ABSTRACT

Effect of using insert and/or nanofluid in the tubular heat exchanger on hydrothermal, energy-exergy-economic performances are numerically and experimentally investigated in this study. Considered water-based Al_2O_3, PCM and CNT nanofluids and Al_2O_3+PCM, Al_2O_3+CNT, Al_2O_3+TiO_2 and Al_2O_3+MgO hybrid nanofluids have been prepared by using two-step methods. The morphology (shape and size) of the nanoparticles has been confirmed with the help of SEM and TEM images. The visual observation and pH value determination have been performed to check the stability of the prepared mono/hybrid nanofluids. The homogeneity test has been performed by measuring pH value and properties of different samples and confirmed the proper dispersion of nanoparticles in the base fluid. The thermophysical properties (density, viscosity, specific heat and thermal conductivity) of mono/hybrid nanofluids for different volume concentrations have been measured. CNT dispersed nanofluids yield higher, whereas PCM dispersed fluids yield lower viscosity as well as thermal conductivity.

The effects of inserting two types of enhancers (modified twisted tape and modified wire coil) in the double pipe heat exchanger using various mono/hybrid nanofluids for different particle volume concentrations, flow rates and inlet temperatures have been studied experimentally under turbulent flow condition. The effects on various hydrothermal characteristics have been studied. The results reveal that the parameter enhancement is more predominant for using enhancers (twisted tape and wire coil) as compared to using nanofluids. This implies that the change in flow structure by the use of enhancers is much more significant as compared to property enhancement and slip mechanism by using nanofluids. The heat transfer coefficient and pressure drop increase with decreasing the twist ratio, increase in depth ratio and decrease in width ratio of V-cut twisted tape. The maximum heat transfer coefficient is observed as 5709.6 W/m^2K for Al_2O_3+CNT hybrid nanofluid at a

higher flow rate (25 lpm). Divergent-type wire coil exhibits more heat transfer and pressure drop enhancements than that of other coil configurations. Heat transfer coefficient to the pressure drop ratio decreases with the flow rate. Al_2O_3+CNT/water shows maximum $h_i/\Delta p$ value (3.37) at a low flow rate of 5 lpm. The $h/\Delta p$ ratio varies from 1.50 to 3.37 for Al_2O_3+CNT, 1.48 to 3.21 for CNT, 1.46 to 3.04 for Al_2O_3+PCM, 1.41 to 3.14 for PCM and 1.45 to 2.72 for Al_2O_3 nanofluids, respectively. Entropy generation decreases by using nanofluids (Al_2O_3+PCM shows the lowest entropy generation). Nusselt number increases and friction factor decreases with inlet temperature. Tapered wire coil yields better hydrothermal performance enhancement as compared to V-cut twisted tape. Among all enhancers, the D-type wire coil shows a higher value of effectiveness than other configurations. As compared to the plain tube with DI water, the effectiveness of the double pipe heat exchanger enhances around 39.41 % using D-type wire coil and hybrid nanofluid.

Experimental studies on hydrothermal performance of shell and tube heat exchanger using different mono/hybrid nanofluids at volume concentrations of 0.01% and 0.1% have been conducted under the laminar flow regime. The results found that the heat transfer coefficient and pressure drop considerably increase with the nanofluid flow rate. The average Nusselt number and friction factor of Al_2O_3+CNT hybrid nanofluid flowing in the tube enhance 38.08% and 15.60%, respectively. Maximum augmentations of 9.18% in heat transfer coefficient, 8.91% in Nusselt number, 5.98% in friction factor and 36.84% in pressure drop were found with an increase in volume concentration. Al_2O_3+CNT hybrid nanofluid shows a higher value of effectiveness among all working fluids. The maximum effectiveness was obtained as 0.164 at the Reynolds number of 1520.

Energy, exergy and economic performances have been investigated with different water-based hybrid nanofluids as a coolant in industrial shell and tube condenser. Results reveal that coolant mass flow rate reduces, effectiveness enhances, pumping power reduces,

irreversibility decreases and second law efficiency increases by using hybrid nanofluids. The operating cost can be reduced with the addition of nanoparticles (Al_2O_3+PCM shows a maximum reduction of 15.69%). The payback period is considerably higher for the use of hybrid nanofluid (Al_2O_3+Ag shows a maximum of 247 years). The payback period can be reduced by reducing nanoparticle cost and increasing nanofluid stability.