THERMAL PERFORMANCE OF SOLAR AIR HEATER BY USING SHOT PEENED ABSORBER PLATE

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ABSTRACT

Solar air heaters have been observed to have generally poor convective heat transfer coefficient from absorber plate to the air. This low heat transfer coefficient results in relatively higher absorber plate temperature leading to higher thermal losses to the environment and hence lower thermal efficiency. It has been found that the main thermal resistance to the convective heat transfer is due to the formation of boundary layer on the heat-transferring surface. Efforts for enhancing heat transfer have been directed towards artificially destroying or disturbing this boundary layer. Ball peening on the absorber plate has been used to create artificial turbulence near the wall or to break the boundary layer. Thus,artificial roughness employed for the enhancement of heat transfer coefficient between the absorber plate and air has improved the thermal performance of solar air heater appreciably.

A critical review of the heat transfer and fluid flow characteristics in artificially roughened ducts has been carried out. Investigations on heat transfer and friction characteristics have been reported pertinent to transitional flow of air in rectangular duct with artificial roughness in the form of ball peening on one broad wall, which is subjected to solar radiation while the remaining three walls are insulated These boundary conditions correspond closely to those found in solar air heaters.Use of artificial roughness to enhance heat transfer rate also results in considerably large increase in friction factor and hence in pumping power.

The present study involved experimental work on an outdoor test facility has been designed and fabricated to generate heat transfer and friction data for flow in a rectangular duct with broad wall with ball peened surface at different air flow rate for a range of surface roughness. The roughness was controlled by different size of balls. Experimental data have also been collected for smooth duct for ensuring the accuracy of the experimental data and also to compare the heat transfer and friction characteristics of roughened and smooth duct. Three plates having different shot peened roughness have been tested for different flow rate. Five flow rates corresponding to a flow Reynolds number between 3000 to12000 have been used for each test set and data were collected under steady state condition.

On the basis of this experimental investigation it is found that the ball peening at one broad wall of the rectangular duct yields up to 1.6- 2.0 fold increase in the heat transfer coefficient and 1.3-1.62 fold increase in the friction factor as compared to a smooth duct for the range of present investigation. The shape and size of shots have a significant effect on heat transfer coefficient and friction factor.

1. INTRODUCTION

Absorber plate of Solar air heaters having artificially roughness by shot peening of one side of the plate (flow side) gives better thermal performance than smooth plate. Artificial roughness due to shot peening on the absorber plate has been used to create turbulence near the wall or to break the boundary layer. Thus, the artificial roughness can employ for the enhancement of heat transfer coefficient between the absorber plate and air and thereby improving the thermal performance of solar air heaters. Since shot peening is a new technique used to create roughness so far no

Detailed specification of Set-up

Duct size	2030 mm x 200 mm x 25 mm
Entry Section	177 mm (2.5□WH)
Exit Section	353 mm (5□WH) z
Test section	1500 mm x 200 mm
Plates Used	Aluminum (3mm Thickness)
Aspect Ratio	8

2.1 Details of Experimental Set-up

The experimental setup is an open flow loop that consists of a test duct with entrance and exit sections, a blower, control valve, orifice plate and various devices for measurement of temperature and fluid head. The test section is of length 1500 mm (33.75 D). The entry and exit lengths were 177 mm (2.5□WH) and 353 mm (5□WH) respectively [7]. The test section of one of the ducts carries the roughened absorber plate at the top; while the other duct surface is smooth absorber plates. The exit section of 353 mm length is used after the test section in order to reduce the end effect in the test section. In the exit section after 100 mm, three equally spaced baffles are provided in 100 mm length for the purpose of mixing the hot air coming out of solar air duct to obtain a uniform temperature of air at the outlet. The outside of the entire setup, from the inlet to orifice plate, was insulated with 25 mm thick thermocol. The heated plate was 3 mm thick aluminum plate with shot peened roughness formed on its rear side and this forms the top broad wall of the duct. Calibrated copper constantan 0.3 mm (24 SWG) thermocouples were used to measure the air and the heated plate temperatures at different locations. A digital milli-voltmeter was used to indicate the output of thermocouples. The cross section of experimental set-up is shown in figure1. The pressure drop across the test section was measured by a micro-manometer.

2.2 Experimental procedure

The test runs to collect the relevant heat transfer data were conducted under steady state conditions. Five values of flow rate were used for each set of test. After each change of flow rate, the system was allowed to attend steady state before the data were recorded. The following parameters were measured:

1. Pressure drop across the orifice plate
2. Inlet air temperature of collectors
3. Outlet air temperature of collectors
4. Temperature of plate
5. Solar radiation intensity

2.3 Artificial roughness

The literature survey reveals that the artificial roughness enhances the heat transfer coefficient between the heat transferring surface and air. Detailed information is available in the literature about heat transfer and friction characteristics for flow in the roughened circular tubes and channel in fully turbulent regime. Different researchers have used different types of roughness e.g. triangular shape, rectangular shape, chamfered shape, V-shaped, circular wire ribs, wedge shape, roughness by sand grains, helical shape, gluing mesh on plate, hemispherical shape etc. For this present investigation,roughness has been created by shot peening using shots

