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CFD Analysis of a W-Ribbed Roughness Solar Air Heater

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ABSTRACT

Solar air heaters are used to heat up air which can be used for various purposes. Computational Fluid Dynamics (CFD) has proved to be a boon for researchers to estimate performance of any machine at design stage only. In the present work, a 3-dimensional CFD investigation has been completed of sun powered air radiator to ponder heat exchange and liquid stream conduct in a rectangular pipe of a sun oriented air warmer with one roughened divider having blend of round and square transverse wire rib harshness. The impact of Reynolds number, harshness tallness, unpleasantness pitch, relative unpleasantness pitch and relative harshness stature on the warmth exchange coefficient and rubbing factor have been considered. From the investigation it has been found that, W-formed harshness gives better warmth exchange rate as contrast with the V rib unpleasantness under comparable working conditions. The most extreme estimation of Nusselt number for W-formed harshness is acquired with the relative unpleasantness pitch (P/e) of 10 past that it begins diminishing.

KEYWORDS: *CFD Analysis, Absorber plate, Enhancement Factor, Reynolds's No., Nusselt No, W-Form*

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INTRODUCTION

Heat transfer enhancement is a subject of considerable interest to researchers as it leads to saving in energy and cost. Because of the rapid increase in energy demand in all over the world, both reducing energy lost related with ineffective use and enhancement of energy in the meaning of heat have become an increasingly significance task for design and operation engineers for many system. In the past few decades numerous researches have been performed on heat transfer enhancement. These researches focused on finding a technique not only increasing heat transfer, but also achieving high efficiency. Achieving higher heat transfer rates through various enhancement techniques can result in substantial energy saving, more compact and less expensive equipment with higher thermal efficiency. Heat transfers enhancement technology has been improved and widely used in heat exchanger application; such as refrigeration, automotives, process industry, chemical industry, etc. One of the widely-used heat transfer enhancement technique is inserting different shaped elements with different geometries in channel flow.

LITERATURE REVIEW:

Yadav et al., 2013, studied about the heat transfer in rectangular duct of solar air heater using CFD approach. Boukadoum and Benzaoui, 2014 used CFD for performance prediction of artificially roughened solar air heater. Kumar et al., 2017, has used CFD for performace prediction of heat exchanger. Sahu et al., 2016, 2017 has discussed about the usage of hot air. Gupta et al., 2017 has used CFD for performance prediction on greenhouse dryer. Rana et al. 2017 covered effect of V shaped roughness using CFD in his research. Jain et al., 2017 performed CFD analysis on W shaped ribs to study their effect on performance of solar air heater. Gupta et al., 2021 experimentally proved usage of hot air for drying purpose.

PROBLEMS AND OBJECTIVES

Problem Identification

Investigate the effect of roughness parameters on various thermal properties of SAH like Reynolds number, Nusselt number, heat transfer coefficient and friction factor in flow and compare the result with smooth plate.

Objective of the work

- To enhance the intensity of solar radiations by increasing the area of collection of solar radiations using W shaped artificial roughness on the plate.
- To increase the heat transfer coefficient with the help of W shaped roughness and compare with the smooth plate respect of Reynolds no. & Nusselt no.
- CFD analysis using the artificial roughness geometry using W shape on the plate under the side of in the rectangular duct of a SAH to enhance the heat transfer and fluid flowing inside it.

METHODOLOGY

In Computational Fluid Dynamics (CFD), study of any system starts with the design of desired geometry and meshing for modeling the domain. Meshing is known as the discretization of the considered domain into tiny volumes wherever the flow equations are resolved by the assistance of repetitive ways. Modeling starts with the describing of the boundary and initial conditions for the dominion. Finally, it's followed by the analysis of the results, graphical plots, computed values using function calculator.

Modeling And Meshing

Heat exchanger has been designed in CATIA. The design specifications are shown in Fig. 1. For next step, the geometric model is imported to ANSYS for CFD analysis

