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M1Or2C-01: [Invited] Dielectric Strength under Shear Stress of Insulating Materials for Fusion Superconducting Magnet

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The dielectric strength of insulating materials was studied under shear stress to evaluate the insulation performance of rectangular conductor coils for fusion reactor. Particular attention was paid to the problem of insulating properties under stress.

In this study, dielectric strength of glass cloth reinforced epoxy under shear stress was measured at room and liquid nitrogen temperature. For the measurement of dielectric strength, first, a dielectric strength test was performed in the parallel to the reinforcement cloth. The sample geometry is a double-notch shear specimen. By compressing the specimen, the inter-laminar shear failure was induced. The dielectric strength in the parallel to the reinforcements was measured by digging holes from both sides of the sample and the insulation strength of the remaining thickness was measured. The reason for digging the holes is to reduce the dielectric breakdown voltage and to prevent creeping discharge. The dielectric strength was measured under the shear stress by compressing the specimen.
In this direction, the growth rate of the mechanical defect was fast, and the crack was introduced from the bottom of the notch, leading to total fracture almost simultaneously. This is because the cracks propagate through the inter-laminar region in this mechanical tests. Concerning the dielectric strength, we have observed that the dielectric strength began to reduce at lower stresses than macroscopic mechanical defects (visually detectable defects) were introduced. The phenomenon was observed not only at room temperature but also at liquid nitrogen temperature. Examination of the discharge path revealed that the discharge path was along the yarn. It was considered that the discharge path was formed by connecting micro-cracks at the interface between the glass filament and the resin accompanying the deformation of the yarn.

A similar test was performed in the direction perpendicular to the reinforcements. Mechanical tests in this direction showed serrations where the stress decreased with the introduction of matrix cracks. This is because the mechanical test in this direction requires the cracks to travel across the reinforcement cloth. The breakdown voltage decreased due to the introduction of cracks into the matrix or subsequent crack opening due to stress. Even if dielectric breakdown occurs, the sample did not lead to the total mechanical destruction. This is because the fibers withstand the stress even if the matrix cracks were introduced.

These phenomena mean that the dielectric withstand voltage of the insulating material is lowered by external stress. The stress level where the dielectric withstand voltage begins to decrease is lower than the mechanical breaking stress of the insulating material. These phenomena could be considered to provide a notion for the insulation design of fusion superconducting magnets.

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Keywords: insulating materials, glass fiber reinforced plastic, dielectric strength under shear stress.

Author: Prof. NISHIJIMA, Shigehiro (Fukui University of Technology)

Co-authors: Prof. IWAMOTO, Akifumi (National Institute for Fusion Science); Prof. YAMANAKA, Atsuhiko (Nagoya University); Dr UTOH, Hiroyasu (National Institutes for Quantum Science and Technology); Prof. TAKAHATA, Kazuya (National Institute for Fusion Science); Dr HIRAI, Masaaki (Arisawa Mfg. Co., Ltd); Prof. NOMURA, Naoki; Prof. IMAGAWA, Shinsaku (National Institute for Fusion Science); Prof. SUNAGAWA, Takeyoshi (Fukui University of Technology); Prof. AKIYAMA, Yoko; Mr TODA, Yoshihiko (Arisawa Mfg. Co., Ltd); Mr TOYAMA, Yoshikatsu (Shoritsu Kogyo Co., Ltd); Dr SAKAMOTO, Yoshiteru (National Institutes for Quantum Science and Technology)

Presenter: Prof. NISHIJIMA, Shigehiro (Fukui University of Technology)

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