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Research Article

Effect of Amplitude Ratio on Pulsating Flow

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Abstract

The numerical analysis of pulsating flow in 2D channel has been carried out with appropriate boundary and initial condition to maximize the heat transfer rate. The wall temperature is kept constant to observe the behavior of air fluid flow in a channel. The user define function (UDF) has been introduced to define the pulsating inlet velocity conditions. The governing parameters like Amplitude ratio (A/D) in the range of 0.1 ≤ A/D ≤ 1 is used to calculate the heat transfer rate. The Strouhal number and Reynold number is also used in the velocity relation. Simulations were carried out by considering variable length to find out the effect of axial velocity and temperature. From the simulation results, the graphs are plotted for axial velocity and temperature. From the graphs it is found that when the Amplitude ratio (A/D) increases, the time average Nusselt number (Nu_{avg}) also increases. Also it is observed that the fluctuation of axial velocity near the wall surface is more; hence the heat transfer rate is high at that particular region. From the results it is concluded that at high amplitude ratio the heat transfer rate is higher.

Keywords: *Amplitude ratio, Axial velocity, Nusselt number, Pipe, Pulsating flow*

1. Introduction

Pulsating incompressible flow in a straight, rigid, circular tube or channel are canonical phenomena of classical fluid mechanics. The pulsating flow is define as the unsteady flow characterized by repeated variation in pressure and mass flow around non-zero mean value which affect the heat transfer (He S., 2009). The heat transfer with pulsating flow is concern to researchers as heat transfer increases or decreases or no change according to fluctuation in different governing parameters and hence it is yet to be clear (Chattopadhyay H., 2006). Due to external imposed pulsations the hydrodynamic and thermal boundary layer of fluid flow disturbs. As the heat transfer rate increases it alters the thickness of thermal boundary layer and thermal resistance. The user define function is required to find the solution of problem of fluid flow in Ansys Fluent program. The proper boundary conditions help to solve the problem exactly. The pulsation can be creating due to pulsation mechanism as per requirement of pulse generation (Habib M. A., 2004).

The Pulsating flow in a pipe or channel is used in many industrial applications like IC engine, refrigeration system, reciprocating compressor, and super charging system of reciprocating engines also in circulating system of blood. Due to its wide existent in various applications with variation in results it is topic of interest for study. The different governing parameters like frequency, amplitude, Nusselt number (Nu), Reynold number (Re), Stanton number (St), Prandtl number (Pr), pulsation method are used in various research with different methodology (Habib M. A., 2004).

The computational fluid dynamics is the one of the tool which used solve the problem of fluid flow, it gives appropriate results which matches the experimental results. Habib M. A resulted that Relative mean heat transfer coefficient depends on frequency of pulsation and frequency of turbulence hence when the pulsation frequency is close to the turbulent bursting frequency resonance interactions affect the increase in heat transfer. Further it was observed prediction of heat transfer characteristics is performed over a range of 104 ≤ *Re* ≤ 4x104 and 0 ≤ ʃ ≤ 70 and resulted that the local Nusselt number increase or decrease for fully developed flow methodology (Elshafei A. M. E., 2008). Experimental work on laminar and turbulent flow in pipe with different Reynold number, flow frequency was conducted and resulted at Reynolds number of 1,643 and pulsation frequency of 1 Hz an increase in heat transfer rate due to pulsation by as much as 30% with flow, depending on the upstream location of the pulsator (Zohir A. E., 2006). The Various results were observed in many papers and it is yet to be clear the Pulsation effect on laminar fluid flow. So there is a need of proper assessment of impact of on heat transfer from circular 2D channel at constant wall temperature when flow consider as pulsating flow. To solve this

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problem a 2D channel is selected with constant wall temperature and the numerical method is used to solve the problem approximately. The flow is thermally and hydraulically developed in a channel. The Amplitude ratio with variable range has been selected to observe the behavior of fluid while keeping the Strouhal number and Reynold number constant. The two dimensional governing equations are used to solve the problem in the Ansys fluent 15 program. The effect of Amplitude ratio (A/D) on axial velocity and temperature profile is observed within the parameter range of 0.1 ≤ A/D ≤ 1 respectively. Also this parameter is used to measure the effect of Time Average Nusselt number (Nu_{avg}) on heat transfer rate.

2. Numerical Work

A 2D channel has been considered to solve the problem of pulsating flow with interpreted UDF profile at the inlet of channel. The channel wall is kept at constant temperature to simulate approximate results. The air is used as a fluid to flow in a channel. The approximate boundary conditions are applied. The X co-ordinate represents the length of channel (L) and the Y co-ordinate represents the radius of channel (r) as shown in Figure 1. The working fluid air having density ρ=1.225 kg/m³ and dynamic viscosity μ=0.00001789 kg/ms with all other thermo-physical properties considered as constant. The Maximum length to diameter ratio (L/D) considered as 250 as L/D=0.05Re.

