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TRANSFER OF GAS-ION MOMENTUM AND ENERGY TO AN ELECTRICALLY CONDUCTIVE SURFACE PARTIALLY COATED BY A THIN DIELECTRIC LAYER

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The dynamic interaction of bodies with a rarefied gas flow is characterized to a significant extent by exchange of momentum and energy, or the corresponding accommodation coefficients. The momentum and energy accommodation coefficients are used to determine aerodynamic characteristics and heat exchange of bodies in a rarefied medium and are an important element of the computation relationships no matter what pattern of gas-atom interaction with the surface is chosen.

The present study will examine interaction of gas atoms with purely crystalline structures. There are available a significant number of studies which have performed numerical simulations of atomic particle collisions with a solid surface and offered approximate analytical solutions characterizing the mechanism of gas-atom momentum and energy transfer to ideal crystalline surfaces [1, 2]. In practical targets with an ideal single-crystal structure are rarely found. In the majority of cases the surface flowed over a polycrystalline structure with individual crystallites randomly oriented. In numerical study of collision of atomic particles with an atomically smooth polycrystalline surface it is necessary to average the interaction characteristics, which significantly complicates the problem [3]. The situation becomes even more complicated for technological materials such as alloys with complex structure and surface relief.

The literature provides an insufficient volume of data on calculated and experimental values of gas particle accommodation coefficients for the velocity range $u_\infty \cong 10$ km/sec which is of practical interest in aerodynamics. Experimental values of the accommodation coefficients are few in number, and refer to varied experimental conditions. Calculations of aerodynamic characteristics and heat exchange of bodies moving in a rarefied medium require knowledge of a complex of parameters characterizing the dynamic interaction of the body with the incident flow. In connection with this it becomes necessary to perform general studies to determine the gas-particle momentum and energy accommodation coefficients on the surface flowed over. The present study will experimentally investigate the effects of a number of factors characterizing interaction of a gas with a surface upon the values of the momentum and energy accommodation coefficients of gas ions with atomic masses from 4 to 131 on the surface of an aluminized polymer film with a conductive face surface coated by a glass screen (dielectric grid with transparency coefficient of $\sim$0.12), the outer surface of vacuum-screen thermal insulation [4].

1. The force action of a flow of partially ionized gas of low density on a surface being flowed over having a "floating" potential is determined by bombardment of electrons, ions, rapid and slow neutral particles produced by ion charge exchange with the residual gas, metastable particles, etc.:

$$F_\Sigma = F_e + F_i + F_n + F_0 + F_m + \ldots = F_e(V) + F_i(V) + \Delta F.$$

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Here F_e is the pressure force produced by electron bombardment; F_i, the pressure force from ions of the rarefied plasma flow; F_n, the contribution of fast neutrals; F_0, the contribution of slow neutrals; F_m, the force produced by metastable particles; ΔF is independent of the potential of the surface flowed over.

Considering the fact that the pressure force produced by electrons on the surface is much less than the force produced by other particles of the partially ionized gas flow, the quantity ΔF can be determined from the force characteristic of a conductive target at surface potentials corresponding to the electron flow saturation region — at positive target potentials relative to the plasma potential $(V = \varphi_w - \varphi_v > 0)$: $F_{V>0} = F_e(V) + \Delta F \simeq \Delta F$.

In a rarefied partially ionized gas flow the "floating"* potential of the face surface of a body ϕ_f as a rule is close to the plasma potential ϕ_v: the relationship $F_\Sigma - \Delta F \cong F_i$ permits separation of the contribution of the ion component to the force effect of the rarefied plasma flow on the target.

With consideration of the relationship between the momentum and energy exchange coefficients and the corresponding accommodation coefficients [1], by using aerodynamic coefficients of the elements of a surface or target in the form of a plane plate (circular disk) [5, 6], the accommodation coefficients for normal σ_n and tangential σ_t momentum can be written in the form [7]

$$\sigma_n = \frac{1 + \left[1 - e(F_x + F_y \operatorname{tg}\theta)/\sqrt{2M_iW_iI_i}\right]/\sqrt{1 + \eta^2/\cos^2\theta}}{1 - \sqrt{\pi k T_w (1 + \eta^2)/4W_i(\cos^2\theta + \eta^2)}},$$
$$\sigma_t = \frac{e(F_x - F_y \operatorname{ctg}\theta)}{\sqrt{2M_iW_iI_i}}, \tag{1.1}$$

