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Determination of the Insulation Classification of Some Nigerian Wood Species

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Abstract: The insulation or dielectric circuit of electrical machines constitutes their weakest member, as copper and steel, the other chief constituents can withstand elevated temperatures. It is therefore, imperative to qualify electrical insulating materials thermally by determining their insulation class. In this study, twelve sample varieties of Nigerian wood species-Abeza, Afara, Agbagum, Aper, Bomba, Danta, Gameliana, Iroko, Mahogany, Obeche, Opepe and White wood were experimented with to determine their insulation classification. The samples were cut into definite dimensions and weighed. Each wood species was made into two samples; one sample was left in its ordinary state while, the other was impregnated with an insulating varnish. Both samples were subjected to a heat-run in a sealed industrial oven. The insulation resistance of each sample was measured at regular temperature intervals, until the sample burns out. The measured values of weight, insulation resistance and temperature are shown in tables. Curves were plotted to show the variation of insulation resistance with temperature. From the experiments, eight of the wood species-Danta, Afara, Obeche, Mahogany, Opepe, Abeza, Aper and Iroko can be used for class H insulation while, the other four species Gameliana, Agbagum, Bomba and White wood are suitable for class F insulation.

Key words: Insulation, wood species, dielectric cirucit, copper, heat-run

INTRODUCTION

The electrical insulation system of rotating machines must be constructed to endure both the electrical stresses and severe mechanical stresses induced by the magnetic field of the rotating rotor a mechanical problem of lesser degree in static apparatus. Another important feature of the insulation of rotating machines is that the multiple winding turns are constrained to the relatively narrow armature (or stator) slots, which are usually grounded. Thus, the mechanical forces on the insulation in the machine slots are very much greater. For example, Mayoux, Oraee, Nelson, Hudon and Crine examined the degradation of insulating materials under electrical stress and the problem of aging and life expectancy of motor insulation (Hudon *et al*., 2000; Mayoux, 2000; Nelson *et al*., 2000; Oraee, 2000; Crine, 2005). High quality insulating materials are expected to have; high dielectric strength, particularly at high temperatures, good heat conductivity, good mechanical properties, non-varying characteristics (permanence), particularly at high temperatures and be non-hygroscopic (Kyritsis *et al*., 2000; Hong *et al*., 2009a, b).

It is noteworthy that considerations of temperature predominate in these characteristics. Both copper and iron, the chief remaining materials employed in machine construction could be operated at temperature very much higher than is at present customary, without adverse effects, so that higher losses could be permitted and the amount of materials reduced. The limiting feature, is however the insulation, which is liable to deterioration at quite moderate temperature (Casalini *et al*., 2001; Li *et al*., 2004; Paraskevas *et al*., 2006). Insulating materials are classified thermally as Y, A, E, B, F, H and C. The allowable temperature for each of the classes are defined in NEMA, BSI and IEC standards. Table 1 shows, the maximum permitted temperature for each class.

The IEEE and IEC have developed practices and procedures for the thermal evaluation of insulation systems for electrical machines. It is important to keep moisture out of woven, fibrous or absorbent material, as the dielectric quality is enhanced by impregnating the material with an insulating varnish or similar substances (Perrier *et al*., 2006; Ali and Hackam, 2008; Lan and Gorur, 2008; Mohiddon and Yodov, 2008). The effect of temperature on the insulation of a machine is of great importance and is a limiting factor in design. In their research, Ishikawa, Lamarre, Rui-Jin, Nagata and Takala investigated the influence of ambient and operating temperatures on the dielectric properties and

Table 1: Temperature limits and insulation class

Insulation class	Y	A	E	B	F	H	C
Max permitted temperature (°C)	90	105	120	130	155	180	>180

The figures are based on a 20 years working life under average conditions aging of insulating materials (Kikuchi *et al.*, 2008; Lamarre and David, 2008; Rui-Jin *et al.*, 2008; Takala *et al.*, 2008; Ishikawa *et al.*, 2009).

The maximum permissible temperature for a class of insulating materials is that which gives an acceptable life for the machine where, the material is employed. Empirical studies show that over 30% of electrical machine failures result from insulation failure (Wiedenbrug, 2003). In this research, experiments were conducted with twelve Nigerian woods species by subjecting both the impregnated and unimpregnated samples to a heat-run and measuring their insulation resistances at regular temperature intervals until they burn out. Thus, their thermal insulation class can be established.

MATERIALS AND METHODS

The wood species used in the experimentation were:

- White wood
- Gameliana
- Mahogany
- Danta
- Afara
- Obeche
- Agbagum
- Opepe
- Bomba
- Abeza
- Aper
- Iroko

Preparations for the wood samples: Each sample of the twelve wood species measured 10×5×0.5 cm. Two samples were cut out from each wood species. One sample of each species was immersed in hot insulating varnish for 15 h to allow the sample to be properly soaked and impregnated with the varnish, while the second sample was left in its ordinary or natural state.

The impregnated samples were slowly dried for 3 days before the commencement of experimentation. 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 impregnated and unimpregnated samples are shown in Table 2.