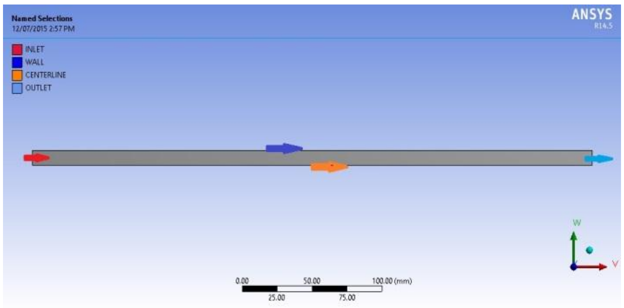


Fig. 1 2D channel Geometry for simulation

The governing equations are used and solved by Ansys Fluent 15 program. In this paper the length, velocity, pipe diameter has been non-dimensionalized. The User Define Function (UDF) contains the inlet velocity profile and the other parameters values. The pressure term is discretized using a standard scheme and the pressure and velocity terms are coupled using SIMPLE (Semi-Implicit method) scheme. The bulk temperature Tb is used to calculate the heat transfer coefficient. However, different inlet conditions (e.g. amplitude and frequency) are to be provided.

The various boundary conditions are given to simulate the channel. The UDF is introduced at the inlet with inlet velocity conditions as given in below equation (1);

$$U = U_{steady}\left(1 + A_0 Sin(2\pi Str)\right) \quad (1)$$

Since quality, number and structure of grid are the three major parameters which will affect the accuracy label of a computational problem, grid generation presents one of the major steps in numerical solutions. The Grid sizes are chosen according to the Re range are 50×5000, 50×7500, 50×10000 and 50×12500 for L/D ratio 100, 150, 200 and 250 respectively as shown in Figure 2.

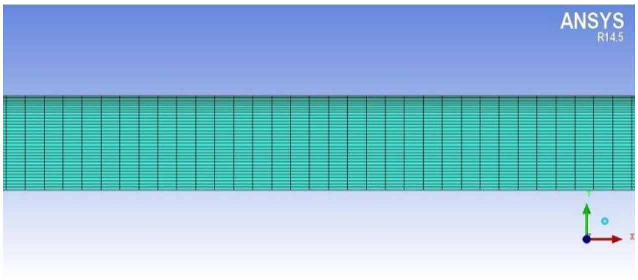


Fig. 2 Structure of grid in computational domain

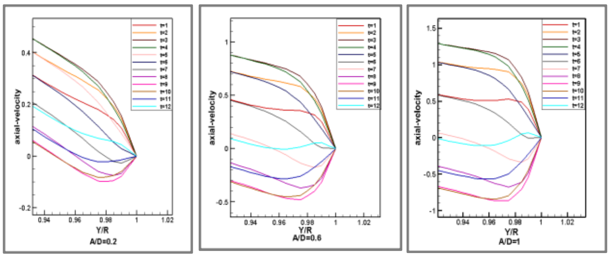
The numerical model is tested to observe the heat transfer characteristics of steady, incompressible flow without pulsation. The velocity profile for steady, incompressible flow without pulsation at Re =200 (5 ≤ L/D ≤ 50) and Re=1200 (5 ≤ L/D ≤250) is tested.

3. Results and Discussion

To study the effect of variation of Amplitude ratio on heat transfer characteristics, it is varied in the range of 0.1 ≤ A/D ≤ 1 at St=5 and Re=1000 respectively with the step size of 200. The effective length of the domain is used much beyond the minimum length requited to develop flow (L/D=0.05Re). As the effective length is the function of Re and it is selected as L/D ratio with the range of 100-250 for different Reynold number (Re). With reference to Analytical results the Grid sizes are chosen according to the Re range are 50×5000, 50×7500, 50×10000 and 50×12500 for L/D ratio 100, 150, 200 and 250 respectively. The study of effect of St and A/D on heat transfer characteristics, the variation of axial velocity and temperature along the channel radius are plotted accordingly.

3.1. Effect of Amplitude Ratio (A/D)

The Amplitude Ratio (A/D) is the function of area and diameter of channel. The value of Amplitude ratio is within the range of 0.1 ≤ A/D ≤ 1 with constant Re=1000 and St=5 selected. The variation of A/D is distributed in the instances of 0.2. The simulations are carried out by changing the value of A/D in the UDF with approximate boundary and initial condition. The variation of axial velocity and the temperature distribution is plotted with the respective angle instances (eg. t=1 for 30º, t=12 for 360º). From Figure 3, it is observed that the thickness of the profile increases as the A/D ratio increases. The variation of axial velocity at different A/D ratio shows the continuous fluctuation near the wall surface is encountered. Hence it is resulted that the particular A/D ratio range is required to enhance the heat transfer in channel.



