International Journal of Electrical and Power Engineering 3 (4): 242-245, 2009
ISSN: 1990-7958

Suitability of Nigerian Cloth Fabrics as Insulating Materials for High Temperature Machine Operations

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Abstract: Two key requirements of electrical insulating materials are; high dielectric strength and non-varying characteristics, particularly at high temperatures. The study presents, an experimental study of twenty sample varieties of Nigerian cloth fabrics to evaluate their suitability for use as electrical machine insulating materials for high temperature operations. Impregnated samples of the cloth fabrics 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, eleven fabrics-Abada, Adire, Cashmier, Cord lace, Cotton, Galilia, George, Plain Guinea Brocade, Satin, Stone Wax and Tafeta, had insulation resistances up to 6 MΩ at 100°C, thus making them suitable machine insulating materials at temperatures not exceeding 100°C. The other nine fabrics-Ashoke, Global Lace, Hollandis, Intorica, London wax, Paper Lace, Poplin, Terelene and UNTL wax, whose insulation resistances were below 6 MΩ at 100°C had insulation resistances up to 8 MΩ at 90°C and so are suitable machine insulating materials at the limiting temperature of 90°C.

Key words: Cloth fabrics, impregnation, heat-run, samples, temperature, insulation resistance, dielectric integrity

INTRODUCTION

Cloth fabrics are cheap and sustainable sources of developing a broad material base for electrical machine insulation. However, it is important to evaluate their suitability for use as machine insulating materials for high temperature operations. High temperature is known to weaken and degrade the insulation integrity of insulating materials. Dissado *et al*. (2001), Mazzanti *et al*. (2001), Casalini *et al*. (2001), Li *et al*. (2004) and Chang *et al*. (2007) examined the influence of temperature on the dielectric dynamics and aging of insulating materials.

The behavior of insulating materials under different thermal and environmental conditions is an important subject of investigation. For example, Gerhold (2002), Husain *et al*. (2002), Ombello *et al*. (2002), Suzuki *et al*. (2002) and Toyota *et al*. (2002) examined the performance of insulating materials under cold and cryogenic conditions while, Bartnikas (2008), Gustavino *et al*. (2008), Hudon *et al*. (2008), Kikuchi *et al*. (2008) and Sharkawy *et al*. (2008) investigated the influence of ambient humidity, temperature and dielectric surfaces on the partial discharge characteristics of insulators. In their research, Denat (2006), Hanaoka *et al*. (2006), Hara *et al*. (2006), Nelson and Shaw (2006), Paraskevas *et al*. (2006), Perrier *et al*. (2006) and Shayegani *et al*. (2006), studied the dielectric behavior of insulating oils for transformer and outdoor operations. In their own contributions to the study of dielectric behavior of electrical insulating materials, Chandrasekar *et al*. (2009), Fuse *et al*. (2009), Shirasaka *et al*. (2009), Singha and Thomas (2009) and Ueta *et al*. (2009) investigated the breakdown characteristics of insulators and the influence of filler loading on the dielectric properties of nanocomposites.

Twenty sample varieties of Nigerian cloth fabrics were used in this experimental work. They were impregnated with high quality insulating varnish in order to improve their dielectric integrity. By subjecting the samples to heat-run, until they burn out, their maximum permissible temperatures can be determined with certainty.

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MATERIALS AND METHODS

The following cloth fabrics were used in the experiments.

- Abada (vegetable wax)
- Adire
- Ashoke
- Cashmier
- Cord lace
- Cotton
- Galilia
- George
- Global lace
- Hollandis
- Intorica
- London wax
- Paper lace
- Plain guinea brocade
- Poplin
- Satin
- Stone wax
- Tafeta
- Terelene
- United Nigerian Textile Ltd (UNTL) wax

Preparation of cloth samples: Each sample of the 20 types of cloth fabrics measured 10×5 cm. The thickness of each fabric was maintained as manufactured in order not to alter the integrity of the fabric. The samples were immersed in hot insulating varnish for 15 h to assure a robust impregnation. The samples were dried slowly, for 55 h. The weights 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 twenty cloth fabrics was subjected to heat-run in a sealed industrial oven. The insulation resistances of the samples were measured at regular temperature intervals of 10°C until, the sample burn-out.

Table 2 shows the values of temperature and the corresponding insulation resistance of the cloth samples during the heat-run.

