STRONG VISCOUS-INVISCID INTERACTION IN THE CASE OF NONCONSTANT WALL TEMPERATURE

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Summary Investigated is a flow in a hypersonic boundary layer in the regime of strong viscous-inviscid interaction. It is supposed wall temperature depends on longitudinal coordinate including region of almost zero wall temperature. For the model of strong viscous-inviscid interaction iteration numerical procedure were used which allowed to take into account base pressure on the flow upstream up to the leading edge. Calculated are pressure and skin friction distributions.

PROBLEM FORMULATION

For strong viscous-inviscid interaction of external hypersonic flow and boundary layer flow it is supposed that [1]

$$M \to \infty, \quad \mathrm{Re}_0 \to \infty, \quad \chi = M^2 \mathrm{Re}_0^{-1/2} \to \infty$$

where M is the Mach number and Re_0 is a Reynolds number based on the body length, the freestream velocity and density, and the viscosity calculated at the stagnation temperature. It was supposed that the flow is steady, laminar and two-dimensional.

The aim of this investigation is twofold. The first one is associated with the numerical procedures which should take into account processes of upstream disturbances propagation. So marching procedure is not applicable for models of interacting boundary layers. As was shown earlier ability for upstream disturbances propagation may be evaluated using special integral to determine average Mach number in the boundary layer. If this Mach number is less than unity than disturbances may propagate upstream and flow is subcritical (as was formulated by Crocco [2]). Otherwise if average Mach number is larger than unity than disturbances may propagate upstream and flow may be formulated as a supercritical one.

Numerical procedure should depend on the flow regime. It may be marching procedure in supercritical regions or it is needed to use some additional iterations in the case of subcritical regime.

It was supposed as well that pressure induced by boundary layer flow is much larger than the pressure induced by body surface. So bodies like wedges or flat plates are considered.

Results of computations demonstrate that flow in the boundary layer may contain regions of supercritical and subcritical flow especially if the wall temperature is not a constant.

Second possible application of results obtained is associated with practical aerodynamics. Upstream disturbances propagation may change pressure distribution on the surface (for example wedge or plate). Pressure redistribution may influence as a result on momentum aerodynamic characteristics. In this sense boundary layer flow control by means of surface cooling or heating may prevent upstream disturbances propagation and suppress this effect inflience on the aerodynamic characteristics.

From physical point of view upstream disturbances propagation effect is associated with the subsonic flow streamlines located near the wall [3]. As it was shown that the subsonic flow subregion is necessary but not sufficient condition for disturbances propagation and average Mach number through the boundary layer flow plays key role. Having obtained longitudinal velocity

$U(\eta)$ and full enthalpy $G(\eta)$ profiles we can calculate speed of upstream disturbances propagation a through the next integral relation which in fact is the modified Pearson [4] relation

$$F-\frac{(\gamma-1)}{2}F_1=0$$

$$F=\int_0^\infty (G-U^2)d\eta\,,\quad F_1=\int_0^\infty \frac{(G-U^2)^2}{(U+a)^2}d\eta$$

From mathematical point of view corresponding system of interacted boundary layer is characterized by weak ellipticity. The last factor is associated with the nonuniquiness of the model equations. Interacting boundary layer equations were solved for the case of nonconstant wall temperature using numerical procedure described in [3].

CONCLUSIONS

Results obtained showed that nonconstant wall temperature may provide aerodynamic characteristics control due to change of flow regime subcritical or supercritical one.

References

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