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International Journal for Scientific Research in Modern
Engineering and Science

International Journal for Scientific Research in Modern Engineering and Science, 3(5): 62- 68 (2022)

INFLUENCE OF ARTIFICIALLY INVERTED L-SHAPED RIBS ON SOLAR AIR HEATER HAVING EQUILATERAL TRIANGULAR CROSS-SECTION USING CFD TO INCREASE THE THERMAL PERFORMANCE

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Abstract

The use of artificial roughness in the form of repeated ribs on a surface is an effective technique to enhance the rate of heat transfer. A numerical investigation on the heat transfer and fluid flow characteristics of fully developed turbulent flow in a rectangular as well as triangular duct having repeated inverse L-shaped sectioned rib roughness on the absorber plate has been carried out. The finite volume method using Ansys Fluent is used to simulate turbulent airflow through artificially roughened solar air heater. The Naviere Stokes equations and the energy equation are solved in conjunction with a variations of Reynolds number RNG turbulence model. For validation, a rectangular duct obtained from literature is performed and this verifications results show good agreement with each other. After verification different configurations of triangular sectioned rib (Re= 3800, 5000, 12000, 15000, 18000; P/e= 7.14, 10.71, 14.28 and 17.85) have been considered. The effects of relative roughness pitch and relative roughness height on Nusselt number and friction factor have been discussed and the results are compared with the inverted L-shaped sectioned rib roughened duct and smooth duct under similar flow conditions to investigate the enhancement in Nusselt number and friction factor. Roughness and flow parameters for artificially roughened solar air heater have been optimized by considering the thermohydraulic performance parameter based on constant pumping power requirement. It has been found that the square sectioned transverse rib roughened duct with P/e= 17.86 and e/D= 0.04 offers the best thermo-hydraulic performance parameter for the investigated range of parameters.

Keywords: *Solar Air Heater, Artificial Roughness, Ribs, Thermal Performance, CFD.*

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1. INTRODUCTION

Improved heat transfer rates are urgently needed in numerous thermal systems to reduce power usage. This is especially important for applications involving elevated temperatures in engineering. Technically speaking, several improvement methods for enhancing heat transfer have been divided into four categories: expanded surfaces, twisted tapes, and wire coiled tube inserts. By taking into account the degree of enhancement, available pressure drops, complexity, and cost, the proper sort of heat transfer enhancement technology can be chosen. The majority of heat transfer augmentations enlarge the heat transfer surface area, prevent the formation of boundary layers, and increase turbulence. These frequently lead to increased flow resistance and pressure decrease, necessitating the use of more pumping power. Finding a new roughness geometry that can improve heat transfer with a little increase in flow friction is therefore a serious problem for researchers. In order to improve the thermal performance of compact heat exchangers, gas turbine blade cooling systems, fuel elements for advanced gas-cooled nuclear reactors, cooling systems for electronic equipment, cooling of scram-jet engine inlets, and electric utility devices, artificially roughened surfaces have been used for many years. The primary goal of the heat transfer enhancement is to produce a secondary flow pattern in addition to disrupting the velocity and temperature profiles near to the walls. Due to the created vortices, this secondary flow pattern enhances the fluid mixing qualities, which in turn boosts the local heat transfer coefficient. The degree of local heat and momentum transmission to the fluid depends on how the roughened surface impacts boundary layer growth. Boundary surface roughness affects the rate of diffusion of characteristics via the neighbouring fluid. Stakeholders, represented by ribs, have expressed interest in various enhancements with various geometries and orientations. Due to the presence of ribs, heat transport is improved by two different ways. The wall sub layer is first disturbed, causing flow turbulence, separation, and reattachment that raises the heat transfer coefficient. Second, the presence of the ribs increases the surface area available for heat transfer. For the aim of intentionally improving heat transmission, it is crucial to understand the hydrodynamic and thermal flow characteristics in the boundary layer next to the heated walls

2. MODELING AND SIMULATION

It can forecast the effects of fluid flows on your product with certainty using computational fluid dynamics (CFD) simulation tools, both during product design and production as well as during end usage. The unmatched fluid flow analysis capabilities of the program may be used to build and optimize new equipment as well as to trouble-shoot currently installed systems. Any phenomenon you're researching—whether it's one or many phases, isothermal or reactive, compressible or not—ANSYS fluid dynamics solutions can help you understand how well a product performs.

