Turbulent MHD Pipe Flow Hydrodynamic Analysis

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Abstract

The focus of this paper is searching the incompressible magnetohydrodynamic steady state turbulent flow hydrodynamic flow characteristic. A circular pipe model was created by Gambit software and computational analyses done by ANSYS Fluent software. Hydrodynamic flow parameters are investigated under the influence of magnetic field induction. Acquired results backed up with the literature studies. Hydrodynamic flow parameters are dynamic viscosity, eddy viscosity, velocity, turbulent intensity, turbulence kinetic energy and density variation by the influence of electromagnetic forces was evaluated. Results showed that turbulent intensity, turbulence kinetic energy, velocity and eddy viscosity decreases, but also density and dynamic viscosity increases.

Key words: Magnetohydrodynamic, turbulent flow, hydrodynamic parameters.

1. Introduction

Magnetohydrodynamic is the science investigates the dynamics behavior of electrically conductive fluids under the effect of magnetic forces. Haq et al. (2015) presented the stagnation point flow of nano fluid with magneto-hydrodynamics and thermal radiation effects passed over a stretching sheet. It is found that rising in Hartmann number gives the resistive type flow within the boundary layer; subsequently velocity profile shows the decreasing behavior with an increase of magnetic parameter [1]. Zhao and Hu (2012) presented an appropriate experimental system, capable of investigate the variation of density. It is concluded that density of magnetic fluid can be increased with magnetic field increase [2]. Dritselis et al. (2011) studied the effect of Lorentz force on particle transport and deposition by using direct numerical simulation of turbulent channel flow of electrically conducting fluids. The overall magnetic damping effect on the fluid turbulence is also demonstrated indirectly by the variation of the mean wall-impact particle velocities [3]. Vire et al. (2011) assessed the performances of three different subgrid scale models in large eddy simulations of turbulent channel flows. It is concluded that in magnetohydrodynamics the Lorentz force brakes the flow and responsible for a decrease of the velocity fluctuations intensity, and therefore, a decrease of the eddy-viscosity [4]. Reuter et al. (2008) reported a parallel implementation of a nonlinear pseudo-spectral MHD code for the simulation of turbulent dynamos in spherical geometry. It is pointed that the magnetic field reacts back on the velocity field and suppresses the turbulence [5]. Nakaharai et al. (2007) studied transverse magnetic field on the local and average heat transfer of an electrically conducting, turbulent fluid flow with high Prandtl number. It is presented that the magnetic field suppresses

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the turbulent velocity fluctuation [6]. Huang and Fang (2007) presented a new numerical method based on the induced-magnetic-field equation that could be applied to a 3D free surface flow in strong and non-uniform magnetic field. The conclusions were that the magnetic field could suppress the turbulent intensity and turbulent viscosity, and delay the fluid separation [7]. Jalil et al. studied turbulent natural convection of molten sodium (low Prandtl number fluid) in a cubic cavity heated from one vertical wall and cooled from an opposing vertical wall with the other walls thermally insulated. The turbulent kinetic energy decreases due to increase in magnetic field strength, affects fluctuation velocity and decays MHD turbulence [8]. Lee and Choi (2001) investigated Lorentz force on near wall turbulence structures using the direct numerical simulation technique with the assumption of no induced magnetic field. It is shown that the wall normal magnetic field is effective than the streamwise and spanwise magnetic fields in reducing turbulent fluctuations and velocity [9]. Zikanov and Thess (1998) studied the transformation of initially isotropic turbulent flow of electrically conducting incompressible viscous fluid under the influence of an imposed homogeneous magnetic field using direct numerical simulation. It is obtained that in the case of a strong magnetic field in agreement with earlier analytical and numerical results for decaying MHD turbulence [10]. Kirilov et al. (1995) presented review of experimental work on magnetohydrodynamic and heat transfer characteristics of liquid metal flows in fusion relevant conditions. It is concluded that transverse magnetic field changes the velocity distribution in channels and suppresses turbulent pulsations [11]. This paper reports the Lorentz force effect on liquid metal turbulent pipe flow hydrodynamic parameters.