where F_x is the resistance force of the surface element; F_y, the lift force of the target in the ion flow; $\eta^2 = (e|V| + \chi)/W_i$; W_i is the energy transferred by ions on the boundary of the perturbed zone; $I_i = I_{0i}\cos\theta$; I_{0i} is the ion saturation current on a plane probe at $\theta = 0$; $\chi = 3.6/d$ is the polarization energy; d is the distance from the conductive target surface at which neutralization of positive ions occurs. For the majority of electrically conductive surfaces and a particle energy range of ~1-100 eV, $d \cong (2\text{-}4)\cdot 10^{-7}$ mm [8]. When a conductive surface partially coated with a thin dielectric layer with $\delta_s > d$ (where δ_s is the layer thickness) is bombarded polarization effects may be neglected.

Equation (1.1) together with the current—voltage, temperature, and force characteristics of the target allows determination of the force interaction of ions in a rarefied plasma flow with an electrically conductive surface partially coated with a thin layer of dielectric. The resistance force of the target and its buoyancy force in the ion flow can be determined by using values of ΔF found in the same flow for the force characteristic of a conductive target at $V > 0$, corresponding to the electron-current saturation region.

The experimental studies to determine the parameters of interaction between gas ions and an electrically conductive surface partially coated by a dielectric grid formed by the outer surface of vacuum screen insulation [4] were performed in a plasma aerodynamic tube in a flow of low-density partially ionized gas generated by a gas discharge accelerator with ionization of the working body by electron collision. The working gases used were helium, neon, nitrogen, oxygen, argon, krypton, and xenon. The accelerated ion flow with intensity $f_\infty \cong 10^{16}\text{-}10^{17}$ cm$^{-2}\cdot$sec^{-1} was fed to the operating chamber which had a residual gas pressure of $\sim 4\cdot 10^{-5}$ Pa. Measurements were performed at an operating chamber pressure of $\sim 1\cdot 10^{-3}$ Pa. Evacuation was performed by an AVED-40/800M vacuum-electrical discharge system. The operating portion of the chamber was screened by panels cooled by liquid nitrogen.

The target used in the measurements had the form of a disk ~36 mm in diameter with $\delta \cong 0.35$ mm. The working portion of the target was formed by aluminized polymer film, with its conductive face coated by a dielectric grid with $\delta_s \cong 0.20$ mm, the outer surface of vacuum-screen insulation. Current leads and thermocouple elements were attached to the conductive surface of the polymer film. Before performing the experiments the sensor was

*The "floating" potential is the equilibrium negative potential which the body takes on in the rarefied plasma flow.

calibrated in a thermostatic chamber and the function $T_W = T_W(E)$ was found, where E is the thermocouple emf.

The target was placed on a compensation-type microscale based on the movement of a type N359 dc milliammeter [7]. To increase the sensitivity of the microscale and decrease the contribution of ΔF to the balance of forces the target holder was placed in a dielectric (glass) tube with internal diameter of $\sim$18 mm. For the same purpose the side and back faces of the target were protected from incident flow action by a screen held at a potential equal to the target potential. The range of forces measurable with a lever arm of $L \cong 450$ mm was $\sim 5 \cdot 10^{-3}$-250 dyn. Target characteristic measurements were performed by an automated technique.

To measure and monitor local values of the flow parameters a system of movable electric probes was used: a planar molybdenum probe with working surface $\sim$3.5 mm in diameter, an isolated cylindrical probe of molybdenum wire 0.04 mm in diameter and 2.3 mm long, and a multielectrode probe-analyzer. The current—voltage characteristics of the probes were processed by the traditional method of [9]. Energy of flow ions was determined by the multielectrode probe, with plasma potential being determined by the second derivative method, and from the electron segment of the probe characteristic, constructed in semilogarithmic scale, which insured quite high accuracy in W_i measurement. Values of W_i, calculated with the assumption that the accelerating potential was equal to the difference between the potential of the course anode and the local plasma potential, agreed satisfactorily with data obtained using the multielectrode probe-analyzer. The scattering in these values did not exceed $\sim\pm 4.5\%$. In the velocity range $u_\infty \cong 7$-20 km/sec ion scattering over energy did not exceed $\sim\pm 10\%$. The isolated cylindrical probe was also used to monitor orientation of the target relative to the velocity vector of the incident flow. The probe axis was parallel to the normal to the target surface. The peak in ion current measured by this probe during rotation about the vertical or horizontal axes corresponds to probe orientation along the flow and permits evaluating the degree of nonisothermality in the flow ($T_e/T_i \cong$ 7-10 for $T_e \cong 4$ eV) [10]. Uncertainty in angular orientation of the target in the flow did not exceed $\pm 20'$.

