Enhanced Solar Air Heaters for Crop Drying

Kamlesh Sahu, Gyaneshwar Sanodiya

Abstract*: Solar air heaters are placed on farms to provide heat for the drying of grain and crop harvesting and harvesting. The results of the thermal study showed that solar air heaters are capable of providing a sufficient increase in air temperature under the majority of crop drying circumstances studied. The restricted thermal capacity of air, as well as the low heat transfer coefficient between the absorber plate and the air flow via the ducting system, both contribute to the overall thermal efficiency of solar air heaters. Solar air heaters must be more efficient in order to be more affordable. This may be accomplished by increasing the heat transfer coefficient between the absorber plate and the air flow passing through the duct. More heat transfer coefficients can be increased by using either active or passive approaches. In most situations, it may be cost-effective to use solar air heaters and incorporate artificial roughness on the absorber plate. The rate of heat transmission from the solar air heater's duct to the fluid flow may be increased by creating artificial roughness on the surface of the duct. The study focused on several roughness element geometries for solar air heater ducts, and the results indicated that there is a link between the two. This paper attempts to find ways to artificially increase the heat transfer capacity of solar air heaters' ducts by using element geometries which have been utilised in solar air heaters' heat transfer devices.

Keywords*: Solar air heater, Crop drying, Solar energy, Heat transfer.

I. INTRODUCTION

In light of the fast depletion of fossil fuel supplies, it is imperative that we seek out and use alternate forms of energy as soon as possible. The solar energy industry stands out as the most promising long-term solution for addressing the world's ever-increasing need for energy among the numerous available options. Solar energy is a free, ubiquitous, and indigenous source of energy that produces a clean and pollution-free environment. It is also a renewable source of energy. Solar collectors, which convert solar energy into thermal energy for use in heating applications, are the most straightforward and efficient method of harnessing solar energy. Because of their fundamental simplicity, solar air heaters are the most commonly utilised collector devices and are also the least expensive (Fig.1). In many applications, including greenhouses, solar air heaters are used to heat spaces with moderate or low temperatures. The several use of sun energy include drying crops etc. Second, the absorber plate's heat transfer coefficient to the duct's air is low. To make them more economically feasible in the long term, the thermal efficiency of SAH must be enhanced. Increasing the heat transfer coefficient between the absorber plate and the air flow via the duct system may help enhance heat transmission. Heat transfer coefficients may be generally divided into two categories: those that are actively controlled and those that are passively managed [1-13].

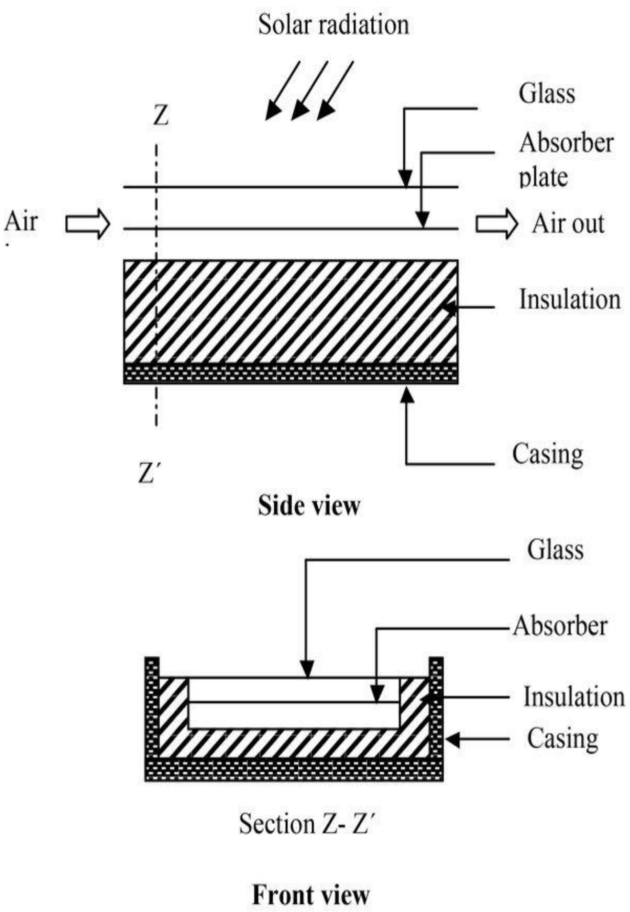

Fig. 1 Solar Air Heater

The methods that use active force need, for example, an electric field, an acoustic field, or surface vibration. The use of a strong electric field to improve heat transfer has been the subject of study for over 80 years. This kind of enhancement uses an electric field and a fluid field to improve heat transfer in a dielectric fluid medium. This kind of flow may be utilised to help with heat transmission as well as for the flow's pressure drop management [14-29].

