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Measurements of natural oils electrical properties

Streszczenie. (Pomiary własności elektrycznych olejów naturalnych). *Ciecze izolacyjne są powszechnie używane w urządzeniach wysokonapięciowych, takich jak: transformatory, kable wysokiego napięcia, przepusty, kondensatory i inne. Ciecze spełniają nie tylko funkcję izolująca, ale równocześnie są stosowane jako czynnik chłodzący. Oleje mineralne jako dobre ciecze izolacyjne są często stosowane, jednak ich wadą jest agresywność środowiskowa i trudności utylizacji. Z tego powodu podjęto badania nad zastosowaniem olejów naturalnych. Artykuł przedstawia wyniki pomiarów własności dielektrycznych i wytrzymałości elektrycznej takich właśnie olejów.*

Abstract*. Insulating liquids are wildly used in electrical high voltage equipment such as transformers, high voltage cables, bushings, capacitors and so on. Liquids fulfill not only an insulating function but as a cooling medium. Mineral oil is often used as good insulating liquid. Its disadvantages are aggressiveness to the nature and a problem with its liquidation. So we decided to do some measurements with natural oil. In this article will be present measurement results of dielectric properties and breakdown strength of natural oil.*

Słowa kluczowe: izolacja, transformator, olej roślinny, własności elektryczne.
Keywords: Insulation, transformers, vegetable oil, electrical properties.

Introduction

For over one-hundred years, petroleum-based mineral oils purified to "transformer oil grade" have been used in liquid- filled transformers. Several billion liters of transformer oil are used in transformers worldwide. The popularity of mineral transformer oil is due to availability and low cost, as well as being an excellent dielectric and cooling medium. Ever since the world oil reserves were tapped in the 1940s, petroleum products have become widely available. Petroleum-based products are so vital in today's world that we cannot imagine a time we may not have them easily available. Transformers and other oil-filled electrical equipment use only a tiny fraction on the total petroleum consumption, yet even this fraction is almost irreplaceable [1].

There are two reasons why we should be seriously thinking of alternate natural sources of insulating fluids:

– transformer oil is poorly biodegradable. It could contaminate our soil and waterways if serious spills occur,
– petroleum products are eventually going to run out, and there could be serious shortages even by the mid-twenty-first century.

Liquid-filled transformers use billions of liters of insulating fluid. They come in various sizes: large, medium and small power as well as distribution, each one using as much as forty thousand liters in each phase of a large power transformer to as small as eighty liters for a small distribution transformer.

In recent years, environmental concerns have been raised on the use of poorly biodegradable fluids in electrical apparatus in regions where spills from leaks and equipment failure could contaminate the surroundings. Contamination of the water supply is considered much more serious than contaminate of the soil.

Due to the utility in biodegradable insulating fluids, research efforts were started in the mid 1990s to develop a fully biodegradable insulating fluid. This effort was started by R&D labs that initiated oil development work. Vegetable oil was considered the most likely candidate for a fully biodegradable insulating fluid. Vegetable oil is a natural resource available in plenty; it is a fairly good insulator, and is fully biodegradable [1].

Preparation of specimens and measurements

Investigations were focused on the measurement of the based electrical properties of vegetable oil and comparison to mineral based transformer oil. As vegetable oils were used two types of fluids: sunflower oil and colza oil. As transformer oil was used inhibit oil ITO100. The following specimens were measured:

- specimen 1.1 – non-filtrated sunflower oil,
- specimen 1.2 - non-filtrated sunflower oil, stays in the bottle for 2 months,
- specimen 1.3 - non-filtrated sunflower oil, stays in the bottle for 3 months,
- specimen 2 - non-filtrated sunflower oil, stays in the bottle for 3 months, without air gap,
- RACIOL – filtrated colza oil,
- ITO 100 – inhibit transformer oil.

Dissipation factor and dielectric constant

Dissipation factor tanδ and dielectric constant ε_r were measured by Schering fully automatic bridge TETTEX AG type 2818. The HV bridge has had a guaranteed sensitivity of dissipation factor better than $\pm 2 \cdot 10^{-4}$ and capacitance better than ±0.05%. The applied voltage was changed from 0.1kV up to 2.0kV by step 0.2kV. First measurement was measured at a room temperature. After that the temperature was increase up to 100°C by step 10°C. For each temperature level voltage measurement of dissipation factor and dielectric constant was made.

