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Heat Transfer between a Wavy and Flat Plates with Constant Wall Temperature

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Abstract

In this paper steady state laminar heat transfer between a wavy and flat plates had been studied numerically. The distance between plates (D) is 0.04 m and plates length (L) is equal to 1 m. The Reynolds number base on D_h are within 50< Re_{eq} <1000. By comparing results of wavy and flate plates with two flat plates it can be seen that heat transfer in wavy and flat plates is 9 to 11.5 percent greater.

Keywords: Heat transfer, numerical, constant wall temperature, wavy plate.

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1-Introduction

Due to the induced breaking and destabilizing as fluid flowing through the wavy surface, the wavy surfaces are a suitable method to improve the thermal performance of heat transfer devices. There are numerous experimental and theoretical studies on the heat transfer and pressure drop in channel with the corrugated surface. Sunden and Skolheden [1] studied on the heat transfer and pressure drop in the corrugated channels and the smooth tubes under constant heat flux conditions. Sawyer et al. [2] considered effect of three dimensional hydrodynamics on the enhancement of heat transfer in the corrugated channels. Nishimura and Matsune [3] simulated and visualized the dynamical behavior of vortices flow in channels. Brunner and Benilov and Yaremchuk [4] investigated the scattering of surface water-waves in a channel with corrugated bottom and walls. Yalamanchili et al. [5,6] applied the LDV to measure the velocity profiles and normal stress of fluids flowing in a corrugated channel with the top and bottom plates sinusoidal with and without polymer additives. Sawyers et al. [7] numerically and experimentally studied effect of three dimensional hydrodynamics on the enhancement of heat transfer in the corrugated channels. Nishimura and Matsune [8] studied on the simulation and flow visualization on the dynamical behavior of vortices generated in channels. Bereiziat and Devienne [9] experimentally studied the flow characteristics of the Newtonian and non-Newtonian fluid in the corrugated channel.

2-Problem description and governing equations

Air with 300 K temperature enters between a wavy and flat pale plates with constant wall temperature 400 (K).

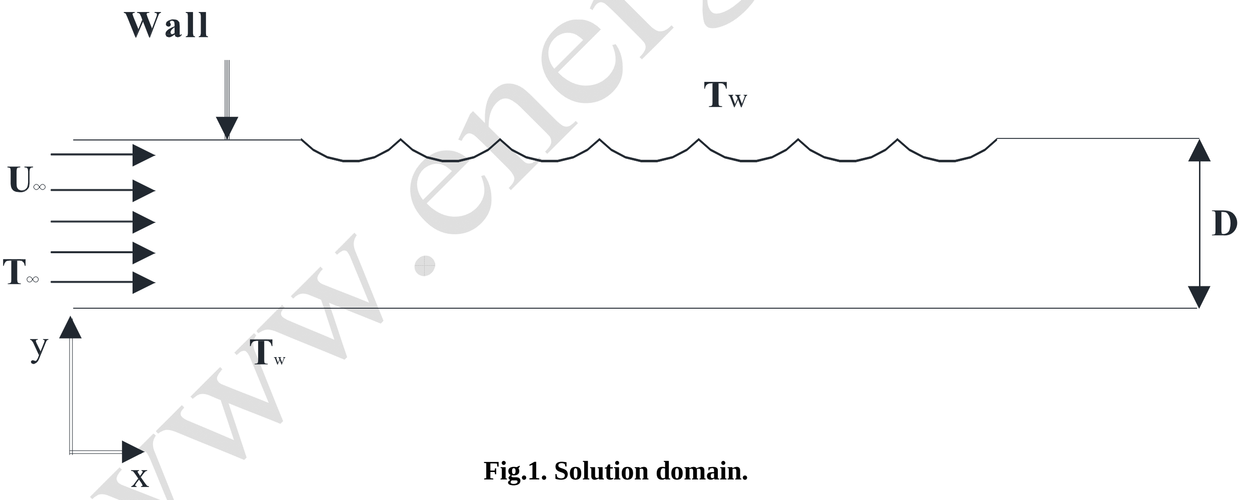

Fig.1. Solution domain.

