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Progress of ITER-TF coil procurement in Japan
日本におけるITER-TFコイルの調達進捗状況

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Japan Atomic Energy Agency (JAEA) started sub- and full-scale trials to qualify and optimize manufacturing procedure of ITER Toroidal Field (TF) coil from March, 2009 under the contract with Toshiba. As major outcome of these trials, feasibility of high accuracy of winding, prediction of the conductor elongation due to heat treatment and radial plate manufacture is confirmed. Therefore, JAEA can mostly establish manufacturing plan for the TF coil and, from 2012, start the first TF coil procurement following to final qualification testing via dummy double-pancake manufacture.

1. Introduction

The ITER superconducting magnet system consists of 18 Toroidal Field (TF) coils, 1 Central Solenoid (CS), 6 Poloidal Field (PF) coils and 18 Correction coils. The Japan Atomic Energy Agency (JAEA), serving as the Japan Domestic Agency (JADA) in the ITER project, is responsible for the procurement of 9 TF coils and structures for 19 TF coils (including one spare). JAEA started sub- and full-scale trials to qualify and optimize manufacturing procedure of TF coil from March, 2009 under the contract with Toshiba [1].

In this paper, the fabrication procedure of the TF coil is briefly explained and then the technical issues in the TF coil manufacture is described. The results of the trials performed to solve these issues are reported.

2. Manufacturing Process and Technical Issues

The manufacturing process of the TF coil is as follows: 1) A radial plate (RP) is fabricated by joining RP sections, which are fabricated in parallel using several facilities; 2) the conductor is wound into a D-shaped double-pancake (DP) winding; 3) the conductor is heat-treated at 650 degree C for approximately 200 hours; 4) the conductor, wrapped in a multilayer glass- polyimide turn insulation, is inserted into the grooves on both surfaces of the RP; 5) cover plates (CPs) are welded to the RP teeth which extend between grooves in the RP, to fix the conductor; 6) a DP is wrapped in a multilayer glass-polyimide DP insulation, and the DP insulation is vacuum-pressure impregnated together with the turn insulation; 7) 7 DPs are stacked together and vacuum-pressure impregnated to form a rigid WP after an electrical connection is established among adjacent DPs by means of an inter-DP joint; 8) WP is assembled with sub-assemblies of a coil case; 9) sub-assemblies are closure welded; and 10) gap between a WP and coil case are filled with resin.

A heat-treated Nb_3Sn cable-in-conduit conductor (CICC) must be put into a groove of an RP. To satisfy this requirement, the discrepancy between heat-treated conductor length and the RP groove length must be controlled within +/-0.023% in conductor length of each turn [1]. The high accurate winding and prediction of conductor elongation/ shrinkage, and highly accurate manufacture of an RP are key technology to achieve this requirement. In addition, impregnation with new resin with high irradiation resistance and CP welding are also key technologies. Accordingly, JAEA performed the following small scale trials; 1) development of winding technology to achieve automatic highly accurate D-shaped winding, 2) heat treatment trial, in which elongation/shrinkage of the heat-treated conductor is estimated, and 3) insulation and impregnation trials. In addition, trial manufacture of a full-scale RP for a dummy DP, which will be made in near future as a final qualification test, was performed.

Furthermore, trials for coil structure, including mock-up manufacture, were performed. These results are reported in [2].

3. Results of Trials

The followings are outcome from the trials.

1) The conductor length can be measured with the expected accuracy of 0.01% at straightened conductor during winding. However, it was found that a bent TF conductor was elongated by about 0.04% [4]. The conductor length

measurement system combining the existing optical system and encoder after bending will be solution. Using the developed winding system, one-third DP winding was successfully fabricated as shown in **Fig. 1**.

