Enhancement of Heat Transfer of Solar Air Heater using Different Artificial Roughness Geometries

Ashish Sharma[1], Alok Chaudhari[2]
[1,2]Assist. Prof. Department of Mechanical Engineering, JBIT, Dehradun (U.K)

Abstract
Solar power is energy from the sun and without its presence all life on earth would end. Solar energy has been looked upon as a serious source of energy for many years because of the vast amounts of energy that are made freely available, if harnessed by modern technology. The simplest and the most efficient way to utilize solar energy are to convert it into thermal energy for heating applications. The most important and basic components of the system required for conversion of solar energy into thermal energy are called solar collector. Artificial roughness applied on the absorber plate is the most efficient method to improve thermal performance of solar air heaters .Experimental Investigations appropriate to distinct roughness geometries shows that the enhancement in heat transfer is accompanied by considerable rise in pumping power Several studies have been carried out to determine the effect of different roughness element geometries on heat transfer and friction in solar air heaters. The objective of this paper is to review various studies, in which different artificial roughness elements are used to enhance the heat transfer rate with little penalty of friction. Heat transfer coefficient and friction factor correlations developed by various investigators for artificially roughened ducts of solar air heaters have also been reported in the present article. The effects of various rib parameters on heat transfer and fluid flow processes are also discussed

1 INTRODUCTON

Energy plays an important role in development process. There two types of energy resources one is alternative source of energy and other is fuel sources. Since rapid depletion of fuel resources, there is need to search new resources of energy.

Solar energy is the ultimate source of energy, which has large quantity in nature, available free of cost, pollution free. Solar energy is collected by solar collectors i.e. by mean of solar devices like solar air heater, solar water heater. As per the geographical condition of India, the solar radiation availability by nature is more efficient. India has agricultural environment and its economy depends on agriculture and industrial field. Solar air heater is most economical solar collecting device. Solar air heaters because of their inherent simplicity are cheap and widely used as collection devices of solar energy and useful for room heating, crop drop drying, solar drier and maintaining moderate temperature at industrial processes in winter season.

1.1 Principle

A conventional solar air heater is essentially a flat plate collector with an absorber plate. It is a transparent cover system at the top and insulation at the bottom and on the sides. The whole assembly is enclosed in a sheet metal container.

As shown in figure below, cold air of inside home is drawn by fan in to duct which is covered by solar collector. The heat absorbing by solar collector is transfer to the air in duct and so air become warm. Warm air has low density as compare to cold air so it flow to upward and thus natural convection current is being set. Air has low co-efficient of heat convection so for increasing velocity blower is used.

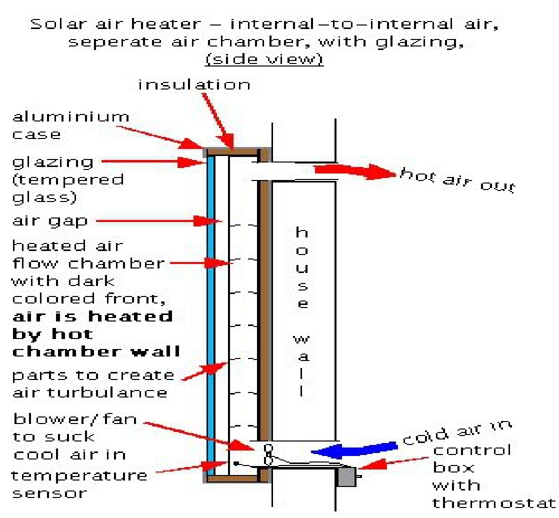

Fig.1.1. Principle of Solar Air- Heater

1.2 Solar Air Heating

As the name suggests, Solar Air Heating is the conversion of solar radiation to thermal heat. The thermal heat is absorbed and carried by air which is delivered to a living or working space. The transparent property of air means that it does not directly absorb effective amounts of solar radiation, so an intermediate process is required to make this energy transfer possible and deliver the heated air into a living space. The technologies designed to facilitate this process are known as Solar Air Heaters.

2 Applications of Solar Air Heater

2.1 Heating

The primary function of a solar air heating system is to provide home heating. The heat generated is extremely energy efficient and as a result there are several significant benefits:

- a higher level of comfort
- lower power bills
- lower carbon emissions

Space heating accounts for 38% of residential energy usage in Australia, with some states such as Victoria as high as 55% (hot water accounts for 23%). Although results vary, case studies have shown some homes to reduce the heating component of their annual energy bills by around 50%, resulting in a total household reduction of around 20% per annum.

2.2 Cooling

Many solar air heating systems can also be used to help cool homes by:

- Transferring cool outside air into the home, especially after sunrise during summer; and/or
- Expelling hot air out of the roof cavity to reduce the transfer of heat from ceiling to inside air.