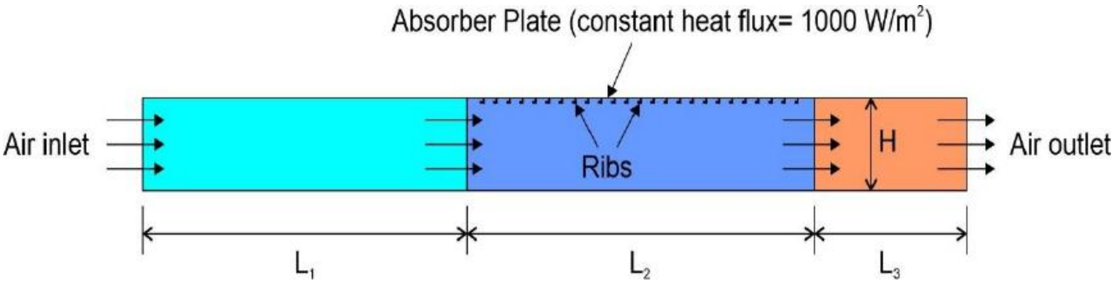

Figure 1. Schematic of fluid domain of SAH

The Ansys Fluent program meshes the computational domain, and the meshed model of the SAH is displayed in Figure 4.9. In order to correctly resolve laminar sub-layers, the structured non-uniform quadrilateral grids are constructed in the CFD domain and very dense grids are positioned close to the hot surface where ribs are placed. The influence of the viscous sub-layer is predicted using quadrilateral grids that are closer to 3 mm from the roughened hot surface [7].

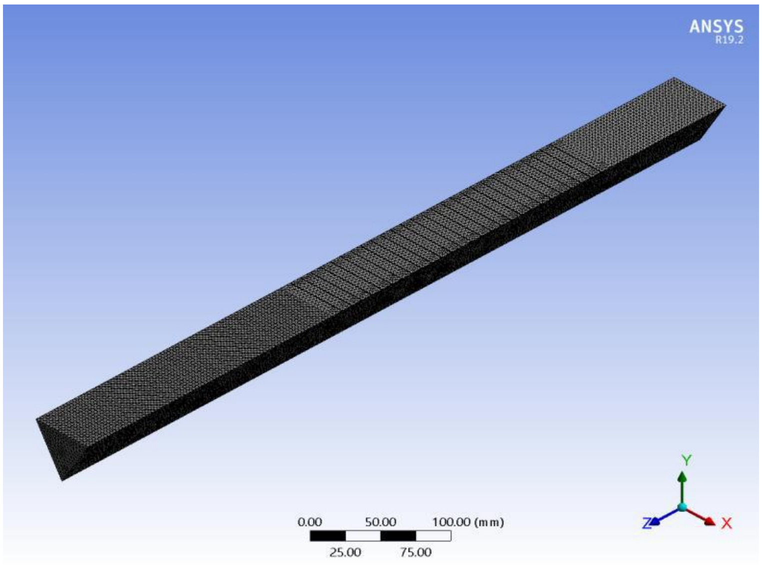

Figure 2. Element/meshed generation of SAH ducts

Table 1. Thermo-physical properties of air and absorber plate [13]

Properties	Air	Absorber Plate (Al)
Density, ρ (Kg/m^3)	1.225	2719
Thermal Conductivity, k (W/m/K)	0.0242	204.4
Specific Heat, C_p (J/Kg/K)	1006.43	871
Viscosity, μ (N/m^2)	1.7894e-5	-

3. RESULT AND CONCLUSION

The impact of an inverted L-shaped rib installed on the bottom of a SAH absorber plate has been attained by numerical study (CFD analysis) of a three-dimensional domain of a SAH of varied parameters. On the heat transmission and friction properties of the SAH duct, the influence of the duct design, Reynolds number, and relative roughness pitch is investigated. The subsection that follows provides an explanation of the findings of this inquiry.

