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Full Length Research Paper

Assessment of the Quality of Cables produced in Nigeria

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The need to carefully assess the quality of electrical cables to ascertain it meets the required standard is highly important because it seeks to determine the mechanical and electrical properties and behaviours of cables prior to usage. To a large extent it also helps in avoiding hazards as a result of low or poor quality products. In this work, cable samples were collected from five (5) Wire and Cable companies in Nigeria. The samples were subjected to quality, uniformity and other tests. This was done to determine the conformity to the available standards. The conformity of the wire and cable tested were justified by t-test and both 90% and 95% confidence levels.

Keywords: Cables, Wire, t-test, confidence level, standards, assessment, quality.

INTRODUCTION

The assessment of the quality of electric wires and cables is important as it seeks to evaluate the quality, make up and properties of wires and cables that will serve safely and efficiently, the lighting appliance and equipment needs of various households, industries and society at large. It is essential that electrical cables and wires meet-up to the required standards, quality and specifications so that installations will be highly efficient, convenient, adequate for good service and free from electrical hazards. The necessary requirement if a cable is that it should conduct electricity efficiently, cheaply and safely.

The past years have witnessed a significant elevation of indigenous electrical wire and cable companies with new ones springing up. This increase in status is the result of progression of activities from a “craft” level to the present day requirement and ever increasing demand from industries and the society. Thus, there is need to carefully assess their product in order to ensure it meets the specified standard of its regulation agencies. It is based on this fact this assessment is done to carefully evaluates the quality of wire and cable produced in Denki Wire and Cable limited, Akure; and indigenous company which specializes in the manufacture of wire and cable for diverse purposes.

Electrical wires are electrical conductor in form of a slender rod while electrical cables are conductors which consist of two more insulated wires grouped together in an overall covering (Stauart, et al., 2000). Wire and cables are made from highly conducting metals namely copper and aluminum, an insulating materials mainly polyvinyl chloride and overall protector. Therefore, a cable has four main parts – the conductor, insulation, the mechanical protection (Jacketing) and the filler materials which may not be present in all electrical cables. Copper is widely used for making electric cables because it is very ductile i.e. can be drawn into than wires and after silver, it is the best metallic conductor of electricity. Also, aluminum is used in making overhead electric cables because it is light and has good conducting property.

Polyvinyl chloride (PVC) also known as polycholodifluroethene is used as an insulating material in cable covering after it is specially treated and hardened to accommodate some degree of heat from the wire and cables. Copper and aluminums are electrical conductors which provide paths for the flow electric current over which an insulating material is formed. Insulation is a non current carrying material which ensures that the current flow will be through the wire (Floyd, 1996).

This is the resistance of a cable with unit length and unit cross-sectional area. (Steve et al., 2000). The resistance of a conductor depends on the followings: nature of the material; the temperature of the sample; and the size of the samples (length and cross-sectional area). In many cases, the changes in resistance with temperature is so small that it can be ignored except under extreme conditions.

Mathematically, R α L and R α 1/A ,

Where L is the length and A is the cross-sectional area. Putting these two relationships together gives

$$R = \rho \frac{L}{A} \quad (1)$$

The constant of proportionality P is the resistivity of the material measured in ohm metre (Ωm).

Generally, cables comprise of four materials namely, conductor materials, insulation, mechanical protector and filler materials. Copper and aluminum are the materials used as conducts in power and lighting cables. Copper has lower resistivity and this higher conductivity than aluminum. This means that copper conductors have small cross sectional area and take up less space than aluminum for the same current capacity. On the other hand, aluminum has about one third the weight of copper hence it is light and suitable for use.

Copper conductors can be annealed or hard drawn. Annealed copper conductors are comparatively soft and pliable and are most suitable for indoor and outdoor wires and cables laid or fixed position. Hardware copper conductors which have a very high tensile strength are used as over head wires mainly in the bare form with some insulating materials but not all copper conductors used to be turned. The respective resistivity of copper and aluminum are 17.51Ω mm and 28.51Ωm respectively suggesting that copper allows better passage of electricity than aluminum.

According to Sieve et al (2000), electrical conductivity is a measure of the extent to which a material will allow current to flow easily through it when a potential difference is applied at a specific temperature. It is the reciprocal of resistivity, given as σ = 1 / P, where σ and P are conductivity and resistivity respectively.

