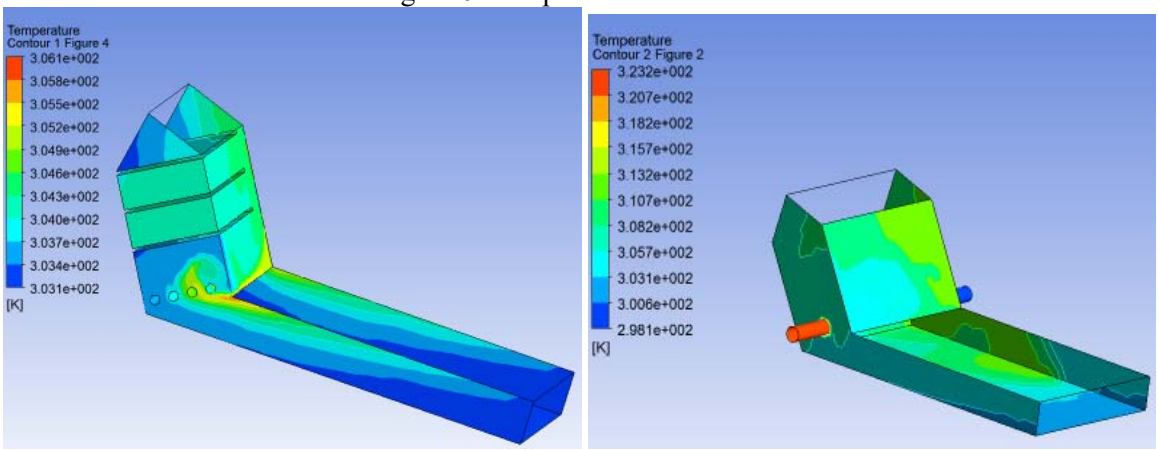

Figure 7. Temperature distribution with exhaust gas

3. Experimental Analysis:

The experimental model of solar crop drier was constructed with wooded chambers having slots to insert three food plate trays. Exhaust gas pipes were inserted at the bottom of the trays. The flat plate collector was fixed at 30^0 to the ground and facing towards the south. The test was conducted at full summer during April and June to have more efficiency of the drier. Figure 8 shows the constructed experimental model of solar crop drier with the exhaust gas heat exchanger. The temperatures are air inlet and at each food plate trays are measured using thermocouples for every hour. The mass flow rate of air was varied from 0.5, 1, 1.5 and 2 kg/s. The slices of cucumber were placed on the trays and moisture content was checked by weighing them.

Figure 8. Experimental set up of solar crop drier with exhaust gas heat exchanger

4. Results and discussions

4.1. Natural Convection

Table 1 gives the data of the removal of moisture by weighing the slices of the cucumber. It shows that as the solar radiation increases the moisture removal increases that can be assured by the weight loss in the crop. Figure 9 show the temperature distribution in three food plate trays during the natural convection.

Table 1. Loss of Weight

Time (hours)	10:00-11:00	11:00-12:00	12:00-13:00
Weight Loss (Grams)	169	150	110

4.2. Exhaust gas heat exchanger

Figure 10 show the temperature distribution in three food plate trays during the exhaust gas flow heat exchanger was used. It was found that copper finned tube is more efficient than copper tubes without fins that exchanges heat from the exhaust gas of the diesel engine. Hence it was continued with all three crops with finned copper tube. Table 2 represents the moisture removed in solar crop drier in natural and exhaust gas drying.

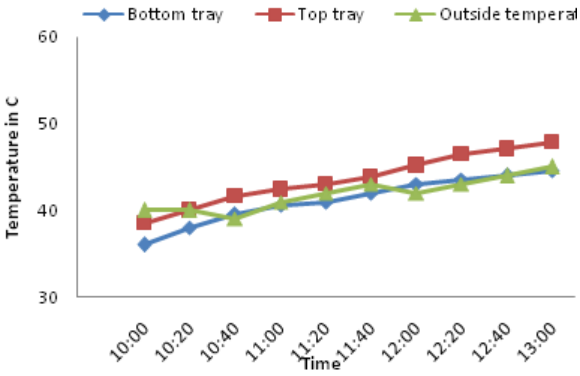

Figure 9. Temp distribution in each tray

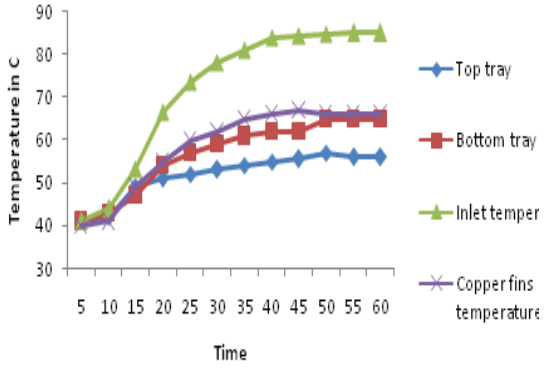

Figure 10. Temp distribution in finned copper tube

Table 2. Weight loss comparision between Natural and Exhaust gas Drying

Time (Minutes)	Weight loss in Natural drying (Grams)	Weight loss in Exhaust Drying (Grams)
20	192	186
40	183	168
60	169	146

5. Conclusion

The CFD and experimental analysis of the solar crop dryer attached with flat plate collector and attached with diesel engine exhaust pipe heat exchanger was done. A comparison study was made between the crop dryer with and without exhaust pipe heat exchanger and found that when the exhaust pipe was attached there was an improvement in the increase in temperature compared without exhaust pipe. The waste heat from the diesel engine was found more effective when it was used with the attachment of the solar crop drier. The copper tubes of exhaust pipe were also added with the fins to improve its heat exchanging efficiency.

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