The two types of SAH ducts assumed for study in the current work are rectangular SAH ducts and triangular SAH ducts. Additionally, variations in the relative roughness pitch ratio (P/e) and Reynolds number are taken into consideration for the inverted L-shaped rid (Re). Here some contour plots of pressure, velocity, turbulent kinetic energy and turbulent intensity obtained from CFD analysis of rectangular and triangular SAH duct with relative roughness pitches ratio P/e= 7.14 and Re = 18,000, are as shown in Figure 3 & Figure 4.

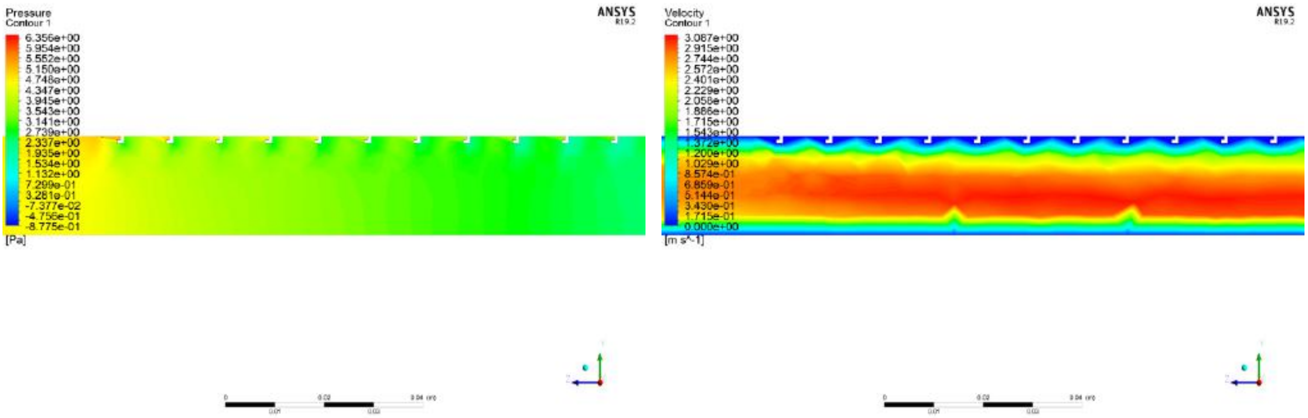

Figure 3. Variation of pressure and velocity distribution at P/e= 7.14 and Re= 18000 on triangular SAH Duct