(a) (b) (c)

Fig. 3 Variation of Axial Velocity at (a) A/D=0.2 (b) A/D=0.6 and (c) A/D=1

The temperature variations are observed and resulted that the temperature curves are overlapping to each other. The temperature in channel decreases as the value of A/D increases as shown in Figure 5. It is also observed that the heat transfer rate is not affected by temperature variation as same like previously observed in St (Shital Nerkar, 2015).

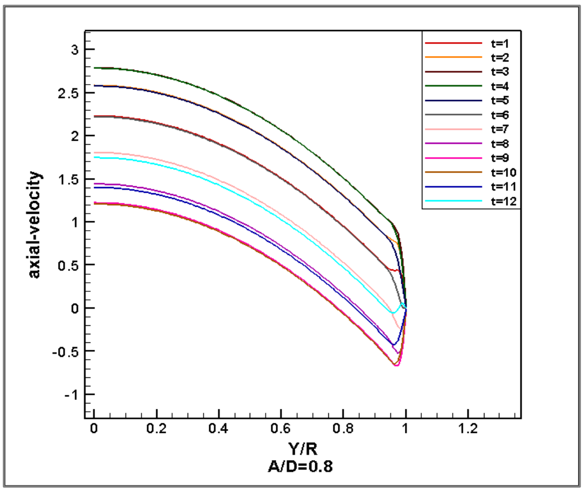


Fig. 4 Axial Velocity at A/D=0.8

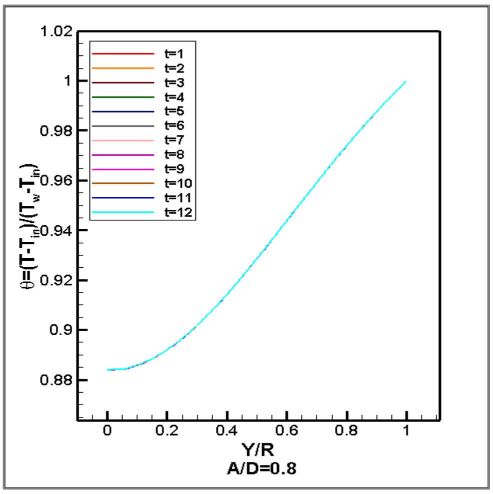


Fig. 5 Variation of Temperature at A/D=0.8

3.2 Variation of Average Nusselt number (Nu_{avg}) at Different Amplitude Ratio (A/D)

The variation of the Amplitude Ratio has been resulted with different value of Average Nusselt no. (Nu_{avg}). The Nusselt number (Nu) is the function of heat transfer hence the variation of Nu_{avg} resulted that the heat transfer rate increases as it is varying continuously from 3.65 at A/D=0.2 to 4 at A/D=1. From Figure 6, it is observed that the Nu_{avg} is increases slowly till A/D=0.6 and at higher A/D ratio Nu_{avg} is increases rapidly. Hence these rapid changes in Nu_{avg} affect the boundary layer thickness and also increase the heat transfer rate. From the results it is clear that the value of A/D is important to maintain in this range for St=5 and Re=1000.

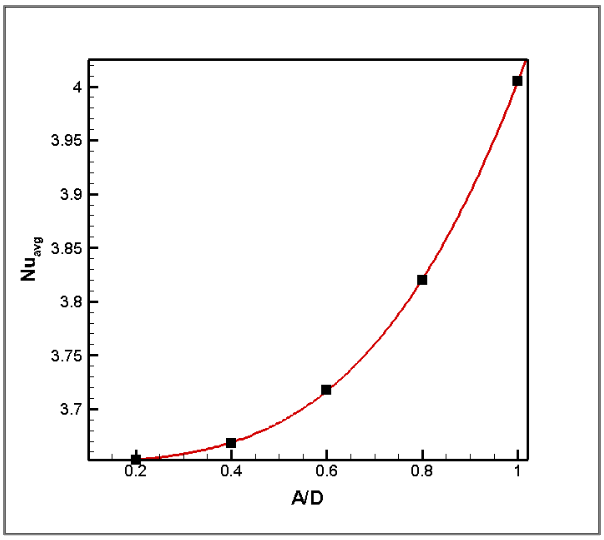


Fig. 6 Variation of Nu_{avg} with A/D

Conclusions

The 2D channel is simulated in ANSYS Fluent program and from the results it is concluded that the variation of axial velocity near the wall surface is more and hence the heat transfer rate is maximum at that particular region. The Amplitude ratio (A/D) results in enhancement in heat transfer due to rapidly variation in Nu_{avg} as compared to Strouhl no. (St). From the results the enhancement of heat transfer in pulsating flow is more as compared to the steady flow in 2D channel.

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