To produce a swirling flow, passive methods need specific surface geometries, such as rough and external surfaces, fluid additives, and swirl flow devices, such as twisted tap inserts. For 140 years, researchers have employed passive methods to increase the rate of heat transmission in a heat exchanger (Fig.2).

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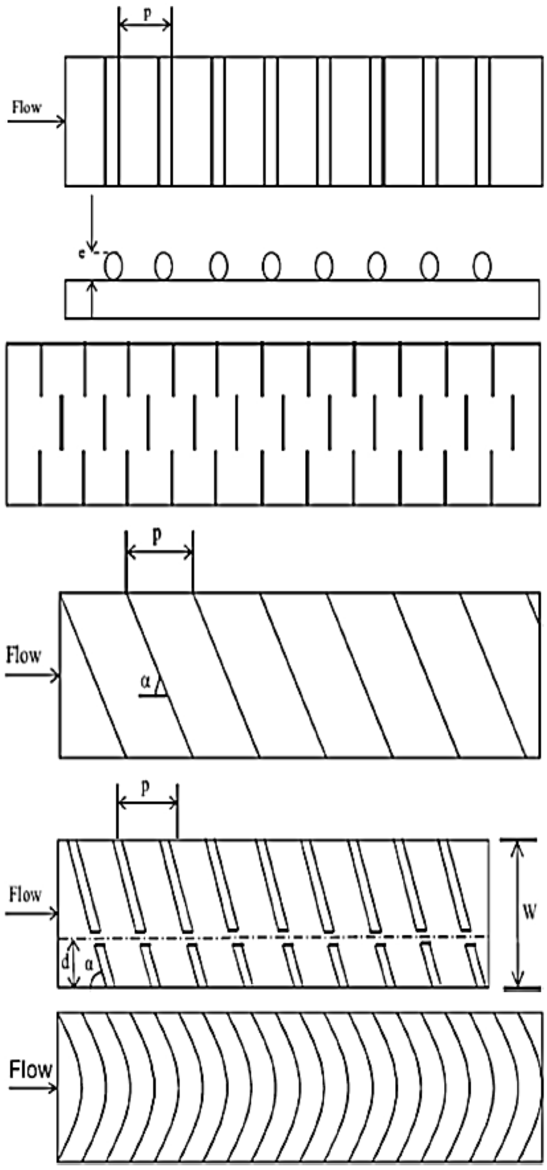

Fig. 2 Various ribs

Artificial roughness may enhance a SAH's THP. In the case of forced convection heat transfer, artificially created roughness has become extensively adopted in order to enhance turbulent flow near the heat transfer surface (Fig. 3). On the other hand, the extra electricity necessary to move air through the duct costs too much money. Due to this, it is suggested that turbulence be created just at the next-to-heat transfer surface region, to help lower power consumption. Roughness components should be kept at a lower height relative to the duct size in order to achieve this goal [30-43]. The critical dimensionless geometrical parameters for characterizing roughness are as follows:

1. Relative roughness pitch: The relative roughness pitch is the distance between two consecutive ribs divided by the rib height.
2. Relative roughness height: The ratio of the height of the ribs to the corresponding diameter of the air channel is known as the relative roughness height.
3. Angle of attack: The angle of attack is the rib's inclination relative to the duct's air flow direction.
4. Shape of roughness element: Ribs in two dimensions or discrete elements in three dimensions, transverse or inclined ribs, V-shaped continuous or broken components with or without gap, are all possible roughness elements. It is also possible to have roughness components in the form of an arc-shaped wire or a dimple or a hollow or a complex rib-grooved pattern. A typical shape for ribs is square, however for the purpose of investigating thermal hydraulic performance, other forms such as circular, semi-circular, and chamfered shapes have also been studied.
5. Aspect ratio: It is the relationship between duct width and duct height. This element is also very important when looking at the thermo-hydraulic performance of a system [44-62].

