Stárnutí kompozitních materiálů různými druhy napětí

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Ageing of Composite Insulation under Different Voltage Stress

Abstract – **This paper describes the assessing the lifetime curves of composite insulation under different kind of voltage stress. This covers several areas that are important for using the electrical insulation properly. First one is the composite insulation. The use of this kind of insulation is rising, new types of composites are being invented and investigated with the aim for the best achievable properties. This kind of insulation has its use in high voltage applications as is large rotating machines (e.g. turbo and hydro generators). This composite was aged by a different kind of voltage applied. The composite was subjected to both AC and DC voltage.**

Keywords – composite insulation; accelerated aging; voltage stress

I. INTRODUCTION

The insulation (dielectric) subsystem of the electrical machine is the most sensitive and most important subsystem. This is well-known fact from years of experience. The lifetime of the whole device depends on this subsystem running smoothly. For proper and smooth function of the whole machine, it is necessary to ensure proper materials that match the function and nature of the device are used. With new materials for construction of electrical machine emerging rapidly, it is necessary to investigate the properties of the newly developed material before usage [1].

II. COMPOSITE INSULATION

High voltage insulation systems are made either with VPI (vacuum pressure impregnation) or resin-rich technology [2, 3]. The two investigated inhomogeneous composite structures in this paper belong to resin-rich technology. They are used for insulation of the end and planar part of the winding.

A. Samples specification

The first of our two composites with inhomogeneous structure consists of calcinated mica paper, polyethylene terephthalate (PET) foil and epoxy-novolac resin. We are going to refer to this sample as Composite 1. The polyethylene terephthalate is linear polyester with good mechanical and electrical properties. The thermal class of the PET foil is 155°C according to the IEC 60 085 [4].

Another part of the composite is the calcinated mica paper that is made from mica. Small particles of mica are heated for water loss, cooled and then processed on the paper machine [5]. The matrix is the last part of the composite. This composite uses the epoxy-novolac resin. Excellent chemical and thermal properties are achieved thanks to the structure of the resin.

The other composite material differs from the first one in replacing the PET foil with glass fabric. Other two components remain the same. We are going to refer to this sample as Composite 2.

III. VOLTAGE STRESS & AGEING

Ageing, or slow deterioration of the whole system, is a process that is inevitable when running the electrical machine. As stated above, the electrical machine consists of several subsystems, of which the dielectric subsystem is the most sensitive one. That also means it is also the most susceptible to environmental conditions. Most of the faults can be found in dielectric or electric subsystem of the electrical machine. The source of these faults most likely has its origin in slow deterioration. Sources show it is up to 20% of faults in electrical machines [6].

There are two main factors affecting the deterioration of the dielectric subsystem (insulation) of large electrical machines. It is heat and voltage stress. For our experiment, we chose voltage (both AC and DC) as out ageing factor. The significance of studying behavior of the new composite under AC voltage is clear, as it is the most common voltage type. The DC voltage, on the other hand, is not so common but its importance is rising with increasing number of DC-DC converters, PWM modulation, switching elements etc. In all these areas we can encounter voltage spikes with more than 10 kV/μs, which deteriorates insulation rapidly [7].

IV. RESULTS

The resulted lifetime curves of this experiment are visible below. Each graph includes the confidence and prediction intervals of 95%. These curves can serve for assessing the rate of degradation for individual composite under each voltage type. The linear regression analysis was used for evaluation of processes. The values of individual voltages are converted to values of intensity of electric field E (kV/mm) for better comparability and times to breakdown are displayed in logarithmic scale. The Table 1 shows slopes for individual materials and voltages. First, there are results for AC voltage stress – Fig. 1 and 2.

