INFLUENCE OF THE POLARIZATION AZIMUTH OF INCIDENT RADIATION ON SPACE-POLARIZATION CHARACTERISTICS OF THE FLUX REFLECTED BY COMPOSITE MATERIALS

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At the wavelength 0.63 µm the degree of polarization, the angle of rotation of the polarization plane, and the indicatrix of the intensity of radiation reflected by the surface of composite materials before and after their heating by radiation of a CO₂ laser were measured.

Composites consisting of a heat-resistant filler and a binding organic resin are being widely used as structural materials and heat-protection coatings. To model radiative heat transfer processes and to solve the thermophysical problem of heating of materials or high-temperature structures by concentrated energy fluxes, it is necessary to know not only the energy but also the space-polarization characteristics of the reflected radiation.

Earlier [1] we measured the degree of polarization and the indicatrix of the intensity of radiation at wavelengths of 0.63 and 1.15 µm reflected by composites illuminated by a laser beam with a fixed polarization plane. The present work is devoted to the influence of the orientation of the polarization plane of the incident radiation on the degree of polarization, the rotation of the polarization plane, and the form of the indicatrix of the intensity of radiation (λ = 0.63 µm) reflected by STK glass cloth-based laminate, PTK cloth-based laminate, and paper-based laminate before and after their heating by CO₂-laser radiation. We investigated samples both with initial and with rough surfaces as well as after heating in air by a CO₂ laser until charring of the surface layer. Moreover, the glass cloth-based laminate was also studied after heating to the state where the charred layer burned up and the glass fibers of the filler were exposed [2].

Measurements were made on a goniophotometric setup [3] with a solid angle of the recording system of 1.5 \times 10^{-4}\text{sr} (in recording the indicatrix) and 3.7 \times 10^{-3}\text{sr} (in determining the azimuth and the degree of radiation polarization). The angular resolution was 0.25 and 5°, respectively. The sounding radiation of an He-Ne laser (model LG-126) was directed perpendicular to the surface of the sample, and the reflected flux was investigated in the same observation plane at different angles θ to the direction of the incident flux. When it was necessary to know the parameters of specular reflection of radiation, we made measurements at angles of incidence of 5–85°. The polarization plane of the sounding radiation was oriented by polarimetric plates at angles of 0, 45, and 90° to the observation plane. With this procedure of measurements in the reflected flux, the total (polarized and depolarized) radiation (indicatrix measurements), the contribution of the polarization component to the total reflected flux (measurements of the degree of polarization), and the polarization component itself (rotation of the polarization plane) were analyzed.

The effective degree of polarization [4] was found from the relationship of the difference and the sum of the extremal intensities of the light passed through a polaroid rotatable about the axis of the recorded radiation. The azimuth of the polarization was determined by the position of the polaroid at which the intensity of the light passed was at its maximum. The main error of the measured quantities depended on the degree of polarization and the random error of measurement of the extremal intensities. The absolute error of a mean result was ΔP = 0.01–0.05 and δφ = 1–6° at a confidence coefficient of 0.95.

It was established that the indicatrices of the intensity of the radiation reflected by the investigated composites with the initial state of their surface are not sensitive to the polarization of the incident flux and correspond closely to specular reflection. Removal of a smooth layer of polymerized resin from the surface by abrasive paper results in broadening of the indicatrices [1]. In this case, the indicatrix corresponding to sounding radiation polarized perpendicular to the plane of incidence $f_\perp(\theta)$ lies systematically somewhat higher than for the radiation polarized in the plane of incidence $f_{\parallel}(\theta)$. After laser annealing of the samples, the indicatrices of the intensity of the reflected radiation, depending on the state of the charred surface, lie between the indicatrices of the composites with the smooth and rough initial surfaces [1]. Here the influence of the polarization azimuth of the incident flux becomes more pronounced, especially for observation angles $\theta > 20^\circ$. If the polarization plane in the incident flux is at $45^\circ$ to the plane of incidence, then the indicatrix of the intensity of the radiation reflected by the rough and charred surfaces of the composites in the direction $\theta$ is equal to the half-sum of $f_\perp(\theta)$ and $f_{\parallel}(\theta)$.

For the glass cloth-based laminate, longer intense heating leads to burnup of the charred surface layer and exposure of the glass cloth [9]. The indicatrix of the intensity of the radiation reflected by the glass cloth-base laminate with this a state of its surface is broader than the indicatrix corresponding to the charred surface [1] and independent of the orientation of the polarization plane of an incident flux.

The measured degrees of polarization $P$ of the radiation reflected by the composites with the initial state of their surface show that only scattered radiation undergoes strong depolarization, whereas the degree of polarization of the specularly reflected radiation remains close to unity (Fig. 1). Moreover, there is some difference in the angular dependence of the degree of polarization of the radiation reflected by the glass cloth-based laminate (Fig. 1a) and the cloth-based and paper-based laminates (Fig. 1b). Independently of the polarization azimuth of the incident flux, the paper-based and cloth-based laminates depolarize scattered radiation more strongly than the glass cloth-based laminate, especially for $\theta = 0 - 50^\circ$ (Fig. 1b). At the same time, radiation whose polarization plane is at $45^\circ$ to the plane of incidence is depolarized by the glass cloth-based laminate more strongly than radiation polarized perpendicular or parallel to this plane (Fig. 1a).

Treatment of the samples surfaces by an abrasive paper, i.e., an increase in surface roughness, enhances the depolarization of scattered radiation in all directions (Fig. 2a). Surface charring of the composites due to laser heating again decreases the depolarization of reflected radiation both in the specular reflection direction and at different angles to it (Fig. 2b). It is pertinent to note that when the charred composite is sounded by a flux polarized perpendicular to the plane of incidence, the degree of polarization of the scattered radiation changes insignificantly with deviation from the specular reflection direction and, for example, for $\theta = 80^\circ$ is 0.9. But when the charred composite is sounded by a flux polarized in the plane of incidence or at an angle of $45^\circ$ to it, the degree of