§1. Study on Electrical Insulation under Practical Condition of a Superconducting Coil Operation

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1. Introduction

A superconducting coil of LHD is exposed to various stresses, such as a thermal, electrical or mechanical one. The LHD coil should be stably operated even under these stresses. In this project, the authors studied electrical insulation under practical coil operation conditions. This year, special efforts were made to clarify [1] degradation process of a solid insulation system by partial discharge (PD) generated in a void and [2] electrical breakdown phenomena in pool boiling liquid helium that is contaminated with metallic particles. Data obtained in this project would be useful for electrical insulation design of LHD coils in Phase II, in which HeII will be employed as liquid coolant as well as electrical insulation medium.

2. Results

2.1 Solid insulation degradation by void PD under transient surge stress [1]

Dc superconducting coils used in the LHD are energized by power source equipments which contain a lot of power electronics circuits such as an inverter. Transient surge voltages, which are generated by the inverter circuit, may influence PD characteristics and resultant electrical degradation process of solid insulation system. In this study, PD characteristics within an artificial air-filled void contained in a solid insulator are experimentally investigated under superimposed sinusoidal voltages of 60Hz and 600Hz at liquid nitrogen temperature (77K) in order to clarify the effect of distorted sinusoidal voltages on PD mechanisms. The results show that PD charge magnitude remarkably decreases and PD occurrence frequency noticeably increases with the decrease in temperature from 298K to 77K. As a result, total PD charge per unit time is almost constant independent of temperature (Fig. 1). This mechanism is discussed by taking the effect of residual electric field into consideration. At 77K, PD occurrence frequency increases with the 600Hz component of the superimposed sinusoidal voltage while PD charge magnitude seems to be independent of applied voltage waveform with a constant wavelength.

2.2 Effects of conducting free particles on breakdown characteristics of pool boiling liquid helium [2]

In Phase II of the LHD project, superfluid liquid helium (HeII) will be employed as liquid coolant as well as electrical insulation medium. HeII has several superior properties to normal liquid helium (HeI) such as lower cooling temperature or higher thermal conductivity. We have investigated bubble formation process in the presence of free conducting particle in liquid helium to understand electrical insulation environment in pool cooled superconducting devices under particle contamination conditions. Experiments were conducted with dc stressed parallel plane electrodes containing a free metallic spherical particle of 1mm radius in saturated normal and saturated superfluid helium. Experimental results show that a single bubble is always generated at the moment of particle collision with the electrode and bubble behavior depends strongly on the state of liquid helium. The bubble expanding and shrinking processes were analyzed on the basis of energy balance among released electrostatic and kinetic energies of the particle at the moment of particle collision with electrode, kinetic energy of liquid driven by bubble growth, work done on environmental pressure and internal energy of bubble gas. The analysis shows a fairly good agreement with experiments.

References

1) Kurihara, T., Tsuru, S., Imasaka, K., Suehiro, J. and Hara, M., IEEE Trans. on. Dielectrics and Electrical Insulation **8**, (2001) 269
2) Nakagawa, H., Shinohara, T., Suehiro, J. and Hara, M., Proc. of Research Meeting on Electrical Discharge (in Japanese), ED-02-23 (2002) 35

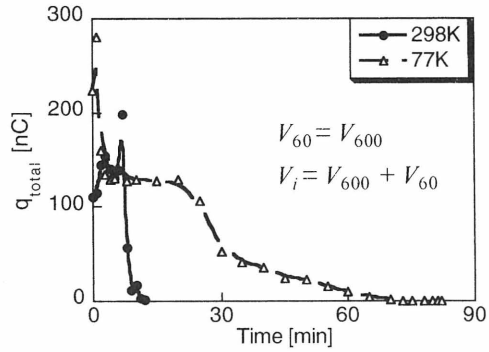

Fig. 1. Temporal variation of partial discharge (PD) charge per second. V_i is PD onset voltage, V_{60} and V_{600} are voltage magnitude at 60Hz and 600Hz respectively.

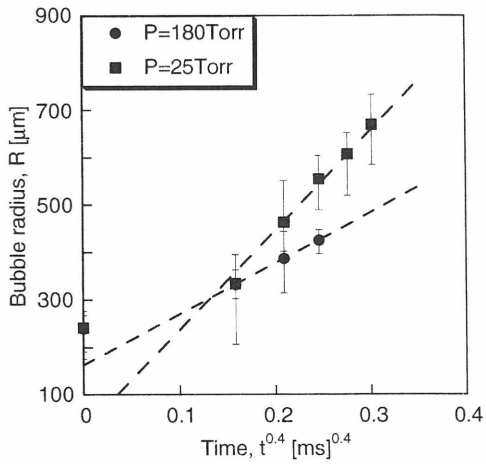

Fig. 2. Bubble radius *vs.* $t^{0.4}$ at the early stage of bubble growth measured at *P*=180Torr (HeI) and *P*=25Torr (HeII).