Special attention was given to the purity of the target working surface. Before measurements were performed a high negative potential $V \cong -250$ V was applied to the conductive surface of the aluminized film, and the target surface was bombarded by ions from a rarefied plasma flow for 10-15 min. Current—voltage, temperature, and force characteristics were measured beginning at $V \cong -250$ V. The results of [7, 11] indicate that upon bombardment of the target by a flow of rarefied plasma with $j_\infty \simeq 10^{16}$-10^{17} cm$^{-2}\cdot$sec^{-1} at $T_W \cong 300$ K the working surface of the target can be maintained in a satisfactory state over the entire course of the measurement process.

Figure 1 illustrates the effect of N_2^+ ion velocity on the value of σ_n at $\theta = 0$ (where θ is the angle of attack): curve 1 is the result of σ_n measurements in the present study on an aluminized polymer film surface; curve 2 is $\sigma_n^{N_2^+}$ values measured on the surface of an aluminized film coated by a dielectric grid formed by the outer surface of vacuum screen thermal insulation; curve 3 is the result of σ_n calculations with numerical modeling of gas-atom collision with a semi-infinite lattice of elastically bound atoms, performed with the data of [12] for $\mu = 1.0$ and $\varepsilon_1 = E_1/\lambda\kappa^2 \cong 0.0001$. Here μ is the ratio of the atomic mases of the gas-surface system; κ, E_1 are the parameters of the Lennard—Johns potential; λ is the elastic constant of the target lattice. To determine σ_n values with the data of [12] the characteristic temprature of Al was taken equal to the target surface temperature: $\theta_d \cong T_W \cong 330$ K. Figure 1 indicates the satisfactory agreement between measured and calculated values of σ_n for bombardment of the conductive surface of an aluminized polymer film by N_2^+ ions.

The effect of atomic mass of the gas ion bombarding the surface of the aluminized polymer film (points I) and the outer surface of vacuum-screen insulation (points II) on the magnitude of σ_n at $u_\infty \cong 10$ km/sec and $\theta = 0$ is shown in Fig. 2. The values of σ_n shown indicate the dominant influence of the ratio of the atomic masses of the gas—surface system in the velocity range considered. The maximum uncertainty in the measured $\Delta\sigma_n$ values does not exceed $\cong\pm 0.05$.

Figure 3 illustrates the character of the change in σ_n/σ_0 (where σ_0 is the value of σ_n for $\theta = 0$) for oblique incidence of ions with atomic masses from 4 to 131 and a velocity $u_\infty \cong 10$ km/sec on the surface of the aluminized film and the outer surface of vacuum screen

