

# **New Trends in the Insulation Technology of Rotating High Voltage Machines**

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## **INTRODUCTION**

The driving force of material and process development in the insulation technology of rotating high voltage machines has changed in the last five to ten years. Being mainly technology driven in the past, cost has become more and more the determining factor in the industry. Improvements in products or processing are only accepted if they reduce overall cost. On the other hand, high voltage motors and generators are long-life capital goods and a reduction in reliability cannot be tolerated. Any development of new insulating materials has to reflect these facts to be successful in the market.

## **TRENDS IN MATERIALS, PRODUCTS AND PROCESSES**

Taking the above stated assumptions for granted, the foreseeable trends in the insulation technology of rotating high voltage machines may be summarised as follows:

### **Materials and products:**

- Mica will remain the main component in high voltage insulation for at least the next ten years.
- Increasing the power of a machine for a given size requires materials with higher thermal stability and – if possible – better thermal conductivity. From this point of view the organic components (binder or impregnating resins, organic films and fleeces) are the weak part of the insulation and must be further developed providing improved thermal characteristics to meet the trend for more power per weight or size of the machine.
- Increasing the power of a machine will also require insulation systems designed to withstand higher electrical stresses. In other words: for a given voltage the insulation thickness will have to be reduced. As a side effect a thinner insulation will also result in a faster conductance of heat generated in the copper wire to the cooling medium.
- The future cost reduction potential of basic materials used for high voltage insulation is limited: For motors there is a trend from glass backed to cheaper film backed mica tapes which also has a positive effect on the voltage endurance of the insulation. Much more cost effective are products with improved characteristics specially adapted for new processing technologies, see below.

## Processes:

- There is actually a strong trend to reduce cost by achieving a higher degree of automation eliminating handicrafts and increasing the manufacturing speed in the production of insulated coils or bars. To realise this, new or improved insulating materials have to be provided such as more robust mica tapes suitable for higher taping speeds or materials with shorter cure cycles to reduce processing times and energy consumption.
- For generators a trend towards the use of roebel bars also in smaller machines and hydro generators can be observed. 540°- or 720°-roebel bars are replacing the traditional 360°-roebel bars to minimize electromagnetic losses (in a 360°-roebel bar each conductor changes once its position in the stack, 540° and 720° resulting in 1.5 and 2 changes respectively).
- For motors up to 13.8 kV the loop winding technology offers a considerable cost saving potential. In this technology the main wall insulation is applied directly on the loop and the resulting flat coil is subsequently formed to a 3-dimensional coil. Applying the mica tape on the loop allows the use of simpler taping machines and higher taping speeds. Moreover the complete coil including the coilends can be insulated in one process. The forming of the coil is not a simple spreading but has to make use of more sophisticated forming machines (Figure 1). Of course the tape has to be designed to withstand the stress of the forming operation.

In the following, some examples of new insulating materials representing these trends are discussed in more details.



Figure 1: Coil forming machine for fully insulated flat coils

## CONDUCTOR INSULATION

A new mica based conductor insulating tape with reduced thickness was developed in order to achieve a higher output of motors with a given magnetic volume by enabling the use of a larger copper section. As additional benefit the thinner insulation provides an improved conductance of heat to the cooling medium. The specifications of the new conductor tape are given in table 1.

		<b>Standard</b>	<b>New</b>
Thickness	mm	0.10	0.06
Mass per unit area	g/m <sup>2</sup>	122	77
Mica paper (Samica <sup>®</sup> )	g/m <sup>2</sup>	75	30
PET film	μ	23	23
Binder content	g/m <sup>2</sup>	15	15
Breakdown voltage	kV	≥ 5	≥ 5
Pressed thickness per layer	mm	0.075	0.045

Like the standard quality the new conductor tape also has a hotmelt adhesive on the outside of the PET film which allows a fast consolidation of the stack in a coil press prior to taping.

In a field study a 450 kW 10 pole 6.6 kV aircooled motor was rewound. The stator winding was redesigned using the new Samicafilm<sup>®</sup> conductor tape. The rotor was restored keeping the original design. During a test run at 450 kW the temperature of the stator windings was measured at 58 °C which is significantly cooler than the 72 – 75 °C according to the design norm. Running at full load the motor capability was extended to 525 kW effecting 16.7 % increase in shaft power output and resulting in a stator winding temperature of 70 °C. This benefit is a direct consequence of the increased copper cross section, reduced current density and enhanced thermal conductivity of the thinner conductor insulation.

## CLASS H MAIN WALL INSULATION

In several publications the features of the class H VPI insulation system Samicabond<sup>®</sup> consisting of Samicapor<sup>®</sup> mica tapes and a polyesterimide based VPI resin have been presented and discussed (1, 2). A new family of mica tapes for main wall insulation was developed to be used together with the polyesterimide VPI resin. The new tapes are very robust in handling and can be easily applied even with less sophisticated taping equipment. In addition these tapes show excellent tan δ values at room temperature and at class temperature (180 °C). This is due to a new epoxy binder resin system. Specifications of the new tapes are given in table 2.

Many products are claimed to be class H without substantial test results taken under realistic conditions. Results given in Figure 2 show actual values of the new Samicabond<sup>®</sup> system measured during ageing under both electrical and thermal stresses applied simultaneously. In this test model bars with an insulation thickness of 3 mm were submitted to an electrical stress



- Mica based mastic and conductive mastic for interstice, Roebel crossover and gap filling. The conductive grade serves as internal corona protection.

The main feature of the new products is a curing cycle of 15 minutes at 120 °C. After this cycle a glass transition temperature of  $\geq 120$  °C is reached which is sufficient to provide mechanical and dimensional stability of the bar or coil for further handling. After the full curing cycle of 3 h at 160 °C the glass transition temperature will be above 150 °C and all fast curing products then meet class F requirements. The shelf life of the products is  $\geq 4$  months at room temperature. The reduction of processing time and saving of oven capacity and energy is substantial.

Typical properties of the rigid separator prepregs for the slot part are given in table 3.

<b>Table 3: Properties of Glasoflex® separator prepregs</b>			
		<b>Standard</b>	<b>Fast curing</b>
Thickness	mm	1.0	1.0
Mass per unit area	g/m <sup>2</sup>	840	855
Epoxy glass fabric	g/m <sup>2</sup>	270	270
Glass fleece	g/m <sup>2</sup>	2 x 50	2 x 50
Epoxy binder resin	g/m <sup>2</sup>	470	485
Curing conditions for mechanical stability		30 min / 160 °C	15 min / 120 °C
Pressed thickness	mm	0.35	0.40

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### **REFERENCES**

1. Rudolf Brüttsch, John Allison, Thomas Thaler and Franz Wolf, „The Importance of Ageing Tests in Assessing the Thermal Rating of High Voltage Insulation Systems for Rotating Machines“, Proceedings of the Coil Winding, Insulation and Electrical Manufacturing, Berlin 1997.
2. Rudolf Brüttsch, John Allison and Thomas Thaler, „Factors Determining Cost and Quality of the Electrical Insulation in the VPI Process“, Proceedings of the IEEE International Symposium on Electrical Insulation, Montreal 1996.