EFFECT OF THE MATERIAL PROPERTIES OF A DIELECTRIC SPECIMEN ON THE ELECTRORHEOLOGICAL STABILIZATION FORCE

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Measurements are reported for the static peeling and shear forces for various flat insulators as indicated by the electrorheological effect.

Research concerning the electrorheological effect has began rather recently, but a whole list of its possible applications has already been drawn up including, for instance, stabilization of mechanically labile nonmetallic and nonmagnetic materials during their transport and processing [1-5].

Studies have been made in the Rheophysics Laboratory at the Institute of Heat and Mass Transfer, Academy of Sciences of the BSSR, to determine the breakaway force and the shear strength of dielectric material specimens stabilized by means of an electrorheological suspension.

The electrodes for this study were designed as shown in [5]. Cylindrical specimens had been prepared with an active end surface S = 10 cm^2 and each with a bearing collar around the circumference to limit the thickness of the working layer of mixture deposited on the contact surface.

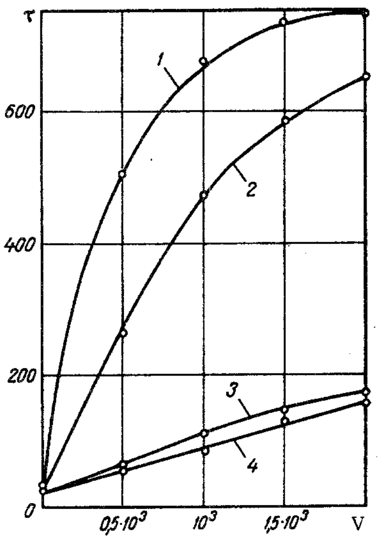

Fig. 1. Breakaway force on dielectric specimens τ(gf/cm^2) stabilized by means of an electrorheological suspension, as a function of the applied voltage V: 1) asbestos cement; 2) Textolite; 3) vinyl plastic; 4) acrylic glass.

Procedure. The arm of a model TT-10 balance, with the hanger and the pan removed, was fastened to a pull rod. The balance was adjusted so as to make it seek its equilibrium position with pull rod harnessed and after preliminary tension has been applied ("slack" position).

The tests were performed at a temperature t = 20 ± 0.5°C in the following sequence.

The counterbalancing arm was loaded by the attraction force between specimen and electrode, first without an electric field applied and then with a voltage V from 0.5 to 2.0 kV but without a film of electrorheological fluid; the gap was first filled with pure transformer oil; the gap was then filled with an electrorheological suspension the effective viscosity of which η_{eff} had been measured with a model RÉVI-70 electroviscometer.

The test procedure provided for excellent reproducibility and repeatability.

We found that:

a) the breakaway force on the specimen in an airpgap with V = 2 kV was insignificant, equal to 0.8-3.5 gf/cm^2 depending on the specimen material. In the case of Textolite, for example, it was 3 gf/cm^2.

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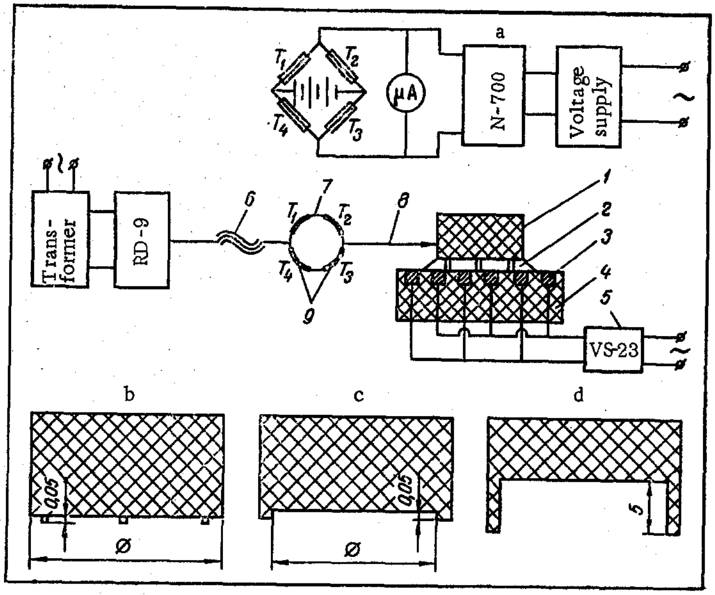

Fig. 2. Schematic diagram of the apparatus for measuring the stabilizing properties of electrorheological systems: 1) Textolite specimen; 2) layer of electrorheological suspension; 3) electrodes; 4) Teflon base; 5) model VS-23 high-voltage source; 6) threaded coupling; 7) spring washer; 8) rod; 9) strain gages.

b) with a layer of pure transformer oil, the maximum force at V = 2 kV was 11 gf/cm^2 in the case of Textolite;

c) according to the results obtained with an electrorheological system, the breakaway force for Textolite was in this case 225 times larger than in test a) and 70 times larger than in test b).

