Turbulent MHD Duct Flow Thermophysical Analysis

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Abstract

In this study, steady state incompressible magnetohydrodynamic liquid metal turbulent flow thermophysical computational analyze has been done. A rectangular duct model constructed by ANSYS Fluent software MHD module and meshed by Gambit software. Externally applied magnetic field induction act on the thermophysical fluid parameters were evaluated and supported with the previous studies. Thermophysical parameters are temperature and heat flux were compared with nonmagnetic flow case. According to the concluded results temperature and heat flux decreases by the increase of applied magnetic field.

Key words: Magnetohydrodynamic, turbulent flow, thermophysical parameters.

1. Introduction

Magnetohydrodynamic is defined simply as the investigation of dynamics of electrically conductive fluids. The fundamental concept of MHD is the creation of magnetoviscous forces on the moving conductive fluid by the induced magnetic field. Gajbhiye and Eswaran (2015) numerically simulated the effect of an imposed magnetic field. Results presented that motion of the fluid is suppressed, hence the Nusselt number and so temperature decreases [1]. Yamamoto and Kunugi (2015) investigated the high-Prandtl number passive scalar transport of the turbulent channel flow imposed a wall-normal magnetic field through the large-scale direct numerical simulation. It is determined that with increasing Ha, the wall-normal turbulent heat flux decreased [2]. Huang and Li (2010) discussed about the characteristics of the fluid flow and heat transfer of the free surface MHD-flow with hemispherical protrusion wall. It is observed that the magnetic field have reverse influence on the thermal performance, and values decrease with Hartman numbers increasing [3]. Zijovin et al. (2010) investigated magnetohydrodynamic flow of two immiscible and electrically conducting fluids between isothermal, insulated moving plates in the presence of an applied electric and inclined magnetic field. It was found that with the increase of the Hartmann number decreases the temperature in the middle of the channel [4]. Huang and Li (2010) simulated numerically some conducting strips aligned with the mean flow direction on the insulating wall of free surface MHD-flow. It is concluded that Lorentz force created by magnetic field damps the motion of the flow and the velocity gradient is sharply decreased [5]. Takeuchi et al. (2008) reported that experimental results on turbulent pipe flow of an aqueous potassium hydroxide solution under magnetic field. It is observed that Hartmann number modificates the mean flow velocity as well as turbulence reduction [6]. Nakaharai et al. (2007) discussed the mean temperature gradient is not influenced compared to the temperature

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fluctuation in the direction vertical to the magnetic field. Magnetic field suppresses the turbulent velocity fluctuation, then the turbulent heat flux and temperature is decreased [7]. Smolentsev et al. (2002) presented the ‘‘K–e’’ model equations for turbulent flows and the free surface boundary condition are adjusted with taking into account MHD effects. The magnetic field increase leads to heat transfer degradation [8]. Kirillov et al. (1995) presented a review of experimental work on magnetohydrodynamic and heat transfer characteristics of liquid metal flows in fusion relevant conditions. A transverse magnetic field changes the velocity distribution in channels and suppresses turbulent pulsations and so dominates the heat transfer [9]. Branover et al. (1995) observed jump-wise growth in fluctuation intensity with magnetic field. The temperature fluctuation intensity decreases while a further field increases [10]. In this study, Lorentz force is created by magnetic field induction effect on liquid metal turbulent flow thermophysical parameters are temperature and heat flux.

2. Materials and Method

Constant wall temperature steady state liquid metal turbulent magnetohydrodynamic (MHD) flow thermophysical characteristic has been studied numerically by CFD software is ANSYS Fluent MHD module. Demonstrated duct model in Fig.1 is created and meshed with Gambit software.