2. Materials and Method

Steady state liquid metal turbulent constant wall temperature pipe model magnetohydrodynamic (MHD) flow has been studied numerically by CFD software is ANSYS Fluent MHD module. Studied pipe model illustrated in Fig.1 is created and meshed with Gambit software.

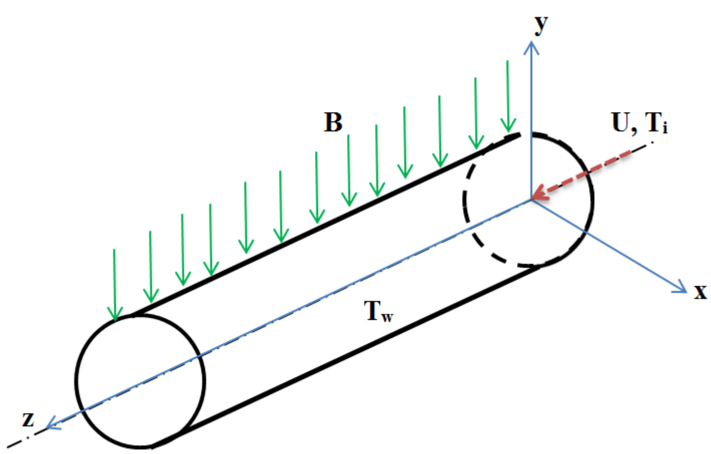

Figure 1. Pipe model.

Optimum grid size of model to obtain accurate results and minimum CPU time has been determined by mesh study with 0.0002 m, 0.00025 m, 0.0005 m, 0.00075 m, 0.001 m grid sized models. Models had been analyzed and obtained data was compared to determine convergence rate of data. Exact convergence error rate of taken data were given in Table 1.

Table 1. Mesh study.

Mesh cell type	Hexahedral grid				
Mesh grid size (m)	0.0002	0.00025	0.0005	0.00075	0.001
Convergence error (%)		0.010073	0.100993	0.109462	0.382714

According to the determined convergence rate in Table 1, it could be estimated 0.0002 m and 0.00025 m grid sized model analyses data was converged to each with a satisfactorily. So, 0.00025 m grid sized model was used to the analyses to obtain smooth surface transition, accurate results and minimum central processing unit time.

3. Results and Discussion

Steady state constant inlet flow velocity (U) and temperature (T_i) liquid metal turbulent pipe flow case has been investigated in constant wall temperature ($T_w > T_i$) pipe model under the applied transverse magnetic field with (B). Hydrodynamic liquid metal flow characteristics have been assessed by the evaluation of dynamic viscosity, eddy viscosity, velocity, turbulent intensity, turbulence kinetic energy and density.

Fig. 2 visualized the variation of dynamic and eddy viscosities by the influence of normally applied magnetic field.

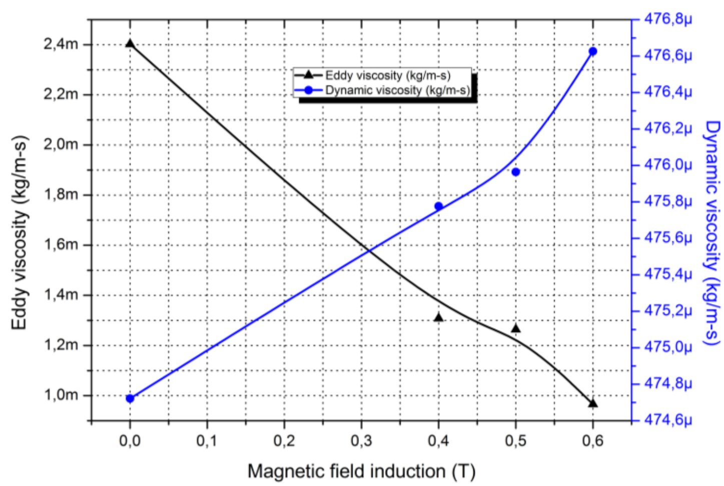

Figure 2. Eddy and dynamic viscosity variation by applied magnetic field induction.

Fig. 2 clearly presents that applied magnetic field induction on electrically conductive fluid flow decreases the eddy viscosity but also in the meantime increases the dynamic viscosity. Similar result evaluated in ref. [4] as Lorentz force brakes the flow and responsible for a decrease of the eddy-viscosity.

