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ScienceDirect
Fusion Engineering and Design 81 (2006) 2577–2582
Fusion Engineering and Design
www.elsevier.com/locate/fusengdes

Flashover characteristics along spacer at cryogenic temperature influenced by minute gaps between spacer and electrode

Atsushi Minoda [a,*], Masayuki Nagao [b], Takehiro Ishizuka [b], Yoshinobu Murakami [b], Naohiro Hozumi [b], Shuichi Yamada [c]

[a] *Matsue National College of Technology, Nishi-ikuma, Matsue 690-8518, Japan*
[b] *Toyohashi University of Technology, Tempaku, Toyohashi 441-8580, Japan*
[c] *National Institute for Fusion Science, 322-6 Oroshi, Toki, Gifu 509-5292, Japan*

Available online 1 September 2006

Abstract

The electric insulation of the large-scale helical device (LHD) consists of the composite insulation of the liquid and spacer. It is very important from a point of superconducting device protection to elucidate surface flashover characteristics along the spacer in liquid. If a minute gap exists between an electrode and a spacer, the electric discharge in a minute gap will serve as a trigger of flashover, it means that the possibility of reducing the flashover voltage becomes high.

We measured the flashover voltage of liquid nitrogen (LN_2) and liquid helium (LHe) along the cylindrical small gap spacer sandwiched between parallel plane electrodes.

The flashover voltage decreased with the decrease of the voltage rising rate when the voltage polarity of the electrode adjacent to the minute gap was negative, but the flashover voltage was almost constant with a decrease of the voltage rising rate when the voltage polarity of the electrode adjacent to the minute gap was positive.

Keywords: Composite insulation; Minute gap; Flashover; Liquid nitrogen; Liquid helium; Spacer

1. Introduction

The world's largest class superconducting coil is used for the large-scale helical device (LHD) [1–3]. Its electrical insulation system might be exposed to considerably severe multiple stresses including cryogenic temperature, large mechanical stresses and strong magnetic fields [4,5]. If a superconductor quenches from the superconducting state to a normal state, the liquid coolant vaporizes very easily and turns into high-density gas at cryogenic temperature, which may reduce its withstanding voltage.

It is therefore very important to study its electrical insulation performance to establish the reliability of the coil. On the other hand, it is very difficult to completely remove minute gaps between the spacer and electrode

* Corresponding author. Tel.: +81 852 36 5208; fax: +81 852 36 5208.
E-mail address: minoda@matsue-ct.ac.jp (A. Minoda).

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doi:10.1016/j.fusengdes.2006.07.022

from the insulated space. If a minute gap exists, the electric discharge in a minute gap will serve as a trigger of flashover [6,7], it means that the possibility of reducing the breakdown voltage becomes high. So it is required to clarify the influence of minute gaps and electrification on the insulation performances.

In this paper, the flashover voltage along the spacer was measured using the electrode system which contains the minute gaps.

2. Experimental procedure with minute gap

In the flashover test with a minute gap, the electrode system used is shown in Fig. 1. The two mirror-finished copper disc electrode of 60 mm diameter consist of the parallel electrodes. A spacer inserted between the parallel electrodes is glass fiber reinforced plastic (GFRP) of G11 equivalent with the relative dielectric constant of 5.1. The diameter of the spacer (φ) was 30 mm and the thickness (t) was 1 mm. The surface roughness of the spacer was measured to be the root mean square value of 0.002 mm.

The spacer was sandwiched between the parallel electrodes as closely as possible to avoid gaps (see Fig. 1(a)). As a minute gap of 0.1 mm provided by cellulose paper was inserted between the spacer and upper electrodes (see Fig. 1(b)).

The sample was immersed in LN_2 and the dc voltage of positive polarity with the increasing rate of 400 V/s was applied to the high voltage electrode. In order to avoid the tracking on the spacer surface at flashover, the current limiting resistor 100 MΩ was used and the power was interrupted instantaneously after the breakdown. According to the visual examination there was no trace of damage on the spacer after the flashover.

The electrode system was set in a doubly shielded cryostat made of glass so that the flashover sites can be observed around the electrodes from the outside.

3. Experimental in LN_2 and LHe

In the flashover test in LN_2 and LHe, the electrode system used is shown in Fig. 2. The configurations of the high voltage (HV) electrode-spacer-minute gap-ground (GND) electrode (i.e. electrode adjacent to the minute gap is negative) or HV-minute gap-spacer-GND (i.e. electrode adjacent to the minute gap is positive) were subjected to the experiments.

The measurement of the flashover voltage was performed in LHe and LN_2. After the electrode system

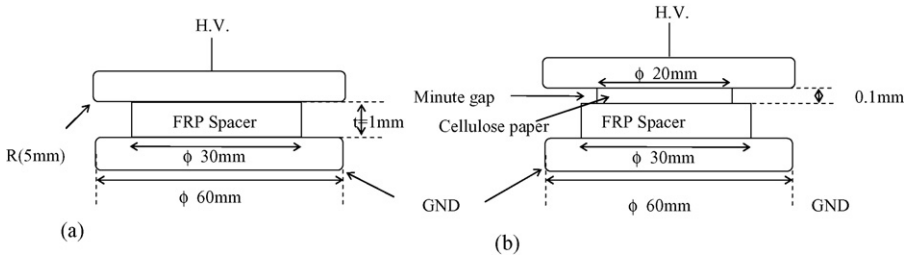

Fig. 1. Electrode system: (a) without gap; (b) with minute gap.

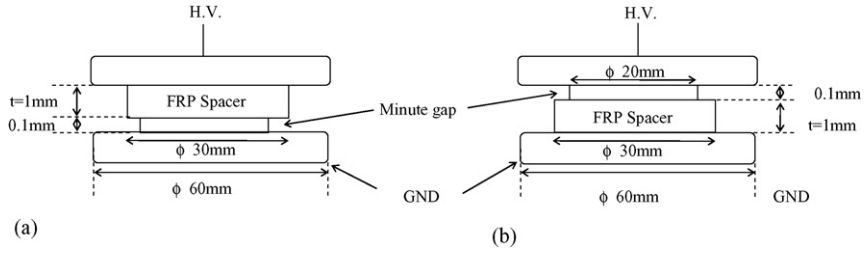

Fig. 2. Electrode system: (a) minute gap exists on GND side; (b) minute gap exists on HV side.