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Full scale trials for qualification of the manufacture of the ITER TF coils in Japan

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HIGHLIGHTS

- High accuracy conductor winding of 0.1% was achieved in TF coil fabrication.
- Conductor elongation due to heat treatment satisfied with the expected value of 0.06% ± 0.02%.
- Commissioning of a transfer tooling without adding strain to conductor was completed.
- Commissioning of a conductor insulation and CP welding was successfully completed.

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ABSTRACT

JAEA performed full-scale trials to qualify and optimize manufacturing procedure of TF coil fabrication prior to series production. In the full-scale trials, conductor winding, heat treatment, conductor transfer, conductor insulation and cover plate (CP) welding trials were performed to resolve some technical issues and to demonstrate the fabrication procedure. The followings are major achievement. (1) High accuracy conductor winding of 0.01%, (2) the evaluation of 0.06% conductor elongation due to heat treatment, (3) conductor transfer in a radial plate (RP) groove with addition strain under 0.1%, (4) conductor insulation without breakage of the insulation tape and (5) flatness of 2 mm of the double pancake (DP) by CP welding. Then JAEA started the 1st TF coil fabrication from March 2014, and has already completed ten conductor windings and heat treatment of nine windings.

1. Introduction

Japan Atomic Energy Agency (JAEA), as Japan Domestic Agency (JADA), has responsibility for procurement of 9 ITER Toroidal Field (TF) coils in ITER [1]. The TF coil consists of a coil case [2] and a winding pack (WP), which consists of five regular double pancakes (DP) and two side DPs [3]. The DP consists of a radial plate (RP) which is a mechanical structure supporting the large electromagnetic forces, a TF conductor using Nb_3Sn cable-in-conduit (CIC) superconductor, a cover plate (CP) and insulation materials.

JAEA signed the procurement agreement for 9 TF coils on November 2008, and contracted with two suppliers in order to accelerate TF coil fabrication schedule. In these contracts, JAEA started sub- and full-scale trials to qualify and optimize manufacturing procedure of TF coils. In addition, JAEA started to fabricate three dummy double pancakes with two coil suppliers in order to confirm the commissioning of tooling for DP fabrication and establish manufacturing techniques of each manufacturing process of DP, conductor winding, heat treatment, conductor transfer, conductor insulation and CP welding as shown in Fig. 1 prior to TF coil fabrication.

The 1st supplier started fabrication of two dummy DPs, dummy rDP using a copper dummy conductor and dummy sDP using the TF conductor as full-scale trials from October 2013, and started series production of the DP for TF coil from March 2014. The 2nd supplier started fabrication of a dummy DP (dummy rDP2) using the TF conductor from August 2014, and also started series production of the DP for TF coil from May 2015.

This paper describes the results of the dummy DP fabrication and status of TF coil fabrication.

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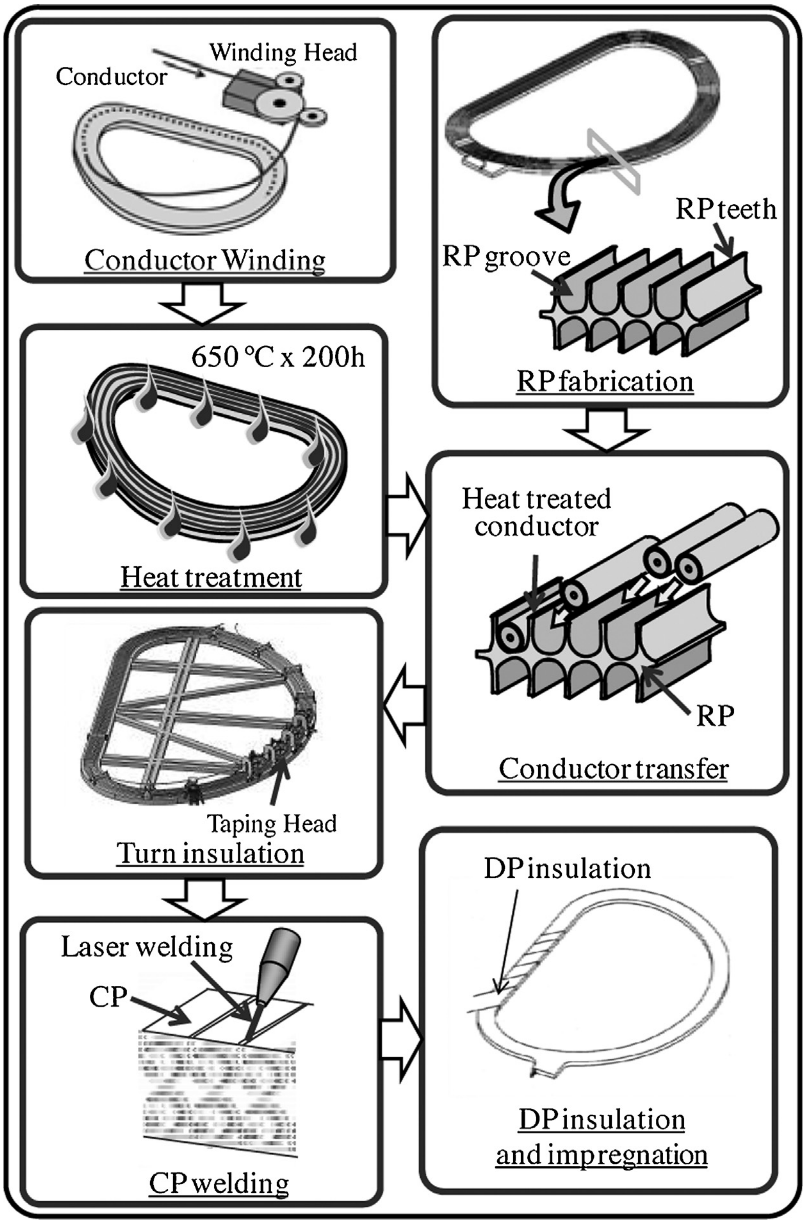

Fig. 1. Manufacturing process of DP.

2. Technical issues on DP fabrication

2.1. Conductor winding

For the conductor winding, it is required to bend the conductor to the target curvature as specified position in order to achieve the required D-shape, and to control the conductor length of the order of ±0.01% in order to insert the bent conductor in the groove of RP since the gaps between insulated conductor and teeth of RP are almost zero at inboard region and 2–3 mm at outboard region. The high accuracy conductor length measurement system using the optical equipments has already developed, and it was confirmed that the measurement system has the sufficient accuracy less than 0.01% [3]. However, it is important for fabrication of conductor winding of TF coil that the winding system including the conductor length measurement system can control the followings, (1) conductor length, (2) bending at the designed position and bending to the designed curvature, (3) the error of conductor length of each turn of a double pancake is within 0.01%.

2.2. Heat treatment

The CIC conductor using Nb_3Sn superconductor elongates due to reaction heat treatment since the thermal expansions of the Nb_3Sn and of the conduit are different. If the conductor elongation is larger than the 2–3 mm gap between conductor and teeth of RP at outboard region, the conductor insertion in the RP groove may be impossible. Therefore, it is important to evaluate the conductor elongation before conductor winding. In case of TF conductor using Bronze route strand, the conductor elongation including the error on conductor length measurement was evaluated as 0.06% ± 0.02% from the small scale trials, the conductor elongation of the conductor winding should be within 0.06% ± 0.02%.

In addition, since error of temperature during heat treatment may affect superconducting performance of the conductor, it is important to control the temperature ±5 °C at 650 °C.