The cooling effect is often likened to an evening breeze bringing in cool air after sunset. The same fan that is used to transfer warm air into the home for heating can be used to transfer air via one of the methods above. The same ducting and thermostat control used to control the heating system can also be utilized, often with no or very little additional hardware.

2.3 Ventilation & Moisture Control

Modern Australian homes are designed and built to seal tight to minimize the amount of heat loss (or heat gain in summer) for the purpose of energy efficiency. While this helps with heating and cooling bills, it can also introduce humidity related problems as it restricts the amount of fresh air entering the dwelling. Moisture from showers, cooking and even breathing can become trapped and lead to condensation on internal surfaces and mound.

2.4 Filtration

Many Solar Thermal Air systems incorporate a high grade air filter to ensure that not only is the incoming air fresh, but well filtered from dust, pollen and larger particles from wood fires and transport emissions. The majority of the air enters the house in this controlled manner, rather than entering randomly through windows and doors.

2.5 Saving With Solar Air Heater

Case studies and university investigations have shown installations to reduce the reliance on conventional heating & cooling systems by over 50%.

3 MATHEMATICAL ANALYSIS

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

Application development, including Graphical User Interface building

3.1 MATLAB Analysis

Matlab “matrix laboratory” is useful in mathematical computation of data and also in comparing the result of different equation and parameters. It provides the interface between the user to analysis the mathematical problem.

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- Modeling, simulation, and prototyping
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- Application development, including Graphical User Interface building.

Matlab is a powerful mathematical tool for matrix calculations and almost any other mathematical function you need. Matlab also has the ability to form windows like applications with its programming language.

3.2 Methodology for Analysis

The following are the steps make for analysis.

- Clear the window and create a new window.
- Uses the code clc to display the output in the same starting position on the screen.
- Entering the parameters of the analysis.
-
- Plot and figures by creating grid.
- Entering the title and colors of various properties by coding.
- Label x and y for graphical presentation.
- Entering the legend to point the values of Nusselt number, friction factor, Reynolds number of different parameters on graph.
- Run the program to generate the graphs.
- Analysis the graphs and make the

results.

- ➢ Conclusion of the analysis and results.

parameters	value
Reynolds number, Re	4000-18000
Width of duct, W	8cm
Mass flow rate of air,m	1.69gm/sec
Height of duct, H	10cm
Temperature rise	30°c-40°c
Specific heat of air, Cp	1.005 kj/kgk
Relative roughness pitch	10
Relative roughness height	0.02-0.04
Angle of attack (α)	30°
Rib chamfer angle	12°
Prandtl number, Pr	0.7
Heat flux, I	700 W/
Hydraulic diameter, D	100mm

4 RESULT AND DISCUSSION

The graphical presentation of various roughness geometries shown by using matlab. The analysis is done by using correlation of each geometry for Nusselt number and friction factor.

The following results are consider from the graphical analysis:

- ➢ The Arc shaped rib shows greater value of Nusselt number and lesser value of friction factor at different relative roughness height.
- ➢ As the range of Reynolds number increases the value of Nusselt number is also increases in case of each geometry.
- ➢ The smooth duct is also preferable in case where the Reynolds number range is small.
- ➢ The metal grit rib is shown less effective as compared to other roughness.
- ➢ The transverse continuous ribs show less friction factor in every parameter.

The wedge shaped rib also shown effective at higher value of relative roughness height (e/D). The thermal efficiency of solar air heat enhance as the improved temperature difference occurs on the absorber surface.The thermal efficiency is also improved likewise the heat transfer rate increases.It shows that for the improvement of solar air heater the artificial roughness is better technique.

4.1GRAPH BETWEEN Re VS Nu for relative roughness height, e/D = 0.02

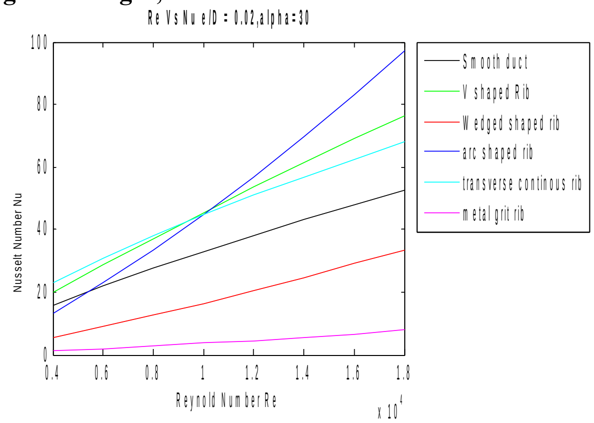

Fig. 4.1 Shows that the effect on Nusselt number with increase in Reynolds number for different roughness