Breakdown voltage and breakdown strength

The breakdown voltage was measured in a test vessel of special measuring instrument VEB TuR Dresden type WPOT 0.25/75. Testing voltage was automatically increased with constant speed 2kV/s up to breakdown. The measuring vessel was equipped with copper spherically-capped electrodes with 2.5mm electrode gap. Measurement of breakdown strength was made by the same measuring instrument with an adjustable electrode gap from 0.1mm up to 3mm (0.1; 0.2; 0.5; 0.8; 1.0; 1.5; 2.0; 2.5 and 3.0mm) at room temperature only.

Measuring results

Evaluation of measuring data was done for each specimen separately. Temperature and voltage dependences of dissipation factor and dielectric constant were made for everyone type of oil. Then these dependences were compared between each other. Besides the breakdown voltage and breakdown strength of different oil were investigated.

Dissipation factor and dielectric constant

Figure1 shows the influence of the temperature on the dielectric constant of oil different type. Characteristic curves have similar dependences on the temperature, but dielectric constant of transformer oil is lower than vegetable oil. Curves of sunflower and colza oil fall down from value 3.2 at the room temperature to 2.8 at 100°C. Transformer oil curve decreases slower than vegetable oil curve: from 2.2 at the room temperature to 2.1 at 100°C.

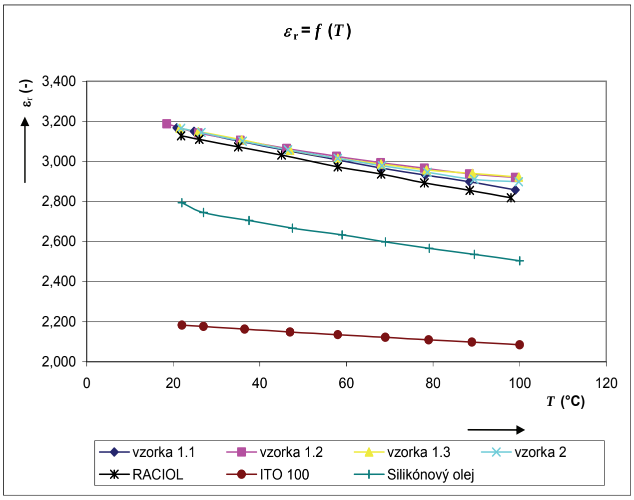

Fig.1: Dielectric constant ε_r as a function of temperature for different oil specimens

Temperature dependences of dissipation factor of different fluids for one voltage level 2kV are shown in the figure 2 and voltage dependences of dissipation factor at 89°C are shown in the figure 3. Dissipation factor of vegetable oil is much higher than tanδ of transformer oil. It is possible to see different between two types of vegetable oil. Filtrated oil has lower dissipation factor than non-filtrated oil.

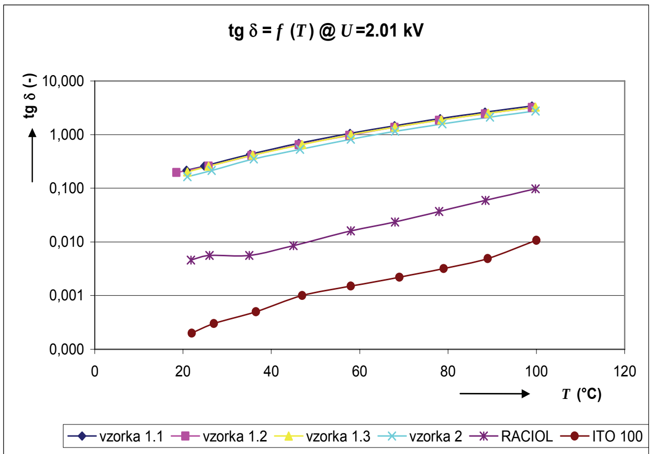

Fig.2: Dissipation factor tanδ as a function of temperature T for voltage U = 2.01kV

Breakdown voltage and breakdown strength

Dependency of the breakdown voltage and breakdown strength on the length between electrodes is shown in figures 4 and 5. Characteristic curves are similar at small electrode gap. Differences begin when electrode gap is bigger than 2mm. It is very important, that at normal electrode gap 2.5mm the breakdown voltage of filtrated colza oil is 57kV and the breakdown voltage of transformer oil is 52kV.

