On an influence of a temperature jump on a molecular heat flow which is taken away from a surface of strongly heated solid spherical aerosol particle

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In zones of laser radiation passage through aerosols (Bennet, U.S.) at their enlightenment, diagnostics and combustion aerosol particles strongly heated by the radiation can considerably influence on a temperature distribution inside the aerosol.

Theoretically the estimation of this influence can be carried out, knowing the formulas, allowing to estimate a value of molecular heat flows which are taken away from the surface of heated particles. Formulas found earlier (Shchukin.E.R.) allow to estimate a value of molecular heat flows without an influence of the gas temperature jump (Loyalka,S.K.) near the particle's surface.

Authors of the report in the quasi-stationary approach, taking into account the temperature jump , carried out a mathematical modeling of the molecular heat exchange process of the motionless solid highly thermal conductive spherical aerosol particle with the surface Knudsen number Kn < 0.3 and the gaseous environment in the one component gas with temperature $T_{e\infty}$ and pressure p_∞ The surface temperature of the particle is $T_p >> T_{e\infty}$. The particle's radius is sufficiently small in order to neglect an influence of a gravitational convection on the heat transport. The thermal conductivity coefficient of the gas κ_e depends on the gas temperature T_e by a power law: $\kappa_e = \kappa_{e\infty} t_e^{\omega}$, where $t_e = T_e / T_{e\infty}$.

The T_e distribution is described by the boundary problem (1) in the considered conditions in the environment of the particle

$$\frac{d}{dr} r^2 \kappa_e \frac{dT_e}{dr} = 0,$$

$$\Delta T_{es} = -c_T \lambda \frac{dT_e}{dr}\Big|_{r=R}, \qquad T_{es} = T_e\Big|_{r=R},$$

$$T_e\Big|_{r\to\infty} = T_{e\infty}, \qquad (1)$$

where r is the radial coordinate, T_{es} is the value of the gas temperature interpolated from the volume, $\Delta T_{es} = T_p - T_{es}$ - is the gas temperature jump at the surface of the particle, c_T is a coefficient of the temperature jump, λ -is the mean free path of the gas molecules at the temperature T_e. The following analytic expression for a dimensionless temperature t_e was obtained in the process of the solution of (1):

$$t_e = \left[1 + (R/r)\left(t_{es}^{1+\omega} - 1\right)\right]^{1/(1+\omega)}, \quad t_{es} = t_p - \Delta t_{es},$$

$$\Delta t_{es} = \left(A_1 - \sqrt{A_1^2 - 4A_0A_2}\right)/2A_2, \qquad (2)$$

where $\varepsilon = (c_T/(1+\omega))(\lambda_\infty/R)$, $\lambda_\infty = \lambda$ at $T_e = T_{e\infty}$, $A_0 = \varepsilon\left(t_p^2 - t_p^{1-\omega}\right)$,

$$A_1 = \left[1 + \varepsilon\left(2t_p - (1-\omega)t_p^{-\omega}\right)\right],$$

$$A_2 = \varepsilon\left[2 + \omega(1-\omega)t_p^{-(1+\omega)}\right]/2.$$

An expression for the molecular stream $Q_T^{(M)}$ taken away from the surface of the particle was found with a help of (2), and is equal to

$$Q_T^{(M)} = 4\pi R \kappa_{e\infty} T_{e\infty} f_T^{(M)},$$

$$f_T^{(M)} = \left(t_{es}^{1+\omega} - 1\right)/(1+\omega). \qquad (3)$$

A numerical analysis carried out with a help of (2), (3) has shown, in particular, that the increase in temperature of the surface of the particle can lead to noticeable monotonous increase of the gas temperature jump and strong increase of the molecular heat flow near the surface of moderately large aerosol particles.

References

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