The rate at which metals conduct electric current, is a function of its resistance to the flow of current. The higher its resistance, the lower is conductivity and the lower the rate of current flow and vice versa. This is given by ohm's law:

$$I = \frac{V}{R} \quad or \quad I = \frac{E}{R + r} \quad (2)$$

Where I is the main current, V is the applied voltage, R is the combined resistance, r is the internal resistance and E is the electromotive force. The terminal potential difference is given as V = E – IR. According to Keith (1990), the quantity Q of electric current I, that passes through a metallic conductor for a time t, is given by the relation Q = It. And the electrical work done when electricity flows from one point to another is

$$W = IVt \quad (3)$$

The amount of electrical work done is called electrical power, given as

$$P = I^2R \quad (4)$$

The insulator must be able to withstand the applied voltage and also any transient over voltage which may occurs. The function of insulation is such to prevent leakage of current in unwanted directions and thus to minimize risk of fire and shock. To this end, insulation normal work. Insulation is arranged to surround the conductor through its length, (Steward et al., 1998).

It entails running of cables with further protection such as wire, armouring, layer of galvanized iron or compounded jute to prevent its failure in services. The larger cables used for underground work and for large interior or power installation may be mechanically protected in various ways. Unarmoured cable may be run without further protection than lead sheathing. A further protection is one or two layers of compounded juke laid over lead sheath. Amoured cables included single wire armouring, double lane armoring and double steel armouring. For underground cables, wire armouring is used where the ground is liable to subsistence, to prevent cables from breaking, whereas steel tape armouring is needed where physical damage from stones or workman's tool may be expected, (Floyd, 1996).

These are cables that are used for carrying electrical power through overhead lines. It is used for power distribution and transmission. These are used where there is high power demand most especially in industries or estate. Overhead electric poles are generally 8m in length with some 7 m out of the ground. The choice of cables to be used is informed by the purpose and area to which it is to be used.

MATERIALS AND METHODOLOGY

The following design tests was carried out on cable in order to ascertain that it meets the required standard and also to enable that it will perform satisfactorily in service: length, area and diameter measurement; voltage test; heat shock test; tensile strength elongation test; hot deformation / pressure test; and insulation resistance

Table 1. NIS Standard Values for Cables and their Properties

Cross sectional (mm^2)	Diameter (mm)	Radial thickness of insulation (mm)	Cable resistance at 20^0C (Ωmm)	Resistivity 20^0C (Ωmm)	Shear Thickness (mm)
1.00	1.30	0.70	18.30	$2.15 X 10^{-7}$	0.90
1.50	1.38	0.70	13.30	$2.0 X 10^{-7}$	0.90
2.50	1.78	0.8	7.41	$1.85 X 10^{-7}$	1.00

Table 2. Data for 1.5 mm^2 –core

No of samples collected	Cross sectional (mm^2)	Diameter (mm)	Resistance Ω	Resistivity Ωm
1	1.40	1.34	13.80	$1.90 X 10^{-7}$
2	1.40	1.34	13.80	$1.93 X 10^{-7}$
3	1.50	1.38	12.30	$1.99 X 10^{-7}$
4	1.50	1.38	13.30	$1.99 X 10^{-7}$
5	1.50	1.38	13.30	$1.99 X 10^{-7}$
6	1.50	1.38	12.70	$2.03 X 10^{-7}$

Table 3. collected properties for 2.5mm^2 3 – core

No of samples collected	Cross sectional (mm^2)	Diameter (mm)	Resistance Ω	Resistivity Ωm
1	2.40	1.75	7.80	$1.87 X 10^{-7}$
2	2.50	1.78	7.41	$1.85 X 10^{-7}$
3	2.50	1.78	7.41	$1.85 X 10^{-7}$
4	2.50	1.78	7.41	$1.85 X 10^{-7}$
5	2.60	1.82	7.02	$1.83 X 10^{-7}$
6	2.60	1.82	7.02	$1.83 X 10^{-7}$

test.

According to the Nigeria Industrial Standard (NIS), a coil of cable is expected to be 100 meters in length. Ten (10) cables of each category were randomly selected and lengths measured between two ends to ensure its length meets the required specification. Other measurements include; diameter, which was done using micrometer screw gauge and the area, calculated using equation (5) or (6).

$$A = r^2 \cdot \pi = \frac{d^2 \cdot \pi}{4} \approx 0.7854 \cdot d^2 \quad (5)$$

$$d = 2 \cdot \sqrt{\frac{A}{\pi}} = 2r \approx 1.1284 \cdot \sqrt{A} \quad (6)$$

Nigeria Industrial Standard has different values, each parameter is expected to at least fall within the range, otherwise such cable is regarded as poor quality product which have great tendency to fail in services.

