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 paper, 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: Wood, insulation, impregnation, samples, species, temperature and 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 and 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 (Kyritis 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 b 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, and 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.

<table>
<thead>
<tr>
<th>Insulation class</th>
<th>Y</th>
<th>A</th>
<th>E</th>
<th>B</th>
<th>F</th>
<th>H</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max permitted temperature, °C</td>
<td>90</td>
<td>105</td>
<td>120</td>
<td>130</td>
<td>155</td>
<td>180</td>
<td>&gt;180</td>
</tr>
</tbody>
</table>

The figures are based on a 20year working life under average conditions.

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 Yadav, 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 work, Ishikawa, Lamarre, Rui-Jin, Nagata and Takala investigated the influence of ambient and operating temperatures on the dielectric properties and aging of insulating materials (Kikuichi et al., 2008, Lamarre and David, 2008, Rui-Jin et al., 2008, Takala et al., 2008, and 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 work, 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 10cm x 5cm x 0.5cm. Two samples were cut out from each wood species. One sample of each species was immersed in hot insulating varnish for fifteen hours 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 three 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 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 and Fig. 2(a, b, c and d) present a very interesting study. Fig. 2 are curves of the insulation resistance versus temperature for the impregnated samples of the twelve Nigerian wood species. Apart from the bomba species, the rest 11 species 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 8MΩ 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 8mΩ.
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°C and 130°C respectively. With motor ambient temperatures of between 33°C 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 its 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 hotspot 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.

<table>
<thead>
<tr>
<th>Wood species</th>
<th>Weight of Samples (g)</th>
<th>Insulation Resistances (MΩ)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before varnishing</td>
<td>Immediately after varnishing</td>
</tr>
<tr>
<td></td>
<td>Impregnated Unimpregnated</td>
<td>Impregnated Unimpregnated</td>
</tr>
<tr>
<td>White wood</td>
<td>9.597</td>
<td>9.829</td>
</tr>
<tr>
<td>Gameliana</td>
<td>16.523</td>
<td>18.830</td>
</tr>
<tr>
<td>Mahogany</td>
<td>15.277</td>
<td>18.127</td>
</tr>
<tr>
<td>Danta</td>
<td>25.376</td>
<td>27.127</td>
</tr>
<tr>
<td>Obeche</td>
<td>20.376</td>
<td>21.127</td>
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<tr>
<td>Agbagum</td>
<td>13.573</td>
<td>15.286</td>
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<tr>
<td>Opepe</td>
<td>17.989</td>
<td>19.680</td>
</tr>
<tr>
<td>Bomba</td>
<td>7.299</td>
<td>9.830</td>
</tr>
<tr>
<td>Abeza</td>
<td>11.918</td>
<td>13.261</td>
</tr>
<tr>
<td>Aper</td>
<td>24.293</td>
<td>25.204</td>
</tr>
<tr>
<td>Iroko</td>
<td>15.649</td>
<td>15.080</td>
</tr>
</tbody>
</table>
REFERENCES


