

CFD Analysis of Solar Air Heater with Various Rib Shapes

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Abstract: Solar air heater has low thermal efficiency as heat transfer coefficient is poor between absorber plate and working fluid (air). In this study, a review on solar air heater performance is presented. For improving heat transfer in solar air heater, several researchers recommended use of Artificial Roughness Element in rib and fine wire form. Different rib shapes are studied and their results are observed. This review presents a detail analysis of performance factor of solar air heater with different rib shapes. An examination of shape, size and orientation of Artificial Roughness element is presented.

Keywords - Air Heater, CFD, Rib Shape, Solar.

I. INTRODUCTION

Modern societies are increasingly depending upon energy for fulfilling their needs. Energy cannot be created nor be destroyed. Maximum utilization of energy from available resources should be considered. Focus is shifting towards renewable energy as fossil fuels are consuming at faster rate, their quantity is limited and they create pollution. Solar energy is available to us in large quantity which can be used in generating heat and power. Solar energy is a green energy source and harmless to environment. Solar air heater absorbs solar energy and uses this energy for agricultural drying and industrial drying. Solar Air heater has low thermal efficiency as heat transfer between working medium and absorber is low. The introduction of artificial roughened rib on absorber surface provides better heat transfer in solar air heater duct. Roughened ribs characterized the flow by shear layer separation with recirculation behind them. Afterwards the flow reattaches and recovery region is formed at the downstream ribs. Roughened rib improves the heat transfer coefficient in solar air heater rectangular duct Yemenici and Sakin [1] numerically analyzed heated roughened rib wall with turbulent and laminar flow. Study took place at 2.7×10^5 and 3.4×10^6 Reynolds number and constant thermo-physical properties. For relative roughness height of 0.04 average heat transfer is 105% in laminar and 32% in turbulent flow as compare with flat plate. Maximum value for heat transfer is obtained at first rib corner and the decrease in coming blocks and last two ribs give minimum value of heat transfer. Different roughened elements are used so far for improving heat transfer rate between absorber side and working fluid. Different studies observed relation between heat transfer coefficient with Reynolds

number, relative roughness height, friction factor, Nusselt number.

Different parameters used in artificial roughened rib analysis are:

- Relative roughness pitch (p/e): It is proportion of distance between adjacent ribs and rib height.
- Relative roughness height (e/D): It is proportion of rib height to air passage equivalent diameter.
- Pitch: Distance between starting points of two adjacent ribs.
- Angle of attack: It is inclination provided to rib with respect to direction of flow in solar air heater duct.
- Aspect ratio: It is proportion of width of duct to height of duct.

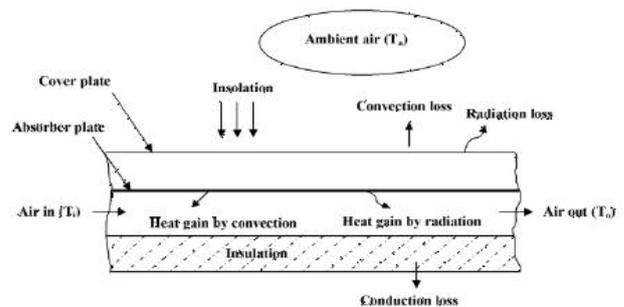


Figure 1. Solar air heater thermal network [2]

II. ARTIFICIAL ROUGHNESS GEOMETRIES USED BY RESERARCHERS

(a) Square

Yadav and Bhagoria [3] performed CFD analysis on solar air heater rectangular duct with square shaped rib placed in transverse direction. Different parameters vary as Reynolds number from 3800 to 18,000, relative roughness height and e/D , from 0.021 to 0.06 at a constant pitch =14.29. Thermodynamics performance factor increases to 1.8 and its dependency on relative roughness is observed. Maximum friction factor observed at 3800 Reynolds number and 0.06 roughness height.

Sahu and Gandhi [4] applied square shaped artificial roughened rib of 2mm with gap and used Realizable $k-\epsilon$

mode for numerical analysis. They fixed different roughened parameter as namely relative pitch of 8, relative roughness height of 0.037, relative gap position of 0.25, and relative roughness angle of 60° and relative gap width of 1. Numerical results were compare with experiment results which was in good agreement and a deviation of 3-20% observed. Friction increases for artificial roughened as compare to smooth duct.

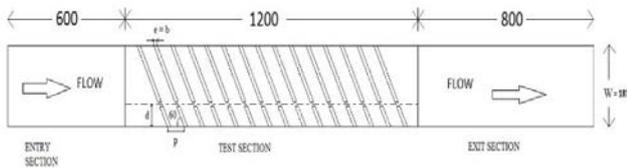


Figure 2. Geometry and solution domain [4]

Kumar and Agarwal [5] used CFD for analysis of trapezoidal artificial roughened rib in solar air heater duct. A relative height of 0.06 observes average Nusselt number to be 2.78 times as compare to smooth duct at 18000 Reynolds number. Friction factor results in a maximum value as 4.24 times of smooth duct at 3800 Reynolds number.