According to the graph in Fig. 1, the breakaway force increased at a fast rate for some specimens (asbestos cement, Textolite) and then decreased at voltages above V = 1 kV, with a subsequent tendency toward saturation; for vinyl plastic and acrylic glass, on the other hand, the breakaway force appeared as a linear function of the voltage V with a low rate of rise.

We also performed experiments to establish the relation between the shearing force and the surface area of a work piece, i.e., to establish the significance of the scale effect. The tests were performed with an apparatus (Fig. 2) which consisted of steel electrodes 3 with flat surfaces, embedded in a nonconductive Teflon base 4. The voltage across the electrodes was varied smoothly up to 3 kV. The gap between the surface of a dielectric specimen 1 and the electrode array was filled with a layer of electrorheological fluid 2 (suspension of diatomite, 50% per weight, in transformer oil). Textolite specimens had been prepared in the form of disks with various endface areas. A uniform thickness of the electrorheological fluid layer was ensured by means of thin dowel pins (Fig. 2b) and collars (Fig. 2c). The shearing force was transmitted from a model RD-9 electric motor to a test specimen through a threaded coupling 6, a spring washer 7, and a rod 8. Strain gages 9 were pasted on the spring washer and connected electrically into a bridge circuit. Signals were read with a model M265M microammeter and recorded on a model N-700 oscillograph.

TABLE 1. Effect of the Collar Surface Area on the Shear Strength

V, kV	τ, gf/cm^2	
	$\frac{S_{collar}}{S_{specimen}} = 12{,}2\%$	$\frac{S_{collar}}{S_{specimen}} = 37\%$
0,5	23	31
1,0	41	62,5
1,5	50	93
2,0	60	114

TABLE 2. Effect of the Specimen Material on the Shear Strength

Specimen material	τ, gf/cm^2 at V= 2.5 kV	Moisture absorbed in 24 h, %	ρ_v, $\Omega\cdot$cm	ε at 50 Hz
Asbestos cement	65	15—25	10^8—10^9	6—8
Textolite	12	0,4—1,0	10^9—10^{11}	4—5
Vinyl plastic	8	0,8—1,0	10^{14}—10^{15}	3,2—4
Ebonite	4	0,02—0,03	10^{14}—10^{16}	3—3,5
Acrylic glass	2,5	0,00—0,02	10^{15}—10^{17}	2,4—2,6 (3.5, according to some sources)

Note. Data for graphs 3,4,5 taken from Élektrotekhnicheskogo Spravochnika, Vol. 1 (1959).

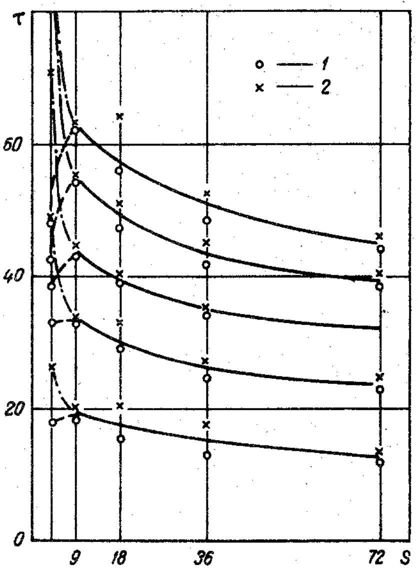

Fig. 3. Effect of the surface area of a work piece to be stabilized S (cm^2) on the unit shearing stress τ (gf/cm^2): 1) specimens of Fig. 2b; 2) specimens of Fig. 2c.

The test results are shown in Fig. 3. Evidently, the curves for both specimens (Fig. 2b, c) almost coincide for $S \geq 9$ cm^2. Differences become apparent only below this limiting size of surface area. This can be explained by an increasing role of the electrorheological effect of the collars under which a thin layer of suspension remain present. The electric field intensity in this layer was much higher than the mean intensity in the gap. As long as the collar area remained small in comparison to the total specimen area (8.5% of S = 72 cm^2), its effect on the test results was small. When it became a larger fraction of the total area (37% of S = 4.5 cm^2), the resulting curve rose sharply. In order to verify this hypothesis, we tested a special specimen (Fig. 2d) with the suspension layer deposited on the collar area alone. According to the results (Table 1), the unit stress, under these conditions, did exceed the mean stress by a factor of 1.5-2. The general trend appears as follows: the unit shearing stress decreases gradually with an increasing surface; eventually, the relation becomes linear. Table 2 illustrates the effect which the material of a specimen to be stabilized has on the shear strength τ. A close correlation is noted between shear strength τ, moisture absorption φ, electrical resistivity ρ, and dielectric permittivity ε. Thus, a new possibility has been established of raising the stabilizing ability of the electrorheological effect in dielectrics on the basis of their moisture content.

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