Comparison of plasma actuator effects under rarefied flow conditions applied to a flat plate and a cylinder

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This investigation is the result of experiments conducted on the rarefied facility Marhy from Icare laboratory and numerical simulations developed at the IUSTI laboratory. This work focuses on the study of plasma actuator effects having an influence on the aerodynamic properties of a rarefied Mach 2 air flow interacting with two different model geometries: a cylinder and a flat plate. For both cases the plasma actuator consists on a plasma discharge created by means a Spellman high voltage power supply delivering a DC voltage up to 20 kV and 400 mA, applied on the surface of the model. The aerodynamic changes produced by the plasma discharge is analysed with an iCCD camera and Pitot tube measurements. Optical emission spectroscopy and thermal infrared measurements helped the understanding of the observed effects.

The main result is that depending on the geometry of the model, the greater cause due to the plasma actuator is not the same, despite the fact that the nature of the plasma discharge and the flow properties are the same.

In the case of the flat plate, it was observed a thickening of the boundary layer, and then an increase of the shock angle of around 4-7 %. Numerical simulations, validated with the experimental measurements showed that this effect is due to the heating of the surfaced plate produced by the plasma. In the case of the cylinder, it was experimentally observed an increase of the standoff distance of the shock, which depends on the electrical power discharge. Thermal effects due to a local surface heating cannot explain the observed modification of the shock shape. It is shown that this modification seems to strongly depend on the ionisation rate of the plasma region whereas the discharge is applied modifying the local isentropic coefficient.

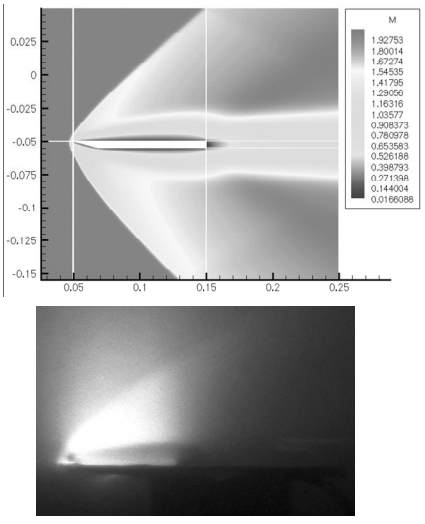

Figure 1: Comparison between the simulated Mach number isovalue for a 90W discharge (top) and the experimental CCD image obtained for 90 W.

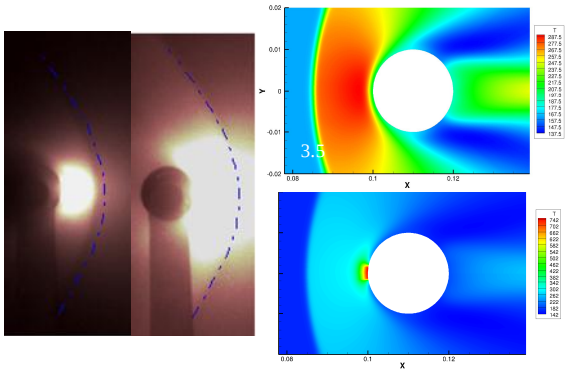

Figure 2: Experimental modification of the shock shape with the increase of the electric power discharge (left). Undisturbed standoff distance shock simulated with an increase of 940 K of the local surface cylinder temperature (wright)

References:

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