THE STRONG SHOCK WAVE STRUCTURE IN LOW DENSITY GAS MIXTURES FLOWS OVER CYLINDERS AND PLATES

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The supersonic rarefied gas flows over bodies in the transition regimes from the free molecular flow to the continuum one were an object of numerous investigations in studies of aerodynamics of space vehicles and their elements. The flows of gases with disparate molecular masses are of interest for the solution of aerodynamic problems of reentry into atmosphere of some planets Very likely, the studies of gas mixture flows has much more significance because of development of the modern vacuum technologies of thin film deposition for surface coating by metals, polymers, semi-conductivities, and biological molecules.

In these last cases the acceleration of heavy atoms and molecules in supersonic free jets of the light carrier gas is used to deposit heavy particles at high velocity. It is possible in rarefied gas at the weak deceleration of heavy particles in a shock layer. New related problems have arisen in the modern mass-spectrometry: acceleration of heavy (e. g. biological) molecular ions in electric field at high vacuum followed by soft landing with a definite velocity behind the gas target.

The theoretical description of the shock wave and the shock layer structures in supersonic flows of gas mixtures by solution of the Navier-Stokes equations is impossible for essentially non-equilibrium flows. Insuperable obstacles exist on the way of using the Boltzmann equation for gas mixtures with internal energy at non-equilibrium level population. The effective instrument for studies of the shock waves and the shock layers in the transition regime is the direct simulation Monte Carlo (DSMC) method [1].

In the present work the transversal supersonic flow over an infinite cylinder and a thin plate (installed perpendicular to the flow direction) was considered by the DSMC method adapted to the particular set of the problem.

The calculations were performed in the range of the Knudsen number from 0.01 to $\propto$. Model gases were presented by variable hard spheres with atomic masses of helium and xenon with mole concentration of Xe from 1 to 5 %. The surface temperature was varied from the translational temperature of the flow to the stagnation temperature. The flow structure was studied at the Mach number from 1.87 to 15.

The calculations allowed getting the following flow characteristics: a) the general structure of the flows; b) the aerodynamic characteristics of the force and heat effects; c) the distribution of macroscopic parameters in the disturbed flow at any point of interest; d) the velocity distribution function in the disturbed flow along the plane of symmetry.

Some important quantitative results were obtained:

a) aerodynamic characteristics;
b) spectrum of energy of particles colliding with the target;
c) conditional criteria of intermolecular collision process influence;
d) dependence of components of the temperature on directions;
e) loss of translational energy of the heavy particles along the flow in the shock layer.

The particular result of this investigation is the proof of possibility to determine the optimal conditions of gas jet deposition in modern vacuum technologies.

Acknowledgements

The work was supported by RFBR (grant N 03-01-00213) and by grant of the President of the Russian Federation for support of the Leading Scientific Schools (N 910.2003.1).

References

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