NUMERICAL INVESTIGATION OF THERMAL-HYDRAULICS CHARACTERISTICS IN ENHANCED TUBES

Under the Supervision of

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Abstract of Ph.D. Thesis

Thermal and hydraulic characteristics of turbulent water flow in a transverse corrugated tube with various corrugation directions (inward/outward/oscillating), and corrugation shapes (triangle, curve, rectangle and trapezoid) are numerically investigated. The influence of combination between the corrugated tube with twisted tape insert and wire-coiled insert is also conducted in the current study. The model of corrugated tubes with 10 mm inner diameter was investigated by changing the geometrical parameters for within a range of Reynolds number from 5,000 to 61,000 and constant heat flux boundary condition. Structured, non-uniform grid system is applied. Momentum, continuity and energy equations were treated by means of a finite volume method using the SIMPLE scheme with the k–ε turbulence model and enhanced wall treatment. The results reveal that corrugation directions and corrugation shapes have perceptible effects upon the heat transfer in the form of a Nusselt number (Nu) and pressure drop in the form of friction factor (f). The average Nu for (inward) trapezoidal, rectangular, curved and triangular corrugation shapes are 52.61%, 50.12%, 47.82% and 44.96%, respectively, higher than the smooth tube. The average Nu for (outward) trapezoidal, curved, triangular and rectangular corrugation shapes are 48.31%, 45.72%, 41.23% and 40.94%, respectively, higher than the smooth tube. The results reveal that both inward/outward curved and triangular roughness shapes have the superior Performance Evaluation Criteria (PEC) than rectangular and trapezoidal. The curved corrugation shape provides the maximum PEC about 1.289, 1.172 and 1.214 for outward, inward and oscillating direction, respectively. Turbulence kinetic energy (TKE) contours show the increase in heat transfer performance for all corrugated tubes compared with a smooth tube. It is concluded to suggest that the corrugated tubes are a promising enhancement technique in terms of energy saving at the low Re values within the studied range.

The influence of a combination between corrugated tubes with, another enhancing passive technique, twisted tape insert (TT) is presented. The analysis of the thermo-hydraulic characteristics of turbulent flow through a combination of various inward/outward corrugated tubes fitted with a traditional twisted tape insert has been conducted. It is found that the average increase percentage of Nu for the inward rectangular, trapezoidal, curved and triangular corrugation shapes fitted with twisted tape are 97.17%, 93.95%, 82.31% and 78.48%,

respectively, higher than smooth tube. Also, the mean increase percentage of Nu for the outward trapezoidal, curved, rectangular and triangular corrugation shapes fitted with twisted tape are 80.31%, 76.54%, 76.28% and 71.9%, respectively, higher than smooth tube without corrugation. Although the increasing percentage of Nu for the smooth tube fitted with TT is 36.47% compared with smooth tube. The results reveal that the tube with outward trapezoidal corrugation fitted with TT provides maximum PEC about 0.986, while for inward trapezoidal corrugation fitted with TT about 0.9673. It is found also that the maximum PEC for the smooth tube fitted with TT is 0.7502.

Finally, the influence of combination between various inward/outward corrugated tubes with, another enhancing passive technique, wire-coiled insert (WCI) is presented. It is found that the average increase percentage of Nu for the inward trapezoidal, rectangular, curved and triangular corrugation shapes fitted with wire-coiled insert are 58%, 56.44%, 51.83% and 45.38%, respectively, higher than smooth tube. Also, the mean increase percentage of Nu for the outward trapezoidal, curved, rectangular and triangular corrugation shapes fitted with wire-coiled insert are 48.71%, 45.76%, 43.19% and 42.11%, respectively, higher than smooth tube without corrugation. Although the increasing percentage of Nu for the smooth tube fitted with WCI is 25.81% compared with smooth tube. The results reveal that the tube with outward trapezoidal corrugation fitted with wire-coiled insert provides maximum PEC about 0.9713, while for inward trapezoidal corrugation fitted with wire-coiled insert about 0.9425. It is found also that the maximum PEC for the smooth tube fitted with wire-coiled insert is 0.8943.

For more understanding and deep study of the fluid flow structure for all studied cases, various contours of velocity, temperature, streamlines, velocity vectors and turbulence kinetic energy have been presented.

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