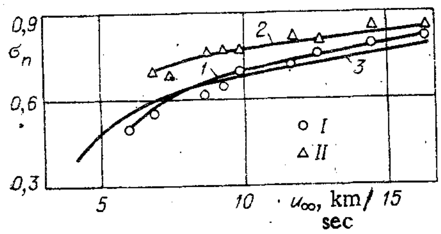

Fig. 1

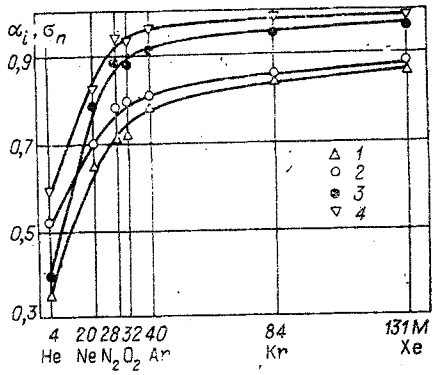

Fig. 2

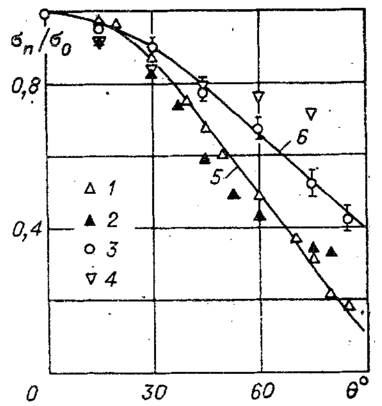

Fig. 3

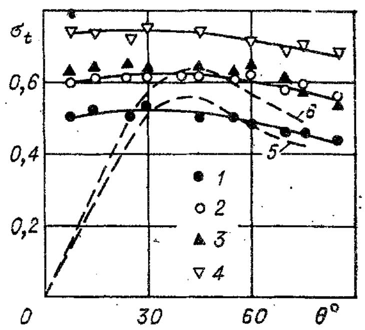

Fig. 4

thermal insulation (points 1, 3). The points 2 are calculated values of σ_n/σ_0 for numerical model of the process of collision of N_2 with an Al surface, modeled by a face-centered lattice at $u_\infty \cong 8$ km/sec, while points 4 are numerical data from [13] for modeling of collisions of N_2 with a rough fiberglass surface at $u_\infty \cong 8$ km/sec. A diamond-lattice model was used for the rough fiberglass surface [13]. Curve 5 is the empirical expression

$$\sigma_n/\sigma_0 \simeq \cos\theta + a_1(1 + 1/\sigma_0)^{-1}\sin^2\theta\,(\sin^2\theta - \sqrt{\cos\theta}),$$

where for N_2^+ $a_1 \cong 0.333$, and curve 6 is described by

$$\sigma_n/\sigma_0 \simeq \cos^{3/2}\theta + a_2(1 + 1/\sigma_0)^{-1}\sin^2\theta.$$

Here $a_2^{\mathrm{He}^+} \sim 1{,}07$; $a_2^{\mathrm{Ne}^+} \simeq 0{,}976$; $a_2^{\mathrm{N}_2^+} \simeq 0{,}913$; $a_2^{\mathrm{Ar}^+} \simeq 0{,}895$; $a_2^{\mathrm{Kr}^+} \simeq 0{,}87$; $a_2^{\mathrm{Xe}^+} \simeq 0{,}846$. Within an accuracy of $\pm 7.5\%$ for $M_i \gtrsim 28$ we may take $a_2 \cong 0.933$, while $a_2 \cong 1.033$ for $M_i \lesssim 20$. Figure 3 shows scattering of σ_n/σ_0 values for these values of the coefficient a_2.

Results of measurements of the corresponding gas-ion tangential-momentum accommodation coefficients $\sigma_t(\theta)$ are shown in Fig. 4: points 1 are for bombardment of the outer vacuum-screen thermal insulation surface by He^+ ions at $u_\infty \cong 10$ km/sec; 2, N_2^+; 3, Ar^+; 4, Xe^+, while curves 5, 6 are calculated σ_t values for numerical modeling of He and N_2 atom collision with a rough fiberglass screen at $u_\infty \cong 8$ km/sec [13]. The data of Fig. 4 indicate the relatively weak effect of the gas–surface system atomic mass ratio and attack angle of the surface upon σ_t: at $\theta = 45°$ $\sigma_t^{\mathrm{Xe}^+} \simeq 0{,}733$, $\sigma_t^{\mathrm{Kr}^+} \simeq 0{,}719$, $\sigma_t^{\mathrm{Ar}^+} \simeq 0{,}651$, $\sigma_t^{\mathrm{N}_2^+} \simeq 0{,}617$, $\sigma_t^{\mathrm{Ne}^+} \simeq 0{,}578$ and $\sigma_t^{\mathrm{He}^+} \simeq 0{,}509$.