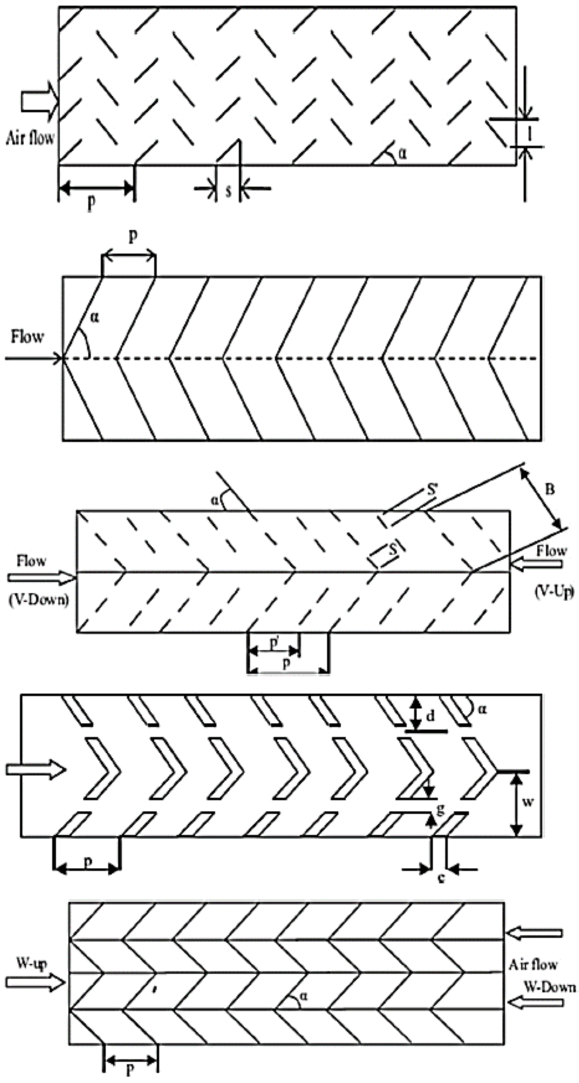

Fig. 3 Various ribs

II. METHODOLOGY

If you have an intentionally roughened Solar Air Heater, you may introduce a uniform air velocity at the intake, while you can also apply a pressure outlet condition, which has a set pressure of 1.013x105 Pa at the exit. In the flow direction, a constant velocity of air with a temperature of 300 K is considered.

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The temperature of the air within the duct is likewise assumed to be 300 K at the start of the experiment. At the mean bulk temperature, it has been assumed that the physical characteristics of air stay constant throughout time. It has been decided to apply the impermeable boundary and no-slip wall requirements to the duct walls, which have already been completed. It is necessary to provide a constant flux of 1000W/m^2 to the absorber plate in order to maintain adiabatic wall conditions on the bottom wall in order to achieve this (top wall). Due to its findings being more comparable to the Dittus–Boelter and Blasius empirical correlation results, the RNG k-ε model has been selected in the present numerical simulation work.

A finite volume approach and a second order upwind-biased scheme are used to discretize all of the governing equations. The FVM is then used to solve them in a segregated manner using the FV methodology. ANSYS FLUENT, a commercial CFD software, is required for the solution of the equations under consideration. Because of the ease of the SIMPLE approach, it was chosen to utilize it to couple pressure and velocity for the incompressible flow calculation. The convergence criteria is specified as 0.001 for all of the dependent variables, with the exception of the independent variables. If convergence difficulties occur, the solution is begun using a first order upwind discretization scheme and subsequently switched to a second order upwind discretization scheme. In the case of an inlet air supply, a uniform air velocity is produced, while in the case of an outlet air supply, a pressure (fixed) outlet condition is created. When applied to the bottom surface of the test section, the adiabatic boundary condition is seen, while when applied to the top surface of the test section, the continuous heat flow condition is observed.