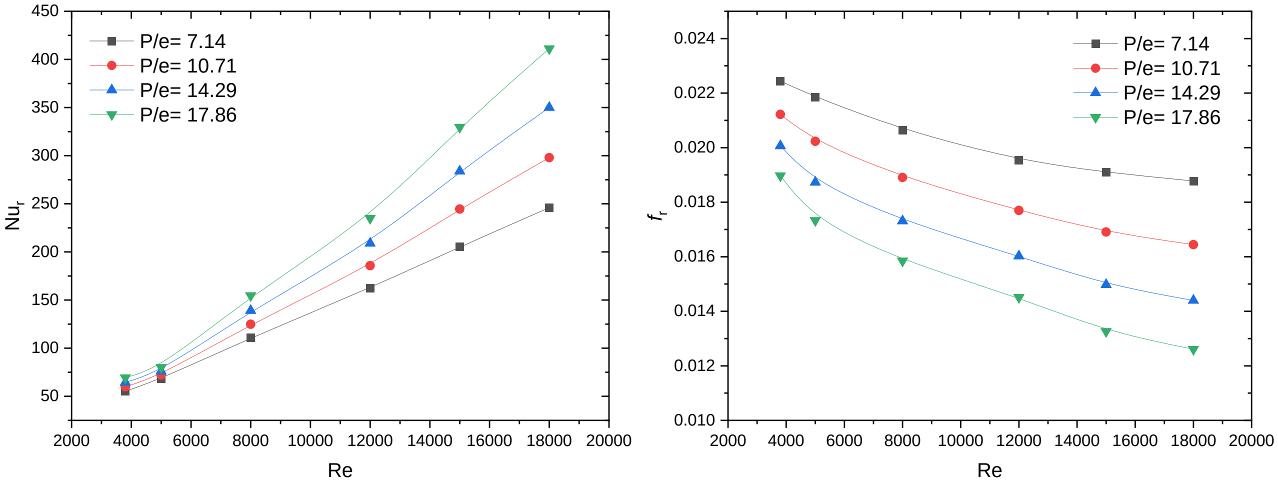

Figure 4. Variation of Nusselt number and friction factor of triangular roughened SAH duct for different P/e ratio versus Reynolds number

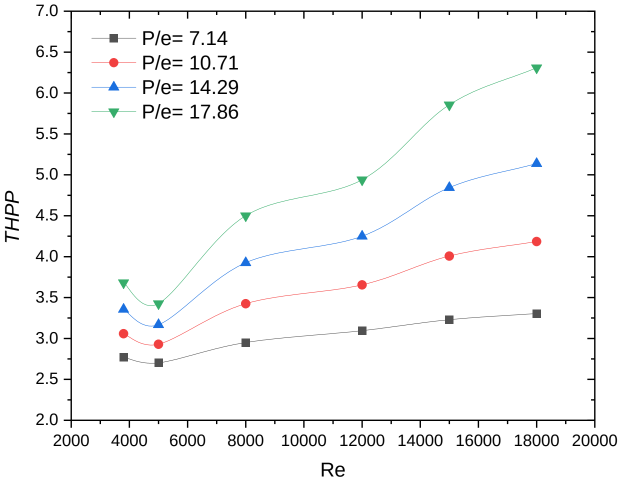

Figure 5. Variation of THPP of triangular roughened SAH duct for different P/e ratio at constant e/w versus Reynolds number

From Figure 5 it has been clearly seen that the variation of Thermo-hydraulic performance parameter (THPP) in triangular roughness SAH duct. It has been observed that SAH roughened with inverted L-shaped rib as artificial roughness elements with e/Dh= 0.04, P/e= 17.86 and Re= 18000 provided the THPP.

4. CONCLUSION

In the current work, 3-dimensional computational fluid dynamics (CFD) analysis is used to take into account the flow characteristics and heat transfer enhancement in ribbed triangular ducts. To investigate the impact of duct shape and P/e on Nu and f, the analysis is conducted for a given range of Re, which varies from 3800 to 18,000. According to findings, the following conclusions are made:

- The rate of heat transfer from the absorber plate to the flowing air is increased by artificially roughening the underside of the solar air heater's absorber plate.
- The Nusselt number increased with increasing in relative roughness pitch and Reynolds number but decreases while considering SAH duct under considered parameters. Under considered parameters, friction factor value is observed decreasing with increase in relative roughness height.
- The thermohydraulic performance parameter (THPP) is found maximum at Reynolds number of 18000. Under this study, the optimum THPP is found at 7.440 for P= 25mm, e= 1.4mm and Dh= 30mm.
- From analysis it has been observed that the THPP in triangular SAH duct is more efficient at P/e= 17.86 and Re= 18000.
- It is advised to utilize this form of surface roughness plate for SAH.
- The work is further extended to different shape of duct, ribs, P/e ratio, e/Dh ratio, e/w ratio and also apply the optimization of considered parameters in optimum condition.

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