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Silesian University of Technology

ZBIGNIEW GACEK* and KRZYSZTOF MAŹNIEWSKI*

Application of the spinning disk system for measurement of electrostatic charge tendency of selected liquids

ABSTRACT

Preliminary measuring results relating to electrification current obtained for octane and benzene (as liquids represented hydrocarbons), methanol and propanol (as liquids represented alcohols), and for mixture of hexane with ethanol (as a reference liquid) are presented. Basing on statistical parameters, they have been compared to each other.

1. INTRODUCTION

The evaluation and measuring verification of electrostatic charge tendency (ETC) of selected liquids during their forced flow is still an impor-

* Silesian University of Technology, Institute of Power System and Control, Krzywoustego 2, 44-100 Gliwice, Poland.

tant problem – particularly when these liquids are flammable and explosive ones. Preliminary results relating to ETC of selected hydrocarbons and alcohols are presented. Measurements have been realised using the spinning disk system, worked by J. Kędzia and recommended by CIGRE [1].

2. CHARACTERISTICS OF TESTED LIQUIDS

In order to measure ETC of hydrocarbons certain liquids and their derivatives have been selected (Table 1). Such a choice is justifiable by their small electric conductivity (possible great electrification effects) and flammability (fire and explosive hazard).

The following liquids have been tested: octane (as one from aliphatic hydrocarbons), benzen (as one from aromatic hydrocarbons), methanol (as an alcohol with small molecules), propanol (as an alcohol with big molecules), hexan and ethanol mixture of 19 : 1 proportion (as a reference liquid – according to [2]).

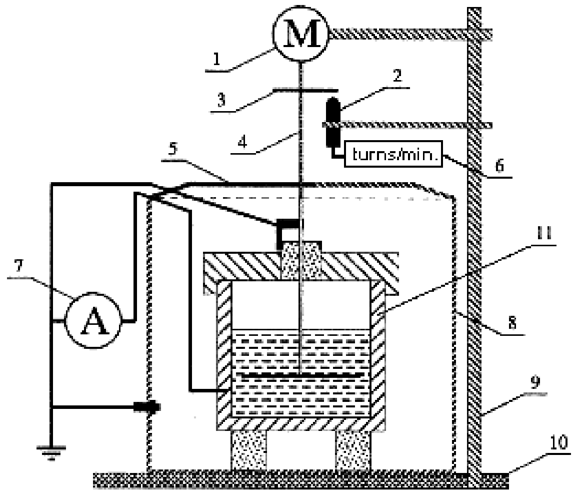
Table 1. Selected physical and chemical parameters of tested liquids

Name	Chemical formula	Molar mass M (g/mole)	Mass density g (kg/dm^3)	Volume resistivity ρ_v (Ω·m)	Relative electric conductivity ε (-)
octane[2]	C_8H_{18}	114.23	0.69	$1.9\cdot10^{11} \div 10^{14}$	2.0
benzene[1]	C_6H_6	78.11	0.88	$2\cdot10^{13} \div 2\cdot10^{14}$	2.3
methanol[2]	CH_3OH	32.04	0.79	$4.3\cdot10^{3} \div 6.2\cdot10^{14}$	32.6÷34.0
propanol[1]	C_3H_8O	60.10	0.78	$10^{4} \div 5\cdot10^{5}$	22.0
hexane[1]	C_6H_{14}	86.18	0.67	$2.9\cdot10^{16}$	1.9
ethanol[3]	C_2H_6O	46.07	0.80	$10^{4} \div 10^{6}$	26.0
[1] – technical clean; [2] – high clean; [3] – extra clean					

3. MEASURING STAND

Electrification intensity of selected liquids has been measured by means of mentioned spinning disk system. It is based on such rule that generation of electrostatic charges appears when a solid phase is moving towards a liquid phase. The spinning disk system is very easy to make continuous measurements and to dynamic balance. Furthermore, it requires small quantities of liquids.

The scheme of measuring stand is presented in Figure 1. In order to eliminate external electromagnetic interferences the measuring vessel has been placed inside the Faraday's cage (metallic screen). The vessel with tested liquid is isolated towards the screen by three cylindrical insulators (height – 30 mm and diameter – 25 mm) made with PTFE. The rotating disk has been driven by a low-power (12 W) free brush a.c. engine, supplied accross the autotransformer. In order to measure rotational speed of the engine (regulated in this way) the speed indicator with optical converter has been used; measuring accuracy 0.5 turns/s for strobing time 2s.



More important dimensions of the measuring vessel:

external diameter
d_e = 120 mm;
internal diameter
d_i = 100 mm;
external height
h_e = 110 mm;
internal height
h_i = 100 mm;
disk diameter
d_d = 80 mm;
volume of a liquid
V = 500 cm^3.

Fig. 1. Scheme of the measuring stand: 1 – engine; 2 – optical converter; 3 – diaphragm; 4 – driving axle; 5 – Faraday's cage cover; 6 – speed indicator; 7 – electrometer; 8 – Faraday's cage; 9 – support; 10 – base; 11 – measuring vessel

4. MEASURING METHOD

The quantity characterised of ETC of a liquid within applied measuring system is the leakage current, measured between a wall of measuring vessel and earthing, after grounding the protective screen. Measurements have been made by a direct method, using an electrometer which enabled us to achieve measuring accuracy up to 10 fA.

Measurements (a dozen or so series for each samples) have been carried out within large rotational speed range (2.5–40 turns/s) attainable for particular liquids and used power transmission system.

