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MECHANICAL PROPERTIES OF EPOXY/GLASS/MICA COMPOSITE AT HIGH TEMPERATURE

WŁAŚCIWOŚCI MECHANICZNE KOMPOZYTU EPOKSYD/SZKŁO/MIKA W WYSOKICH TEMPERATURACH

Abstract: The stator windings of large rotating machines are insulated with mica-glass fabric impregnated with epoxy resin. These composites are exposed to thermal, mechanical and electrical stresses. The mechanical behaviour of two different forms (foil and tape) of cured epoxy/glass/mica composite was studied during this experiment. Specimens were made of calcinated mica paper and a glass cloth, bonded together with epoxy-novolac resin. These materials are used for the insulation of coils and bars of the electric machines in thermal insulation class F.
The aim of this experiment is to compare the present material with the modified one. The improvement is based on the use of innovated glass cloth and in modification of epoxy-novolac bonding resin. Tensile and bending strength of these materials are investigated at room temperature and at temperatures 130, 155 and 180 °C. Decreasing of tensile strength and bending strength of both materials with increased temperature is shown.

1. Introduction

Insulation system is the key element of each electric machine. Nowadays, there are two basic types of insulation systems which differ in the type of construction – Resin Rich and VPI (Vacuum Pressure Impregnation). Both of them use composite materials which can be modified to achieve required quality.
The modification can be based on a change of electrical, mechanical or thermal properties of every component in the composite material.
Because it is not simple to build a mathematical model of composite material, it is still necessary to compare new materials with the present by the measurement.

2. Experimental part

The aim of this experiment is to compare the present material (marked as standard) with modified one. The improvement consists in the use of innovated glass cloth and in modification of epoxy-novolac bonding resin.

2.1 Materials

Two variants of new epoxy/glass/mica insulating system were fabricated. In the first variant a glass cloth was used to create a board-type insulation material (marked as foil); in the other variant the glass tape was used as a reinforcement of the composite (marked as tape). Because the resulting foil material is an anisotropic composite, the both directions of the glass cloth are tested (warp and fill). The warp direction was marked as foil 1, the fill direction as foil 2. The same bonding resin and muscovite mica paper were used in both cases. The foil material was prepared from the appropriate number of glass/mica prepreg layers by pressing in a heated press. The tape material was prepared from mica/glass tape with 22 mm in width. The tape was wrapped around the solid desk with 50 % overlap and then cured under pressure. After the curing process, the edges were cut off. Specimens were prepared from these boards using circular saw.

2.2 Methods

The bending strength test was done on universal testing machine Labtest 3.100 (Labortech s.r.o.) in accordance with EN ISO 178. The foil specimen dimensions was 125×6,5×10 mm, the tape specimen 180×6,5×10 mm. The bending strength was measured at temperatures 23, 130, 155 and 180°C.

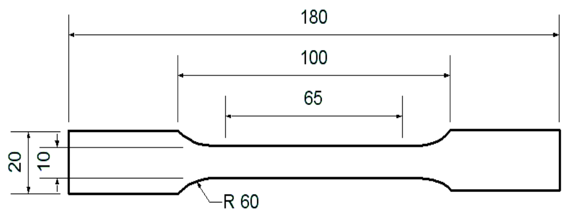

Figure 1: Geometry of foil specimens

The tensile strength test was done in accordance with EN ISO 527 on the same testing machine as the bending test. The foil specimen dimensions was 180×6,5×10 mm, the tape specimen 180×6,5×20 mm. The bending strength was measured at temperatures 23, 130, and 155°C. Geometry of foil specimen is in figure 1.

3. Results and discussion

The bending strength of all material variants was measured at temperatures 23, 130, 155 and 180°C. The results of this measurement are in table 1. The temperature dependence of bending strength is shown in figure 2.

Table 1: Bending strength (MPa) and variation coefficient (%) for all material variants at temperatures 23, 130, 155 and 180°C

°C	tape	foil 1	foil 2	stand.
23	106,71	238,13	118,79	225,09
	9,4 %	10,9 %	15,2 %	3,6 %
130	87,08	190,95	115,25	183,55
	15,2 %	6,8 %	17,3 %	3,9 %
155	80,07	157,00	98,47	160,55
	15,2 %	17,7 %	14,1 %	6,4 %
180	71,34	129,22	78,34	137,13
	11,3 %	12,2 %	13,0 %	7,9 %

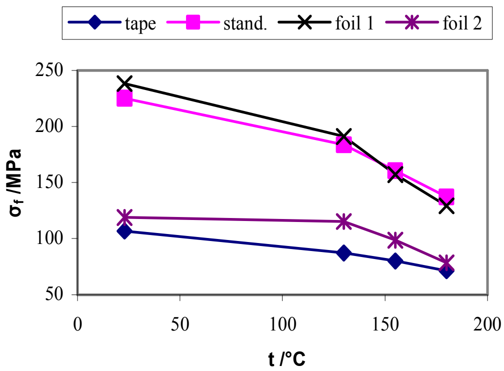

Figure 3: Temperature dependence of bending strength (σ_f) for all material variants

It could be seen that there is a decrease of bending strength with increase of temperature. At room temperature the tensile strength value in the warp direction is 230 MPa by both materials; at 180 °C the value is approximately 130 MPa, the decrease is 40 % of the starting value. The fill direction of the foil material and the tape material behave similarly. It is important for the practical application of these materials, because it means that the foil material can be replaced with the tape. It simplifies the production process.

The tensile strength of all material variants was measured at temperatures 23, 130 and 155°C. In addition the tape material was measured at 180°C. The results of this measurement are in table 2. The temperature dependence of tensile strength is shown in figure 3.

Table 2: Tensile strength (MPa) and variation coefficient (%) for all material variants at temperatures 23, 130 and 155 °C

°C	tape	foil 1	foil 2	stand.
23	61,47	130,00	68,56	126,60
	13,7 %	12,7 %	19,6 %	16,0 %
130	51,87	94,58	88,05	103,99
	11,2 %	19,7 %	8,1 %	3,1 %
155	54,87	88,90	70,09	87,35
	17,7 %	15,6 %	22,8 %	15,1 %

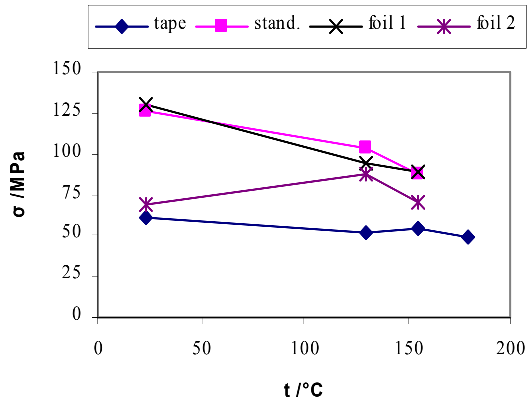

Figure 2: Temperature dependence of tensile strength (σ) for all material variants

The decrease of tensile strength with increasing temperature is also evident analogously to the bending strength. The tensile strength values are approximately on 70% of starting values at 155°C. Tensile strength of the modified material in fill direction is invariable and temperature independent as in the case of the tape material.

4. Conclusion

The comparison of original and modified epoxy/mica/glass composite materials based on the measurement of tensile and bending strength was done. It is possibly to say that modification doesn't influence in any way mechanical properties and both materials are comparable. Because these composites are used as insulation materials in electric motors, their behaviour at high temperature is also important. Therefore mechanical properties were measured at 130, 155 and 180°C. Decreasing of tensile and bending strength of both materials with increasing temperature was shown.

5. Acknowledgment

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6. Literature

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