Abstract

In the present study, the thermal and fluid characteristics of a sinusoidal wavy wall are studied numerically and experimentally to increase the heat transfer rate of the turbulent wall jet. To do so, the sinusoidal profile ($y = A * sin(\omega_N x)$) is used for the wavy wall, where $\omega_N = 2\pi N/L$ is the frequency with suffix N denoting the number of cycles for the given length L and A is the amplitude. The study is done in three parts. In the first part, the influence of amplitude and frequency of wavy wall has been numerically studied on the flow and thermal behaviour of turbulent wall jet; the amplitude is varied from 0 to 0.8 for frequency ω_{10}. The influence of frequency is studied for frequencies from ω_4 to ω_{12}, to find out the optimum amplitude and frequency for which the heat transfer rate is maximum. In the second part, the wavy wall is modified to a partial wavy wall and a partially linearly decaying (LD) wavy wall. The partial wall is created by giving a segment of wall a wavy pattern from the leading edge followed by the plane wall; the wavy wall segment varies from 10% to 100% of the wall. The amplitude of wavy surface has also been varied from 0.2 to 0.8. For a partially linearly decaying wavy wall, a segment of wall from the leading edge is made with a constant amplitude of 0.8 followed by the segment of LD wavy wall. In the region of a LD wavy wall, the amplitude of wavy wall varied linearly from 0.8 amplitude to 0 in the downstream direction. In the third part, the experimental and numerical study is done for the adiabatic wavy wall with the amplitudes 0.2, 0.4 and 0.6 and the results are compared with the results of plane wall jet case. The experimental study measures, the mean and turbulent velocities using a constant temperature anemometer manufactured by Dantec Dynamics. For temperature measurement over the wall and within the flow domain, the FLIR camera and k-type thermocouple are used, respectively. For all the numerical studies, low Reynolds number RNG $k-\epsilon$ model has been used. The jet is heated to 330K and the velocity is uniform at the inlet with a Reynolds number of 15000 in all the studied cases. With these conditions, the results are discussed for different flow and heat transfer characteristics. It has been observed that in the case of a simple wavy wall, the heat transfer increases with the amplitude and frequency and achieves a maximum heat transfer rate for 0.7 amplitude and ω_9. The heat transfer reduces with the further increase in the amplitude and frequency as the recirculation zone becomes severe. By reducing the recirculation area, the heat transfer increases in the modified wavy wall cases. Among them, the partially linearly decaying wavy wall gives the best performance with the highest heat transfer rate and thermal hydraulic performance (THP). The experimental analysis shows that the influence of the wavy surface on the flow and thermal characteristics of the turbulent wall jet is more pronounced in the near flow field. The turbulent

intensity increases with the increasing amplitude, which shows a higher intermixing of the surrounding fluid within the jet.

Keywords: wavy wall; Fluid flow characteristics; Heated jet characteristics; Low Reynolds number model; Experimental analysis; heat transfer enhancement.