Insulating properties of oil based magnetic liquids

F.Herchl[1], P.Kopčanský[1], K.Marton[2], L.Tomčo[3], M.Timko[1], M.Koneracká[1], V. Závišová, I.Potočová[1]

[1] *Institute of Experimental Physics SAS, Watsonova 47, 043 53 Košice, Slovakia*
[2] *Faculty of Electrical Engineering and Informatics, Technical University, Letná9/A, 041 20 Košice, Slovakia*
[3] *Faculty of Aeronautics , Rampová 7, 041 21 Košice, Slovakia*

Introduction

Magnetic liquid is a suspension of very fine magnetic particles of the order of 10 nm. Oil based magnetic fluids enable better cooling of transformers than pure transformer oils. The presence of foreign particles in liquid dielectric has a great effect on its breakdown withstand. The particles tend aggregate in the region of higher electric field if they have higher permittivity than the surrounding liquid and they form bridges. This can lead to breakdown. Even though, the DC impulse insulating voltage in magnetic fluid was found higher than that in pure transformer oil [1].

Experimental results

It was found, that addition of certain amount of magnetic particles into transformer oil improves its breakdown withstand also by DC voltage. Our measurements were carried out using electrodes of a uniform gap of electric field – Rogowski profile in transformer oil Technol US 4000 based magnetic liquid with magnetite particles of the average size of 8.6 nm coated with oleic acid. The conversion between better and worse breakdown properties is at particle volume concentration Φ=0.01 corresponded saturated polarisation I_s=4mT. In Fig.1 an example of dielectric breakdown strengths of magnetic fluid with Φ=0.0025 in zero magnetic field is shown. Magnetic field has not great effect on dielectric insulating strength if this is not oriented parallel to the electric field. Dielectric insulating strength is smaller in the case of parallel orientation of electric and magnetic field (B=31mT) than that in the case of perpendicular orientation or zero magnetic field if the electrode distance is 0.1mm. In presence the effect of particle volume concentration on dielectric breakdown strengths of magnetic liquids by AC voltage is investigated too.

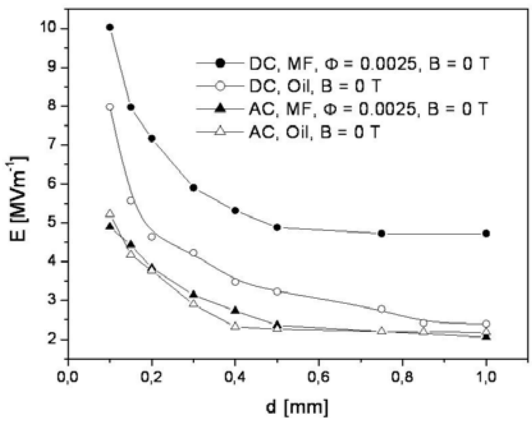

Figure 1: The DC and AC dielectric breakdown strengths E vs. distance between electrodes d for magnetic fluid (Φ=0.0025, I_s=1mT) and pure transformer oil.

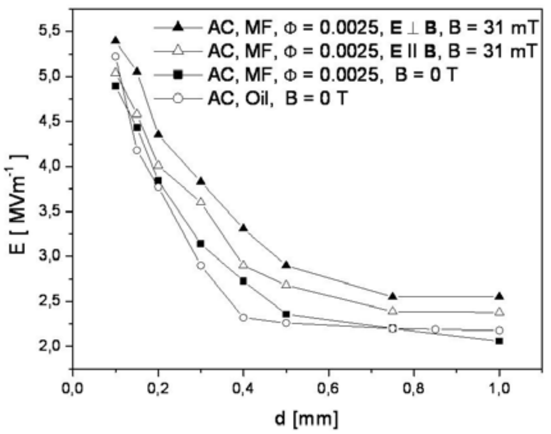

Figure 2: The AC dielectric breakdown strengths E vs. distance between electrodes d for magnetic fluid (Φ=0.0025, Is=1mT) at different orientations of electric and magnetic field and pure transformer oil.

Dielectric breakdown strength is comparable with that in pure oil at Φ=0.0025 (Fig.1). Magnetic field has not great effect on AC dielectric breakdown strength (Fig.2). Breakdown fields are slightly higher at nonzero magnetic field. Breakdown fields show great variations from average breakdown field.

Discussion and conclusions

The DC breakdown followed immediately after initial partial discharges appear. According to theoretical predictions [2], initial breakdown field distribution $F_L(E)$ should have the Duxbury and Leath form (1)

$$F_L(E) \approx 1 - \exp\left[-cd^3 \exp\left(-\frac{k}{E}\right)\right] \quad (1),$$

where k is constant depended on particle volume concentration Φ, d is electrode distance, E is breakdown field and c is constant, or the Weibull form (2)

$$F_L(E) \approx 1 - \exp\left(-cd^3 E^m\right) \quad (2),$$

where m is constant. Form (1) corresponded to the average initial breakdown field E (3)

$$E \approx \frac{1}{A(\Phi) + B(\Phi)\cdot \ln(d)} \quad (3),$$

where A(Φ) and B(Φ) are constants depended from particle volume concentration. Form (2) corresponded to the average initial breakdown field E (4)

$$E \approx \frac{1}{d^{3/m}} \quad (4).$$

Measured dependences of breakdown fields as a function of electrode distances not allow determine the breakdown field distribution in magnetic liquid (Fig.3) because correlation coefficients of approximation (3) R=0.975 and approximation (4) R=0.979 are almost the same. We can conclude, that magnetic fluid with particle volume concentration Φ<0.01 has better dielectric properties at DC voltage and comparable but not worse dielectric properties at AC voltage. On the base of present measurements we don't know to determine the distribution function of breakdown fields. Therefore, in future the distribution function will be investigated directly and compared with theoretical predictions.

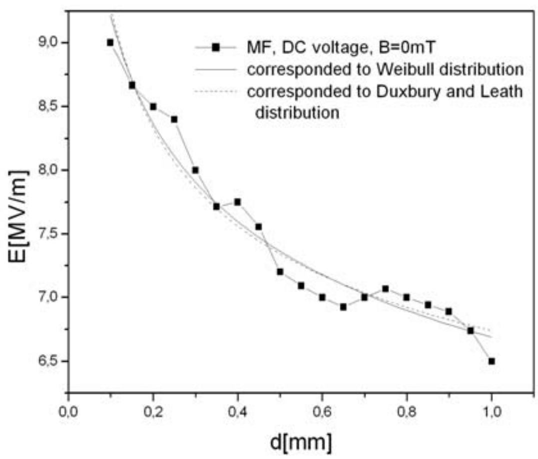

Figure 3: The DC dielectric breakdown strength E vs. electrode distance d for magnetic fluid (Φ=0.0025, I_s=1mT) and approximations corresponded to Weibull breakdown field distribution and Duxbury and Leath breakdown field distribution.

Acknowledgment

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References

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