SOME FACTORS AFFECTING THE ROTATION OF A DIELECTRIC IN AN ELECTRORHEOLOGICAL MEDIUM

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It has been shown experimentally that the rotational speed of a dielectric in a nonconducting disperse medium depends on the concentration of the disperse phase and on the electrode geometry. The results are compared with those pertaining to the rotation of a dielectric in a pure homogeneous nonconducting fluid.

It was noted in [1-5] that a dielectric rod in a homogeneous one-phase medium rotates spontaneously upon the application of an external electric field.

In the experiments with a dielectric motor [3], the rotor material was varied as well as the fluid medium (homogeneous) and the electric field intensity.

Hypotheses have been proposed concerning the mechanism of this phenomenon. Neither the phenomenon nor its technical aspects were explored further, however, because of the negligibility of such a rotation in pure homogeneous fluids.

In the meantime, new low-viscosity dielectric disperse composites, i.e., electrorheological suspensions have been produced and used in the laboratory of the Institute.

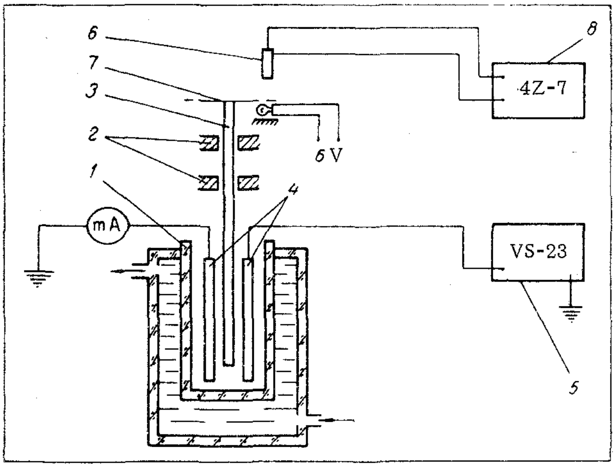

Fig. 1

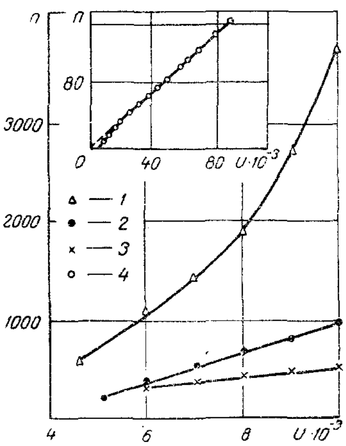

Fig. 2

Fig. 1. Schematic diagram of the test apparatus: 1) plexiglas cylinder; 2) bearings; 3) dielectric rotor; 4) electrodes; 5) high-voltage source; 6) photocell; 7) perforated disc; 8) frequency meter.

Fig. 2. Rotational speed (n rpm) of a dielectric rotor as a function of the fluid composition and of the dc field intensity (U kV): 5% (1), 0.05% (2), 0.02% (3) diatomite suspended in transformer oil; pure transformer oil (4).

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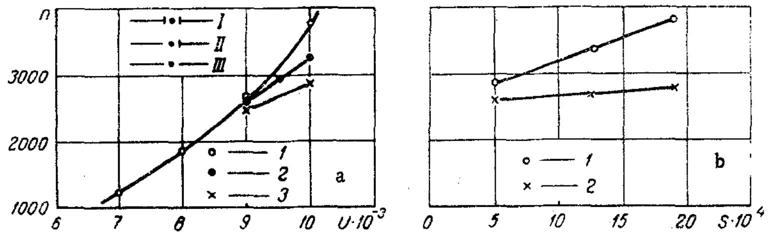

Fig. 3. Rotational speed (n rpm) of a dielectric rotor (a) as a function of the voltage (U kV) with the electrode configuration variant I (1), II (2), III (3) and (b) as a function of the electrode geometry (area S m^2) at E = 40 kV/cm (1), 36 kV/cm (2).

Unlike pure one-phase fluids, such systems, while remaining poor electrical conductors, usually contain a large quantity of free charge carriers. This exactly is the basis for using electrorheological suspensions as the working medium in a dielectric motor.

The test results in [5] have revealed that the spontaneous rotation in such disperse systems becomes much more pronounced than in one-phase fluids (under the same conditions).