Equations are written for conservation of mass and momentum in two dimensions. Cartesian velocity components U and V are used, and it has been assumed that the flow is steady and laminar, while the fluid is incompressible and Newtonian with constant transport properties. Furthermore, the effect of viscous dissipation is neglected. The governing equations consist of the following three equations for the dependent variables U, V, P and T:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

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$$\rho\left(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=-\frac{\partial P}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right) \tag{2}$$

$$\rho\left(u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}\right)=-\frac{\partial P}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right) \tag{3}$$

$$\frac{\partial}{\partial x}(uT)+\frac{\partial}{\partial y}(vT)=\alpha\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right) \tag{4}$$

Pressure drop is define by

$$f=\frac{2D_h\Delta P}{L\rho U^2} \tag{5}$$

Where L is plates length.

The Nusselt number inside plates is define by where q is the total rate of heat transfer to the fluid which calculted from equation (8) and D_h is hydraulic diameter of plates:

$$Nu=\frac{hD_h}{k} \tag{6}$$

$$h=\frac{q}{A\Delta T_{LMTD}} \tag{7}$$

$$q=\dot{m}C_P\left((T_s-T_{b,i})-(T_s-T_{b,i+1})\right) \tag{8}$$

$$\Delta T_{LMTD}=\frac{(T_s-T_{b,i+1})-(T_s-T_{b,i})}{Ln\left((T_s-T_{b,i+1})/(T_s-T_{b,i})\right)} \tag{9}$$

3. Numerical Method

The meshes are produced by GAMBIT software. Computational grid information is imported from GAMBIT in to FLUENT and computational mesh is generated using quadrilateral elements. Numerical simulations are performed using ANSYS FLUENT 12, a commercially available general-purpose Computational Fluid Dynamics code [10]. This package solves the governing equations using control-volume based technique.

The second order upwind scheme was chosen for interpolation of the interpolation of the flow variables. The SIMPLE algorithm [11] has been adapted for the pressure velocity coupling. This problem considers a 2D section of plates. For the simulations presented here, depending on the geometry used, fine meshes of 88300 elements were used. A sample of the mesh is shown in Figure.2. In this domain quadrilateral cells are used in the regions surrounding the wavy wall and the rest of the domain. In all simulation, a convergence criterion of 1×10^{-6} was used for all variables.

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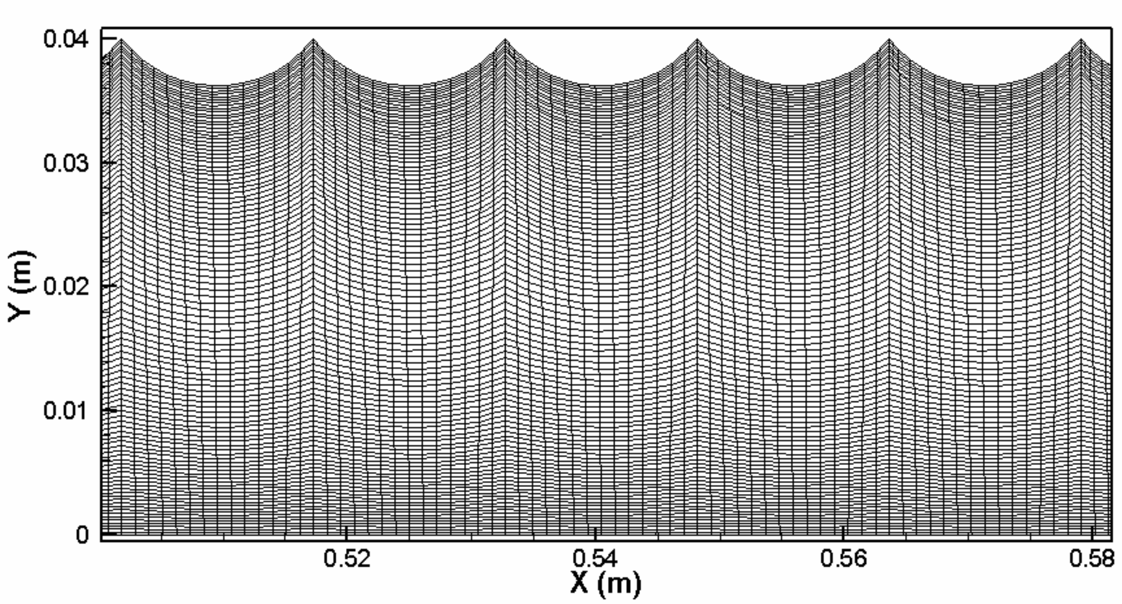

Fig. 2. Computational grid.

