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Turbulent Heat Transfer in Elliptical tube with Dimples

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Extended Abstract

Heat exchangers play an essential role in heating and cooling in many industrial applications such as cooling towers, aerospace, oil and gas production, and chemical processing. Various heat transfer enhancement technologies are developed to overcome the limitations of conventional heat exchangers and minimize energy consumption. These technologies are classified into active methods, which use external energy, and passive methods, which include geometric modifications like fins, ribs, twisted taps, wire coils, insert devices, and dimples. Passive methods are efficient, reliable, cost-effective, and can be easily implemented, but they come with a penalty in pressure drop. The dimples on the surface have a relatively low-pressure penalty, hence widely studied [1].

The objective of this study is to numerically investigate the thermo-hydraulic performance of an Elliptical tube with tear-drop dimples. A turbulent convective heat transfer with Reynolds number ranging from 5000 to 30,000 along with variation in depth of the tear-drop dimples is simulated and results are compared. Flow characteristics and heat transfer mechanisms of different cases are investigated under the single-phase condition. This study provides suggestions for the potential application of the elliptical tube with tear-drop dimples. The simulations are performed using steady-state conditions. Governing equations of continuity, momentum, and energy are solved to predict velocity and temperature fields. The realizable $k - \epsilon$ turbulence model is adopted in this study to close the governing equations.

Vortices generated due to the dimples disrupt the boundary layer and increase overall mixing in the flow leading to enhanced heat transfer. These configurations are compared to understand the mechanism of heat transfer enhancement both qualitatively and quantitatively. The average Nusselt number quantifies the net heat transfer rate. Around 75% increment in the average Nusselt number is observed in the forced convection process. The performance evaluation criteria (PEC) is analyzed to study the overall effectiveness of the heat exchanger. PEC > 1 signifies effective heat transfer with a reasonable pressure penalty. The maximum PEC value of 1.1 is obtained at a Reynolds number of 15,000 using tear-drop dimples with a depth of 3mm. The results of this study indicate that including tear-drop dimples in an elliptical tube can augment the heat transfer in all configurations with less pressure penalty.

References

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