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Effect of Vortex Generator on a Wavy Wall Heat Exchanger Performance for Turbulent Nanofluid Flow under a Magnetic Field

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ABSTRACT: Today, in the industry for improving the performance and reducing the energy consumption of thermal systems, much attention has been paid. Use of a magnetic field, wavy wall heat exchanger and dispersion of nanoscale particles are the new methods for improving the thermal systems performance containing fluid flow and heat transfer. Flow vortex, which is formed by means of chips, or appendages such as blades or fins, is very effective in improving the heat transfer rate. In this study, the effect of magnetic field application and vortex generator on the flow field and heat transfer in compulsory displacement is investigated separately and simultaneously inside the wavy wall heat exchanger. In the present work, a wavy wall heat exchanger is simulated in various geometries of the Vertex generator under magnetic fields in various Hartmann and Reynolds numbers filled with nanofluid. The system of nonlinear governing equations is solved explicitly using a fluent software based on the basic pressure solver and finite volume method. The results show that with increasing Reynolds number, the Nusselt number and friction coefficient increase and decrease respectively. As the Hartman number increases, the Nusselt number increases and the friction coefficient decreases.

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1. INTRODUCTION

Tube–fin heat exchangers are employed in a variety of applications such as chemical processes, domestic and industrial applications, air conditioner, and automotive radiators. Because of their extensive applications, they are responsible for exchanging huge amounts of energy. Environmental considerations and energy costs are the factors to motivate attempts to investigate for better performance over the new and creative designs.

Effects of an external delta-wing vortex generator on the flow and heat transfer characteristics in fan flows and uniform flows were experimentally investigated and compared by Chen and Shu [1]. The increase in the turbulent kinetic energy by the delta-wing has little effect on heat transfer in the inherently vortical fan flows. Consequently, the delta-wing vortex generator in fan flows has little effect on the heat transfer augmentation. Leu et al. [2] conducted numerical and experimental analyses in order to study the heat transfer and flow in the plate-fin and tube heat exchangers with inclined block shape vortex generators mounted behind the tubes. Their results indicated that the proposed heat transfer enhancement technique is able to generate longitudinal vortices and to improve the heat transfer performance in the wake regions. Zhang et al. [3] presented a study on the effects of the span position of Vortex Generators (VGs) on local heat transfer on three-row flat tube bank fin. The present results reveal that: VGs should be mounted as near as possible to the tube wall; Paul et al. [4] presented an experimental investigation on the concentration of heat transfer along the tube wall of the compact heat exchanger through the use of winglets placed on the louvers. An experimental analysis of the effects of delta-winglet vortex generators on the performance of a fin and tube radiator is presented by Allison and Dally [5]. They found that the winglet surface had 87% of the heat transfer capacity but only 53% of the pressure drop of the louver fin surface. In an experimental study [6] the effectiveness of a 3VG alternate-tube inline array of vortex generators is compared to a single-row vortex generator design and the baseline configuration. The results indicate that vortex generator arrays can significantly enhance the performance of fin-tube heat exchangers with flow depths and fin densities typical to those used in air-cooling and refrigeration applications. Tang [7] conducted a study on air-side heat transfer of a fin-and-tube heat exchanger. The increase of vortex generator attack angle or length, or decrease of vortex generator height may enhance the performance of vortex-generator fin.

The main objective of this research is the study of the effect of magnetic field application and vortex generator on the flow field and heat transfer. In the present work, a wavy wall heat exchanger is simulated in various geometries of the vertex generator under magnetic fields in various Hartmann and Reynolds. For this purpose, Navier Stokes equations, the conservation of mass, momentum, and energy equations with incompressible flow assumption were used.

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2. PROBLEM STATEMENT

Figs. 1 and 2 demonstrate the view of the heat exchanger with delta wing-let and computational domain. As it is shown in refereed figures upper and lower boundary conditions are periodic, and left and right sides have the symmetry boundary condition. Inlet velocity for inlet and pressure outlet conditions for the outlet of the domain were used. Required simulations for Hartman number from 70 to 100 were done and by using these results variations of the friction factor and Nusselt number were presented. Base on the obtained results, the best case that having maximum thermal performance were presented.

In the next step system of governing equations employing $k-\varepsilon$ model for simulation of Reynolds stress tensors were solved. In the next step, independent grid study and validation test were done. According to the obtained results from the present study, it is clear that the results are in very good agreement with valid published data. In the next step, more important results were presented.