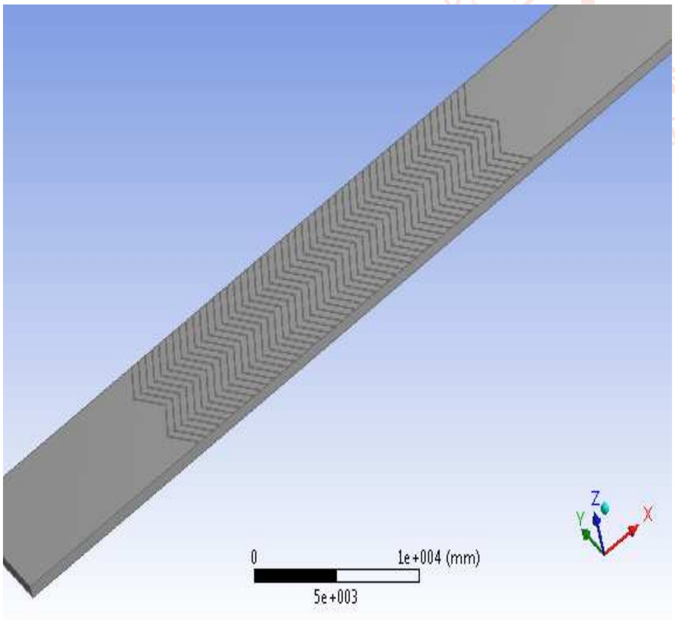

Fig 1: Geometry of W shaped roughness

The next action is to discretize the domain. Automatic meshing has been used for descritisation. The grid independence test is carried out by varying elements from 281550 to 377102.

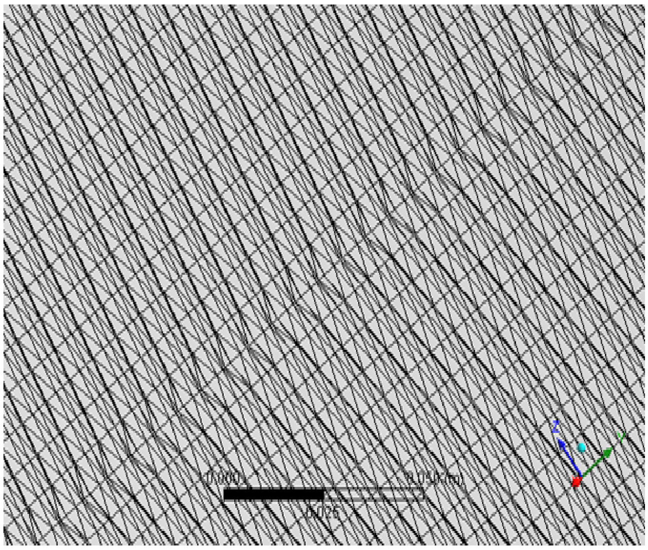

Fig. 2: Non-uniform mesh generation over the domain

Boundary Conditions

For any simulation boundary conditions are needed to be specified. The specified boundary conditions are specified in Table 1.

Table 1: Boundary Conditions

Location	Boundary Type	Boundary Detail	
Air Inlet	Velocity Inlet	Velocity	Reynolds Number
		1.163	4000
		1.74	6000
		2.32	8000
		2.90	10000
		3.49	12000
		4.07	14000
Outlet	Pressure Outlet	Gauge Pressure 0	
Left Side, Right Side, Bottom	Wall	No slip, Adiabatic insulated wall	
Absorber Plate	Wall	Heat Flux 1000 W/m^2 Material Aluminium	