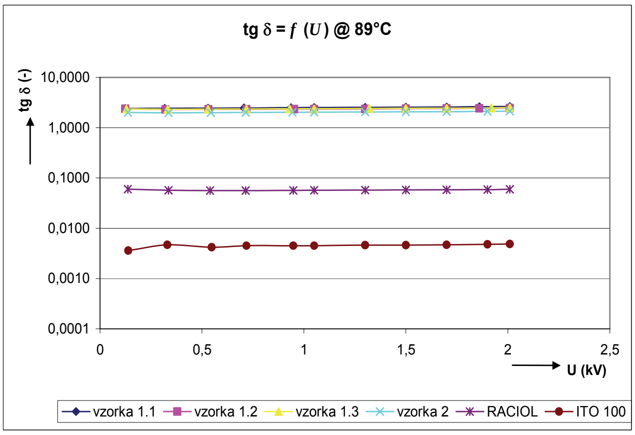

Fig. 3. Dissipation factor tanδ as a function of voltage U at temperature T= 89°C

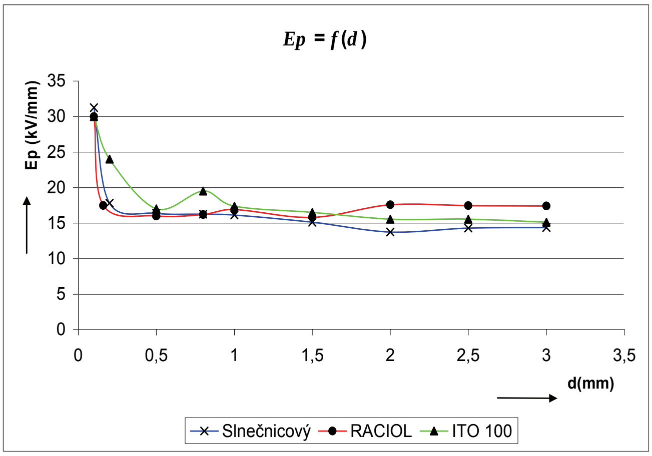

Fig. 4. Breakdown strength as a function of electrode gap length for different oils

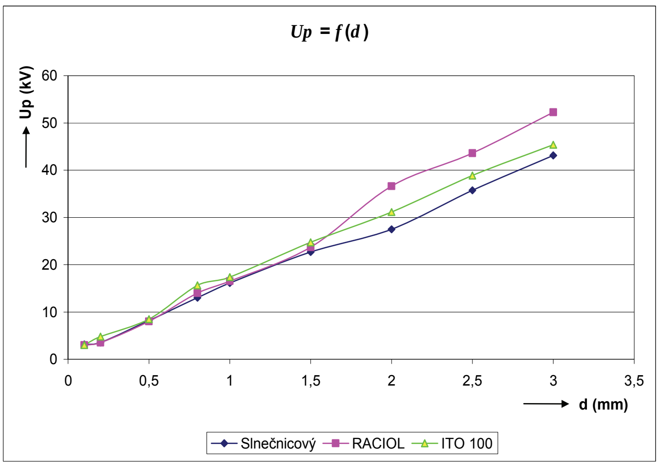

Fig. 5. Breakdown voltage as a function of electrode gap length for different oils

Conclusion

First investigations of electrical and dielectrical properties of vegetable oils were made. The electrical properties of oils were compared with mineral transformer oil characteristics. The results show that it would be possible to use vegetable oils in practice. It appears that filtrated colza oil is better than non-filtrated sunflower oil. It has higher value of dissipation factor and dielectric constant (it is not very good) and higher value of breakdown voltage (it is very good) in comparison to transformer oil.

It needs to make more measurements to say that vegetable oils are ready to be used in practice. There are more important properties to study.

This work was supported by Scientific Grant Agency of the Ministry of Education of Slovak Republic and the Slovak Academy of Sciences under the projects VEGA č.1/3142/06 and APVV-20-006005.

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