III. RESULT AND DISCUSSION

A numerical study is carried out by [24], In order to obtain the results numerically, codes are developed in MATLAB using fixed values of operating and system parameters. It has been shown that the rib geometry in arc form has a maximum THP parameter of a value of Re = 15,000 when compared to the total roughness elements examined, compared with other ruggedness geometries.

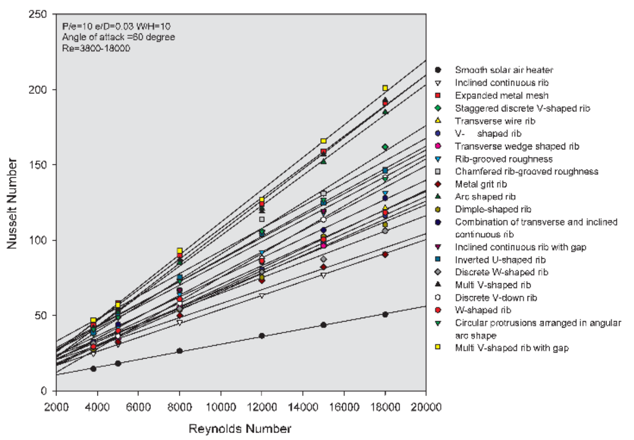

Fig. 4 Re vs. Nu

As illustrated in Fig. 4, the Nusselt number grows with each successive term in the series. Nusselt number, when the Reynolds number is equal to or greater than 18,000, is the maximum for V-shaped rib.

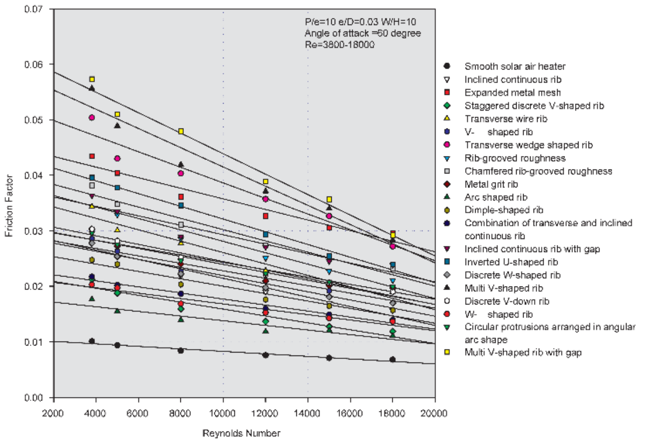

Fig. 5 Re vs. f

Friction factor is a measure of how difficult it is to move anything. As can be seen in Fig. 5, friction factor diminishes with each successive movement. This can also be observed that the friction factor reaches its maximum at low Reynolds number (Re = 3,800), with the V-shaped rib.

IV. CONCLUSION

The following conclusion may be made on the basis of an examination of the article for roughness on solar air heaters:

1) When compared to a smooth surface design, the use of artificial roughness on the surface of an air heater substantially enhances heat transfer and overall thermal efficiency of the device.
2) It has been found that artificial roughness geometry of various forms, sizes, and orientations may be used to enhance performance.
3) The application of artificial roughness increased the amount of pumping power needed since the frictional value was raised, according to this research. As a consequence, it is critical to design solar air heaters in such a way that they consume less pumping power while attaining greater thermal efficiency.
4) According to the results of this literature review, there has been a substantial amount of work published on the design of solar air heaters using an experimental approach. This research also reveals that just a few studies on the computational fluid dynamics (CFD) evaluation of solar air heaters have been performed.
5) Numerous researchers have established a number of relationships and equations to predict or calculate the thermo-hydraulic efficiency of a solar air heater with a roughened surface.
6) The form of the traverse rib enhances heat transfer by splitting and producing vortices in both streams (i.e., upstream and downstream) of the rib, as well as reattaching flow in inter-rib gaps.
7) A standard solar air heater was used to generate the two-dimensional flows in this study, and the results of these calculations indicate that the Renormalization-group K– model produces the best results for these flows.

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8) The multi-V-shaped rib roughness with gap has the highest Nusselt number of all roughness components examined, relative to other roughness geometries for the investigated parameter range.
9) The multi-V-shaped rib roughness with gap has the highest friction factor when compared to other roughness geometries within the range of parameters considered in this research.

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