New inspection method of joint resistance at room temperature for ITER TF Coil

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1. Background

The ITER TF coil consists of several superconducting conductors wound to D-shape, called as double-pancake (DP). The adjacent DPs are electrically connected via joints. This joint resistance (Rj) should be sufficiently small such as several nano-ohm. The soundness of Rj is confirmed by full size joint sample (FJSJS) test performed in National Institute for Fusion Science (NIFS), in addition to the severe process control during the joint fabrication. However, it is of course more effective if the soundness of real TF joints can be confirmed directly. This will be able to reduce the risk of high Joule heating at joint in TF coil operation. However, Rj measurement on TF coil is not practical from viewpoint of schedule and cost because huge equipment to cool down the whole of TF coil to 4 K is necessary in terms of huge mass and size of TF coil.

2. Objectives

- Development of the simple inspection method for real TF joint, which enables to detect some abnormality in the joint at room temperature.
- Investigation of the validity and sensitivity of this developed method.

3. ITER TF Joint

- Joint Configuration
  - The joint boxes, which consists of explosion bonded copper sole and stainless steel box, are assembled at the both ends of DP
  - The cable, which consists of 900 superconducting and 522 copper strands, is inserted into the joint box. Then the cable is compacted from the void fraction of 33 % to 25 %.
  - After completion of the joint box fabrication, the joint is heat treated with the DP to react superconducting materials. Then, the adjacent joints are electrically connected by soldering between the copper sole.

4. Inspection Method

- Joint resistance (Rj)
  - Rj should be below 3 mΩ in ITER TF joint.
  - As Rj is considered to be sufficiently small and Rc can be controlled by process control and visual check during the soldering, these are not significant issues.
  - In contrast, it is impossible to check the soundness of Rj, although there is possibility that Rj may be sensitive to even slight contamination through manufacturing process.
  - Thus, as there is uncertainty in Rj, we focused on development of inspection method of Rc.

5. Results

- Measurements were performed for seven real TF joints and NIFS FSJS before excitation.
- As Rj, could be measured in NIFS FSJS, soundness of TF joints could be confirmed by comparing Rj values obtained.
- Timing of inspection is just after heat treatment for both the FSJS and TF joints.

6. Sensitivity of this inspection

- All of results were in good agreement with calculation of good joint case (1mΩ). In addition, all of results of TF joints were repeatable and agreed with one of NIFS FSJS. As it was revealed that Rj of FSJS was 1.1 mΩ, i.e. good joint, in FSJS test, it could be said that TF joints were also good joints.
- From these results, soundness of real TF joints were confirmed and the validity and utility of this developed inspection method were shown.

7. Conclusion

- The newly inspection method for soundness of fabricated TF joint was developed. This method is to acquire of voltage profile of copper sole of joint box at room temperature during charging 20 A of current into copper sole and then evaluate the gradient of voltage profile, dV/dz.
- The measurements were performed for real TF joints and NIFS FSJS before excitation. All of measurement results of real TF joints were repeatable and agreed with one of NIFS FSJS, whose joint resistance had been known as good in FSJS test. From this results, it could be confirmed that real TF joints are also good as same as NIFS FSJS. Thus, validity of this developed inspection could be confirmed.
- To see the sensitivity of this developed inspection, the measurement for NIFS FSJS after excitation, whose condition of cable in the joint was slightly changed due to electromagnetic force in FSJS test, was also performed. As a result, significant difference on evaluation of dV/dz was seen in FSJS after excitation compared with FSJS before excitation. This is because current distribution inside joint was changed before and after excitation.
- Thus, it can be said that the developed inspection method is very sensitivity even for small disturbance of condition inside joint. If there is some abnormality in the fabricated joint, the abnormality will be able to be detected.

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