5. Conclusions

Surface roughness influences heat transfer to flowing air. Roughness for this purpose has been created by various methods:

1. By Sand blasting
2. By fixing wires on one side of plate
3. By giving different ribs
4. By shot peening

However, as shot peening is also now well-controlled and proven technology for heat transfer enhancement. It was essential to develop technology to create requisite roughness and proportionate Reynolds number for adequate benefits. For this application we have developed technology of ball peening and could do ball peening using 3.1mm and 4.8mm diameter steel balls. It was found that 3.1mm ball gave higher intensity of peening and higher roughness at hundred percent coverage giving 80.2 % thermal efficiency while 4.8 mm ball peening at lesser roughness and lesser coverage could provide higher thermal efficiency. It is thus evident that in peening surfaces roughness alone is not important but coverage area plays an important role. On the basis of this investigation on heat transfer and friction factor characteristics in solar air duct having ball peened on absorber plate, the following conclusions have been drawn :

1. While comparing Experimental values of Nusselt number and friction factor with predicted values, it is found that the experimental values are within a range of ±11.31%. and ±3.49% of predicted values respectively. Therefore, the experimental set-up is correct for data collections.
2. Roughened duct yields about 1.3 -1.62 times increment in friction factor and 1.6-2.0 times increment in heat transfer coefficient as compared to smooth duct under similar operating conditions over the range investigated.
3. On the basis of the temperature profile of air along the length of the collector, it is found that the temperature rises at a faster rate in the beginning and the rate of temperature rise declines towards the exit section. Thus indicating lower heat gain and higher heat losses from the collector towards the exit end.
4. Roughened area of the plate has a significant effect on the heat transfer coefficient.
5. The experimental values of the thermal efficiency of the three roughened absorber plates tested have been compared with that smooth plate. Plate 2 having roughness by using 4.8mm shots with 80% coverage gives highest efficiency of 83.62%.
6. As compared with a conventional smooth duct solar air heater, the thermal efficiency becomes almost 1.5 times for a particular Reynolds no. i.e. for Re=3000, thermal efficiency of smooth plate is 43.04% and for same Reynolds No. the efficiency of plate having roughness by using 4.8mm shots with 80% coverage gives thermal efficiency of 64.24%.
7. Solar air heater with roughened absorbers perform better as compared to smooth heaters when intensity of solar radiations is high .
8. The solar air heater gives the best performance at about 12.15pm , when the solar intensity is maximum.
9. Friction factor decreases with increase in Reynolds number.
10. An optimum operating condition exists for a given intensity of solar radiation and this condition shifts to a higher value of Reynolds as intensity of solar radiation increases.

FIG.-1 Cross Section View of Experimental setup

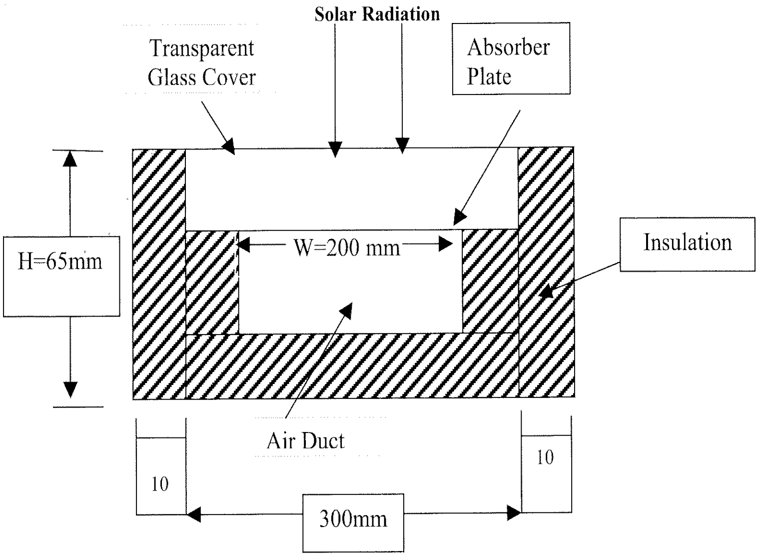

FIG. – 2 : Comparison of friction factor with predicted value

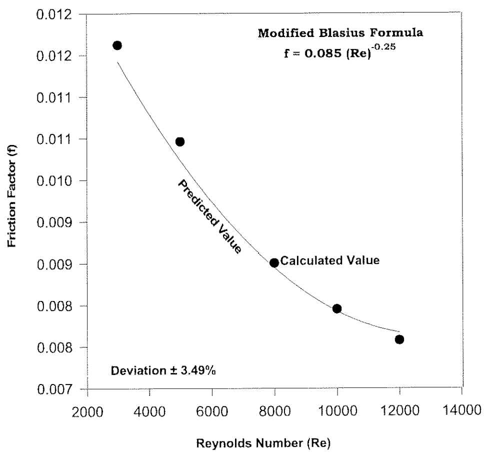

Fig. 2 : Comparison of Friction Factor with Predicted Value