Fretting Resistance of Insulation on the ITER Magnet Feeder Busbars

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Outline

• Brief overview of the feeders
• Insulation specification of the Feeders
• Aims of Test & Overview of Testing Apparatus and Specimen
• Results -
• Conclusions
Brief Overview of Feeders

- 31 separate ‘feeders’ to supply the magnets with electrical current, cryogens and instrumentation

- Length from 20 m to 30 m.
- Weight ~50 tonnes.
- Current carried by superconducting bus bars with lap joints. HTS current leads for transition to room temperature bus bar.
Feeder Current Carrying Elements

Cylindrical bus bars

Lap joints (‘twin-box joint’) with rectangular cross section

Current leads, largely cylindrical but with cone sections and helium cooling pipes
Feeder and Insulation Specifications

- Feeder bus bars, joints and current lead cooled by a forced flow of helium at 4 K, in vacuum
- The total length of each busbar + joints is ~ 20 m & 44 or 22 mm dia. The bus bars shaped before applying insulation
- Insulation to 30 kV including Paschen test
- Insulation is 9 half lapped layers of 0.25 mm S-glass pre-preg & and 0.025 mm polyimide plus one half-lapped glass layer as at start and finish of insulation
- Conducting veil included as a ground screen before wrapping final two pre-preg layers
- 2 mm radial clearance between clamps and busbar
Aims of Test

Aim: To simulate operational conditions of insulation and assess insulation performance:

- Insulated bus bar supported in clamps
- During cool-down, the bus bar will slide in the clamps by up to 30 mm - ITER is designed for 100 cool-downs
- In operation, the bus bar will slide up to 5 mm in the clamps at each of design 30,000 pulses
- The machine is designed for 30000 pulses
- During operation a large Lorentz force on the bus bar (15kN per clamp) is reacted through the clamps
Overview of Test Apparatus
Specimen for Test

Specimen 1 after test
Results

Results are considered under three separate headings:

- (a) Wear on insulation
- (b) Estimate of Friction Factor
- (c) Electrical Characteristics
Specimens After Test

Specimen #1 and clamp after 60,000 cycles

Specimen #2 and clamp after 60,000 cycles
Note presence of wrinkle

Specimen #3 and clamp after 60,000 cycles
Typical Test Results – Specimen # 3

The magnitude of the up-stroke force is generally larger than the down-stroke force – reason is not completely clear.

The axial forces are increasing slightly with cycle number

Average of up-stroke and downs-stroke coefficient of friction (COF) ranges from 0.2 to 0.4.
Wear on insulation

Wear is confined to pre-preg capping layers

Variation in fretting results
Electrical Characteristics

- Two specimens (#3 and #4 - fitted with integrated ground-screens) were evaluated before & after mechanical testing.
- Resistance was measured between the steel thread and the veil ground-screen at 1 kV DC for 1 minute.
- The insulation resistance of #3 was found to be 2 x 10^9 Ohms.
- #4 was found to be 1.8 x 10^9 Ohms exceeding the ITER requirements.
Electrical Characteristics (2)

- The specimen geometry did not permit a breakdown test
- Partial discharge measurements showed large surface discharges (>2 nC) & were limited to 10 kVrms for a period of 30 minutes
- PD signal did not increase over the duration of the test, indicating that the electrical performance of the insulation was maintained.
Conclusions

- A series of fretting tests on insulation specimens representing the ITER feeder busbars showed that:
  - Wear varied between specimens, but was small & confined to the outer two pre-preg layers.
  - High voltage insulation was intact electrically after the fretting test.
  - Friction force used to derive an approximation for the coefficient of friction in the range of 0.2~0.4.

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