4-Results and Discussion

For the purpose of the validation of the solution procedure, it is essential that numerical simulations be compared with other experimental and numerical data. Figure.3 shows Nusselt number between to infinite flate plates. It can bee seen that for fully developed region Nusselt number is 7.54 which is the same as refrence [12] for heat transfer between two infinte plates with constant wall temperature. It can therefore be concluded that the CFD code can be used to solve the flow field for similar geometries and conditions.

Figure 4 compares pressure drop across a wavy and flat plates with two flat plates. Results show that pressure drop between a wavy and flat plates is about 28 to 34 percent greater than two flat plates.

Figure 5 shows temperature contours at Re=1000. It can be seen that temperature of flow between a wavy and flat plates increases faster.

Figure 6 compares heat transfer between a wavy and flat plates and flat plates. By comparing these results it can be seen that Nusselt number of a wavy and flat plates is about 9 to 11.5 percent greater than flat plates.

5- Conclusions

In this study heat transfer of heat transfer between a wavy and flat plates had been studied numerically. Results show that pressure drop and heat transfer between a wavy and flat plates is about 28 to 34 and 9 to 11.5 percent greater than heat transfer between flat plates respectively.

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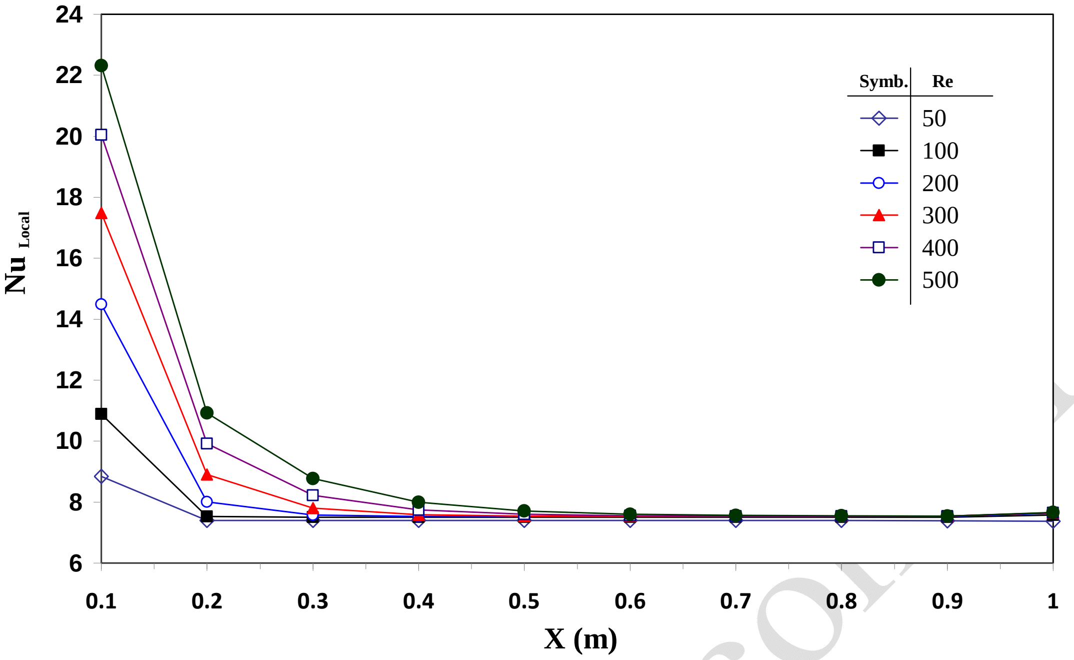

Fig.3. Heat transfer between two flat plates with constant wall temperature.