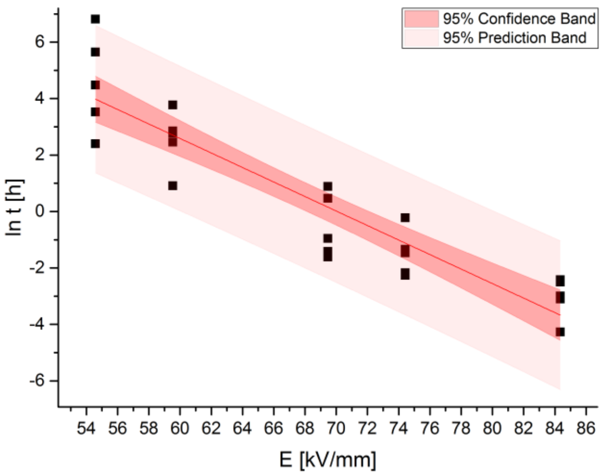

Figure I. **Composite 1 under AC voltage**

Considering the influence of AC voltage on composites, the greater influence (slope of the curve), therefore faster degradation, can be found at Composite 1. The difference is not huge, but it is there, as is shown at Table I.

The situation is similar with the influence of DC voltage (Fig. 3 and 4) but the difference is more visible. The Composite 2 seems to be deteriorating at faster rates then Composite 1, making it worse choice for the insulation system. The voltage levels are significantly higher at Composite 1. Nevertheless, both composites comply with requirements for developing electrical machines.

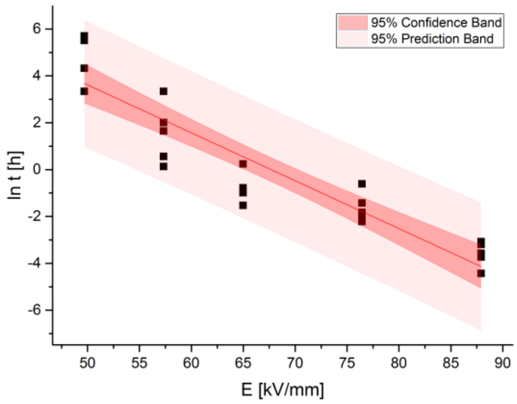

Figure II. **Composite 2 under AC voltage**

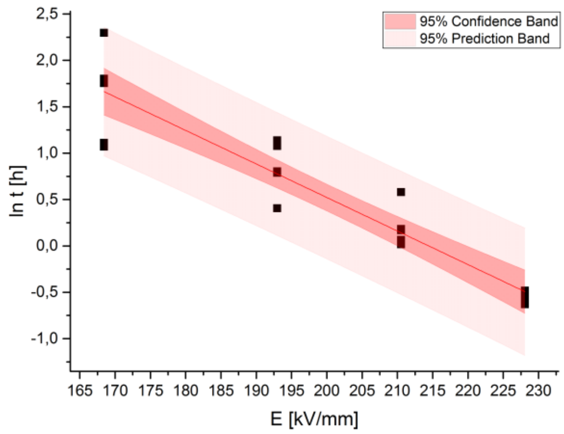

Figure III. **Composite 1 under DC voltage**

One more thing can be seen from the graphs and that is the significantly higher level of DC voltage. That simply imply that the AC voltage is much more aggressive than the DC voltage so it has a bigger impact on the state of insulation. This corresponds with slopes of lifetime curves as shown above.

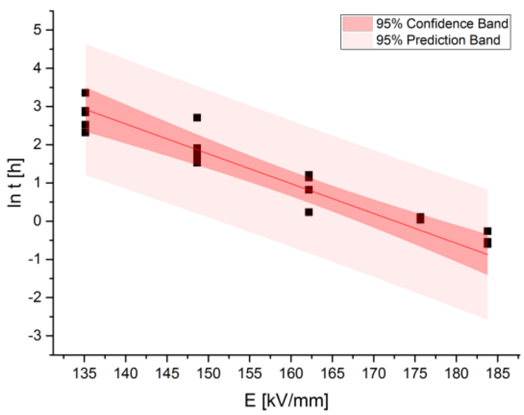

Figure IV. **Composite 2 under DC voltage**

V. CONCLUSION

This paper describes the ageing experiment with two inhomogeneous composite insulation samples, whereas the ageing factor the AC and DC voltage was chosen. As stated above, both samples are viable materials for insulation subsystem of the electrical machines. The Composite 1 (PET-based composite) shows slightly better results withstanding DC voltage, and therefore is a better choice for DC applications. The Composite 2 (the glass fabric based composite), on the other hand, shows slightly better results withstanding AC voltage.

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