The method employed in this work include: personal visit to the companies, physical assessment of the samples, collection of data from quality control departments, collection of different cables size samples and conduction of tests on these cable sample sizes. The following tests were carried out on the samples: Voltage Test; Heat Shock Test; Tensile Strength/Elongation Test; Hot Deformation/Pressure Test; Insulation Resistance Test; and Cable Resistance Test. The cable samples used include: 1 – core 2.5 mm^2**;** 2 – core 1.5 mm^2**;** and 3 – core 2.5 mm^2**.**

The data collected was used to test for the quality of the wires and cable using t-test. The t-distribution statistical approach is preferred because of the small nature of the samples gotten and unknown sample mean value.

RESULTS AND DISCUSSION

The standards for cables and wire as given by Nigeria Industrial Standard (NIS, 2009), is presented in Table 1.

The collected data from one of the companies are given in Tables 2 to 4.

Due to the limited samples, the t-distribution statistical

Table 4. collected properties for 2.5mm^2 – core

No of samples collected	Cross sectional (mm^2)	Diameter (mm)	Resistance Ω	Resistivity Ωm
1	2.40	1.75	7.80	1.87 X 10^{-7}
2	2.50	1.78	7.41	1.85 X 10^{-7}
3	2.50	1.78	7.41	1.85 X 10^{-7}
4	2.50	1.78	7.41	1.85 X 10^{-7}
5	2.60	1.82	7.02	1.83 X 10^{-7}
6	2.60	1.82	7.02	1.83 X 10^{-7}

Table 5. Resistance for 1.5mm^2 2 – Core

No of samples	Measured Resistance (Ω)	/X – X/	/X – X/^{2}
1	12.70	0.66	0.440
2	13.30	0.06	0.0036
3	13.30	0.06	0.0036
4	13.03	0.06	0.0036
5	13.80	0.44	0.1936
6	13.80	0.44	0.1936

Table 6. Result summary compared with standards

SAMPLE	NIS STANDARD FOR RESISTANCE	NIS STANDARD FOR DIAMETER (mm)	POPULATION MEAN OF RESISTANCE (Ω) AT 95% CONFIDENCE	STANDARD DEVIATION OF DIAMETER (MM) AT 95% CONFIDENCE
1.5mm^2 2 - CORE	12.30	1.38	13.00 – 13.60	1.835 x 10^2 – 7.21 x 10^{-2}
2.5mm^2 3 - CORE	7.41	1.78	7.11 – 7.50	1.44 x 10^{-2} – 5.66 x 10^{-2}
2.5mm^2 1 - CORE	7.41	1.78	7.12 – 7.60	1.99 x 10^{-2} – 2.4 x 10^{-2}

approach was used in testing for the quality of the cable samples at 90% and 95% confidence levels. Since quality of a product is a measure of its population mean, thus t-distribution is used to predict the population mean from sample mean. Sample of the calculation is shown in Table 5, using resistance for 1.5mm^2 2 – Core as example.

$\sum X$ = 80.2 , $\sum /X – X/^2 = 0.838$

$$\bar{X} = \frac{\sum x}{n} = 13.36\ \Omega, \qquad S = \sqrt{\frac{|X-\bar{X}|^2}{n-1}} = 0.409\ \Omega$$

At 90% confidence level

1 – α = 1 – 0.95 = 0.05, and α/2 = 0.025 , where: t0.05.5 = 2.015

13.000 ≤ μ ≤ 13.60Ω

Similarly for 90% confidence

13.00Ω ≤ μ ≤ 13.400Ω

This procedure was repeated for all others sizes the results are as follows:

2.5mm^2 3 – Core

At 95% confidence level, 7.1035Ω ≤ μ ≤ 7.500Ω and at 90% confidence 7.1035Ω ≤ μ ≤ 7.600Ω

For 2.5mm^2 1 – Core

At 95% confidence 7.1231 Ω ≤ μ ≤ 7.600, also at 90% confidence 7.01Ω ≤ μ ≤ 7.800Ω

The process was repeated for other parameters. The summary is given in Table 6.

DISCUSSION OF RESULT

The sample mean of the six cable samples which represents the sample average was found to be 13.360Ω. However, the population mean of the resistance measured is calculated to be minimum of 13.0Ω and maximum of 13.40Ω at 90% confidence level. At a higher confidence level of 95%, the sample mean is calculated is fall within the range of 13.0Ω and 13.60Ω.

Comparing the value of the population mean gotten at both levels of confidence with Nigeria Industrial Standard (NIS) which is 13.0Ω, this value of the resistance according to NIS falls within the range of the calculated mean for both levels of confidence, that is, minimum of 13.40Ω at 90% confidence level. At a higher confidence level of 95% it also fall within the range of 13.0Ω and 13.60Ω. As the confidence tend to approach the standard value better.

