Investigation of supersonic inlet flow control based on plasma discharge technology

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Abstract: In order to reduce the total pressure recovery coefficient decrease at off-design conditions of the supersonic inlet, this paper tries to apply the plasma discharge control technology to improve supersonic inlet performance at off-design conditions by plasma discharge on the compression surface. The finite volume method is used to solve the Reynolds-averaged Navier-Stokes equations in this paper. The electromagnetic field and aerodynamic equations are coupled to calculate the plasma discharge effect. Numerical simulation and previous wind tunnel experiment results are contrasted, the results are well inosculated which validate the feasibility of the simulation methods. By applying the plasma discharge on the two-dimensional double wedge ramp inlet at mach number ranges from 2.9~4.0, the plasma flow control effect is obtained through numerical simulation. Results show that the shock wave occurs on the compression side of the supersonic inlet moved forward and the shock wave angle increased by applying the plasma discharge. Compared with the baseline case, the total pressure recovery coefficient of the supersonic inlet increased by 7.7% at Ma 4.0, which validate the effectiveness of the plasma flow control method for improving the performance of the supersonic inlet.

Keywords: Plasma discharge, Supersonic inlet, Flow control, Numerical simulation, Wind tunnel experiment, Shock wave, Total pressure recovery coefficient

With the development of supersonic aircraft, the aerodynamics is confronted with new challenge[s][1-4]. The strong shock wave could lead to a sharp increase in the drag of the aircraft and the decrease of the inlet performance at off-design conditions, which seriously hinders the development of the supersonic aircraft. Therefore, how to reduce the drag, control the shock wave and improve the performance of the inlet has become the focus of research in the field of flow control.

Recent years, the application of plasma flow control technology in supersonic aircraft has drawn more and more attention from many country. A series of theoretical, numerical and experimental research has been carried out and some progress has been made[5,6].

In this paper, the plasma flow control on the supersonic inlet flow field has been investigated. The numerical method has been set two directions of component for the magnetic field which are vertical and parallel to the airflow. The focus of this paper is to investigate the influence of the position and the discharge parameters for the plasma flow control on the performance of the 2D supersonic inlet. Thought the plasma discharge interaction coupled electromagnetic fields, the supersonic inlet can still keep the shock wave set on the lip position, even under the off-design conditions, the total pressure recovery coefficient of the supersonic inlet could be increased.

Numerical simulation method was verified by former plasma flow control experiment result.

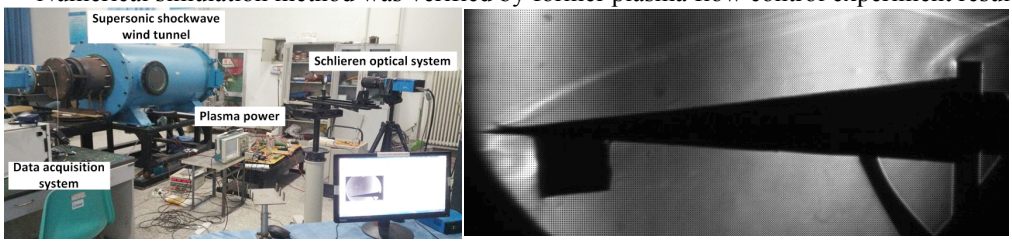
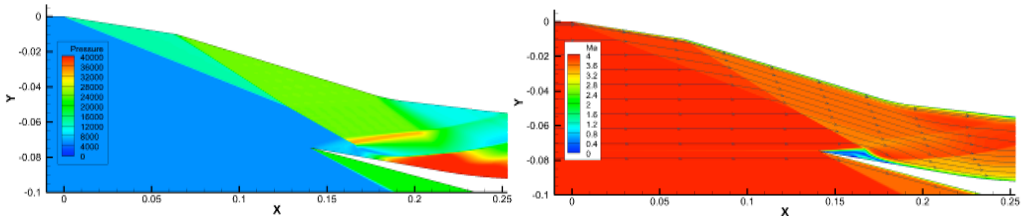
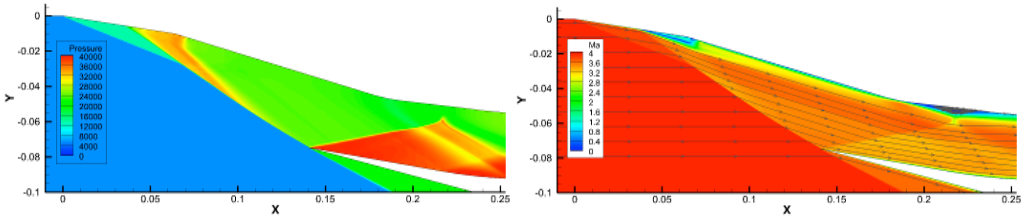


Figure 1: Experiment result for plasma discharge shock wave control.



(a) Static pressure and Mach contour for baseline case, no discharge



(b) Static pressure and Mach contour for discharge electric field intensity 330kV/m

Figure 2: Effect of discharge electric field intensity on inlet shock wave control at Ma4.0

This paper investigate the supersonic inlet flow control based on plasma discharge technology. The supersonic inlet Flow field simulation by plasma discharge or not, mach number ranges from 2.9~4. The calculation results show that the supersonic inlet shock wave angle can be controlled by plasma discharge, which reveals the inlet flow field control are feasible. The higher the Mach number, the more plasma discharge energy takes to control the inlet shock wave to meet the Shock-on-Lip principle. Under off-design conditions, the total pressure recovery coefficient of supersonic inlet can be increased by 7.7% through the plasma discharge interaction coupled electromagnetic fields.

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