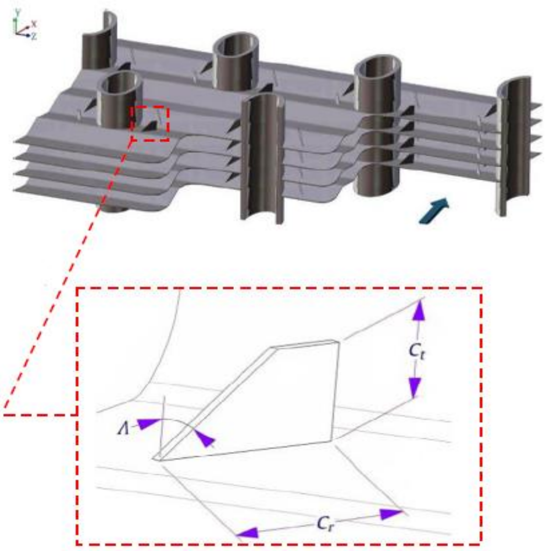

Fig. 1: Heat exchanger with delta wing-let

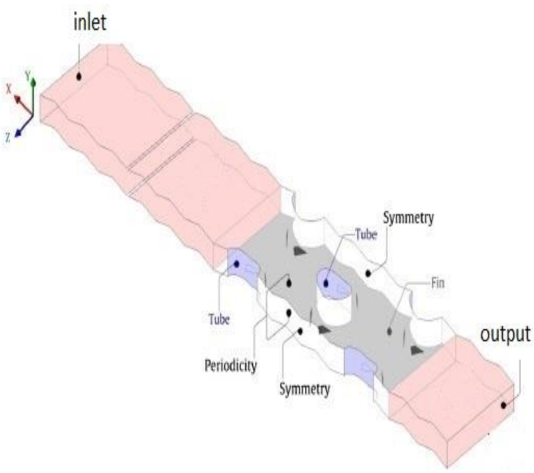

Fig. 2: Simulation domain of the problem

3. RESULT AND DISCUSSION

In Figs. 3 and 4 variations of friction factor and Nusselt number with Reynolds number at each wing-let vortex generator angle between 15 and 75 degree are presented. As can be seen form Fig. 3, friction factor was decrease with Reynolds number. This effect can be expected from the behavior of the fluid flow.

In addition, the values of friction factor increased with wing-let vortex generator angle. In fact, increasing the wing-let vortex generator angle increases the barrier for fluid flow.

Fig. 4 presents the variation of Nusselt number with Reynolds number at various wing-let vortex generator angle. As can be seen, Nusselt number increases with increasing Reynolds number. Increasing the Reynolds number increases the kinetic energy of the fluid and therefore heat exchange between the fluid and solid surface is increased. In addition, the value of the Nusselt number decreases with increasing the wing-let vortex generator angle. The behavior is expected from the results of the friction factor (Fig. 3).

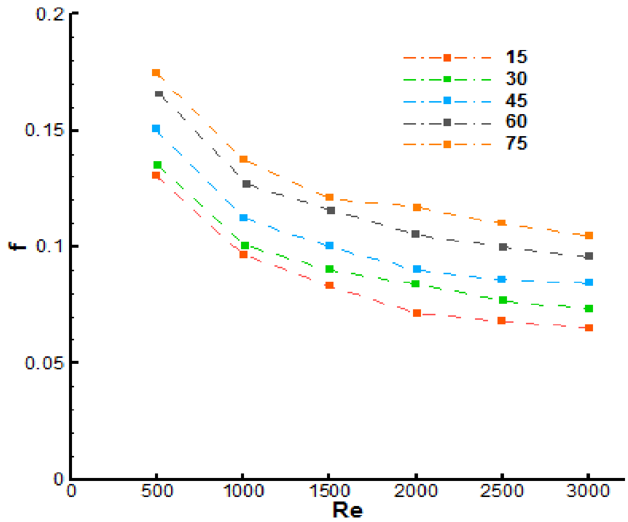

Fig. 3: Variation of friction factor with Reynolds number at various wing-let vortex generator angle.

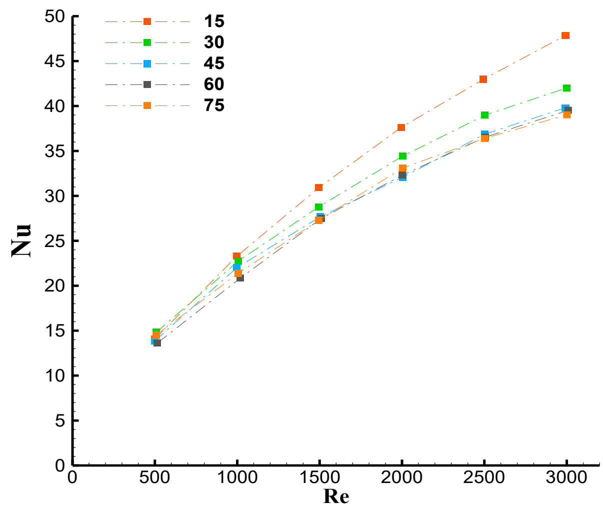

Fig. 4: Variation of Nusselt number with Reynolds number at various wing-let vortex generator angle.

4. CONCLUSIONS

In this study, the effect of magnetic field application and vortex generator on the flow field and heat transfer in compulsory displacement is investigated separately and simultaneously inside the wavy wall heat exchanger. The results show that with increasing Reynolds number, the Nusselt number and friction coefficient increases and decreases respectively. As the Hartman number increases, the Nusselt number increases and the friction coefficient decreases.

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