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Suitability of Nigerian Paper Products as Insulating Materials for High Temperature Machine Operations

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Abstract: Electrical insulating materials are required to maintain electrical and mechanical integrity sufficiently to prevent turn-to-turn or turn-to-ground shorts during operation, particularly at elevated temperatures. In this study, 10 sample varieties of Nigerian paper products were experimented upon to evaluate their suitability for use as electrical machine insulating materials for high temperature operations. Impregnated samples of the paper products were subjected to heat-run in a sealed industrial oven. The insulation resistance of each given sample was measured at regular temperature intervals, until the sample burns out. Tables show the values of weight, insulation resistance and temperature. Curves were plotted to show the variation of insulation resistance with temperature. From the results, all the paper samples could not produce insulation resistance above 8 MΩ at a temperature of 90°C while, at 110°C, they were all burnt. Thus, they are only suitable as electrical insulating materials for lower temperature operations, below 90°C.

Key words: Paper products, impregnation, insulation, samples, temperature, Nigeria

INTRODUCTION

Impregnated paper insulating materials are widely used in electrical industry-in transformers, cables, electric motors and small generators. It is therefore, necessary to have precise information about the limiting temperature of a given paper insulating material, as insulation failure is responsible for over 30% of electrical machine failures (Wiedenbrug, 2003). Singha and Thomas (2008), Tagami *et al.* (2008), Murakami *et al.* (2008), Takala *et al.* (2008) and Maity *et al.* (2008) examined the dielectric properties of nanocomposites as insulating materials and fillers in electrical machine systems. Suehiro *et al.* (2008), Swaffield *et al.* (2008), Okubo *et al.* (2008), Sarathi *et al.* (2008), Okabe *et al.* (2008), Koppisetty and Kirkici (2008) and Marzinotto *et al.* (2008) carried out investigations into the partial discharge characteristics and breakdown voltage-time pattern of some liquid and gaseous insulating materials. The behavior of insulating materials under different thermal and environmental conditions has become an important subject of investigation. For example David *et al.* (2007) used a DC ramp test to examine the dielectric response of a stator winding insulation, while, Ohki and Hirai (2007) examined the electrical conduction and breakdown properties of several biodegradable polymers.

Excessive temperatures can cause complete failure of insulation due to melting, softening or burning, resulting in machine failure. Nigeria, being a tropical country in the equatorial belt suffers from high ambient and environmental temperatures. This adverse thermal condition has contributed to the high level of industrial machine failures. The research, conducted with ten locally available paper materials is to determine the maximum permissible temperature for impregnated samples of each of the materials and thus, their suitability for use as insulating materials for electrical machines.

MATERIALS AND METHODS

The following study products/samples were used in the experiments;

- Carton paper
- Chiboard
- Emboss card
- Emboss wood
- Glossy paper
- Manila paper
- Newsprint
- Strawboard
- Sixty gram paper
- Eighty gram paper

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Table 1: Initial parameters of the paper samples

Paper products	Weight of samples (g)			Insulation resistance (MΩ)
	Before impregnation	Immediately after impregnation	After drying	
Carton paper	5.50	9.24	8.82	200
Chiboard	1.26	1.52	1.41	200
Emboss card	1.04	1.69	1.59	200
Emboss wood	1.29	2.16	1.88	200
Glossy paper	0.91	1.15	1.01	200
Manila paper	1.13	1.41	1.33	200
Newsprint	0.24	0.62	0.52	200
Strawboard	4.42	5.10	4.81	200
60 g paper	0.30	0.38	0.31	200
80 g paper	0.41	0.53	0.50	200

Table 2: Heat run and insulation resistance measurement of impregnated samples of the paper products

Paper product	30°C (MΩ)	40°C (MΩ)	50°C (MΩ)	60°C (MΩ)	70°C (MΩ)	80°C (MΩ)	90°C (MΩ)	100°C (MΩ)
Carton paper	150	125	100	70	40	24	8.5	1.0
Chiboard	150	125	100	70	40	25	8.5	1.0
Emboss card	150	125	100	75	50	30	8.0	-
Emboss wood	150	125	100	76	50	30	8.5	1.0
Glossy paper	150	125	100	70	40	25	8.0	-
Manila paper	150	125	100	75	50	30	8.0	-
Newsprint	150	112	75	46	20	12	4.0	-
Strawboard	150	125	100	65	30	20	8.0	-
60 g paper	150	112	75	52	30	17	4.0	-
80 g paper	150	112	75	57	40	23	4.0	-

Sample preparation: A sample was made from each of the paper products, measuring 10×5 cm. The thickness of each type of paper was maintained as manufactured in order not to alter the integrity of the paper material. The samples were immersed in hot insulating varnish for 15 h to assure a robust impregnation. The samples were slowly dried for 55 h. The weight of the samples before impregnation, immediately after impregnation and after drying, as well as the initial insulation resistance (at room temperature) of the dried samples are shown in Table 1.

Heat run: Each sample of the ten paper materials was subjected to heat-run in a sealed industrial oven. The insulation resistances of the samples were measured at regular temperature interval of 10°C until the given sample burns out. Table 2 shows the insulation resistance measurement of the paper materials during the heat-run.

RESULTS AND DISCUSSION

The variation of insulation resistance with temperature for the 10 paper samples are shown in Table 2. Analyzing Table 2 , it could be shown that for all the samples, the insulation resistance has a negative relationship with temperature. Higher temperature results in lower insulation resistance. Secondly, the relationship is non-linear for most of the samples.

Table 2 shows that 7 of the 10 samples-carton paper, Chiboard, emboss card, emboss wood, glossy paper, manila paper and strawboard had insulation resistances up to 8 MΩ at 90°C and so are suitable for use as machine insulating materials up to a temperature of 90°C. Three samples-newsprint, 60 g paper and 80 g paper had insulation resistance of 4 MΩ at 90°C and so are unsuitable for use as machine insulating materials at 90°C. However, from Table 2, it could be deduced that newsprint has an insulation resistance of 8 MΩ at 85°C, 60 g paper at 87°C and 80 g paper at 88°C. Thus, newsprint, 60 g paper and 80 g paper are suitable as insulating material up to the limiting temperatures of 85, 87 and 88°C, respectively.

CONCLUSION

The heat-run experiment showed that seven of the ten paper products-carton paper, chiboard, emboss card, emboss wood, glossy paper, manila paper and strawboard had insulation resistances up to 8 MΩ at 90°C and so are suitable as machine insulating materials up to 90°C while, newsprint, 60 g paper and 80 g paper have lower limiting temperatures of 85, 87 and 88°C, respectively, as their insulation resistances reached 8 MΩ at those temperatures.

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