2. The expressions obtained for $\sigma_n/\sigma_0(\theta)$ and $\sigma_t(\theta)$ were used to calculated C_x of a sphere with external surface coated by vacuum-screen thermal insulation. The results were compared to measurements of C_x of a sphere ∿38 mm in diameter, coated by aluminized film and vacuum-screen thermal insulation, performed in flows of rarefied He^+, N_2^+, Ar^+, Kr^+, and Xe^+ at $u_\infty \cong 10$ km/sec. To determine C_x of the sphere the expression

TABLE 1

Resistance coefficient	Xe^+	Kr^+	Ar^+	N_2^+	Ne^+	He^+
C_x^{Al} sphere	1,94	1,93	2,04	1,97	2,11	2,28
$C_{x\,sphere}^{SVTI}$	2,04	2,01	2,09	2,02	2,14	2,37

$$C_x^{\text{sphere}} \simeq (2e/M_i)\,F_x/I_i u_\infty. \tag{2.1}$$

was used. Measurements of the frontal resistance force F_x were performed at sphere surface potentials equal to the plasma potential ($V_f \cong 0$, Al), and "floating" potential ($V_f \cong \phi_f - \phi_\nu$, vacuum-screen thermal insulation). Results of the sphere C_x measurements are shown in Table 1. Calculated values of C_x^{Al} for a sphere can be found in Table 2 of [7] (aluminum alloys AMg6-BM, D16AT).

Results of numerical and experimental studies of the flow and perturbed zone structure about axisymmetric bodies in a supersonic flow of rarefied partially ionized gas [14] indicate that at $R/\lambda_d \gtrsim 10^2$ (where R is the characteristic dimension of the body, λ_d is the Debye radius of the undisturbed plasma), the dynamic interaction is characterized by particle interaction with the face surface of the body. Therefore to determine the uncertainty of the sphere and disk C_x measurements produced by flow inhomogeneity, Eq. (13) of [15] for a hemisphere was used. The data of [16] permit representing the relationship between aerodynamic coefficients in homogeneous and inhomogeneous flows in the form

$$C_x^{(0)}/C_x^{(N)} \simeq 1 + \Delta C_x^{(N)},$$

where $C_x^{(0)}$ are the body resistance coefficients in a homogeneous flow, while $C_x^{(N)}$ are the corresponding coefficients in an inhomogeneous flow and $(1 + \Delta C_x^{(N)})$ is a correction factor. For the range of gas-ion normal and tangential momentum accommodation coefficients characterized by Figs. 2-4 of the present study and Figs. 4, 6 of [7], $\Delta C_x^{(N)} \lesssim 0.04$. With consideration of Eq. (2.1) the uncertainty in measurement of the resistance force is $\sim\pm 2\%$, and given the accuracies of the instruments used the total relative uncertainty in C_x measurement for the sphere in the present study does not exceed $\sim\pm 6\%$.

At a gas-ion flow velocity $u_\infty \cong 10$ km/sec for all gas—surface systems considered except He^+—surface, the data of the table characterize C_x values of a sphere measured for $\chi \ll W_i$, which correspond to interaction of a sphere with a neutral flow. Within the limits of $\sim\pm 10\%$, the values of C_x obtained for the aluminum sphere agree with the results of [17] in an N_2 flow for $u_\infty \cong 7$-37 km/sec for an aluminized polymer film and aluminum coated by an amorphous phosphate: $C_x^{\text{sphere}} \cong 1.9$-$2.2$. Moreover, the values of C_x for a sphere of technological materials (Table 1 of present study and Table 2 of [7]) measured or calculated from results of measuring $\sigma_n(\theta)$ and $\sigma_t(\theta)$ agrees with $\sim\pm 7\%$ with the calculated values of the frontal resistance coefficient of a sphere in a hypersonic free molecular flow for various patterns of particle interaction with the surface ($C_x \cong 1.859$-2.165 [18]) and data obtained by statistical processing of ~ 3100 measurements of spherical body orbits in the ionosphere ($C_x \cong 1.981$ [4]).

The measured values of C_x correspond to a regime of free molecular flow over a sphere by a supersonic flow of partially ionized gas at $30 \lesssim Kn \lesssim 140$; $2.1 \leqslant u_\infty/\sqrt{2kT_i/M_i} \leqslant 14$ and $T_w/T_i \ll 1$ ($Kn = \ell_{ii}/R$ is the Knudsen number, ℓ_{ii} is the mean path length for ion—ion collisions).

