RECONSTRUCTION OF PRESSURE PULSE FORMS

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In recent years the acoustical probing method [1-4] has become widely used for measuring internal electric field distributions in solid dielectrics. This method allows one to reconstruct a one-dimensional electric field (potential or charge) distribution for a plano-parallel solid dielectric specimen from voltages measured across external electrodes using the equation [1]

$$U(t) = (2 - 1/\varepsilon)\chi \int_{0}^{z=ct} p(t - z'/c) E(z')\, dz', \tag{1}$$

where U(t) is the potential difference across the electrodes during probing; ε, χ are the dielectric permittivity and compressibility of the specimen material; c is the speed of sound in the material; t is time; z is the current coordinate; E(z') is the electric field distribution in the dielectric; $p(t - z'/c)$ is the form of the pressure pulse.

When the duration of the probe pressure pulse is significantly less than the time required for its passage through the dielectric (i.e., the pressure pulse can be represented as a delta-function [2]), it is necessary to know only the pulse amplitude, which can be measured by traditional methods.

For specimen probing by pressure pulses of arbitrary form, solution of Eq. (1) for E(z) is complicated by the fact that it is necessary to know not only the amplitude, but the form of the pressure pulse.

In a number of studies [3, 4], piezoelectric sensors have been used to measure pressure pulse form. However it is well known that to reconstruct the form of a pressure pulse from the signal generated by a piezoelectric sensor, it is also necessary to solve the converse problem [5].

The present study will describe a simple method for reconstruction of pressure pulse forms (for pressures which do not lead to plastic deformation of the specimen).

It is evident from Eq. (1) that if a macroscopically homogeneous electric field E(z') = E = const is created within the dielectric, then

$$U(t) = (2 - 1/\varepsilon)\chi E \int_{0}^{z=ct} p(t - z'/c)\, dz', \tag{2}$$

which after differentiation of both parts yields $p(t - z'/c) = dU/(2 - 1/\varepsilon)\chi cE dt$, or in terms of finite increments of the measured signal for a constant differentiation step $\Delta t = \tau$: $p_j = \Delta U_j/(2 - 1/\varepsilon)\chi cE\tau$, where j = 1, 2, 3,..., N, N being the number of steps: $N = t_M/\tau$; $t_M = d/c$ being the time for pulse passage through the specimen; d is the thickness of the dielectric.

To calculate p_j, it is necessary to find U_j and ΔU_j for each j from the U(t) oscillograms; ε, χ, c are tabular values. After determining p_j we construct the function p = f(t). Thus, from the measured time dependence U(t) across the external electrodes of the dielectric, within which a homogeneous electric field is created, we can reconstruct the form of the acting pressure pulse.

The proposed method of pressure pulse form reconstruction was realized in an apparatus in which pressure pulses were created by an electrical discharge within a dielectric liquid [6, 7]. The form of the dielectric specimen is shown in Fig. 1. The specimen consists of a "sandwich" of two dielectric plates 2, between which is located an auxiliary electrode 3, connected to a dc voltage source. In the general case the ratio between d_1 and d_2 may be arbitrary, while in our experiments the plate size was 50 × 50 mm, while d_1, d_2 were varied from 0.6 to 2.8 mm.

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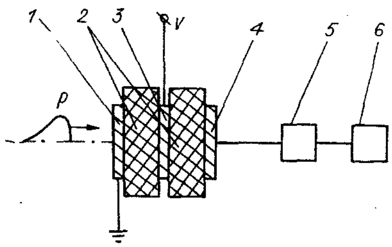

Fig. 1

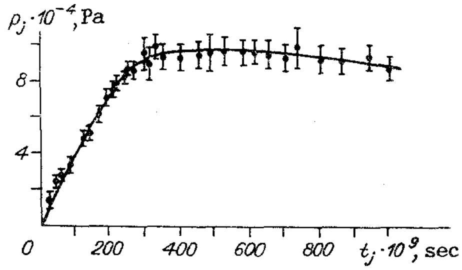

Fig. 2

To eliminate errors produced by instability in the dc source, after charging the geometric specimen capacitance, the auxiliary electrode was disconnected from the source before the application of the pressure pulse. Thus a homogeneous electric field $E = V/d$ was created within the plates with V being the potential on the auxiliary electrode. Upon pulse action a potential difference U(t) was created across the measurement electrodes 1, 4, related to the value of the electric field within the specimen by Eq. (1). The potential difference across the measurement electrodes was recorded by amplifier 5 and oscilloscope 6.

Both polar (polymethylmethacrylate) and nonpolar (polyethylene and polytetrafluorethylene) polymers were used as dielectrics; platinum electrodes were deposited on the specimen. Constant voltages of positive and negative polarity from 500 to 3000 V were applied to the auxiliary electrode. Electrode potential was monitored by an electrostatic voltmeter.

Figure 2 shows the form of the pressure pulse as reconstructed by the proposed method from measurement results on 20 specimens of various thickness with various values of electric field intensity E. It should be noted that, independent of the value of E, the polarity of the applied voltage, and d, the statistical error in determination of p_j values for specimens of various materials does not exceed 11%.

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