MHD-Control of a Shock Wave Structure at a Hypersonic Flow

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There are reasons to believe that at present an advance of hypersonic flights to the mesosphere is one of the directions of the aerospace science development. It seems to be possible to fly at these altitudes with the speed higher than 2500 – 3500 m/s at certain conditions. The high velocities create the preconditions for using of magnetohydrodynamic techniques of flow control at low magnetic induction (less than 1 T). Magnetoplasmadynamic (MHD) effect on the air flow around bodies at hypersonic flight conditions permits to change a shock wave structure of the flow significantly. MHD-interaction localized on a flat plate has been considered at present paper.

One of the perspective MHD-technologies is the MHD-parachute concept. The concept has been considered at numerical simulation in ref. [1]. The main goal is to reduce the velocity of the reentry vehicle in the upper atmosphere down to the values that could assure a low heat load in the dense atmosphere. It has been shown that a strong MHD interaction leads to the formation of the detached bow shock and increases the drag of the model significantly. This concept has been studied experimentally in ITAM on the MHD-test rig based on a shock tube [2, 3]. The test-rig allows simulating flow parameters that are similar to hypersonic flight conditions at 30-50 km. The electromagnet generates magnetic field up to 2.2 T. The flow ionization has been generated by electrical discharge. Experimental results have shown that both the thin plate and the wedge generate the attached oblique shock wave in the air flow with the Mach number of 6. The shock wave slope angle is increased at the magnetic field B = 0.1-0.34 T, using the pulse discharge as an ionizer. At strong MHD-interaction (B = 0.6-0.8 T) the attached oblique shock wave transforms to the detached normal shock, that demonstrates the MHD-parachute effect.

Experimental study of the MHD-effect with RF-discharge as an ionizer has been carried out at the same conditions. Using of the RF-discharge is rather interesting because the local conductivity area is created with practically constant resistance and electrical contact between the electrodes. Under such conditions the MHD-interaction occurs and the flow decelerates. The pictures of the discharge in the flow show that the RF-discharge is localized between the electrodes without the flow. While the flow blows the discharge of the plate, the magnetic field returns the discharge into the electrodes area. In this case the discharge region generates a new oblique shock wave with the angle of 18 degrees at B = 1.75 T. The angle corresponds to the hypersonic flow near the plate in the flap down position with 8 degrees. Such alteration can be interpreted as “MHD-flap”.

It has been shown experimentally that both the pulse and the RF discharge can be efficiency used for the flow ionization in the transverse B-field and for the generation of the nonequilibrium conductivity. In this case the MHD-interaction permits to control the shock wave structure of the flow and generate control forces and moments on the surface streamlined at test conditions.

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