3. In the steady-state regime energy exchange of the surface in a flow of rarefied plasma is characterized by the energy balance equation

$$Q_n + Q_\alpha + J + Q_\nu - Q_r - Q_\tau = 0. \tag{3.1}$$

Here Q_n is the quantity of heat transferred to the target by the neutral particles per unit time, Q_α is the quantity of heat transferred to the target by charged particles; J is the Joulean heat; Q_ν is the plasma radiation; $Q_r = A\varepsilon_r\sigma_r(T_w^4 - T_c^4)$ describes radiant losses;

Q_τ is the heat loss due to thermal conductivity; ε_r is the emissivity of the target material; σ_r is the Stefan–Boltzmann constant; T_c is the chamber wall temperature. For the target material at $T_w \leqslant 350$ K $\varepsilon_r \simeq 0{,}8$ [19]. At a chamber pressure of $\sim 10^{-3}$ Pa and degree of plasma ionization of $\alpha \gtrsim 10^{-4}$ the contribution of the neutrals Q_n may be neglected.

Heat losses due to thermal conductivity Q_τ can be determined by a special calibration procedure. Two identical targets with a plane conductive surface coated by a dielectric grid and joined at their face surfaces are installed in the vacuum chamber at a pressure of $\sim 10^{-4}$ Pa in the absence of plasma. A heater in the form of a planar spiral wire is placed between the working surfaces of the sensors. A family of curves is taken at various heater powers: $T_w^{vac} = T_w P_{vac} \Delta t_{vac})$, where P_{vac} is the power transferred and Δt_{vac} is the time interval involved. For the same sensor, within the plasma the function $T_w^\nu = T_w(P_\nu \Delta t_\nu)$ is measured. In a steady-state heating regime the points of this curve are characterized by $T_w^{vac} = T_w^\nu$ and Δt = const, $Q_\tau \simeq Q_\tau^{vac} \simeq 0{,}5 P_{vac} \Delta t_{vac}$. Here P_ν is the power supplied to the plasma, and Δt_ν is the time interval.

The thermal flux produced by radiation of the rarefied plasma $Q_\nu \cong I_\nu A$ (where A is the area of the working portion of the sensor, I_ν is the intensity of the ionized gas radiation [20]) can be determined by a plane thermoanemometric probe with a metallic surface. To determine Q_τ^M of the sensor with metallic working surface the calibration procedure described above can be used. In calibrating metal targets a plane spiral heater coated by a thin layer of KPT-8 silicone paste is placed between their surfaces. The silicone is a dielectric with high thermal conductivity and low vapor pressure, the properties of which remain unchanged as it is heated to high temperatures. This insures transmission of the heater thermal power to the sensor sufaces with minimal losses. The values of Q_τ^M obtained in this manner than permit us to use the temperature $T_w = T_w(V)$ and current–voltage $I_\Sigma = I_\Sigma(V)$ characteristics of the thermoanemometric probe with metallic working surface, measured in a rarefied plasma flow, together with relationships presented in [11, 21, 22] to determine the complex of parameters characterizing energy exchange and Q_α^M of the gas–metal system. Then using Eq. (3.1) and points of the family of curves $T_w = T_w(P\Delta t)$ measured in vacuum and in a plasma under steady-state conditions at $T_w^{vac} = T_m^\nu$ and $\Delta t_{vac} = \Delta t_\nu$, we can evaluate $Q_\nu \cong I_\nu A$.

Considering that at negative target surface potentials $Q_\alpha = Q_i + Q_e + Q_f \simeq \alpha_i P_{nom} + (I_e/e)(2kT_e) + I_i V_f$, where ($P_{nom} \simeq I_{0i} W_i / e$, V_f is the "floating" potential of the surface, $I_e \cong I_i$ is the current to the target at the "floating" potential V_f), after substitution of the values of Q_τ and Q_ν in Eq. (3.1) we determine the gas-ion energy accommodation coefficient on an electrically conductive surface partially coated by a thin layer of dielectric in the form

$$\alpha_i \simeq e(Q_\tau + Q_r - Q_e - Q_f - J - Q_\nu)/I_{0i} W_i. \tag{3.2}$$

The measurements were made by sensors in the form of disks approximately 11 mm in diameter with thickness $\delta \cong 0.15$ mm (metallic working surface) and $\delta \cong 0.35$ mm (dielectric grid-coated surface).