5. MEASURING RESULTS

Table 2 gives exemplary relative electrification current values for octane (basing on 10 measuring series). Since electrification current I_{e0} when the disk does not move (last column in Table 2) is not equal zero then it has been treated as a basic size (the so-called "background"). That is why relative electrification current values I_r (i.e. absolute values I_e in relation to "background" I_{e0}) are considered.

Table 2. Relative electrification current for octane

Rotat. speed (turns/min.) / $I_r = I_e/I_{e0}$ (pA/pA)	330	450	600	750	900	1050	1200	1350	1500	1650	1800	"Background" for rotational speed equal to zero I_{e0} (pA)
serie I	0.80	1.00	1.00	1.40	1.20	2.00	3.20	7.00	10.00	8.40	5.60	-5
serie II	1.10	1.10	1.30	1.50	1.60	1.40	1.80	2.00	2.30	2.00	1.20	-10
serie III	1.10	1.10	1.10	1.00	0.90	1.00	1.20	1.90	3.20	2.00	1.80	-10
serie IV	1.00	1.00	1.00	1.08	1.17	1.67	1.83	1.92	2.33	1.83	1.58	-12
serie V	1.13	0.93	1.20	1.13	1.27	1.33	1.47	1.67	1.93	1.53	1.47	-15
serie VI	0.86	0.86	0.71	0.71	0.57	0.57	0.43	0.43	0.29	0.14	0.00	-7
serie VII	1.00	2.00	2.00	3.00	3.00	3.00	4.00	5.00	7.00	10.00	11.00	1
serie VIII	0.50	0.60	0.60	0.60	0.70	0.80	1.00	1.00	1.10	1.20	1.20	10
serie IX	1.00	1.11	1.22	1.22	1.33	1.11	1.44	1.33	1.67	1.44	1.44	9
serie X	0.89	1.00	1.00	1.11	1.11	1.22	1.22	1.33	1.67	1.56	1.67	9

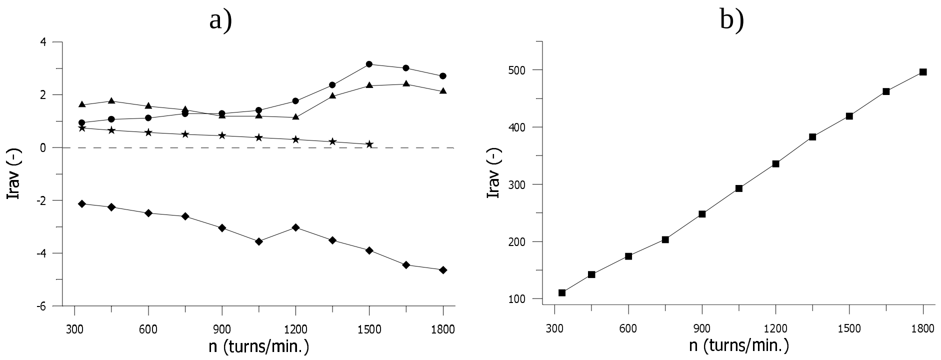


Fig. 2. Average relative electrification currents for: a) tested liquids: octane (•); benzene (♦); methanol (▲); propanol (★); b) reference mixture (■)

Table 3. Coefficients of variation for tested liquids

Rotat. speed (turns/min.) / $\Delta I_{rav\%}$ (%)	330	450	600	750	900	1050	1200	1350	1500	1650	1800
octane	21.28	41.12	39.64	59.38	59.69	54.61	64.20	88.14	97.46	103.65	128.89
benzene	68.22	71.68	67.47	76.25	92.79	95.22	61.72	60.23	57.18	52.81	54.53
methanol	36.02	41.71	25.00	21.68	21.01	18.49	53.51	32.99	49.15	44.17	33.96
propanol	20.27	26.15	26.32	30.00	37.78	40.54	50.00	54.55	116.67	–	–
ref. mixture	20.14	25.32	27.05	27.66	27.04	27.04	33.10	32.44	31.97	32.17	30.96

Diagrams in Figure 2 show how average relative electrification current I_{rav} of all tested liquids (acc. to several measuring series) change in rotational speed function. Coefficients of variation for tested liquids (calculated according to [3]) are included in Table 3.

6. CONCLUSIONS

The article gives only selected measuring results. Every tested liquids revealed several hundred times slighter ETC than the reference mixture. Electrification current values measured in this mixture for motionless disk were very small ones – only a few pAs in relation to several hundred pAs during spin of the disk. Dependence of average relative electrification current of the mixture versus rotational speed of the disk is almost linear one, whereas coefficient of variation is the smallest between tested liquids and it is nearly independent of rotational speed.

Benzene and octane have revealed the biggest ETC; benzene has electrified negatively towards "background". Alcohols (methanol and propanol) have electrified towards "background" with little less intensity than octane. ETC of all tested liquids except propanol had a tendency to grow when rotational speed increases.

Absolute values of electrification current, after removal a correction connected with "background", are as follows:

propanol	5 ÷ 170 nA
methanol	–10 ÷ –38 nA
octane	–0.2 ÷ –8.6 pA
benzene	–70 ÷ –123 pA
reference mixture	–103 ÷ –478 pA

In order to get more univocal stochastical dependencies concerning ECT of liquid hydrocarbons and alcohols further investigations should be made. Complementary measurements are in the course of their realization.

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