Determination of Tensile Strength and Dielectric Strength In XLPE Power Cables Using Acoustic Emission Technique

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Abstract

Cables are an integral part of the power transmission and distribution network. As the voltage level increases, amount of insulation used in the cable increases. Therefore a need arises for a material with better insulation characteristics to be used in cables. The overall strength of cable depends on many factors such as aging, thermal effects and stress developed. In this work, the failure of conductor is determined by investigating its ability using a Non Destructive Method for detection and monitoring the strength and stiffness. For different mechanical properties, the dielectric strength of various Cross linked polyethylene (XLPE) cable were analyzed. Finally, a comparison is made between the result of measurement and the actual value of the pure specimen. The results describes that the development of Acoustic Emission (AE) technique is to evaluate the performance degradation of power cables and identify the pin-point location of initial damage during tension which ensure the integrity and safety of the underground power lines on laying. These tests are most important in high voltage applications and its maintenance. Also, it is observed that before the breakdown these cables have the ability to elongate at a range of 150\% to 200\%.

Keywords : XLPE cables; Tensile strength; Acoustic Emission; Failure, Elongation.

1. Introduction

Electrical power cable is made either by Aluminum or copper its testing includes type test, acceptance Test, routine Test. In order to investigate the strength of cable acceptance test via. Tensile test, Wrapping test, routine test, conductor resistance test, High voltage test and Insulation resistance test are important [1]. These tests shall be carried out between conductors and screen. The test shall be carried out in a required voltage at room temperature. A cable conductor is often subjected to pull from one end during laying, installing and manufacturing hence it should be strong enough to tolerate the pulling force as well [2-4]. Hence it becomes necessary to ensure that the conductor material has sufficient tensile strength as per IS: 10810 (Part 37)-1984 [5-7]. Currently, once the cable has reached its lifetime estimate, the cable is replaced, whether it needs to be or not [8-10].In this paper, Investigation of tensile strengths of various Aluminium conductors in XLPE power cables are analysed using Acoustic Emission Technique.

2. Experimental Setup for Tensile Test

Tensile Testing Machine is an automatic machine, with two end grips properly designed to hold the conductor with sufficient strength so that the conductor cannot slid by any means during the test [11]. The machine has 100 Ton capacity to apply required tension during test. The
experimental set up is shown in Fig.1. For continuous monitoring of entire system, two Acoustic Emission (AE) sensors are mounted both sides of the cables.

**2.1 Specification of AE System**

| AE Inputs   | : 4 channels |
| Input Impedance | : 50 ohms |
| Frequency Response | : 10 KHZ, 2.1 MHZ, 1.0 dB |
| Noise MinimumThreshold | : 18dB AE |
| Maximum Signal Amplitude | : 100dB AE |
| Dynamic Range | : Less than 82 dB |

**3. Preparation of specimen using Nano powder**

Six number of single core XLPE cables with various cross section Aluminum conductors are studied under tensile testing. These are consisting of 19 wires in each cable. An attempt is made to add filler material namely, Aluminium dioxide (Al₂O₃) with insulating material to improve additional dielectric strength and mechanical properties in the cable insulation. Aluminium dioxide is also known as Alumina which consists of high thermal conductivity and conduct electricity easily. It has very hard and wear resistant in nature. Its melting point is around 2072°C. The preheated Alumina nano powder of size 150 microns is fed into vortex of the molten aluminium which is placed inside the coke fired graphite crucible at 250°C and mechanical stirring takes place [12,13]. Once the nano powder is mixed with molten metal this metal matrix composite (MMC) is poured into proper die and allowed to solidify. After solidified in order to make electrical conductor, the larger rods with 0.500 inches are drawn through the series of smaller dies to reduce the rod to wire of the desired diameter [14-16]. The quality of the electrical conductor is depends on wire drawing followed by annealing process to temper the Aluminium. The cross section area of the conductor desired its stiffness. In this experiment, the square plate with 150mm x 150mm x 20mm is prepared using shaping machine. Then the square plate is made into six number of required shape specimen dimensions with 140mm x 30mm x 7mm. The incorporation of Aluminium with Alumina is merged in three steps with the ratios viz. 1.800kg: 150g, 1.450kg: 250g and 1.220kg: 350g respectively. The various specimens used in this experimentation is shown in Fig.2. The samples are prepared as per ASTMD 638 - 08 for tensile properties of plastics. The optimum results of three specimens are shown in Table.1.
Fig:1 Universal Testing machine with AE set up