Elwekeel et al. [6] numerically investigated rectangular solar air heater duct with trapezoidal and square roughened rib. Air, air/mist, steam and steam/mist were used as coolant fluid. For computational analysis the shear stress transport (SST) model of turbulent was selected. It was observed that the trapezoidal rib performed better than square rib for all coolants in terms of heat transfer. Trapezoidal ribs saves 9%, 68%, 16% and 118% for air, steam, air/mist and steam/mist respectively compare to that of air in square shape rib.

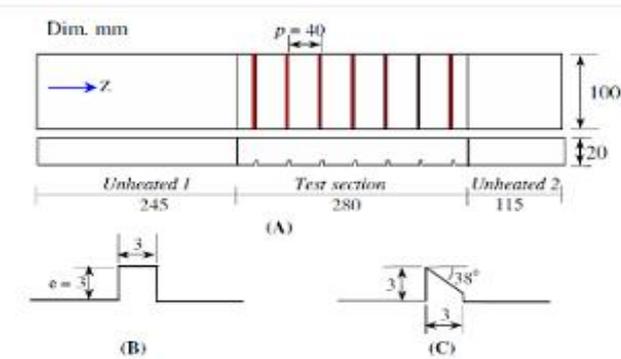


Figure 3. (A) Geometry (B) Square rib (C) Trapezoidal [6]
(b) Triangular rib

Saurav and Bartaria [7] numerically analyzed triangular rib in rectangular solar air heater duct by Ansys Fluent. The study focuses on heat transfer, flow characteristic and friction factor in solar air heater. Rise in temperature is noticed in triangular rib portion due to wake and form development in that region. Maximum local heat transfer coefficient and local surface heat transfer observed at reattachment point.

(c) W shape rib

Kumar et al [8] experimentally analyzed discrete W-shaped roughness in solar air heater with aspect ratio of 8:1. Artificial roughness enhances nusselt number to a maximum 2.16 and friction factor to 2.75 times as compare to smooth duct at 60° attack angle. Parameters vary in the analysis, Reynolds number from 3000 to 15000, the angle of attack from $30-75^\circ$ and relative height from 0.0168–0.0338. Discrete W-shaped roughness provides better heat transfer results. Experimental values of friction factor and nusselt no. deviated $\pm 5.3\%$ and $\pm 3.8\%$ from predicted correlation.

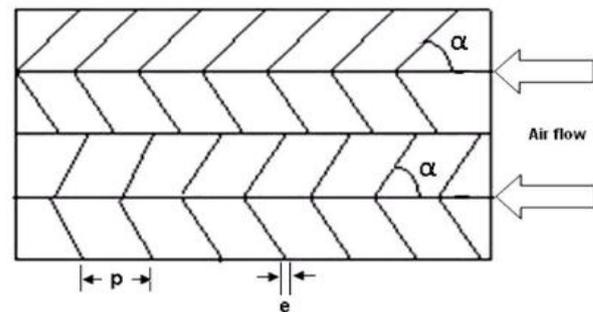


Figure 4. Roughness Geometry [8] (d) Wire mesh rib

Nowzari et al. [9] conducted experimental study on the single and double pass collectors on solar air heater with perforated and plane cover. They used wire mesh matrix in place of absorber plate. By analyzing different configuration of design they observed that double pass solar air collector provides the maximum efficiency.

III. 3 D CFD ANALYSIS OF ARTIFICIAL ROUGHNESS RIB

Karupaaraj et al. [10] investigated 3D model of solar air heater with square wire roughened rib placed in transverse condition. Renormalization-group (RNG) $k-\epsilon$ model is used for analyzing the fluid flow characteristics and heat transfer. Nusselt number increases 2 to 2.6 times as that of smooth duct.

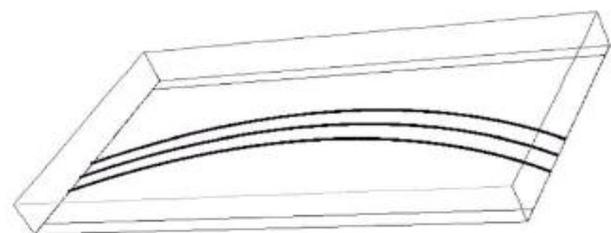


Figure 5. Solution Geometry for CFDB analysis [11]

Kumar and Saini [11] used CFD model for analyzing solar air heater performance using artificial roughened. Thin circular wire is used as roughened rib in arc form and its effect on heat transfer was observed. Different roughened parameter vary for study as namely relative roughness angle from 0.333 to 0.666 and relative roughness height

from 0.0299 to 0.0426. Overall enhancement ratio was observed to be 1.7 for parameter range.

IV. CONCLUSION

Improvement in thermal efficiency of solar air heater is observed by using Artificial Roughness Rib. Heat transfer coefficient in solar air heater with roughness rib depend upon performance parameters namely, relative roughness height, Relative roughness pitch, angle of attack and shape of roughness rib. An increment in Nusselt number and friction factor is noticed by several researchers with IJSPR the use of artificial roughness element. Hence, Use of Artificial roughness elements desirable. This paper is helpful for future investigators in improvement heat transfer of solar air heater.

V. REFERENCES

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