ISSN 1810-2328, Journal of Engineering Thermophysics, 2016, Vol. 25, No. 2, pp. 236–238. © Pleiades Publishing, Ltd., 2016.

Study of Stability Against Oxidation of Rapeseed Oil

M. A. Anikeeva[1]* and S. M. Korobeynikov[2]

[1] *Novosibirsk Division of JSC "Electrosetservice of UG," Novosibirsk, Russia*

[2] *Novosibirsk State Technical University, Novosibirsk, Russia*

Received May 15, 2015

Abstract—Some physical and chemical features of rapeseed oil with antioxidant additive were studied in connection with the stability against oxidation. The most optimal antioxidant was defined for rapeseed oil in order to use it in oil-filled high-voltage equipment.

DOI: 10.1134/S1810232816020089

INTRODUCTION

Vegetable oils as raw materials for renewable energy sources are world-wide established since the 1980s. Nevertheless, in our country the great energy reserves of traditional mineral sources for power engineering [1] lead to moderated development of studying their properties. These liquids are used as biodiesel more often than fluid for electrical equipment. The idea of vegetable oil application as an insulating fluid instead of mineral oil is relatively new [2]. Data on the use of any vegetable liquid as an insulating fluid in our country are absent. This paper is devoted to studying the rapeseed oil stability against oxidation and discussing the first results.

THE RESEARCH METHODOLOGY AND RESULTS

The study included the following stages:

—preparation of the rapeseed oil samples both inhibited and non-inhibited;

—standard physical-chemical tests of prepared oil samples;

—definition of the oxidative stability of rapeseed oil by different methods.

The breakdown voltage of oil, and also moisture content were determined in accordance with GOST 6581-75 (Table 1).

The dielectric properties of rapeseed oil were measured with the help of a transformer oil tester BAUR DTL (Table 2).

The stability of rapeseed oil (RO) against oxidation was investigated by application of several methods.

Method A. Definition of stability of commercial rapeseed oil (without inhibiting additives) according to GOST 981-75, which defines the test procedure for fresh transformer oil.

After oxidation tests during 2–3 hours these oil samples have became dark and viscous due to polymerization.

Method B. It follows from the GOST R 51487-99. The test procedure consists in determination of peroxide number for rapeseed oil with addition of different antioxidants. This study of antioxidant activity of monofunctional and sulfur-containing phenolic antioxidants was fulfilled in collaboration with the Research Institute of Antioxidant Chemistry (Novosibirsk).

As antioxidant additives for rapeseed oil we selected both well-known monofunctional phenolic antioxidants: ionol and butyl hydroxyanisol and also sulfurous antioxidants. The induction periods of rapeseed oil oxidation are shown in Table 3.

* E-mail: ama@nspb.ru

Table 1. Determination of physical and chemical properties of rapeseed oil with antioxidant additives (0.3%)

The studied feature	Rapeseed oil without additives	Rapeseed oil with ionol	Rapeseed oil
Breakdown voltage, kV	60.2	64.8	64.3
Water content, ppm	178.2	178.3	179.6

Table 2. Dielectric parameters of RO with the addition of antioxidant additive 2-dodecilthio-metylhydroquinone

Tan δ, %	Relative dielectric permittivity	Specific volume resistivity, Ohm × m
5	**2.8**	**3×10^9**

Table 3. Induction periods of oxidation of rapeseed oil with different antioxidants

Antioxidant	Induction period, days, for samples with antioxidant, mass content, %	
	0.1	0.2
Commercial rapeseed oil (without additives)	3–4	
Butyl hydroxyanisol	—	7
Ionol	4–5	5
Tiofan	—	13
Tiofan M	16–17	43
Tiofan M (o)	—	42
2,5-dodecylthiomethylhydroquinone	33–34	64
2-dodecylthiomethylhydroquinone	**51**	**87–88**

Method C. Definition of stability against oxidation of vegetable oil with special inhibitor, i.e., 2-dodecylthiomethylhydroquinone according to IEC 1125: 1992 (method C, taking into account conditions specified in IEC 62770:2013 for oils based on complex natural esters).

The main test results:

—volatile low-molecular weight acids 0.05 mg KOH/g;

—soluble acids 14.2 mg KOH/g;

—oil sludge less than 0.002%.

These features comply with requirements for the most popular brands of transformer oil, except for acid number.

DISCUSSION

The most interesting result is that the rapeseed oil has a high value of breakdown voltage despite the high water content inside the liquid. In our opinion this fact may be explained by high viscosity of rapeseed oil in comparison with viscosity of mineral transformer oil. The matter is that viscosity of rapeseed oil is 4 times higher than that of transformer oil. It is well known that dielectric strength of liquid strongly depends on viscosity [3].

The fact that non-inhibited rapeseed oil quickly oxidizes could be explained by its molecular structure. The main components of the mineral oil are saturated liquid paraffins C_nH_{2n} and naphthenes CnH_{2n+2} with an average molecular weight of (220–340) atomic units [4].

The main ingredients of rapeseed oil are esters of erucic (13-docosenoic) acid $CH_3{-}(CH_2)_7{-}CH{=}CH{-}(CH_2)_{11}{-}COOH$, olein (9-octadecanoic) acid $CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$, and linoleic (9,12-octadecadienoic) acid $CH_3(CH_2)_3{-}(CH_2CH{=}CH)_2(CH_2)_7COOH$. One should mention that all these substances contain molecules with double bonds [2], which is the reason of their great reactivity.

Our data on peroxide number of rapeseed oil with the addition of various sulfurous antioxidants in different concentrations indicate that all of them inhibit the ability of the oxidation of rapeseed oil. The most popular antioxidants of mineral oil, namely, ionol and butyl hydroxyanisol, show inadequate results for rapeseed oil. The maximum values for the oxidation induction periods were obtained with doping of 2-dodecylthiomethylhydroquinone in rapeseed oil.

CONCLUSIONS

We have measured some physical-chemical and dielectric properties of rapeseed oil with the antioxidant additive and without it. Different methods were applied to evaluate the stability of rapeseed oil against oxidation. These tests have shown that the standard method of oxidation (for fresh transformer oil) is not suitable for oils obtained from vegetable raw materials due to their chemical composition.

The tests of rapeseed oil have shown that the breakdown voltage is quite consistent with the fresh transformer oil for equipment of all system voltages. The relatively high value of the dielectric losses ($\mathrm{Tan}\,\delta$) can be explained by the presence of large quantities of high-molecular-weight oil polar elements. The physical and chemical features of rapeseed oil did not deteriorate after adding the additives. The best antioxidant for rapeseed oil was determined during studying the peroxide number. It is 2-dodecylthiomethylhydroquinone. It is important not only for oil filled power equipment but also for storage of vegetable oils for renewable energy sources.

REFERENCES

1. Nakoryakov, V.E., A Note on Power Engineering in Russia, *J. Eng. Therm.*, 2014, vol. 23, no. 3, pp. 171–172.
2. Martin, D., Wang, Z.D., and Cotton, I., The Use of Natural and Synthetic Ester-Based Transformer Oils in Power Transformers, *Proc. XIV Int. Symposium on High-Voltage Engineering*, Tsinghua University, Beijing, 2005, pap. C–11.
3. Korobeynikov, S.M., *Electro-Physical Processes in Gaseous, Liquid and Solid Dielectrics. Processes in Liquids*, Novosibirsk: NSTU, 2010.
4. Lipshtejn, R.A. and Shakhnovich, M.I., *Transformer Oil*, Moscow: Energoatomizdat, 1983.