Local MHD Influence on Shock Waves Position

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A possibility to control the position of a bow shock wave arising due to supersonic streamlining of a semicylindrical body by magnetohydrodynamic (MHD) methods with the aim of drag reduction or increase is reported. Local MHD action was organized in the region between the bow shock wave and the body by means of a near surface gas discharge and magnetic field orthogonal to discharge current. It has been shown that against a background of electrogasdynamic (EGD) action, which shifts the bow shock wave only into direction from a body, it is possible to change the bow shock wave position (to move the wave away from the body or to bring it nearer to the body) by changing the Lorentz force direction and MHD interaction parameter.

The aim of this work was to show a possibility to control the position of the bow shock wave arising due to supersonic streamlining of a half-cylindrical body by the magnetohydrodynamic (MHD) method realized due to the action of the Lorentz force that arises in the presence of transverse magnetic field and surface discharge near the front edge of the model. This allows one to realize drag reduction or increase at supersonic flow around the body used as an aircraft model. The main task was to investigate how the bow shock-wave position changes when MHD interaction increases in the near surface region between the bow shock wave and the body. The Stewart parameter, i.e., the ratio between the Lorentz force work in the interaction zone and doubled kinetic energy of the flow in unit volume $St = \frac{jBL}{\rho u^2}$ is the general characteristic of the MHD action degree. Here B is the magnetic induction, ρ and u are the incoming flow density and velocity, L is the interaction zone width. MHD action is realized against the background of electrogasdynamic (EGD) action on a body streamline. EGD action results from gas heating in the gas discharge that gives rise to a gas pressure increase in the region between the shock wave and the body.

Experiments were conducted at the setup based on a shock tube [1, 2]. A working chamber in the form of a supersonic nozzle was connected to the end of a low-pressure chamber. At a distance of 20 cm from the nozzle entrance, at its axis, a body in the form of a half-cylinder was placed. The setup included systems of gas discharge and transverse magnetic field generation. Xenon was used as a working gas. This allowed us to model the EGD and MHD effects on the supersonic streamline of an aircraft head part without additional energy expenditures on ionization. The distance d from the bow shock wave to the body's nose part was determined from schlieren pictures of the flow. Gas discharge current was organized through special electrodes mounted into the body. The current embraced the nose part of the body along the half-circle trajectory as shown in Fig. 1. If current I runs from the bottom electrode to the top one as in Fig.1, it is Connection 1. When orthogonal magnetic field is switched on, the Lorentz force F acts on gas in the direction from the body. If current changes its direction to the opposite one, the Lorentz force is directed to the body (Connection 2). If we change the discharge current value and its direction, we change the intensity and direction of the MHD action which compresses or expands the gas behind the bow shock wave. In this way we can control the bow shock wave position by using the near surface discharge and magnetic field.

Figure 1a,b,c shows schlieren pictures of body streamline obtained at the same discharge intensity j=3.5·10^6 A/m^2 (I=600A) and different MHD action directions. For clearness, all pictures in the bottom part are combined with the schlieren photo of the flow in the absence of any action. The streamline picture in Figure 1a was obtained without magnetic field. There is a small wave shift from the initial position away from the body due to electrogasdynamic action. The picture on Figure 1b was obtained for Connection 1 in magnetic field B=1.4T. In this experiment the shock wave approaches the model, the extent of approach being the largest above and below central model axis. Distance d in this case is smaller as compared with d at EGD action alone (Fig.1a). Note that here the Lorentz force action is directed from the model but the bow shock wave approaches the model. Apparently, this takes place due to Lorentz force promotes removal of gas from the body behind the bow shock, which results in gas pressure decrease near the body surface [3] and wave approach to the body. The picture obtained with magnetic field *B*=1.4 T at Connection 2 is shown in Fig. 1c. There is additional wave shift from the body as compared with the wave position in the case of the same discharge without magnetic field (Fig. 1a). The dependence of effective plasma conductivity (estimated from voltage-current characteristics of the discharge) on discharge current is presented in Fig. 2a. The conductivity obtained for different current directions and with or without magnetic field is presented by points of different colors and shapes. It can be seen that conductivity increases with increasing current.

