ISSN 2348-1218 (print)
International Journal of Interdisciplinary Research and Innovations ISSN 2348-1226 (online)
Vol. 3, Issue 4, pp: (57-60), Month: October - December 2015, Available at: www.researchpublish.com

Indigenization of Mineral Insulated Cable for Heaters

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Abstract: **This paper elaborates simple and efficient technique to manufacture mineral insulated cable indigenously. At present very few industries in India are manufacturing this type of cables. These cables are very important for power and signal transmission in high temperature environment. It is equally important to make thermocouples also. We have made an attempt to manufacture mineral insulated cable indigenously of 12mm OD, 2 cores for power application.**

Keywords: **MI Cable, MgO, swaging, annealing.**

I. INTRODUCTION

Mineral Insulated (MI) cable is a variant of electrical cable of metallic sheath and mineral insulation between the conductors. This cable is also known as Mineral Insulated metal sheathed cable(MIMS) or Pyro Cable (based on the name of the manufacturer of this cable, M/s Pyrotenax UK). The requirement of MI cable is growing day by day because it is the only alternative in high temperature applications, mainly in Nuclear Reactors, Fire Alarm Systems, Thermocouples, Oil Refineries, Furnaces, Heaters, Power Station etc. Normally the core temperature of Breeder reactors will be in the range of 400°C to 500°C. The signal transmission of neutronic sensor is impossible without MI cable. Normally, magnesium oxide (MgO) is used as insulation to separate the conductors as well as to insulate between the conductor and the outer sheath. We have used copper conductor and copper sheath because copper has a pure anti-ferromagnetic property thereby resulting in negligible electromagnetic interference during signal transmission. For the insulation, we have used MgO due to its superior dielectric withstandability and high temperature tolerance even though it is highly hygroscopic. During the selection of dielectrics, electrical resistivity of the insulation was studied at operating temperature with specified density. High electrical resistivity infers better insulation resistance. So thermal conductivity of the insulation was also taken as an important criteria during insulation selection.

II. COMPARATIVE STUDY ON INSULATION AND MECHANICAL PROPERTY OF MgO

Basically, Insulation resistance of a dielectric will depend upon total leakage current. Increase in leakage current offer low IR whereas low leakage current provides high insulation resistance with better dielectric withstandability. At any instant, the total leakage current is the sum of displacement or capacitive current, resistive or conductive current, surface leakage current and polarization current. During the insulation design, the effect of all specified four current components was minimized by optimizing the required parameter of the dielectrics. Coefficient of thermal expansion was chosen as minimum as possible within the operating temperature to avoid thermal stress on the metal sheath. Density of the dielectric was increased as high as possible to provide better compactness which will also increase the dielectric strength. Modulus of rupture was also studied properly to ensure effective swaging (this operation crushes the mineral blocks).

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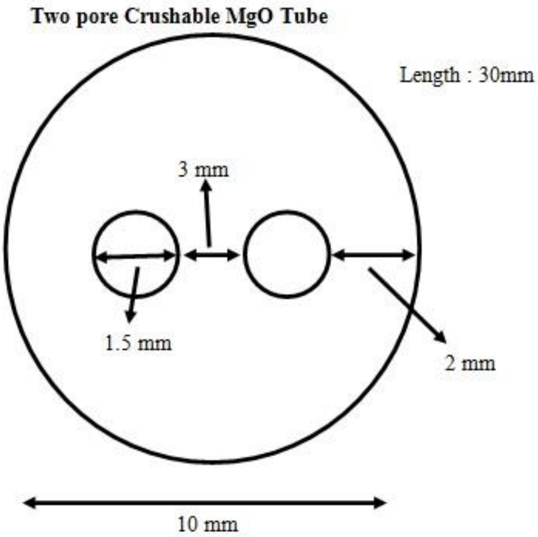
III. DEVELOPMENT OF CRUSHABLE MgO BLOCK

Crushable MgO blocks were made using high quality steatite, also known as soapstone. Basically, it is a type of metamorphic rock. These MgO blocks are medium-hard so that it can be crushed easily. The chemical composition was chosen to obtain excellent thermal shock and better heat resistance. The electrical breakdown value and leakage resistance was studied and the results are in agreement with the requirement of MI cable to be used in PFBR. Geometry and photo of the MgO block used for our application is given below.