2) The heat-treated conductor was elongated by 0.064 – 0.074% [3], which is more than twice as our expectation from previous trials. This result forced us to apply a backup option, such as final machining so as to correct discrepancy in dimension and/or geometry between the heat-treated winding and RP groove. Note applicability of such method has been demonstrated by EUDA [4].
3) The impregnation and curing with a new resin with high irradiation resistance, Cyanate ester (CE) and Epoxy blend resin, is successfully done. The impregnation of the one-third DP was successfully performed as shown in **Fig. 2**.
4) The results of the CP welding test using 1.4-m mock-up indicate that the expected flatness of 1 mm can be achievable.
5) Material fabrication and welding procedure for the structure have been qualified. In addition, trial manufacture of two mock-ups, whose manufacturing is the most difficult in all sections of the coil case, was performed [2].
6) Material fabrication for a full-scale RP has been qualified. In addition, fabrication of a full-scale RP was successfully carried out as shown in **Fig.3**.

4. Future Plan

From the above mentioned trial results, it may be concluded that most of the major technical issues have been solved and that it is time to move to final qualification testing via a dummy DP trial fabrication to completely demonstrate the feasibility of the TF coil Winding Pack manufacturing procedure. Thus, JAEA is planning to start contract for dummy DP manufacture with qualification of toolings and, in addition, the first TF coil from 2012.

5. Summary

Since the major technical issues have been solved through sub-scale trials for winding pack and full scale trial for RP, JAEA is ready to start full-scale trial of dummy DP manufacture. From 2012, JAEA is also planning to start contract for the first TF coil manufacture flowing to the dummy DP trial.

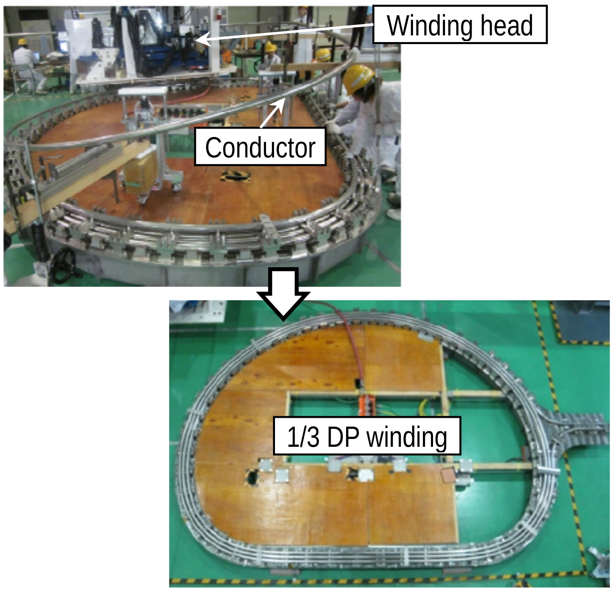

Fig.1 One-third DP winding.

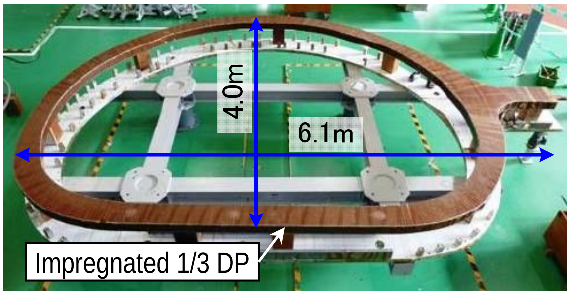

Fig.2 Impregnated one-third DP.

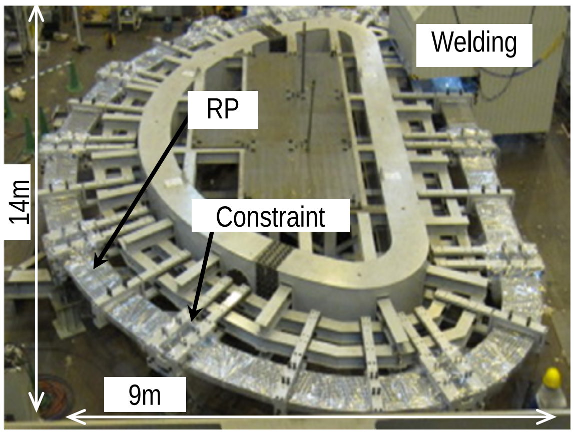

Fig.3 Full-scale RP.

References

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