GENERALIZED BOLTZMANN PHYSICAL KINETICS AND ITS APPLICATIONS IN RAREFIED IONIZED GAS DYNAMICS

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In 1872 L Boltzmann published his famous kinetic equation for the one-particle distribution function *f* (**r**, **v**, *t*). He expressed the equation in the form

$\frac{Df}{Dt} = J^{st}(f)$, where J^{st} is the collision ('stoß') integral, and

$\frac{D}{Dt} = \frac{\partial}{\partial t} + \vec{v} \cdot \frac{\partial}{\partial \vec{r}} + \vec{F} \cdot \frac{\partial}{\partial \vec{v}}$ is the substantial (particle) derivative, $\vec{v}$ and $\vec{r}$ being the velocity and radius vector of the particle, respectively. *Where is the weak point of the Boltzmann kinetic theory?*

For the better understanding let us consider the rarefied neutral gas. In this case the particle interaction scale r_B presents only one of the scales (and the shortest ones) in the scales hierarchy in molecular systems, where the λ scale (related to the particle mean free path) and the hydrodynamic L scale (for example, for flow in tube this scale can be connected with the length or diameter of the tube) always exist. BE is valid only on the distances of the λ, L - order, but not valid for the r_B scale. It means that from the position of BKT all Boltzmann's particles are the material points and appearance of cross sections of the particle interactions in the collision integral is one of the contradictions of BKT. From the strict theory of Bogolubov hierarchy of kinetic equations follows that changes of the distribution function on the all three mentioned scales are of the same order. What can be done in this situation and how to write down the generalized Boltzmann equation (GBE)? The additional terms in GBE cannot be omitted in spite of the value of Knudsen numbers. In this sense the classical Boltzmann equation is wrong. It means also that GBE covers the total area of application of the classical Boltzmann equation and all known results based on classical Boltzmann equation should be reconsidered from the point of view of generalized Boltzmann physical kinetics. For a multi-component reacting gas, the generalized Boltzmann equation can be rewritten as

$$\frac{Df_\alpha}{Dt} - \frac{D}{Dt}\left(\tau_\alpha \frac{Df_\alpha}{Dt}\right) = J_\alpha^{st,el} + J_\alpha^{st,r},$$

where f_α is distribution function for a particle of the α-th kind, τ_α is mean free time for a particle of the α-th kind, and $J_\alpha^{st,el}, J_\alpha^{st,r}$ are the Boltzmann collision integrals for elastic and inelastic collisions, respectively. I indicate the directions of investigations which were realized in the recent years on the basement of GBE (see for example [1,2]): 1.The general problems of the kinetic theory 2.The generalized hydrodynamic equations including the strict theory of turbulence and the problem of intermediate Knundsen numbers. 3.Acoustics. 4.Gas dynamics including the theory of shock waves. 5.Transport processes in semiconductors. 6.Plasma physics. 7.Physics of partly ionized gas. 8.Kinetic theory of liquids.

References

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