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Suitability of Nigerian Wood Species as Insulating Materials for High Temperature Machine Operations

A.M.O. Obiazi, F.I. Anyasi and P.A. Otubu
Department of Electrical and Electronics Engineering,
Ambrose Alli University, P.M.B 14, Ekpoma, Edo State, Nigeria

Abstract: Tropical countries across Africa, Asia and America suffer from high ambient temperatures leading to high operating temperatures for electrical machines. Under this adverse temperature condition, it is taxing for insulating materials to maintain electrical and mechanical integrity sufficiently to prevent turn-to-turn and turn to ground shorts during operation. The study presents an experimental study of 10 sample varieties of Nigerian wood species to evaluate their suitability for use as electrical machine insulating materials for high temperature operations. Impregnated samples of the wood species 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, the 10 wood species Abeza, Afara, Agbagum, Aper, Danta, Gameliana, Iroko, Mahogany, Obeche and Opepe had insulation resistance above 6 MΩ at 170°C, thus, making them suitable as machine insulating materials for operations at temperatures not exceeding 170°C. Four of the wood species Aper, Danta, Iroko and Opepe had insulation reistance of 9 MΩ at 170°C. They are thus, more thermally stable and suitable wood insulating materials at the elevated temperature of 170°C than the other 6.

Key words: Wood, impregnation, temperature, insulation, samples, dielectric integrity

INTRODUCTION

The ability of an insulating material to maintain dielectric integrity at elevated temperatures has been a subject of research for many years. For example, Okubo *et al*. (2008) investigated the partial discharge activity in electrical insulation for high temperature super conducting cables while, Reddy and Ramu (2007) examined the intrinsic thermal stability in HVDC cables. Miyata *et al*. (2007) and Strachan *et al*. (2008) described the phenomenon of partial discharges in electrical machine insulation. David *et al*. (2007), Ohki and Hirai (2007), Singha and Thomas (2008) and Chen *et al*. (2008) have conducted investigations into the dielectric response of stator winding insulation; dielectric properties of epoxy nanocomposites; electrical conduction and breakdown properties of several biodegradable polymers and the effect of water absorption on the dielectric properties of epoxy nanocomposites, respectively.

Emperical studies show that over 30% of electrical machine failures result from insulation failure (Wiedenbrug, 2003), as the dielectric circuit of a machine constitutes its weakest member. Thus, the temperature response of a machine insulating material is of critical importance. High quality insulating materials are expected to have high dielectric strength, particularly at high temperatures, good heat conductivity and good mechanical properties. By using materials of higher permissible temperature, machines of the same physical size may be rated for greater power output (Say, 1985; Kosow, 1972). Quality insulating materials are expensive and for many developing countries, they are imported. This experimental heat run is an effort to develop quality insulating materials from renewable and cheap sources which, can be used for electrical machine operations at elevated temperatures. Thus, serving as viable alternative insulating materials to the imported ones. Ten wood species abundantly available in Nigeria were used in the experimentation.

MATERIALS AND METHODS

The following wood species were used in the experiments:

Corresponding Author: A.M.O. Obiazi, Department of Electrical and Electronics Engineering, Ambrose Alli University, P.M.B 14, Ekpoma, Edo State, Nigeria

Table 1: Initial parameters of the wood samples

Wood species	Weight of samples (g) Before impregnation	Immediately after impregnation	After drying	Insulation resistance (MΩ)
Abeza	11.95	13.31	12.28	200
Afara	15.32	18.22	16.64	200
Agbagum	13.55	15.33	14.66	200
Aper	24.24	26.25	25.05	200
Danta	14.63	16.28	15.89	200
Gameliana	15.51	17.68	16.29	200
Iroko	14.66	15.11	14.73	200
Mahogany	16.48	18.89	17.81	200
Obeche	28.42	31.31	30.20	200
Opepe	17.97	19.71	18.82	200

Table 2: Heat run and insulation resistance measurement of impregnated samples of the wood species

Wood species	30°C	40°C	50°C	60°C	70°C	80°C	90°C	100°C	110°C	120°C	130°C	140°C	150°C	160°C	170°C
	MΩ														
Abeza	200	200	200	190	180	165	150	110	80	55	40	26	15	11	8
Afara	200	190	180	165	150	130	110	92	75	51	30	22	15	12	8
Agbagum	200	190	180	165	150	130	110	92	75	52	30	23	16	11	6
Aper	200	200	200	190	180	165	150	125	100	75	50	35	20	15	9
Danta	200	200	200	190	180	160	140	115	90	65	40	30	18	14	9
Gameliana	200	190	180	165	150	125	100	88	75	53	30	22	15	11	6
Iroko	200	200	200	190	180	165	150	126	100	75	50	35	20	15	9
Mahogany	200	190	180	165	150	130	110	95	80	60	40	27	15	11	8
Obeche	200	200	200	178	150	130	110	93	75	58	40	30	18	13	8
Opepe	200	200	200	178	150	140	130	106	80	60	40	30	18	14	9

- Abeza
- Afara
- Agbagum
- Aper
- Danta
- Gameliana
- Iroko
- Mahogany
- Obeche
- Opepe

Sample preparations: A sample was made from each of the wood species, measuring 10×5×0.5 cm. The samples were immersed in hot insulating varnish for 24 h to ensure adequate impregnation. The samples were then slowly dried for 60 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: The impregnated samples of the 10 wood species were 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 each sample burns out. Table 2 shows the insulation resistance measurement of the wood species during the heat run.

RESULTS AND DISCUSSION

The values of the insulation resistance of the wood samples during the heat run as shown in Table 2 reveals an interesting performance by the wood species. The variation of the insulation resistance with temperature for the 10 wood species is shown in Table 2.

Table 2 reveal a non-uniform variation of insulation resistance with temperature for the 10 wood species. The curves show that below 50°C, the insulation resistance falls gradually with increasing temperature. Between 50 and 130°C, the fall of insulation resistance becomes more rapid and above 130°C, the fall again becomes gradual. Table 2 shows that all the 10 wood species had insulation resistance ≥6 MΩ at 170°C, thus, making them suitable insulating materials at that temperature. Four wood species-Aper, Danta, Iroko and Opepe had insulation resistance of 9 MΩ at 170°C. Thus, they are more thermally stable and suitable wood insulating materials at the temperature of 170°C than the other 6. The salient implication of this finding is that these 10 wood species, when impregnated, can be used as machines insulating materials for high temperature operations as they can stably withstand elevated temperatures up to 170°C. This would assist tropical and developing countries with adversely high ambient temperatures to develop a renewable and cheap material base for the insulation of machine windings, slots and coils.

CONCLUSION

For electrical machines to operate at high ambient temperatures as experienced in Nigeria and other tropical countries and still have long life span, its winding and slot insulation must have high thermal integrity and stability. The insulation should be able to stably withstand the hot-spot temperature of the machine. The heat run experimentation showed that the 10 wood species of Abeza, Afara, Agbagum, Aper, Danta, Gameliana, Iroko, Mahogany, Obeche and Opepe, when properly impregnated and dried can be used as machine insulating materials for operation at elevated temperatures up to 170°C.

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