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ECT of ethanol and hexane mixtures in the spinning disk system

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Abstract

The paper presents the research results of electrostatic charging tendency (ECT) of ethanol and hexane mixtures, a liquid of a simple chemical structure and high purity (pro analysis). The research work was carried out in a spinning disk system, where the factors influencing the value of the electrification current registered were the composition of the mixture and the rotational speed of the disk. The research results showed that the biggest ECT changes occur in the range of up to 10% of ethanol content in hexane and the electrification current characteristic has a visible maximum for the mixture, the contents of which constitute 95% of hexane volume and 5% of ethanol by volume. In the next stage of the research work physicochemical and electric parameters were measured in order to determine the connection between the properties of the mixtures under study and the amount of the electrification current generated.

Keywords: Static electrification; Electrification current; Transformer oil; Pure hydrocarbons; Aliphatic alcohols; Spinning disk system

1. Introduction

The development of the measurement methods of dielectric liquid electrification is connected with the hazard caused by this phenomenon in electrical power and petrochemical industries. The research work on hazard to power transformers with forced oil circulation has been developed intensively on account of economic loss connected with the failure of such units and the costs of the energy undelivered [1–4]. Mineral insulation oils are liquids of a complex physicochemical structure. The research work on insulation oil mixtures [5] showed that a proper selection of the percentage content influenced the changes in electrification of the liquid. In operating practice the preparation of oil mixtures to control their tendency to electrification is not easy. The differences in their chemical composition, the content of solid and liquid impurities, and the use of inhibitors can worsen basic dielectric properties of such mixtures. Therefore it is advisable to test liquids of a simple chemical structure and high purity (pro analysis) that enter into the composition of electroinsulation oil (pure hydrocarbons) and other compounds, e.g. alcohols [6–11]. These liquids could be used, among others, for the initial testing of measuring systems, carrying out comparative research work or they could serve as the base to which the results of the electroinsulation oil electrification obtained would be referred. Research on simple mixtures can lead to finding the ways of limiting their tendency to electrification and, in the further stage, help develop the inhibitors of the electrification process of insulation oils. The research on the electrification phenomenon is carried out by using measuring systems of various types. These are big systems using power transformers [12] or overflow [13] and spinning [14,15] laboratory systems.

2. Measuring set-up

Fig. 1 shows a system for the measurement of static electrification of liquid. The process of generating electric charge, causing the electrification of liquid, takes place due to disruption of the double layer on a disk surface during its spinning. The charges, carried by centrifugal forces, get to the inside surface of the isolated measuring container, from where their flow to the ground is measured with an electrometer. The whole measuring set-up is protected against the influence of electrostatic fields with the a Faraday cage. For the research tests a Keithley 6517A

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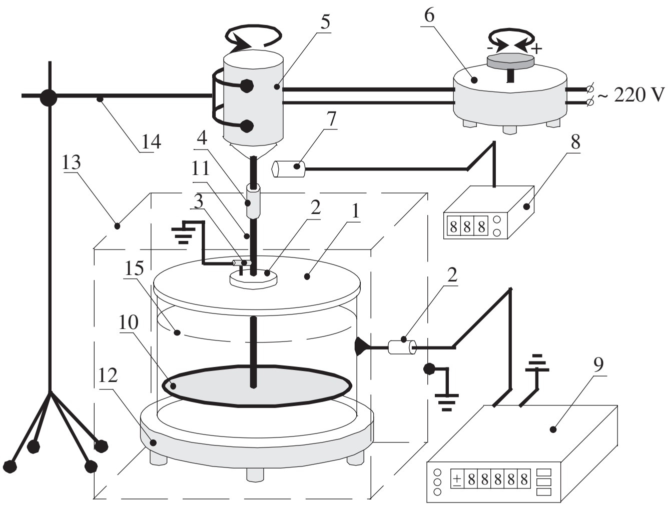

Fig. 1. Diagram of the measuring set-up with a disk spinning in liquid for research on insulation liquid electrification: 1—measuring container, 2—teflon insulator, 3—earth electrode, 4—insulating clutch, 5—motor, 6—voltage regulator, 7—sensor, 8—speed meter, 9—electrometer, 10—disk, 11—metal mandrel, 12—Teflon insulator, 13—Faraday cage, 14—stand, 15—level of the liquid under study.

