WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A Review on CFD Analysis of Effect of Various Shapes of Roughness on Solar Air Heater

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ABSTRACT

Solar air heaters are the devices which are used to heat up air which can be used for various purposes. A lot of researchers have worked for the heat enhancement of solar greenhouse dryers. Computational Fluid Dynamics (CFD) along with experimental techniques has proved to be a boon for new developments to estimate performance of any machine at design stage only. In the present work, researches in the field of solar air heaters have been discussed in detail. It can be concluded for the study that CFD approach can be the most promising one in predicting the performance and improving it.

Keywords: CFD Analysis, Solar air heater, Absorber plate, Enhancement Factor

1 INTRODUCTION

Solar air heating is a technology which uses energy of sun to heat up an absorbing medium which is transferred to air and finally that hot air can be used to heat up space or it can be utilized for other purposes [Hussain et al. 2016] [Nilay et al., 2017] [Kumar et al.,2017] [Sahu et al., 2016] [Gupta et al., 2021] . This technique is cost effective and has wide applications. So, the prime motto of researchers is to enhance the heat transfer of solar air heater. Earlier this was only done with the help of experimentation. But now with the developments in the field of computers and numerical methods, CFD can be used for enhanced design of such machines [Gupta and Prasad, 2012] [Gupta et al., 2016]. Few of the noteworthy contributions are described below.

2 LITERATURE REVIEW

Yadav et al., [2013] numerically presented the study of heat transfer in a rectangular shaped duct for a solar air heater which had triangular ribbed roughness on the absorber plate. The effect of various non dimensional numbers such as Reynolds number on Nusselt number was investigated in detail. The value of Reynolds numbers was varied from 3000- 18000. Simulation was done using ANSYS Fluent. Numerical results were found to be in agreement with the experimental results along with the theoretical approaches. It was found that the Nusselt number increases with increase in Reynolds number.

Rana et al., [2017] carried out computational fluid dynamics (CFD) analysis of a solar air heater using v-shaped ribs as artificial roughness on the absorber plate. Parameters such as relative roughness pitch, Reynolds number, and relative roughness height, angle of attack were been selected as design variables of V-shaped rib for analysis. ANSYS FLUENT was used with k-ε turbulence model for the analysis of computational domain. The enhancement of Nusselt number and friction factor with Reynolds number along with the effect of angle of attack and Reynolds number on

enhancement of Nusselt number and friction factor have been presented. It has been found out that the optimum value of rib configuration based on constant pumping power requirement has been obtained maximum at angle of attack of 60° and P/e = 10.

Jain et al., [2017] designed an artificially roughened solar air heater using discrete W-shaped ribs to study heat transfer and friction factors using commercial CFD code ANSYS FLUENT to investigate the effect of relative roughness height, Reynolds number and angle of attack on duct thermal performance and results and compared the results with smooth duct. Constant heat source of 1000 W/m^2 has been used to heat the surface and remaining three sides are kept insulated. Maximum Nusselt number (Nu) and friction factor (f) are found to be 96.83, 0.45 and 52.19, 0.024 for artificially roughened duct and smooth duct respectively. Enhancement in Nusselt number by 120 % in roughened SAH over the smooth duct was observed. Optimum parameters for roughened duct were found to be: angle of attack (α) = 60°, relative roughness height (e/D_h) = 0.0338, relative pitch ratio (p/e) = 10 and aspect ratio (W/H) = 8.

Boukadoum and Benzaoui [2014] did numerical analysis for enhancement of convective heat transfer in solar air heaters with artificially roughened absorber. CFD numerical simulations were carried out to analyze the flow and heat transfer in the air duct of a solar air heater with transverse rectangular ribs. As the flow was turbulent, the RANS formulation was used to model the flow. Continuity, momentum and energy equations were solved using: k-ε RNG, k-ε RZ, k-ω Standard, k-ω SST. A two-dimensional non uniform grid was generated with local refining near the wall, to critically examine the flow and heat transfer in the inter-rib region. The effect of major parameters (Reynolds number, Nusselt number, friction factor, global thermohydraulic performance parameter…etc) were found out and have been presented. The obtained results are in agreement with those of literature. It has been concluded that the heat transfer was clearly enhanced.

Singh and Singh [2018] investigated the effect of breaking of laminar sub-layer near the absorbing surface in the solar air heater by employing ribs for roughness. However, the gain is obtained at the expense of increase in pressure drop. This paper also discusses about the researches of various investigations made on artificial roughness on solar air heater summarizing their outcomes. Paper also describes that on increasing the roughness, the efficiency of the air heater increases.

Kumar et al., [2018] conducted various experiments to improve heat transfer rate for solar air heater. It has been suggested that the heat transfer rate can be increased by providing various artificial roughnesses to the collector plate. Providing various types of roughness like dimple, v shaped rib roughness on absorber plate inclined as well as the transverse rib on absorber plate enhances the heat transfer. Work of various other authors has also been covered to study effect of various parameters on the performance of solar air heater.

Yadav and Bhagoria, [2013] presented heat transfer and fluid flow processes in an artificially roughened solar air heater using Computational Fluid Dynamics (CFD) approach. The effects of change in diameter of transverse wire rib roughness on heat transfer and fluid flow have been investigated in detail. Design variables chosen are Reynolds number, relative roughness pitch (P/e) and relative roughness height (e/D). ANSYS Fluent has been used for two-dimensional CFD simulation. The Renormalization-group (RNG) k–ε model was selected as the most appropriate turbulence model. Results were validated with the available experimental data. It has been found out that the turbulence created by small diameter of transverse wire ribs result in greater increase in heat transfer over the duct. However, the use of artificial roughness resulted in higher friction losses. It has been found out that the average Nusselt number and average friction factor increase with increase in the relative roughness height while giving opposite trend with increase in relative roughness pitch.

Yadav & Bhagoria [2013] presented detailed review of the literature dealing with the application of CFD in the design of solar air heater. It has been proposed that CFD is a simulation tool which uses powerful computer and mathematics to model fluid flow situations for the prediction of heat, mass and momentum transfer and optimal design in various heat transfer and fluid flow processes. The results obtained from CFD are highly acceptable. ANSYS Fluent has been used to simulate conventional solar air heater. It has been found out numerically that the Renormalization-group k–ε model yields the best results for two-dimensional flow through conventional solar air heaters.

Kumar et al., [2017] suggested that by providing artificial roughness to the absorber plate, performance of solar air heater can be improved. As per author, many literatures are available on circular, semi-circular, triangular and rectangular rib roughened solar air heater. Similar kind of conditions were used for simulating flow properties on elliptical ribs on absorber plate using ANSYS Fluent. The 2 D model has been analysed and the results have been compared with the available experimental results. It has been concluded that the rib width has significant effects on heat transfer enhancement

3 CONCLUSION

Hot air has got a lot of applications. With the use of renewable source, air can be easily heated to high temperatures. Solar air heaters are simple machines that can be employed for such purposes. So, efficiency enhancement for getting high temperatures is one of the mottos of the researchers. High temperatures can be obtained by using artificial roughness on the absorber plate of the solar air heater. Various factors have direct effect on the performance of solar air heater which includes Reynolds number, pitch, relative pitch ratio, etc. Computational Fluid Dynamics is an important tool which can be used for predicting the performance and enhancing it during design stage only.

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