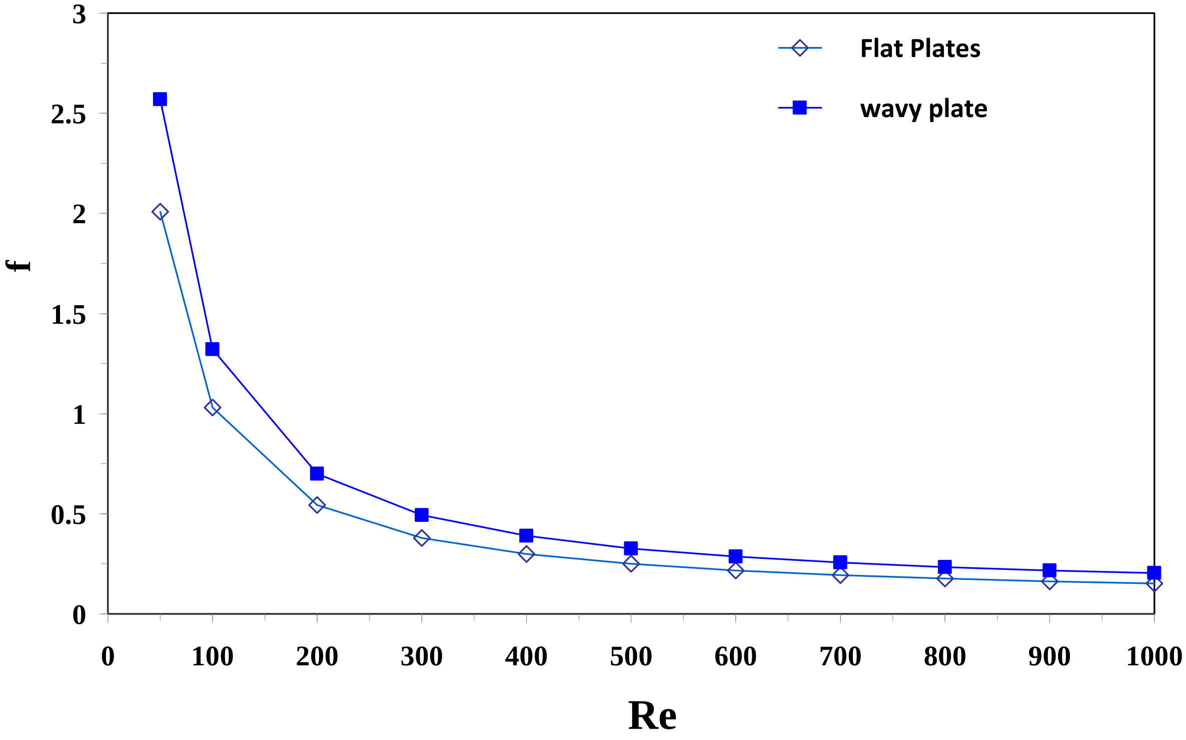

Fig.4. Pressure drop across flat plates with wavy and flat plates

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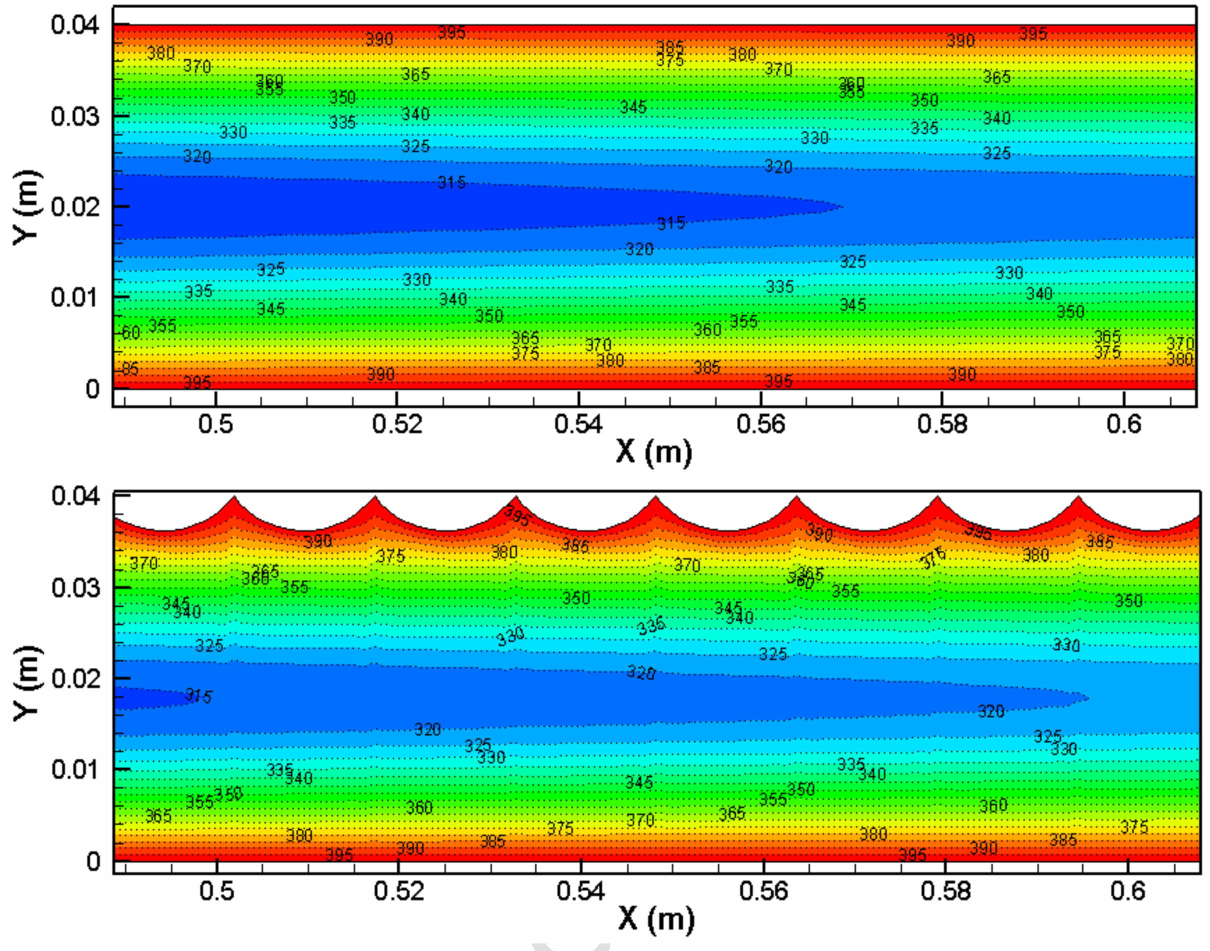