RESULTS AND DISCUSSIONS-

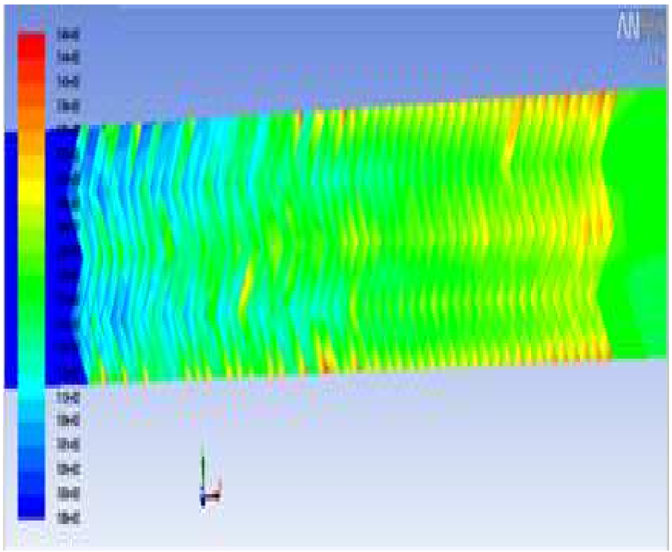

Fig 2: Contour of temperature at P/e=10

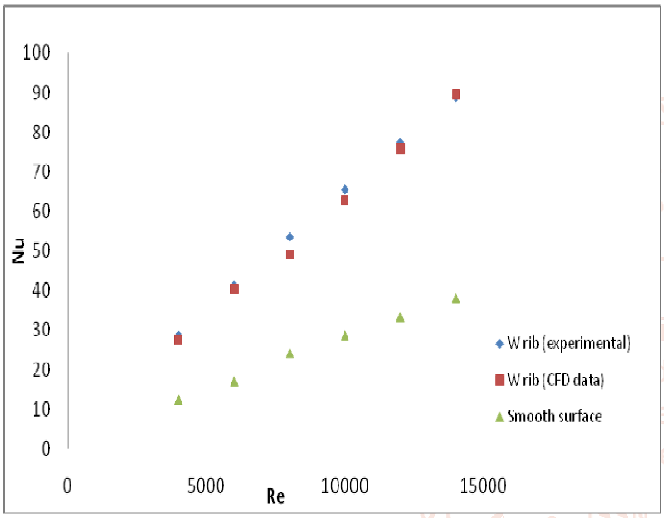

Fig 3: Comparative graph of W-shaped roughness

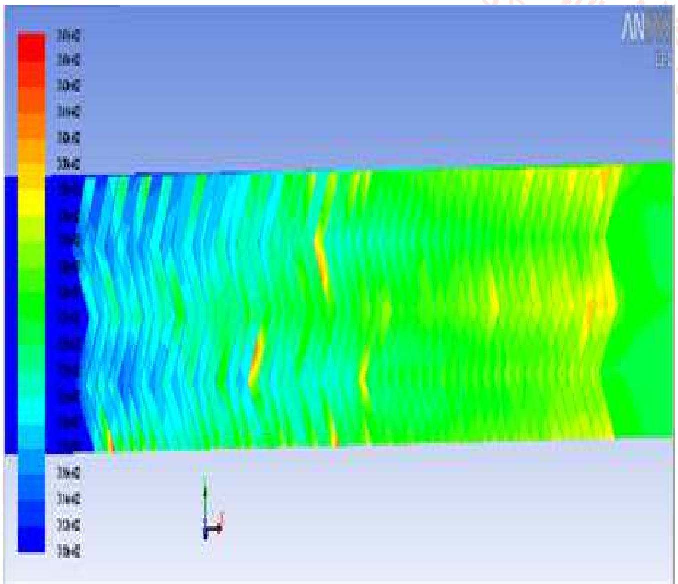

Fig. 4: Contour of temperature at P/e=12

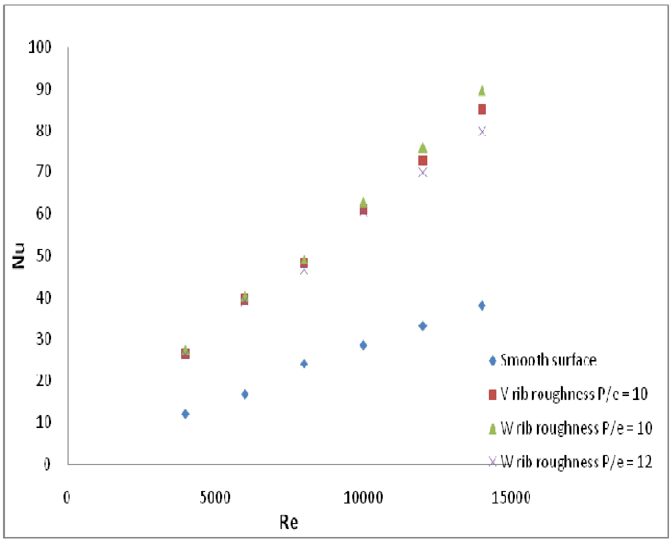

Fig. 5: Comparative graph for V rib and W rib roughness performance

CONCLUSIONS

The present CFD based study has been carried out by using W-shaped roughened solar air heater for analyzing fluid flow and heat transfer characteristics and it also shows that the CFD results are found in agreement with experimental results. On increasing the Reynolds number the Boundary layer thickness decreases which increase the convective heat transfer between the absorbing plate and the air by decrease the convective resistance it results increase in Nusselt number. The following conclusion has been made from the present analysis

1. Multi inclination geometry increases the heat transfer characteristics of solar air heater.
2. W-shaped roughness gives better heat transfer rate as compare to the V rib roughness because of more secondary flow development in W rib under similar operating conditions.
3. The maximum value of Nusselt number for W-shaped roughness is obtained with the relative roughness pitch (P/e) of 10 beyond that it starts decreasing i.e. at P/e = 12.
4. The maximum increment in Nusselt number for W-shaped roughness is found to be 2.34 times as compare to the smooth surface at Re = 14000.
5. The maximum increment in Nusselt number is found to be 1.15 times as compare to the V rib roughness at Re = 14000.

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