Table 1: Initial parameters of samples of cloth fabrics

Cloth samples	Weight of samples (g) Before impregnation	Immediately after impregnation	After drying	Insulation resistance (MΩ)
Abada (vegetable wax)	0.70	1.21	1.17	200
Adire	0.53	1.01	0.92	200
Ashoke	2.40	3.68	3.46	200
Cashmier	1.08	1.51	1.39	200
Cord lace	1.55	2.40	2.36	200
Cotton	0.56	1.01	0.93	200
Galilia	0.57	0.92	0.87	200
George	0.65	1.21	1.15	200
Global lace	1.48	2.51	2.31	200
Hollandis	0.63	1.12	0.98	200
Intorica	0.77	1.20	1.16	200
London wax	0.36	0.83	0.63	200
Paper lace	0.73	1.32	1.30	200
Plain guinea brocade	0.58	0.99	0.91	200
Poplin	0.44	1.02	0.74	200
Satin	0.28	0.62	0.56	200
Stone wax	0.89	1.61	1.41	200
Tafeta	1.18	1.80	1.65	200
Terelene	1.04	1.50	1.45	200
UNTL wax	0.65	1.06	0.93	200

Table 2: Heat-run and insulation resistance measurement of impregnated samples of cloth fabrics

Cloth samples	30°C	40	50	60	70	80	90	100	110
Insulation resistance (MΩ)									
Abada (vegetable wax)	200	175	150	100	50	32	10	6	0.4
Adire	200	175	150	100	50	34	15	8	0.8
Ashoke	200	175	150	95	40	25	9	5	0.6
Cashmier	200	175	150	112	75	43	10	6	0.4
Cord lace	200	175	150	112	75	47	20	11	2.0
Cotton	200	175	150	112	75	47	20	10	1.0
Galilia	200	175	150	113	75	44	9	6	0.2
George	200	175	150	100	50	30	10	6	0.4
Global lace	200	175	150	100	50	30	8	5	0.3
Hollandis	200	175	150	95	40	25	9	5	0.2
Intorica	200	175	150	95	40	25	8	5	0.3
London wax	200	175	150	95	40	25	8	5	0.4
Paper lace	200	175	150	100	50	30	8	5	0.3
Plain guinea brocade	200	175	150	95	40	25	9	6	0.8
Poplin	200	175	150	112	75	40	8	5	0.2
Satin	200	175	150	100	50	32	15	8	0.3
Stone wax	200	175	150	100	50	30	10	6	0.5
Tafeta	200	175	150	112	75	42	10	6	0.6
Terelene	200	175	150	112	75	42	8	5	0.3
UNTL wax	200	175	150	100	50	28	8	5	0.2

RESULTS AND DISCUSSION

A close examination of the figures reveals that the variation is non-linear for the twenty fabrics. Secondly, the gradient of the curve becomes markedly low at high temperatures for all the samples. In addition, the relationship between insulation resistance and temperature is negative, as the slope is negative for all the samples. Higher insulation resistance is obtained at lower temperatures while, high temperatures, result in low insulation resistance. From Table 2, we can deduce that at the class Y limiting temperature of 90°C, all the cloths fabrics had insulation resistances up to and above 8 MΩ. In fact, four fabrics-Adire, Cord Lace, Cotton and Satin had insulation resistances up to 15 MΩ. Thus, they maintained higher dielectric integrity at the class Y limiting temperature than the other sixteen fabrics. At the higher temperature of 100°C, eleven fabrics-Abada, Adire, Cashmier, Cordlace, Cotton, Galilia, George, Plain Guinea Brocade, Satin, Stone wax and Tafeta had insulation resistances up to 6 MΩ. They are thus, suitable machines insulating materials at temperatures not exceeding 100°C. The other nine fabrics-Ashoke, Global lace, Hollandis, Intorica, London wax, PaperLace, Poplin, Terelene and UNTL wax, whose insulation resistances were below 6 MΩ at 100°C had insulation resistances up to 8 MΩ at 90°C and so are suitable machine insulating materials at the limiting temperature of 90°C.

CONCLUSION

Of the twenty cloth fabrics used in the experimentation, eleven-Abada, Adire, Cashmier, CordLace, Cotton, Galilia, George, Plain Guinea Brocade, Satin, Stone Wax and Tafeta are suitable machine insulating materials up to the limiting temperature of 100°C while, the remaining nine fabrics-Ashoke, GlobalLace, Hollandis, Intorica, London wax, Paper Lace, Poplin, Terelene and UNTL wax are suitable machine insulating materials up to a limiting temperature of 90°C.

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