IV. MANUFACTURING PROCESS DURING THE DEVELOPMENT

Slightly higher diameter tubes and conductors was taken during development. The conductors will be inserted into the copper tube and it will be properly spaced in the sheath pipe using crushable mineral insulation blocks. These MI blocks will provide insulation between the conductors as well as with the sheath wall. The electrical, dielectric, mechanical properties of MI blocks was studied to confirm the specification criteria mentioned in ASTM E585 and E1652. The sequential manufacturing process is pointed below:

A. ***Cleaning of tubes:*** Cleaning of the copper tubes which will be used for outer sheath is very important because presence of moisture or impurities will cause significant deterioration of insulation, dielectric properties of MgO. They are scrubbed inside using isopropanol to remove any traces of dirt and oil. A snapshot is given below.

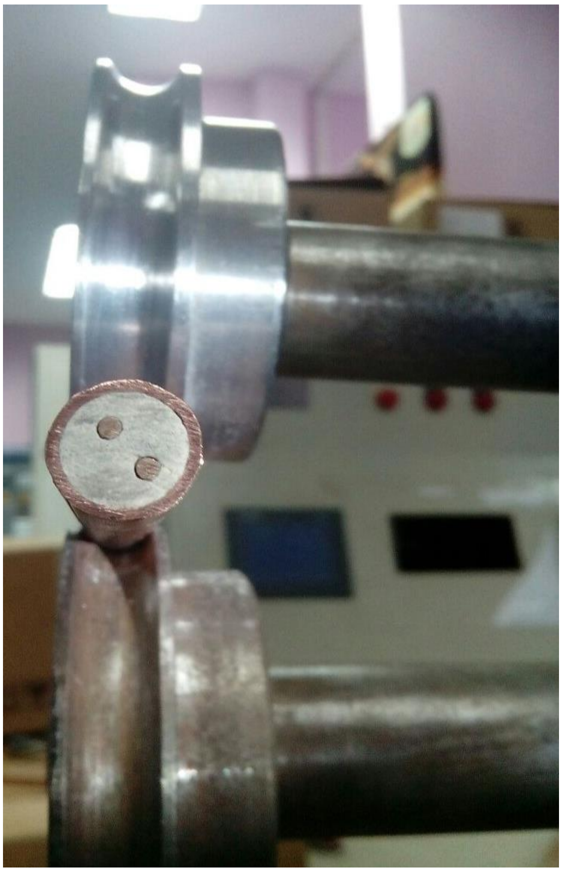
B. Filling: Next, the two copper conductors which are going to be inserted into MgO are also cleaned with isopropanol. Once cleaning is done, the two conductors are inserted into a chain of MgO blocks of the required length. Now they are inserted slowly into the copper tubes.

C. Swaging: The next important process in manufacturing is swaging. Swaging is done in order to uniformly distribute the mineral insulation inside the copper tubes along with achieving the uniformity of the outer diameter of the tubes. At our facility, we have designed a swaging setup which takes care of the above requirement. Two circular dyes are introduced using which we achieve crushing of MgO blocks as well as maintaining the uniformity of the tube. The two dyes are stacked on top of each other thereby facilitating a circular provision for insertion of copper tubes. Once this assembly is powered up, the copper tubes are to be inserted multiple times within the circular enclosure. After about 5 such repetitions, the MgO blocks are crushed and the tubes are checked for uniformity.

D. Annealing: Annealing is a metallurgical procedure which involves heat treatment. Due to swaging and drawing of copper tubes, the atoms get disarranged resulting increasing of hardness and brittleness of the tubes. Hence they cannot be used in site applications. To overcome this, annealing is preformed which rearranges the atoms back to their original form thereby reducing the hardness of the tube and making it ductile. Annealing is done by heating the metal at above of its recrystallization temperature and cooling it. This ensures the metal of its original properties. After completion, the ends of the tubes are covered with non-hydroscopic polymeric seal thereby making the MI cable ready for use in industrial applications.

V. CONCLUSION

Using the above method, we have successfully developed mineral insulated cable of 12mm OD of two core which qualifies all the electrical requirements. A finished cable we have developed is shown below,



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