A COMPOSITE ELECTRICAL INSULATION IN SUPERCONDUCTING MAGNETS

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ABSTRACT

A composite electrical insulation tape has been developed for superconducting magnets in high-energy particle physics experiments. It is composed of glass-cloth(s)/polyimide-film (Upilex) laminations bonded with epoxy resin. The polyimide film provides optimum performance in electrical insulation and the glass-cloth contributes to reliable mechanical bonding of the superconductor to the other components. Reliable mechanical bonding is also essentially important to realize reliable conductive cooling in a superconducting magnet indirectly cooled by using forced two phase helium flow in cooling tube attached to the coil structure. The optimization has been made in the process of the lamination with some treatment on the polyimide surface and with optimized epoxy resin to realize the best mechanical bonding. This paper will describe development of the composite electrical insulation, including brief test results.

INTRODUCTION

Glass-fiber cloth pre-impregnated with epoxy-resin has been widely used as a composite electrical insulation in various electrical industrial products. It is very convenient because of its flexible condition before curing and to provide good electrical insulation as well as mechanical bonding. However, the pre-impregnated epoxy-resin usually has voids remaining after curing and it is necessary to keep thicker insulation to eliminate local electrical breakdown due to the void.

According to recent advances in superconducting magnets especially in indirect cooling magnet, thinner and more reliable insulation has been required to get better thermal conduction and better mechanical bonding as well as excellent electrical insulation. In order to optimize those characteristics, advanced composite electrical insulations have been developed. They consist of multi-layers of glass cloth and polyimide film (Upilex) in combination with pre-impregnated epoxy-resin. The glass cloth pre-impregnated with epoxy-resin may provide good mechanical bonding, and the polyimide film may provide superior electrical insulation characteristics.

Two kinds of composite insulation have been developed. One consists of two layers of glass-cloth pre-impregnated with epoxy-resin and of a single layer of polyimide (Upilex) film at the center. It is so called "GUG", and has been developed mainly for ground insulation. Another design consists of the single layer of the glass-cloth pre-impregnated with epoxy-resin and another layer of the polyimide film (Upilex) coated with pre-impregnated epoxy-resin. It is so called “UG”. It has been developed mainly for turn-to-turn insulation. Those insulations have been used in a prototype thin solenoid [1] and in the BELLE superconducting solenoid for KEK-B project [2]. It is also planned to be used in the ATLAS solenoid in the LHC project at CERN [3].

DEVELOPMENT OF THE COMPOSITE ELECTRICAL INSULATION

Figures 1 shows the cross sectional views of the developed composite insulations of GUG and UG. Their characteristics are summarized in Table 1 and their fabrication is described as below.

Glass-Upilex-Glass (GUG) Insulation

The glass cloth, which is treated with silicone coupling agent to improve the mechanical bonding strength and the thickness is about 0.05 mm, is impregnated with a modified epoxy resin by “a dipping tower machine”. This epoxy resin is modified with high molecular weight polymers as two-dimensional linear polymer to get the high mechanical bonding strength and good handling. This impregnation of glass cloth is carried out continuously. The glass cloth is passed through a vat containing very low viscosity epoxy resin, which is dissolved in organic solvent such as methyl-ethyl-ketone, dried to remove only the solvent from the glass cloth and control the prepreg stage by heated hot air in this machine. After that Upilex was laminated by using hot pressure rolls with these two glass cloth prepregs, the resin becomes a little sticky B-stage. We have chosen this GUG sandwich fabrication to get the higher mechanical bonding strength, because the glass cloth prepreg indicates better mechanical bonding more than resin film only. This Upilex is also treated by “the corona treatment” to improve the mechanical bonding strength.

Upilex-Glass (UG) Insulation

This hybrid tape is made by almost the same method as GUG. But the glass cloth thickness is about 0.03 mm. The polyimide film is coated on one side with the modified epoxy resin by “a knife-coating machine”. The epoxy coated Upilex is laminated with the glass cloth prepreg. We have chosen this UG design, which is made thinner by eliminating one glass prepreg to get the higher heat conduction than GUG, to cool down the coil indirectly by using forced two phase helium flow.