EFFECT OF THE SURFACE STRUCTURE OF A COMPOSITE MATERIAL ON SPATIO-POLARIZATION CHARACTERISTICS OF REFLECTED RADIATION

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The polarization degree, rotation of the polarization plane, and strength indicatrix of radiation with a wavelength of 0.63 \( \mu m \) reflected from the surface of a unidirectional superhigh-modular organic plastic are investigated.

High-modular organic fiber-based composite materials are characterized by a lower (compared to glass-reinforced plastics) density and improved strength, electric, and thermal insulation parameters. In thermal stability, they rank only below composite materials with carbon and boron fillers [1]. These properties of high-modular organic plastics make them an important group of heat-shielding coatings.

Very little information on the radiation properties of composite materials, in particular organic plastics, for solving problems of heat transfer in high-temperature constructions is available. In this case information on both the reflection coefficients and the parameters of the material that determine the spatio-polarization properties of the reflected radiation is required.

We investigated the effect of fiber disposition in a unidirectional superhigh-modular organic plastic on the spatio-polarization properties of the reflected radiation of a He-Ne laser with a wavelength of 0.63 \( \mu m \) for various orientations of the polarization plane of the incident flux. We measured the strength indicatrices of the radiation reflected by an organic plastic with an epoxy binder and the degree of polarization and rotation of the polarization plane of the reflected flux.

As a result of the partial transparency of the composites [2], component formed upon scattering of the incident flux by optical inhomogeneities in the material is present in the reflected radiation. In this case the smooth surface layer of the polymerized binding resin plays the role of an amplitude-anisotropic element by polarizing additionally the radiation emerging through this layer, which is depolarized within the material [3]. In order to exclude the effect of the binding resin film on the spatio-polarization characteristics of the radiation reflected by the sample under investigation, we sheared off its surface layer and uncovered organic filler filaments coiled unidirectionally.

Measurements were carried out on a goniophotometric setup [3, 4] that included a He-Ne laser (LG-126) whose linearly polarized radiation was directed normally to the sample surface, and the reflected flux was investigated in a single plane (the observation plane) at various angles \( \alpha \) with respect to the incident beam. The plane of polarization of the probing radiation was oriented by polarimetric plates at angles of 0, 45, and 90 deg with respect to the observation plane. Samples under investigation were fixed in three different positions so that the filler fibers were oriented at angles of 0, 45, and 90 deg with respect to the observation plane, i.e., measurements were carried out when the plane of polarization of the incident radiation coincided with the orientation of fibers on the sample surface, made an angle of 45 deg with, or was perpendicular to them. By linking a Cartesian coordinate system with the sample under investigation so the fibers on its surface were directed along the z-axis, and with the beam propagated in the negative direction along the x-axis, we investigated the following three cases: in the first case we investigated the characteristics of the radiation scattered in the \( xz \)-plane; in the second case, in the plane passing through the \( x \)-axis and making an angle of 45 deg with the \( xy \)-plane; and in the third case, in the \( xy \)-plane.

Fig. 1. Strength indicatrices of radiation scattered by organic plastic in plane perpendicular to (a), parallel to (b), and making an angle of 45 deg (c) with the fiber direction for a polarization azimuth of the probing flux with respect to the observation plane equal to 90 (1), 45 (2), and 0 deg (3), and the strength indicatrix of radiation of a Lambertian reflector (4). $\alpha$, deg.

A more detailed description of the setup along with estimates of errors of measurement of rotation of the plane of polarization, polarization degree, and strength indicatrices of the reflected radiation can be found elsewhere [2-4].

We found that the organic plastic scatters the incident radiation in the $xy$-plane, which is perpendicular to the direction of fiber orientation. In this case the shape of the strength indicatrices of the reflected radiation approaches that of the indicatrix of a Lambertian scatterer and does not depend on the polarization azimuth of the incident flux (Fig. 1a). With an increase in observation angle $\alpha$ of from 0 to 40 deg, the ratio of the measured and Lambertian indicatrices $f(\alpha)/\cos \alpha$ decreases from 1.0 to 0.75. A further increase in $\alpha$ to 75 deg does not lead to changes in the $f(\alpha)/\cos \alpha$ ratio, which equals 0.75. In the observation plane coincident with the fiber direction the radiation is scattered in a more specular manner (Fig. 1b). In this case the scattering indicatrix of probing radiation polarized perpendicular to the observation plane and correspondingly to the fiber direction (curve 1) is higher than that for radiation polarized in the observation plane (curve 3) or at an angle of 45 deg with respect to it. In an observation plane oriented at an angle of 45 deg with respect to the fiber direction, the scattering differs little from scattering by the sample in the plane parallel to fibers (Fig. 1c). In this case the dependence of the shape of the indicatrix of the scattered radiation on the polarization azimuth of the probing flux is less pronounced.

Polarization measurements have shown that the polarization degree of the reflected radiation in the plane perpendicular to the direction of the fibers of the organic plastic is close to unity and is virtually constant for various observation angles when the radiating flux is polarized in the observation plane ($P_{11}^\perp$) or normally to the plane ($P_{\perp\perp}^\perp$) (Fig. 2a, curves 1, 3). In this notation, the subscript characterizes the fiber disposition and the superscript denotes the orientation of the vector $E$ in the incident flux with respect to the observation plane. When the sample under investigation is irradiated by a flux making an angle of 45 deg with the observation plane, the polarization degree of the reflected radiation ($P_{11}^{45}$) also depends only slightly on the scattering angle, although the reflected radiation itself is substantially depolarized (Fig. 2a, curve 2). When the observation plane coincides with the fiber orientation, a substantial angular dependence of the polarization degree of the reflected flux is revealed for all polarization azimuths of the probing flux (Fig. 2b).

It is known that, due to differences in Fresnel reflection coefficients for polarized components of radiation, the plane of polarization of linearly polarized light reflected in a specular direction by a smooth surface (except for radiation with azimuth $\gamma = 0$ or 90 deg) rotates towards the normal to the incidence plane, and that of the transmitted radiation rotates in the opposite direction [5]. Similar behavior is characteristic of changes in the polarization azimuth of radiation reflected by a rough surface of nontransparent materials [6] and by isotropic partially transparent composites [3]. In this case an increase in the multiplicity of scattering of radiation leads to an increase in the angle of rotation of the plane of polarization. As regards the effect of the fiber orientation on the rotation of the plane of polarization, it has not been studied so far.

We measured the rotation of the plane of polarization of the radiation reflected by an organic plastic at a polarization azimuth of 45 deg in the incident flux with respect to the observation plane. The angle of rotation of the polarization plane $\Delta \gamma$ of the reflected radiation was considered to be positive when the rotation towards an