Fig. 3 demonstrates the changing the hydrodynamic parameters are average central flow velocity and turbulent intensity by the imposed magnetic field.

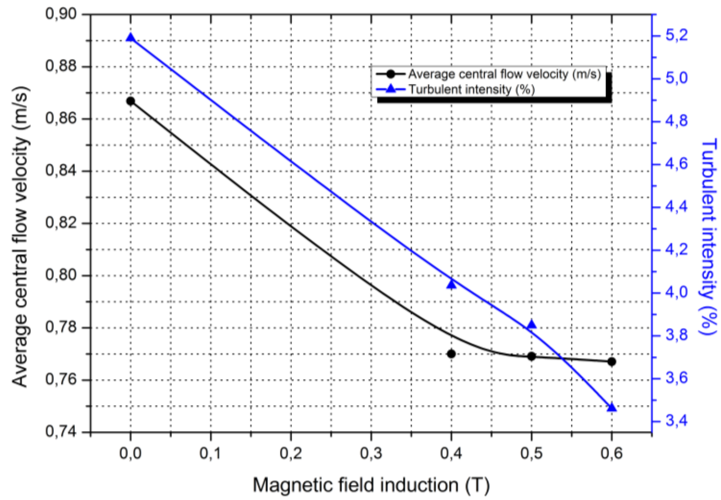

Figure 3. Change of average central flow velocity and turbulent intensity by applied magnetic field induction.

Fig. 3 determines that externally applied magnetic field induction on flow domain declines the central flow velocity and turbulent intensity. This known common MHD principle is clarified in ref. [9] as the wall normal magnetic field is effective on reducing turbulent fluctuations and velocity and also in ref. [7] the magnetic field could suppress the turbulent intensity and delay the fluid separation.

Fig. 4 presents the magnetic field induction influence on liquid metal density and turbulence kinetic energy.

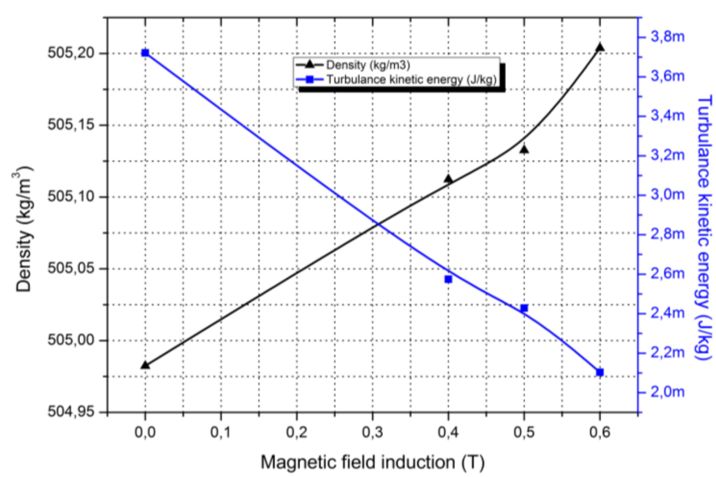

Figure 4. Variation of density and turbulence kinetic energy by applied magnetic field induction.

Fig. 4 shows that increase in applied magnetic field induction on electrically conductive fluid flow increases the liquid metal density but also suppress the turbulence kinetic energy. Similar evaluation commented in ref. [2] as the density of magnetic fluid can be increased with magnetic field increase. In ref. [8], turbulent kinetic energy decreases due to increase in magnetic field strength, affects fluctuation velocity and decays MHD turbulence.

Conclusions

Externally applied magnetic field induction on the streamline of the flowing electrically conducting fluids creates a reverse directional force is called Lorentz force to the flow direction on the flow domain. This force dominates the turbulent pulsations of the flow body. Decrease of turbulent fluctuation means the more ordered flow line. According to the analyse result and theoretical background it is evaluated that increase in applied magnetic field induction suppressed the turbulence and so turbulent intensity, turbulence kinetic energy, velocity and eddy viscosity decreases, but also decrease in turbulence directly decreased the flow domain temperature and so density and dynamic viscosity is increased.

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