Analytical Model of Translational Nonequilibrium Flow with Internal Degrees of Freedom

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It is well known that the Navier-Stokes equation (NS), which provides a continuum description of viscous f1uid f1ow, begins to breakdown under rarefied conditions. Failure of the NS equation in hypersonic transitional flow occurs both in the shock front and in the region of shock layer immediately adjacent to the body surface (i.e. Knudsen layer). In these regions the continuum equations are not valid and the particle simulation technique such as the direct Simulation Monte-Carlo method (DSMC) usua1ly is used. However the main reason for not applying the DSMC method to all f1ows is its prohibitive numerical cost at high-density conditions. For the study of normal hypersonic shock wave structures were the Burnett equations employed, too. However these equations set is more difficult to solve numerica1ly than the NS and will in any case fail when the degree of rarefaction is sufficiently high. There are also questions about appropriate boundary conditions for the Burnett equations. Early in the articles of authors and in the professor's H.K.Cheng et al. [1] artic1es the new methods to the solving of viscous shock 1ayer problem in continuum-transition regime were developed. These methods based on asymptotic relations are deduced from the thin-1ayer version of moment equations of the gas-kinetic theory.

Here the essence of new method to the solving of viscous shock layer problem in continuum-transition regime was developed. This method is based on kinetic moment equation with internal degrees of freedom and asymptotical analysis of these equations. Maxwell transport equations are used for derivation of closed system of macroscopic equations describing gas flows in viscous shock layer and hypersonic boundary layer. In contradistinction to the Navier-Stokes equation (NS) the new moment approaches have the non1inear re1ation-ships for shear stress and heat transfer, what concise with the NS re1ation-ships by the sma11 degree of rarefaction оп1y. Moreover in contradistinction to the known continuum local equilibrium approaches based on the Chapman-Enskog method the analytical expressions for frequencies of inelastic binary collisions, taking into account the translational nonequilibrium effect are obtained.

1. Cheng H.K. and Emanuel G. Perspective on Hypersonic Nonequilibrium flow // AIAA Journal. 1995. Vol. 33. N. 3. pp. 385-400