ON THE EFFECT OF THE THERMOMAGNETIC PRESSURE DIFFERENCE AND THE SCOTT EFFECT

L. A. Paltsev

The effect of the thermomagnetic pressure difference and the Scott effect are considered, accounting for nonlinear temperature stresses. For a gas of linear diamagnetic molecules, shear nonlinear temperature stress coefficients are determined as functions of the magnetic field frequency. For multi-atomic gas, shear and bulk temperature stress coefficients are obtained in the absence of a magnetic field.

In [1], transfer equations were obtained that can be used for describing slow flows of multi-atomic gas in the presence of an external alternating magnetic field. In particular, the equations describe flows arising in the effect of the thermomagnetic pressure difference and in the Scott effect for the case of small Knudsen numbers. In order to explain these effects, the following stationary flows of multi-atomic gas are considered: first, in a narrow channel with zero mass flux and, second, between two coaxial cylinders in the presence of an external magnetic field directed normal to the flow. The temperature difference between the channel sides, in the first case, and between the walls of the coaxial cylinders, in the second, is assumed to be nonzero. Such flows have been studied theoretically and experimentally only for the case of a small relative temperature difference, where the velocity fields and thermomagnetic pressure differences depend only on viscous stresses, and the moments of forces acting on the cylinders are caused only by viscous and linear temperature stresses [2-7].

In the present paper, such flows are considered for the case of large relative temperature differences and an external alternating magnetic field. Velocity fields, thermomagnetic pressure differences, and the moments of forces acting on the cylinders are obtained, accounting for nonlinear temperature stresses. For gases of molecules with slightly nonspherical intermolecular interaction, the flows considered here are examples of Stokes flows (Reynolds number \( \text{Re} \ll 1 \)). However, in contrast to usual Stokes flows, here the velocity fields are determined not only by viscous stresses, but by nonlinear temperature stresses as well. For a gas of linear diamagnetic molecules with slightly nonspherical intermolecular interaction, the coefficients of shear, linear, and nonlinear temperature stresses are determined as functions of the amplitude and frequency of the magnetic field. The coefficients of the shear and volume temperature stresses of a multi-atomic gas are obtained in the one-moment and two-moment approximations, respectively, in the absence of a magnetic field.

1. Consider a two-dimensional stationary flow of multi-atomic gas with zero mass flux for \( u^* = \mu \) [1] through a flat channel \((-\infty < x < \infty, -l/2 < y < l/2, -\infty < z < \infty\) with an external magnetic field \( \mathbf{B} = e_1 B_0 + e_2 B_1 \cos \omega t \) applied. Here \( e_1 \) is the unit vector along the \( z \) axis, which is directed normal to the flow. Let \( T_{ij} \) be the temperatures of the lower \( (j = 1) \) and upper \( (j = 2) \) walls of the channel and \( \Delta T_0 = T_{01} - T_{02} > 0 \). In this case, it follows from (1.2.1)^2, (1.2.10), and (1.2.16) that local macroscopic variables depend only on the coordinate \( y \). The only nonzero component of the local velocity \( u = u(y) \) is the \( x \)-component: \( p = uT \) and \( p^{(1)} = u^{(1)} + T^{(1)} \) are constant. For the local temperature \( T = T(y) \) and

---

1 Central Aerohydrodynamical Institute, Zhukovsky, Moscow Region, Russia.
2 Hereafter, we refer to, say, Eq. (2.1) from [1] as (1.2.1), etc.

local velocity $u$, we obtain the following equations:

$$
\nabla_2 (\lambda(\omega) \nabla_2 T) = 0.
$$

$$
\nabla_j p^{(2)} = \frac{1}{p} \nabla_2 \left[ \eta^{2}(\omega) \nabla_2 u - \frac{2}{T} \Delta_j^{2}(\omega) (\nabla_2 T)^2 \right]. \quad j = 1, 2,
$$

where

$$
(r^1, r^2) = (x, y), \quad \lambda(\omega) = \lambda^{22}(\omega),
$$

$$
\eta^{2}(\omega) = \eta^{221}(\omega) + \eta^{212}(\omega),
$$

$$
\Delta_j^{2}(\omega) = \Delta_2^{222}(\omega) - T \frac{d \log \lambda(\omega)}{dT} \Delta_1^{222}(\omega).
$$

System (1.1) is solved for the boundary conditions $T(y_j) = T_{w_j}, \quad u(y_j) = v_j(\omega)$, where $y_j = (-1)^{j/2}$ and $v_j(\omega)$ is the velocity of temperature sliding on the $j$th surface.

As is known (see, e.g., [8]), the velocity of temperature sliding can be found by solving kinetic equation (1.1.1) in the Knudsen layer, provided that the Wigner operator (1.2.4) is given for the gas volume. This problem is extremely complicated even for the case of monatomic gas and is not considered in the present paper. Note that $v_j(\omega)$ is obtained only for the simplest models of interaction between the molecules and the surfaces, and only in a steady magnetic field. Indeed, in [9], the velocity of temperature sliding for the diffuse reflection of molecules from a surface is obtained from the stationary Waldmann–Snyder equation. The result is in good agreement with the experimental data for a gas of linear diamagnetic molecules [6]. In [5, 10], the velocity of sliding was obtained, accounting for the Kagan vector and polarization of the molecules due to their reflection from the surface.

Taking into account (1.2.4), we assume, analogously to the case of a steady magnetic field, that

$$
\nu_j(\omega) = V_j(\omega) \left( \frac{dT}{dy} \right)_{y = u_j}.
$$

When estimating the thermomagnetic pressure difference as a function of the magnetic field frequency, the function $V_j(\omega) = V_{xy}(T_{w_j}, p, \omega, B_0, B_1)$ can be obtained, for instance, from the Waldmann equation [7], or from the formula given in [9], replacing the kinetic coefficients there by the corresponding kinetic coefficients depending on the magnetic field frequency.

Under the condition of zero mass flux

$$
\int_{-l/2}^{l/2} \frac{n \, dy}{T} = 0,
$$

from (1.1) in combination with (1.2), we obtain

$$
n(y) = U(y) + k_{12}(y) \frac{dp^{(2)}}{dx},
$$

$$
\frac{dp^{(2)}}{dx} = - \int_{-l/2}^{l/2} \frac{U(y) \, dy}{pT} - \int_{-l/2}^{l/2} \frac{k_{12}(y) \, dy}{T}.
$$

(1.3)