Heat run: The two samples of each of the twelve wood species were subjected to a heat-run in a well-lagged industrial oven shown in Fig. 1. The insulation resistances of the samples were measured at regular temperature

Table 2: Initial parameters of wood samples

	Weight of samples (g)			Insulation resistances (MΩ)	
Wood species	Before varnishing	Immediately after varnishing	After drying	Impregnated	Unimpregnated
White wood	8.597	9.829	9.529	200	150
Gameliana	15.427	17.626	16.266	200	150
Mahogany	16.523	18.830	17.760	200	200
Danta	14.623	16.224	15.871	200	200
Afara	15.277	18.127	16.632	200	150
Obeche	28.367	31.276	30.176	200	150
Agbagum	13.573	15.286	14.670	200	200
Opepe	17.989	19.680	18.798	200	150
Bomba	7.299	9.830	7.330	150	50
Abeza	11.918	13.261	12.262	200	90
Aper	24.293	26.204	25.041	200	150
Iroko	14.649	15.000	14.710	200	150

Table 3: Heat run and insulation resistance measurement of wood samples

	30°C		50°C		70°C		90°C		110°C		130°C		150°C		170°C	
Wood species	V MΩ	nV MΩ	V MΩ	nV MΩ	V MΩ	nV MΩ	V MΩ	nV MΩ	V MΩ	nV MΩ	V MΩ	nV MΩ	V MΩ	nV MΩ	V MΩ	nV MΩ
White wood	200	150	180	150	150	110	100	80	75	50	30	20	15	10	6.0	4.5
Gameliana	200	150	180	150	150	100	100	75	75	40	30	15	15	9	6.0	5.0
Mahogany	200	200	180	150	150	100	110	75	80	40	40	20	15	11	8.0	5.5
Danta	200	200	200	200	180	150	140	100	90	75	40	30	18	13	9.0	7.0
Afara	200	150	180	150	150	100	110	80	75	60	30	20	15	10	8.0	6.0
Obeche	200	150	200	150	150	100	110	80	75	50	40	30	18	11	8.0	4.0
Agbagum	200	200	180	150	150	100	110	75	75	40	30	20	16	9	6.0	4.0
Opepe	200	150	200	150	150	100	130	80	80	50	40	30	18	10	9.0	4.0
Bomba	150	50	100	40	80	30	50	20	20	15	15	9	10	5	4.5	2.0
Abeza	200	90	200	90	180	75	150	50	80	30	40	18	15	10	8.0	5.0
Aper	200	150	200	150	180	120	150	80	100	50	50	30	20	15	9.0	8.0
Iroko	200	150	200	150	180	120	150	75	100	40	50	30	20	15	9.0	7.0

V: Varnished, nV: Non Varnished

Fig. 1: The inner chambers of the oven

interval of 20°C, until the given sample burns out. Table 3 shows the insulation resistance measurement of the wood samples during the heat run.

RESULTS AND DISCUSSION

Table 3 presents, a very interesting study. Apart from the bomba species, the rest 11 specie gave a good account of themselves, comfortably withstanding temperatures beyond 150°C. In fact, eight of the species Mahogany, Danta, Obeche, Afara, Aper and Iroko, at the temperature of 170°C had insulation resistance of 8 MΩ and above for the impregnated samples. From the curves, the eight wood species can very well be used for class H insulation, whose limiting temperature is 180°C. The remaining four species white wood, Gameliana, Agbagum and Bomba are suitable for class F insulation, since at the class F limiting temperature of 155°C, they had insulation resistances well above 8 MΩ.

This could be an opening key for self reliance in the quest of Nigeria and other developing countries to develop their material base for the insulation of machine windings, slots and coils. If these wood materials through some careful chemical synthesis can be made more malleable, these developing countries can reduce their dependence on imported insulating materials and save much foreign exchange.

At a more fundamental level, research has shown that the ambient or room temperatures in Nigeria (similar to other tropical countries) are adversely high. Most of the industrial and domestic drives in Nigeria are imported and many of the drive motors come with classes E and B insulating materials. These insulating materials would fail at room temperatures above 120 and 130°C, respectively. With motor ambient temperatures of between 33 and 47°C being common experiences in Nigerian industries, little wonder electric motors fail frequently in Nigeria even when, the motors do not undergo sustained overloading. There is a compelling need therefore to upgrade the class of insulating materials used in electric drive motors in Nigeria and other tropical countries to classes F, H and C. This research has shown that the eight wood species named earlier can serve this purpose and ensure that the electric drives remain stable in performance inspite of the high environmental temperatures encountered in the tropical countries. With these materials retaining high insulation resistance at these high temperatures, there would be a higher guarantee of long motor life and durability even when, operated at elevated temperatures.

CONCLUSION

The operating temperature of an electric motor is the sum of the ambient temperature and the temperature rise of the motor resulting from its loading. For an electric motor to operate at a high ambient temperature as experienced in Nigeria and other tropical countries and still have a long life span, its winding and slot insulation must have high thermal stability, implying the use of higher classes of insulating materials. The insulating material used in a given drive should be in such a class, whose limiting temperature is well above the possible hot-spot temperature of the drive, as the insulation represents the weakest constituent member of the motor. Hence, for optimum performance and long life span of electric drives in Nigeria, the minimum class of motor insulating materials should be class F. A viable solution to the upgrading of the insulation class of electrical machines in Nigeria and other tropical developing countries was provided through the heat-run experimentation with samples of twelve wood species. Danta, Afara, Obeche, Mahogany, Opepe, Aper and Iroko can be used for class H insulation, while Gameliana, Agbagum, Bomba and White wood are suitable for class F insulation.

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