electrometer of the following parameters was used: current measurement range (1fA–20 mA), basic accuracy (±0.5%). An aluminium disk of the roughness coefficient $R_a = 0.38\,\mu m$ was suggested for the research purposes. The measurement taking procedure consisted in a thorough cleaning and degreasing of the disk and container surfaces, their several hours' sterilization and a twenty-four hours' seasoning of the disks in liquid, which was then subject to tests. Proper measurements were taken after the hydrodynamic and electrical conditions in the liquid were stabilized and repeated a few times in different time intervals. The tests of electric parameters were carried out in compliance with the standards (ASTM D 257-99 and ASTM D 924). The measurements of the relative permittivity were taken with a Good Will Instrument Co., Ltd. LCR-819 SERIES meter of the parameters: frequency range (12–100 kHz), basic accuracy (±0.05%). The resistivity of the liquids under study was measured with a Megger BM25 meter of the parameters: test voltages (d.c. 50–5000 V), insulation range (10 kΩ–5 TΩ), insulation accuracy (±5% at 1 MΩ–1 TΩ at 5 kV). The liquid density was marked with a densimeter. The limiting error of the densimeter used was 2 kg/m^3. Dynamic viscosity was marked with a traditional Höppler globular viscometer, the measurement uncertainty of which was 0.5%.

3. Characteristics of the measurement results

Hexane (C_6H_{14}), which is the representative of paraffin hydrocarbons, and ethanol (C_2H_5OH) were suggested for the research on electrostatic charging tendency (ECT). Tens of samples of in percentage terms of different content of these liquids in mixtures were made in the laboratory.

Table 1
Properties of the liquids (at 20° C) under study and the parameters of the measuring system for the research on ECT

Property, parameter		Value	
		Hexane	Ethanol
Density (ρ)	[kg/m^3]	659	785
Viscosity (v)	[cP]	0.326	1.078
Molecular diffusion coefficient (D_m)	[m^2/s]	3.48×10^{-9}	8.75×10^{-10}
Relative permittivity (ε_r)	—	1.89	24.55
Conductivity (γ)	[S/m]	1×10^{-16}	1.4×10^{-9}
Container diameter (d)	[cm]	10	
Container height (h)	[cm]	13	
Disk distance from the bottom (h)	[cm]	2.5	
Disk diameter (d)	[cm]	4	
Liquid volume (V)	[ml]	500	

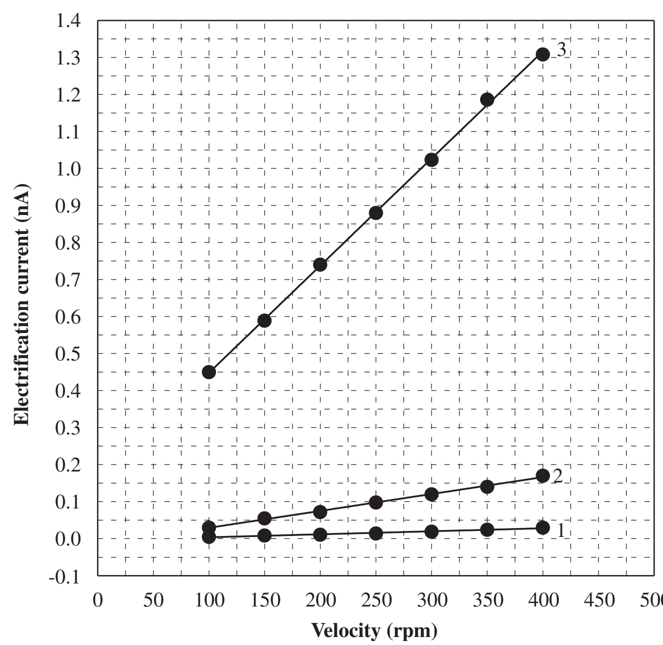

Fig. 2. Dependence of the electrification current on the rotational speed of a disk of the diameter of 4 cm for: 1—ethanol, 2—hexane, 3—mixture (95% hexane-5% ethanol).

The parameters of the measuring set-up and the properties of the liquids under study are shown in Table 1.

Fig. 2 shows the dependences of the electrification current of the liquids under study as a function of the rotational speed of a disk of the diameter of 4 cm. On the diagrams there can be observed a practically linear increase of the current characteristics with increasing spinning speed of the disk. The values of the electrification current for hexane and ethanol are similar and remain in the range of a few tens of pA. However, the mixture made from these liquids, the volume of which constitute 95% of hexane and 5% of ethanol, is characteristic of the electrification at a