The sample mean of the resistance measured was found to be 7.35Ω, and the standard deviation is 2.93 X 10^{-2}Ω. At 90% confidence, the population means was found to be minimum of 7.00 Ω and maximum of 7.60 Ω. Similarly, at 95% confidence the population mean of the resistance was found to be minimum of 7.10 Ω. The NIS value for the cable size is 7.41 Ω which fall within the ranges of the minimum and maximum values of the population mean for both confidence level. As the confidence level increase, the calculated value of population mean approaches the NIS value.

The sample mean of the resistances measured found was found to be 7.41 Ω, and the standard deviation is 3.48 X 10-2 Ω. At 90% confidence, the population mean was found to be minimum of 7.01 Ω and maximum of 7.80 Ω. Similarly, at 95% confidence, the population mean of the resistance was found to be minimum ,of 7.12 Ω and maximum of 7.60 Ω. The NIS value for the cable size is 7.41 Ω which fell within the ranges of the minimum and maximum values of the population mean for both confidence level. As the confidence level increases, the calculated value of population mean approaches the Nigeria Industrial Standard (NIS) value.

The sample mean of the cable diameter for the six samples is 1.37mm and the standard deviation is found to be 2.94 X 10-^{2}mm. The standard deviation of the cable for the population deviation of the cable diameter for the population was found to be minimum of 1.97 X 10^{-2}mm and maximum of 6.14 X 10^{-2}mm at 90% confidence. Similarly at 95% confidence level the population standard deviation was found to be minimum of 1.85 X 10^{-2}mm and maximum of 7.21 X 10^{-2}mm. Thus, it is observed that the deviation in the uniformity of diameter for the samples gotten from the value prescribed by the Nigeria Industrial Standard (NIS) which is 1.38mm was very small, almost negligible for both levels of confidence.

The sample mean of the cable diameter for the six samples is 1.79mm and the standard deviation is found to be 2.31 X 10^{-2}mm. The standard deviation of the cable diameter for the population was found to be minimum of 1.55 X 10^{-2}mm and maximum of 4.88 X 10.$^{-2}$mm at 90% confidence. Similarly, at 95% confidence level, the population standard deviation was found to be minimum of 1.44 X 10^{-2}mm, and maximum of 5.66 X 10^{-2}mm. Thus, it is observed that the deviation in the uniformity of diameter for the samples gotten from the value prescribed by Nigeria Industrial Standard (NIS) which is 1.78mm was very small, almost negligible for both levels of confidence.

The sample mean of the cable diameter for the six samples is 1.83mm and the standard deviation is found to be 3.19 X 10-^{2}mm. The standard deviation of the cable diameter for the population was found to be minimum of 6.75 X 10^{-2}mm and maximum of 2.10 X 10^{-2}mm at 90% confidence. Similarly, at 95% confidence level, the population standard deviation was found to be minimum of 1.99 X 10^{-2}mm, and maximum of 2.4 X 10^{-2}mm.

Thus, it is observed that the deviation in the uniformity of diameter for the samples gotten from the value prescribed by the Nigeria Industrial Standard (NIS) which is 1.78mm was very small, almost negligible for both levels of confidence.

CONCLUSION

After tests and measurements have been carried out on the quality and uniformity of cable samples with the results statistically analyzed, the following conclusions were drawn: Cable sizes of 1.5 mm^2 2 – cores are of good quality and highly uniform in diameter, because the contains the Nigeria Industrial Standard value of the cable resistance with little deviation. Furthermore, the diameters are highly uniform in dimension with almost negligible deviation when it values were compared with required standard. Thus, this cable size is said to have good quality of low resistance which permits good flow of electric current. Cable sizes of 21.5 mm^2 2 – core are equally of good quality with low resistance and high uniformity in diameter because the range of its population mean meets up to the required standard as given by the Nigeria Industrial Standard (NIS) value for cable resistance and diameter respectively with little variation. Furthermore, the cable overall dimension is uniform with almost negligible deviation. Thus, this cable size will permits good flow of electric current and perform satisfactorily in service without failure. Cable sizes of 2.5 mm^2 1 – core are of good quality product as evidenced in its uniformity in diameter and characteristic low resistance. The range of its population mean contains the Nigeria Industrial Standard value of the cable resistance and diameter with little deviation. Thus, this cable size is said to have a good quality of low resistance which will efficiently conduct electric current and uniformity in dimension. It can be truly said that the electric cable produced by Nigeria wire and cable are good quality cables that will perform satisfactorily in service and that the cables are manufactured in line with the required standard as given by the Nigeria Industrial Standard, though there is still room for much improvement.

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