Optimization of MHD effect on the ionized flow past the circular cylinder at high values of Hall parameter

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Nowadays in many works a huge number of attentions is focused on the study of MHD effect on the flow in order to control its characteristics. The control methods for following situations are concerned: flow in air intake of flying vehicle, processes of flow mixing, processes in engine of high speed flying vehicle, location of bow shock wave, heat flux on the streamlined surface. Theoretical analysis of MHD effect on ionized flow around circular cylinder done in [1] in approach neglecting the Hall parameter demonstrated significant decrease of heat flux on the surface due to MHD effect. Experimental researches [2] of MHD control of the flow under conditions with large Hall parameter (about 180) demonstrated only slight decrease of heat flux on the surface caused by MHD effect. It demonstrates the necessity to study the properties of MHD effect on the flow in detail, especially under large Hall parameters, in order to decrease the drawback of the Hall effect in MHD control applications.

In our work the equations for electric field in locally ionized MHD flow around a circular cylinder were obtained. Analytical solution for these equations for special case of potential flow was obtained. Numerical method and analytical approaches for finding electric field in the case of different shapes of MHD interaction zone were developed. The calculation of locally ionized MHD flows in [3] show that the effectiveness of MHD flow control is mainly determined by the spatial distribution of Lorentz force. By this way, it is reasonable to choice the configuration of MHD interaction zone for specific applications on the base of analysis of distribution of Lorentz force in the MHD interaction zone. In our work we obtain analytical formulas to define volume density of

Lorentz force in the locally ionized MHD flow past a cylinder, where the zone of local ionization is restricted by parameters: $r_0 < r < r_1$; $\varphi_1 < \varphi < \varphi_2$, as shown in fig.1. The influence of material of cylinder surface (conductive or non-conductive) is concerned. It is showed that for the case of conductive surface, Lorentz force near by the surface may lead to flow acceleration. The influence of geometry of MHD zone, Hall parameter, and external electric field on Lorentz force in the MHD interaction zone was concerned. It is shown that in the case when the ionized zone catches a large part of the region around cylinder (for example at $r_1 > 2r_0$ and $\varphi_1 = 0,\ \varphi_2 = 2\pi$) the increase of the Hall parameter significantly decreases the work of the Lorentz force that result in flow deceleration. Calculations made using different values of r_1, φ_1 and φ_2 show that the configuration of the MHD interaction zone apparently influences the Lorentz force. The decrease of angular interval of the MHD interaction zone $\varphi_2 - \varphi_1$ and the decrease of the thickness of the MHD interaction zone $r_1 - r_0$ lead to decreasing the drawbacks of the Hall effect on the Lorentz force. In particular, under conditions with Hall parameter $\beta_0 = 10$ and $r_1 = 2r_0$, using the ionized zone restricted by the values of $\varphi_1 = 3\pi/4$ and $\varphi_2 = 5\pi/4$ makes the value of Lorentz force closer to the values obtained in approach neglecting the Hall effect. By this way, for situation with large Hall parameter, the change of configuration of MHD interaction zone allows one to apparently enhance the effectiveness of MHD flow deceleration for flow around transverse cylinder. For optimization of MHD effect on the flow, we took care about the choice of configuration of MHD interaction zone, which guarantees maximum value of work of Lorentz force to decelerate flow, under fixed power consumption for flow ionization. The choice of optimized configuration of MHD interaction zone will be done under assumption that the ionization of flow is realized by electron beam.

References:

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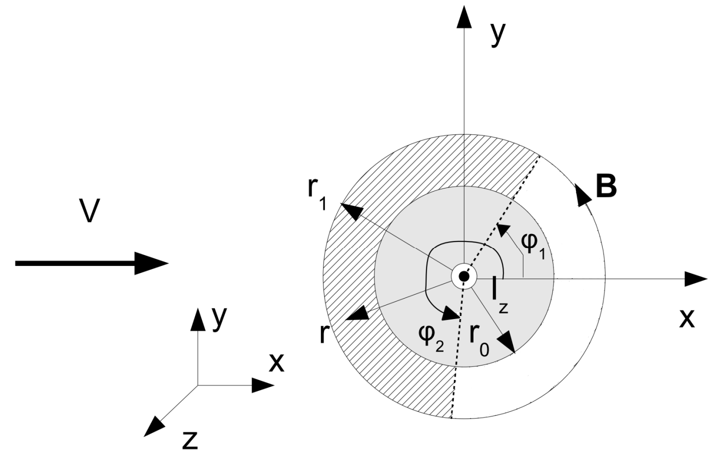

Fig.1 Geometry used for analysis of MHD effect on locally ionized flow around cylinder with radius r_0, in non-uniform magnetic field produced by current I_z. The ionized zone is shaded.