Figure 2b shows the dependence of bow shock wave shift d-d_0 with EGD and MHD action on discharge current and Stewart parameter. All data are normalized to d_0 (bow shock wave position without any action). Curve 0 (squares) is obtained without magnetic field, only at EGD action. It can be seen that the distance between the body and shock wave increases with increasing current. Curve 1 (circles) is obtained with magnetic field 1.4 T for the current in near surface region from bottom to top (Connection 1). At low currents the shock wave approaches the model and wave shift is negative. As current further increases, the bow shock wave moves away from the body because the EGD action starts to dominate over MHD action. Curve 2 (triangles) is MHD interaction at Connection 2. There is additional shift of bow shock wave from the body due to combined MHD and EGD actions. At high current values, the curves 0, 1, and 2 are close to each other.

It can be supposed that it is possible to control magnetohydrodynamically the bow shock wave position by switching-on external magnetic field orthogonal to the flow and near surface gas discharge current. The Lorentz force removes gas from the model or presses gas to the model, i.e., decreases or increases pressure between the body and the bow shock wave depending on the current direction. By changing the Lorentz force direction and MHD interaction parameter *St,* it is possible to change the bow shock-wave position on given value, i.e., to displace it from the body or to the body. It means that drag reduction or increase by local MHD action is possible [3].

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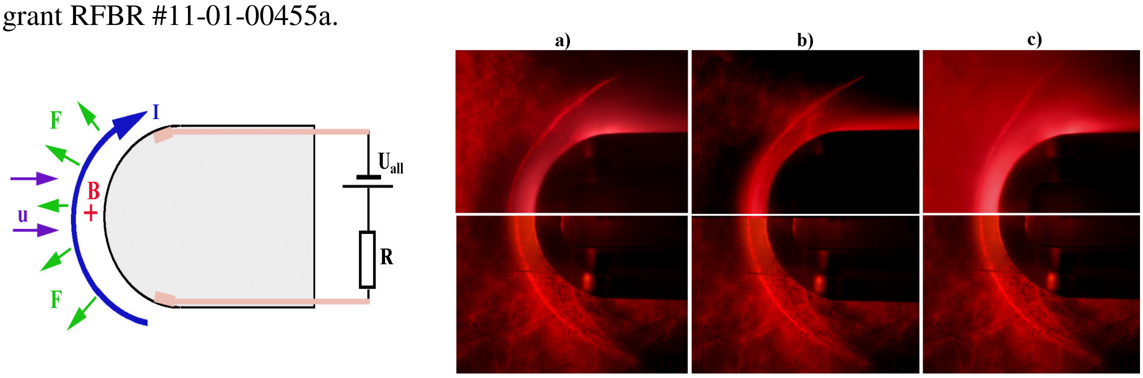

Fig. 1: Illustration of Lorentz force action. Schlieren flow pictures at different direction of MHD action: a) B=0; b) Connection 1, B=1.4T; c) Connection 2, B=1.4T.

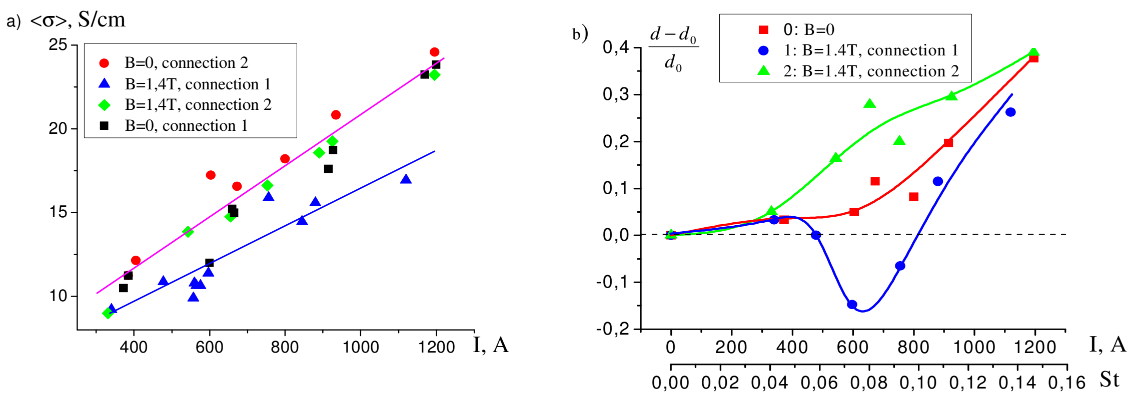

Fig. 2: a) Xenon plasma conductivity vs near surface gas discharge current. b) Relative bow shock wave shift at different intensities of EGD and MHD action.

References

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