Fig:2 Various specimen used for tensile test

**Table 1.** Results obtained from tensile test with the addition of Alumina

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Weight % of Al₂O₃ Particulates (gms)</th>
<th>Peak Load (KN)</th>
<th>Yield Stress (MPa)</th>
<th>Ultimate Tensile Strength (MPa)</th>
<th>Percentage of Elongation %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>150</td>
<td>7.44</td>
<td>48</td>
<td>62</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
<td>8.205</td>
<td>53</td>
<td>68</td>
<td>4.66</td>
</tr>
<tr>
<td>3</td>
<td>350</td>
<td>9.45</td>
<td>65</td>
<td>79</td>
<td>5.33</td>
</tr>
</tbody>
</table>
Fig: 3 Tensile strength of Aluminium alloy with 250g Alumina

Fig: 4 Various AE graphs of Aluminium alloy with 350g Alumina
4. Results And Discussion

The investigation of the mechanical behavior in the conductors and its tensile tests were carried out using computerized uni-axial universal testing machine. Three specimens were used for the test and its corresponding obtained value is reported. The tensile properties such as ultimate tensile strength, yield strength and % elongation are noted and the graphs were plotted in Figures 3 & 4. It is clear that the fracture strength of conductors is increasing gradually at 150, 250 & 350 gms of Alumina powder. Moreover, it is indicated that the tensile strength increases with increase in amount of reinforcement, while there is decrease in ductility with increasing amount of reinforcement. Increase in strength is possibly due to the thermal mismatch between the metallic matrix and the reinforcement, which is a major mechanism for increasing the dislocation density of the matrix [17]. However, the conductor materials exhibit lower elongation than that of unreinforced specimens. It is obvious that plastic deformation of the mixed soft metal matrix and the non-deformable reinforcement is more difficult than the base metal itself. As a result, the ductility of the conductor drops down when the amount of reinforcement increases. Microstructure was visualized using an optical microscope. For this, three specimens were cut down into small cuboids shapes after that, these samples were grind on different grit size papers sequentially. After grinding, the specimens were mechanically polished by alumina paste and then etched by Keller’s reagent to obtain better contrast. The specimens were visualized on different magnifications (50X and 200X) to show the presence of reinforcement and its distribution on the metal matrix. The microstructure of all the samples is shown in Fig.5. The distribution of Al₂O₃ particles in a matrix alloy is fairly uniform. The average size of Al₂O₃ particles is around 30nm-50nm. The shape of most Al₂O₃ particles is irregular in nature. It is found that as the percentage of reinforcement increases the area fraction also increases as shown in optical micrograph. It also observed that there is increase in hardness and wear resistance this can be attributed to the increase in interfacial bonding of reinforcement with the aluminium matrix alloy. Good interfacial bonding can be obtained by pre-heating of Al₂O₃ particulates before adding in the matrix. It is also further observed that the electrical resistivity, relative conductivity and current carrying capacity were increased due to the usage of nano powder which is identified by the obtained AE graphs at various power and voltage level.

5. conclusions

Aluminium based metal matrix composites have been successfully fabricated by stir casting technique with fairly uniform distribution of Aluminium oxide particulates. The results confirmed that stir formed Al alloy 6061 with Al₂O₃ reinforced composites is clearly superior to base Al alloy 6061. Strength of prepared composites both tensile and yield was higher in case of composites, while ductility of composites was less when compared to as cast 6061Al. Further,
with increasing wt% of Al$_2$O$_3$, the tensile strength shows an increasing trend. Dispersion of Al$_2$O$_3$ particles in aluminium matrix improves the wear resistance of the composites. Addition of Alumina particles tends to decrease the wear rate. It was revealed that the hardness of composite increased with increasing the weight percentage of Al$_2$O$_3$ particles. The present work showed that the damage analysis of composite specimens using AE is possible. Failure can be viewed at early as 50% of failure load using various major AE parameters. Heat treatment of the metal matrix composites at different temperature range and quenching media like water, oil and brine solution etc. can be used to achieve better results. Using this approach, one can use Aluminium as conductor in any power distribution field instead of copper conductors for obtaining more economic attraction and better performance under high voltage level.

Nomenclature

- AE - Acoustic Emission
- MMC - Metal Matrix Composite
- XLPE - Cross Linked polyethylene
- NDT - Non Destructive Technique

References