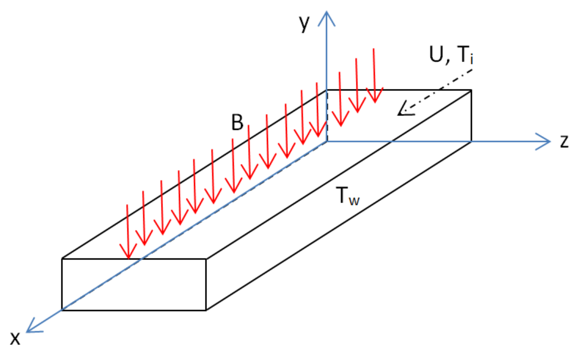

Figure 1. Figure caption

Mesh study occurred with 0.0002 m, 0.00025 m, 0.0005 m, 0.00075 m, 0.001 m grid sized models and convergence error rate of taken data shown 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 (%)		0.018	0.02	1.07	3.89

Given convergence error rate in Table 1 presented that 0.0002 m and 0.00025 m grid sized model analyses data was converged to each with a satisfactorily difference. 0.00025 m grid sized model was used to the analyses to obtain accurate results and minimum CPU time.

3. Results and Discussion

In this study, constant inlet flow velocity (U) and temperature (T_i) liquid metal turbulent flow has been investigated in constant wall temperature ($T_w > T_i$) rectangular duct model under the influence of transverse magnetic field with (B). Thermophysical characteristic of liquid metal has been determined by the evaluation of temperature and heat flux.

Central temperature of liquid metal flow under the applied transverse magnetic field is given in Fig. 2.

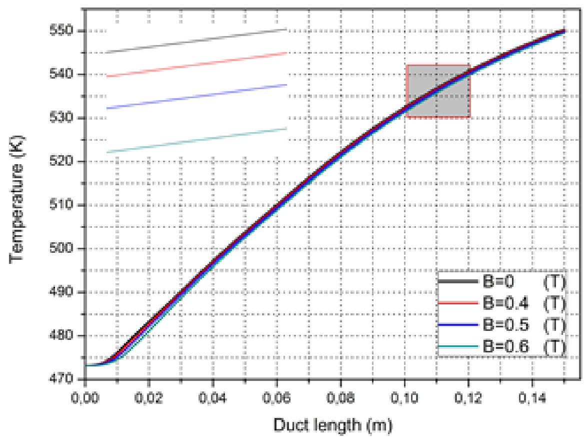

Figure 2. Model central temperature.

Fig. 2 presents that applied magnetic field decrease the central flow temperature through the model length. In ref. [4], concluded that increase of the Hartmann number decreases the temperature in the middle of the channel. Similarly in ref. [7] argued that magnetic field suppresses the turbulent velocity fluctuation, and then temperature is decreased.

Fig. 3 shows the magnetic forces effect on surface heat flux while liquid metal flow in a closed conduit.

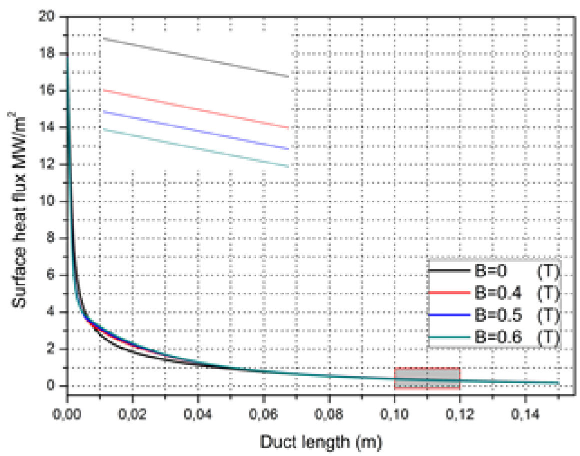

Figure 3. Model surface heat flux.

Heat flux from the model wall declined by imposed magnetic field. This assessment discussed in ref. [2] as increasing Ha, the wall-normal turbulent heat flux decreased. Also, in ref. [7] Magnetic field decreases the turbulent heat flux.

Conclusions

Applied magnetic field on electrically conductive moving fluid creates a backward force is called Lorentz force on the flow steam lines. This reactional force depresses the turbulent fluctuations of the flow domain. Decrease of turbulent fluctuation means the regulation of the flow lines of the fluid. Further increase of magnetic field induction suppresses the flow domain more and more and so temperature and heat flux was directly influenced. These thermophysical parameters are decreased by each step of increase the magnetic field induction.

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