Graph shows comparison between the Nusselt number and Reynold number. The Nusselt Number curve of Arc shaped, V-shaped rib and transverse continous rib show greater value of Nusselt number, for e/D = 0.02. The curve of metal grit rib show smaller value of Nusselt number at minimum relative roughness height.The smooth duct curve is above wedge shaped rib and metal grit rib which shows that for small relative roughness height, the normal absorber surface also preferred.Figure shows that the arc shaped ribs roughness, increases the value of Nusselt number approx double, as compared to smooth duct.The wedge shaped and metal grit rib shows the small value of Nusselt number as compared to smooth duct.

4.2 Graph between Re vs. Fs for roughness height e/D= 0.02

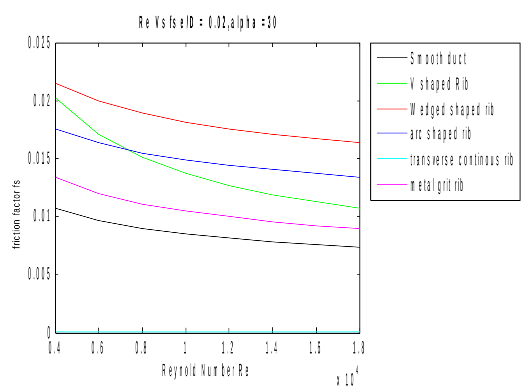

Fig. 4.2 shows the effect of friction factor with Reynolds number for different roughness

Graph shows comparison between different geometries.The curve of transverse continuous rib shows the minimum value friction factor below 0.002.The wedge shaped rib shows the maximum value of friction factor and at large range of Reynolds number, its value of friction factor decreases at a minimal rate.The smooth duct curve shows that the smooth duct generate lower friction factor as compared to other geometries.The curve of V-shaped rib shows a rapid and continues decreases in friction factor as the Reynolds number range increases.The graph shows that the generation of friction factor in case of arc and wedge shaped has a great possibility, and the decrease rate of friction factor with increase in reynolds number is also have a issue.

4.3 Graph between Re vs. fs for e/D = 0.04, α=30°

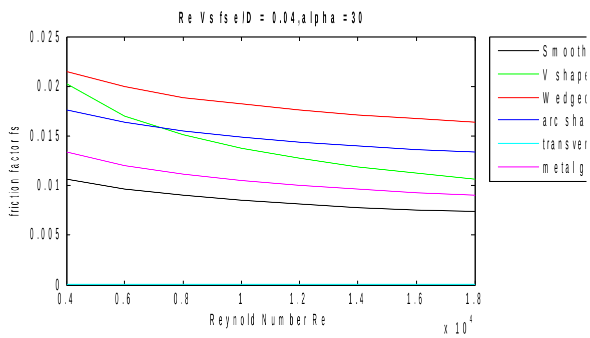

Fig. 4.3 shows the effect of friction factor for different geometries

The friction factor curve for wedge shape roughness is shows higher value with Reynolds number. The curve of V- shaped ribs is shows the rapid decrease in friction factor, as range of Reynolds number go increases. The wedge shaped geometry shows less decrease in friction factor, and also shows higher value of friction factor, which is also higher as compared to smooth surface and other roughness. The transverse continuous rib shows the minimal value of friction factor at every value of relative roughness height. The metal grit rib and Arc shaped rib shows the small change in friction factor with increase in Re.

5 CONCLUSION

Thermal efficiency of solar air heater can be increased by enhancing heat transfer between the absorber plate and the air flowing in the duct. Thus increasing the contact area between air and absorber plate is essential. Various roughness geometries provided shows comparable result in the improvement of heat transfer, for solar air heater. Friction offered to air flow by these roughness geometries, accounted as friction factor, act as a penalty with enhancement of thermal performance of solar air heater using roughened duct.

From the results the following points is concluded:

➢ Roughened duct shows appreciable increase in heat transfer as compare to smooth duct.

➢ Different roughness geometries provided on the plate shows different heat transfer charactertics when compared to each other as well as to smooth plate.

➢ Friction factor also improves.

➢ The V-shaped ribs shows rapid decrease in friction factor as the Reynold number goes on increases.

➢ The Transverse continous ribs at α=30° & 60° at different relative roughness height show lesser friction factor.

➢ For Nusselt number and heat transfer rate, arc shaped rib is concluded as the effective roughness as compared to other geometries of this present work.

➢ The efficiency is also improved as shown, if the temperature difference increases upto 10°-15°, there is a improvement of 5% in efficiency.

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