The thermal flux produced by plasma radiation, as measured by the molybdenum thermoanemometric probe, is comparable in order of magnitude Q_α and Q_τ. The values of Q_ν thus obtained, as well as the Q_τ values measured with the calibration procedure described above allow use of Eq. (3.2) to determine α_i on the surface of an aluminized conductive film coated by a dielectric grid. The effect of atomic mass of the gas ions upon α_i on the surface of an aluminized conductive film without dielectric coating (curve 3) and a film coated with a dielectric grid of fiberglass (curve 4) at $u_\infty \cong 10$ km/sec and $\theta = 0$ is shown in Fig. 2. The maximum uncertainty in the measured $\Delta\alpha_i$ values does not exceed $\cong +0.04$.

The character of the change in α_i for oblique incidence of gas ions on the surface at $u_\infty \cong 10$ km/sec is illustrated in Fig. 5 (α_0 measured at $\theta = 0$): point 1, α_i, measured on the conductive surface of a polymer film; 2, on the surface of vacuum screen thermal insulation; 3, calculated α_n values at $\mu \cong 0.3$ on the atomically smooth surface of a solid modeled by a planar quadratic lattice [23]; 4, α_n at $\mu \cong 0.3$ on a rough solid surface; 5,

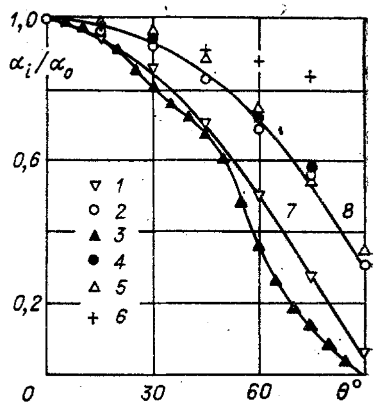

Fig. 5

data from $\alpha_i^{N_2^+}$ measurements of [24] on surface of polycrystalline Al and Mo, coated by an adsorbing layer at $\mu \cong \mu_1$ (where μ_1 is the atomic mass ratio of the ion–adatom system $N_2^+ - CO + N_2$); 6, calculated values of $\alpha_n^{N_2}$ on surface of rough fiberglass at $u_\infty \cong 8$ km/sec from [L3]; line 7, empirical approximation $\alpha_i/\alpha_0 \simeq \cos\theta + b_1(1 + 1/\alpha_0)^{-2}\sin^2\theta(1 - \cos\theta)|\sin\theta - \cos\theta|$, for N_2^+ $b_1 \cong 0.333$ [11].

In the presence of a dielectric grid on the conductive surface (curve 8)

$$\alpha_i/\alpha_0 \simeq \cos\theta + b_2(1 + 1/\alpha_0)^{-2}\sin^{5/2}\theta,$$

where $b_2^{N_2^+} \cong 1.333$. In its effect on the function $\alpha_i = \alpha_i(\theta)$ such a grid is to some degree equivalent to the presence of an adsorption layer at $\mu \cong \mu_1$ or to a change in the degree of roughness of the surface bombarded.

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QUANTITATIVE THEORY OF THE ELECTRIFICATION OF FALLING AEROSOL PARTICLES IN A ONE-DIMENSIONAL RISING AIR CURRENT

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Electrical phenomena in the lower strata of the atmosphere are known [1-3] to be determined essentially by the presence of ascending and descending air currents. These flows transport ions that exist in the atmosphere, where they are created mainly by radioactive emission. The atmospheric electric field, which also affects the motion of ions, in turn, depends itself on the concentration of those ions. The distribution of the ion concentrations and the electric field in rising air currents must be known, e.g., in calculating the charge of raindrops as a result of ion capture. The converse influence of drops on the ion and electric field distributions can be neglected in this case if the concentration of the drops is sufficiently small. Analogous phenomena are also encountered in the charging of aerosols in electrohydrodynamic devices that utilize special radioactive emission sources for the ionization of a gas [4, 5].

In this article we develop a theory to describe the distribution of the ion concentrations and electric field strength in one-dimensional air flows, as well as the electrification of falling aerosol particles in those flows in the case of a low particle concentration. The condition of one-dimensionality of the flow and the electric field is only approximately satisfied in a certain restricted zone of the air flow in practice. However, this customary assumption [1] makes it possible to formulate characteristic model problems that mirror extremely complicated natural and industrial processes. Their solution can be used as a basis for obtaining estimates of various quantities and pursuing qualitative studies of physical phenomena.

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