THE CONNECTION BETWEEN DIELECTRIC SUSCEPTIBILITY
AND WEIGHT BY VOLUME OF VITREOUS PLASTICS

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Experimental results of measurements of dielectric susceptibilities of vitreous plastics by use of SHF electromagnetic waves are presented. A connection is shown between the dielectric susceptibility over the specimen as it depends on the technological pressing process. A series of works [1-3] on the use of radio microwaves for revealing various defects in objects manufactured of composition plastic without destroying them has recently been published. However, for a complete estimate of the quality of a composition article, for example, objects of vitreous plastic, and the determination of its durability properties, internal flaw detection of the object and finding the volume of foreign inclusions, breaks in continuity, and failures of adhesion in it are insufficient. This is explained by the fact that vitreous plastics represent materials for which the durability properties are largely determined by uniformity of distribution of the binder, percentage contents of components, etc. The uniformity of distribution of the binder depends substantially on the technology of preparation of the article, pressure, temperature of treatment, as well as the method of impregnation of the glass fiber, and the like. At the same time, the content of components and the uniformity of their distribution in the object exert an influence on the dielectric properties of the object: the distribution of the dielectric susceptibility $\varepsilon$ and the distribution of the tangent of the loss angle, $\tan \delta$.

When the average distribution of the dielectric susceptibility with respect to thickness is known over the entire object, it is also possible to form an opinion about some parameters which determine the quality of the object.

Many different methods of measuring electrical parameters are known. To find the correlation between electrical parameters and the parameters which characterize the durability properties of an object, it is better to use methods of measurement which allow determination of the dielectric susceptibility without destroying the object. Interferometric methods are included in such methods [1, 4, 5]. Interferometric measurements of $\varepsilon$ are based on comparison of the phases of two waves – waves passing through the specimen being studied, and waves passing through free space or through a standard specimen. The phase difference which arises as the result of lagging of the wave passing through the specimen being studied is measured by transposition of the receiving antenna of one of the arms of the interferometer or is measured by use of a phasemeter. The distance between the receiving and radiating antennas is made great enough that the radiated linearly polarized wave can be considered to be plane. The operation of the interferometer and its constructional features are mentioned in more detail in [6].

For dielectrics which have low losses ($\tan \delta < 0.05$), the dielectric susceptibility is calculated by the formula

$$\frac{\varepsilon - 1}{\varepsilon + 1} \tan \left( \frac{2nd}{\lambda_0} \right) = 2 \tan \psi,$$

where $\varepsilon$ is the dielectric susceptibility of the specimen, $d$ is the thickness of the specimen, $\lambda_0$ is the wavelength in free space, and $\psi$ is the phase shift caused by insertion of the specimen.
Fig. 1. Graphs of the interdependence between dielectric susceptibility and density for vitreous plastics of the DSV-4R-2M type (a) and polyurethane foam plastics (b). 1) Experimental curve; 2) calculated curve.

Fig. 2. Graphs of distribution of dielectric susceptibility along median line in specimens of DSV-4R-2M type vitreous plastic prepared by pressing under different conditions. a) Temperature 145°C; pressure 20 (O), 100 (●), and 300 kg/cm² (Δ). b) Pressure 300 kg/cm²; temperature 120 (O), 130 (Δ), 145 (Δ), and 160°C (●).

It is necessary to make some remarks in regard to formula (1). This formula makes allowance for interference phenomena arising inside the specimen from multiple transmission and reflection of waves in the specimen. The error in calculation of the dielectric susceptibility from formula (1) depends on the accuracy of determination of the phase angle $\psi$. For an angle $\psi$ close to $\pi/2$, the error in determination of $\tan \psi$ is large, but, on the other hand, for $\psi$ close to 0 the error in determination of $\tan \psi$ is minimal.

If, during measurements, it is found that the angle $\psi$ is close to $\pi/2$, the specimen being studied must be shifted by a distance of $\lambda_0/4$. This is not expressed in the result of calculation but reduces the error in determination of $\tan \psi$ to a minimum, since in this case the angle $\psi$ is found to be less than 45°.

If $\psi \leq 45°$, the error in $\tan \psi$ does not exceed ±0.006. A disadvantage of calculating the dielectric susceptibility by formula (1) is the ambiguity of determination of the phase of the wave at $2\pi n$, which can be removed if the value of $\epsilon$ is known approximately. An approximate determination of $\epsilon$ can be carried out by use of the spectrometric method [4] or by means of the common solution of some equation of the type of (1) for plates of various thicknesses prepared from the same material.

Let us examine the correlation between $\epsilon$ and the density as an example of the connection between a technological parameter and dielectric susceptibility.

Specimens of vitreous plastic prepared under various processing methods with different weights by volume were investigated. Measurements were done with wavelength of $\approx 8$ mm by use of the interferometer described in [3].

A graph of dielectric susceptibility as a function of weight by volume $\gamma$ for proportioned glass fiber materials of the DSV-4R-2M type with chaotic arrangement of glass fiber is shown in Fig. 1a. The graph was plotted from weighted mean values of $\epsilon$ measured for the respective density values.

The dielectric susceptibility rises and tends toward a limiting value of $\epsilon = 7$ with increase in density of the material. The greatest scatter of dielectric susceptibility is observed in the range of densities 1.2-