Enhancement in Performance of Solar Air Collector using Right-angle Triangle Corrugations for an Indirect Type Solar Dryer

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ABSTRACT

In this article, a 2D numerical analysis was carried out to investigate the effect of right-angle triangle corrugations on the thermo-hydraulic performance of rectangular cross sectioned duct solar air collector (SAC) for an indirect type solar dryer. Nusselt number (*Nu*), friction factor (*f*) and thermo-hydraulic performance parameter (p_{th}) were evaluated by varying Reynolds number (*Re*) (seven values, 4000 – 22000), corrugation height (*e*) (seven values, 4 – 20 mm), and corrugation pitch (*P*) (six values, 27.5 – 200 mm). A constant heat flux of 1000 W/m^2 boundary condition was applied on the corrugated absorber plate of SAC. ANSYS Fluent (version15) was used to solve the problem. The *Nu* (25 – 113) increased and the *f* (0.01 – 0.055) decreased with rise in *Re* value. The maximum *Nu*, and *f* for the corrugated plate were 2.57, and 5.56 times the flat plate, respectively. The maximum p_{th} (1.48 – 1.74) was obtained for P = 50 mm (P/e = 10), e = 5 mm (e/D = 0.036), and corrugation angle (θ) = 10°. The numerical model was validated with Dittus-Boelter equation, the results were compared with the existing literature and were found to be with in the acceptable range.

1. INTRODUCTION & OBJECTIVE

The quality of the dried product from the indirect type solar dryer (ITSD) is better than that from open sun drying (OSD) and direct type solar dryer. Solar air collector (SAC), a component of ITSD, provides hot air and is used for drying of products. The absorber plate of SAC receives solar energy, gets heated, and convective heat transfer takes place from the plate to air. One method of improving the convective heat transfer is by providing corrugations on the absorber plate. But, this also increases pressure losses. Both numerical and experimental works wer done to investigate the effect of corrugations on the performance of SAC [1, 2]. Some these corrugations were of different shape such as square shaped [3], and semi-circular shaped [4]. Most of the research work selected RNG k-ε model for turbulence and performance parameters such as Nusselt number (*Nu*), *Nu* ratio, friction factor (*f*), *f* ratio, and thermo-hydraulic performace parameter (p_{th}) were evaluated [5].

To the best of author's knowledge, research work related to the effect of reverse right-angle triangle corrugations on the performance of SAC for ITSD is not available. Hence, the objectives of the present work are; (i) to develop a 2D numerical model for the SAC with reverse right-angle trainagle corrugations on the absorber plate, (ii) to analyze the flow turbulence and heat transfer behavior of fluid flow over the corrugations, (iii) to estimate *Nu*, *Nu* ratio, *f*, *f* ratio and p_{th} of the SAC for a given *P*, *e*, and *Re*, and (iv) to investigate the effect of varying *P* and *e* on the performance of the SAC and propose optimum values for *P*, *e*, and θ.

2. METHODOLOGY & HIGHLIGHTS OF RESULTS

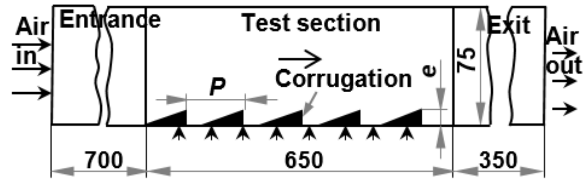

Fig. 1. 2D computational domain with dimensions in mm

The flow is assumed to be 2D, steady, and incompressible. The absorber plate is considered as homogeneous and isotropic. Body forces and radiation heat transfer are neglected. No slip condition is engaged on the surfaces. Air at 300 K and 1 atm is used as the working fluid and its properties are assumed as constant. As shown in Fig. 1, the 2D computational domain is divided into 3 sections (entrance, test, and exit). The dimensions are selected as per the setup of the SAC for ITSD, which was constructed at the National Institute of Technology Warangal (NITW), India [6]. The right-angle triangle corrugated absorber plate of test section (bottom edge) is subjected to a constant heat flux of 1000 W/m^2. Seven values of *Re* (4000, 7000, 10000, 13000, 16000, 19000, and 22000), six values of *P* (27.5, 50, 75, 100, 150, and 200 mm), and seven values of *e* (4, 5, 6, 7, 10, 15, and 20 mm) are used as input variables. Continuity, momentum, energy, and RNG k-ε turbulence models are used as the govering equations and ANSYS Fluent (version 15) tool is used to solve the numerical problem. The entire work was divided into two parts (part-I and part-II). In part-I, the *P* and *Re* were varied (by fixing *e* as 10 mm) and the results were analyzed to obtain optimum *P* value. Next, in part-II, the *e* and *Re* were varied (by fixing the optimized *P* value that was obtained from part-I) and the results were analyzed to obtain optimum e value. Here, a total of 84 simulations were peformed. Finally, optimum value of P and e were used to the optimum θ value.

The numerical model was validated with Dittus-Boelter equation, grid independence study was carried out, the numerical results were compared with the existing literature [1, 4] and were found to be with in the acceptable range. Flow separation from corrugation tip, formation of low velocity and recirculation regions behind the ribs, and reattachment points were observed from the contours of velocity, turbulent kinetic energy, and streamlines. The *Nu* (25 – 113) increased and the *f* (0.01 – 0.055) decreased with rise in *Re* value. The maximum *Nu*, and *f* for the corrugated plate were 2.57, and 5.56 times the flat plate, respectively. The p_{th} decreases with *Re* and maximum p_{th} (1.48 – 1.74) was obtained at e/D = 0.036, P/e = 10. Therefore, P/e = 10 (P = 50 mm), e/D = 0.036 (e = 5 mm), and θ = 10° are the proposed dimensions for this right-angle triangle corrugated SAC of ITSD.

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