The mechanism by which a dielectric rod rotates in a nonconducting medium has not yet been sufficiently well explored, however. No criteria have been established for the optimum selection of parameters (voltage, kind of working medium, geometry of the active components, etc.).

By a new series of tests, the authors succeeded in establishing certain important relations between the process characteristics.

The test apparatus (Fig. 1) consisted of a hollow Plexiglas cylinder 1 with a removable lid, a glass rotor 3 mounted inside in two miniature bearings 2, and two metallic electrodes 4 each in a mounting plate with radial slots.

This construction made it possible to vary the relative position of the electrodes and the gap between them.

An electric field was produced with a model VS-23 stabilized voltage supply 5 and was regulated in 0.5 kV steps over the 0-10 kV range.

The rotational motion was recorded with a photocell 6 by sending light through a perforated disc 7 mounted on the rotor and by counting the signals with a model ChZ-7 frequency meter 8.

This entire assembly was placed in an oil bath inside a model I-10 thermostat for maintaining isothermal conditions in the system.

The interelectrode gap remained the same in all tests, and the rotational speed was determined as a function of the electric field intensity, the solid-phase concentration, and the total active electrode surface area.

1. Effect of the Dispersed-Phase Concentration. No rotation was noted up to the top voltage 10 kV, when the vessel was filled with pure dielectric fluids (kerosene, transformer oil, AMG fluid). The addition of even negligible quantities (traces) of a solid phase to these fluids, i.e., the formation of an electrorheological suspension produced a rotation. According to Fig. 2, a higher solid-phase concentration increases the rotor speed to several thousand rpm and affects the trend of the speed-voltage curve. While at microconcentrations of the solid phase the speed remains an almost linear function of the voltage and increases with voltage at a slow rate, at higher concentrations up to 5% the curve becomes very nonlinear and steep. In this case raising the voltage from 4.5 to 10 kV, i.e., slightly more than doubling it increases the speed almost 8 times; a higher concentration of the solid phase widens the lower range of speed regulation by the voltage method. At much higher concentrations (above 20%), however, the viscosity of the system increases so much under the influence of the electric field that it finally stalls the rotor.

2. Effect of the Active Electrode Area. Three electrode designs were tried. The tests were performed with a 5% diatomite suspension in transformer oil at T = 293°K.

The best results were obtained with variant 1 when the rotor speed reached almost 4000 rpm and the range of speed regulation by the voltage method was appreciably wider than with variants 2 and 3 (Fig. 3a).

The electric field intensity E affects the rate at which the rotor speed increases with an increasing active electrode surface area. An increase of this area by a factor of 3.7 causes the rotor speed to increase by 11.4% at E = 36 kV/cm but by 32% at E = 40 kV/cm (Fig. 3b).

For comparison, in Fig. 2 is also shown the relation between rotor rpm and voltage U according to the data in [4]. Those tests were performed in a homogeneous one-phase medium: purified transformer oil. It is to be noted that the rpm are quite low here (below 150 rpm), even at voltages 10 times above our test voltages.

NOTATION

U is the voltage;
E is the electric field intensity;
n is the revolutions per minute (rpm);
S is the electrode surface area.

LITERATURE CITED

1. G. Quinke, Ann. Phys. u. Chem. [in German], new series, 59, No. 11 (1896).
2. I. I. Sumoto, Phys. Soc. Japan, 10, No. 6 (1955).
3. V. A. Krasnoperov and Yu. T. Okunev, in: Trudy SPO LÉTI, No. 2 (1957).
4. Yu. S. Karpov, V. A. Krasnoperov, Yu. T. Okunev, and V. V. Pasynkov, in: Physics of Dielectrics (Trans. All-Union Confer., November, 1958)[in Russian], Izd. Akad. Nauk SSSR, Moscow (1960).
5. A. V. Lykov, R. G. Gorodkin, and Z. P. Shul'man, in: Heat and Mass Transfer [in Russian], Minsk (1969), Vol. 2.
6. G. Keinat, Electrical Measurement Techniques [Russian translation], Izd. KUBUCh, Leningrad (1935).
7. V. O. Arutyunov, Electrical Measurements and Measuring Instruments [in Russian], Gosénergoizdat (1958).