Fig.5. Temperature contours at Re = 1000.

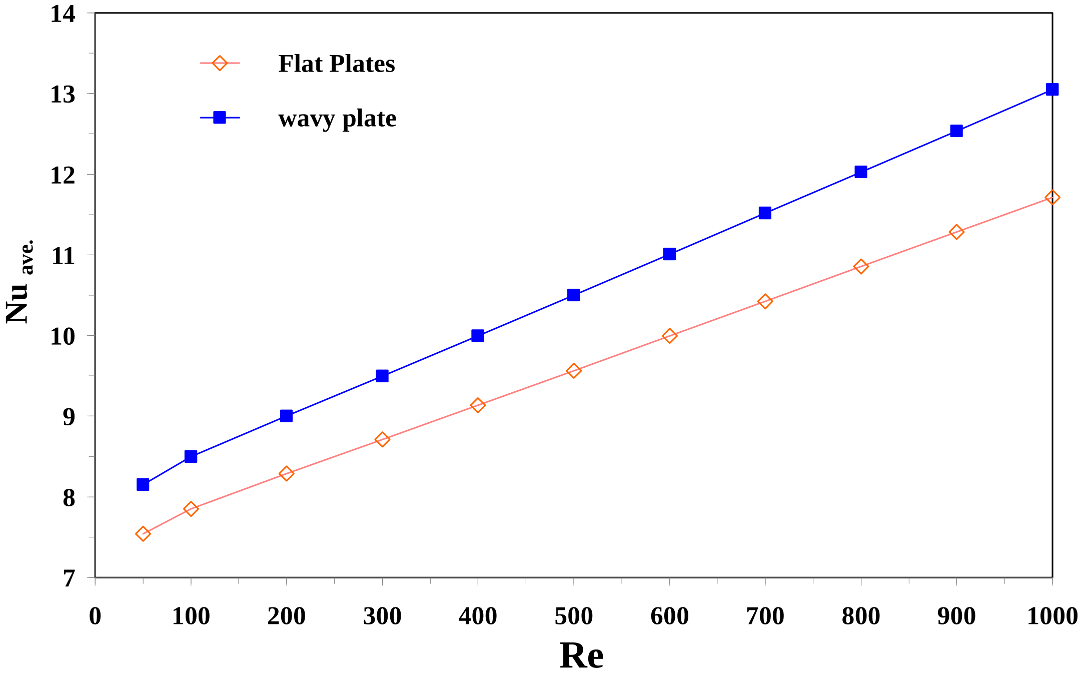

Fig.6. Comparing heat transfer between a wavy and flat plates with two flat plates.

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