§30. Investigation of Helical Winding Application of Nb3Sn Cable-In-Conduit Conductor after Heat Treatment

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A cable-In-conduit conductor (CICC) is one of the most promising conductor for larger-scale magnet for fusion devices, such as Force Free Helical Reactor (FFHR). However Nb3Sn is the popular one as a CICC construction material for the conductor in high field region, its mechanical characteristic, of fragile against electromagnetic force during operation is still big issue for applying it to the large scale magnets. That is why we need to introduce the Wind and React (W&R) method for coil fabrication, which is widely introduced for coil construction.

In order to design larger-scale helical magnet for FFHR, we have to consider alternative method of coil fabrication due to the difficulty of applying W&R method to helical coils. React and Wind (R&W) method is supposed to be the most reliable and promising one for designing the coils except for the problem of handling.

Our approach which assess the adaptability of the conductor to larger-scale helical coils is described as follows: Firstly, the CICCs both with straight and curved shape after heat treatment are impregnated by epoxy resin to harden the strand positions to prevent wire movement during slice process. Secondly, the CICCs are cut into pieces with 10 mm in thickness. Finally, resistance measurement in LHe temperature between strand cross sections on both side of the pieces enables us to identify where the strand positions on the two sides of slice sample, i.e. strand trace along the conductor axis in 10 mm long. The strand traces in sample CICCs are obtained by connecting the strand positions along conductor axes. Totally different traces would be obtained, which give us the bending strain distributions. The details of the measurement has been already presented.[1)]

Before the epoxy impregnation, the investigation of the effect of epoxy impregnation caused by the difference of coefficients of thermal expansion between strands and epoxy has been performed through the conductance measurement of long conductor sample (450 mm). The measurement for different conductor had been performed by our group.[2)] The conductors are untangled into 2nd sub cables before heat treatment. After that, epoxy impregnation is performed to one conductor. The two conductor samples are set to the vacuum vessel to cool down to LHe temperature and 1 base strand and other 36 selected strands whose distance between base strand and the selected strands are different each combination are connected to current feed as shown in Fig. 1. The voltage taps are attached to all selected strands. Constant current of 20 A is provided to measure the line-average contact resistances, which might be affected by epoxy impregnation.

Fig. 2 shows the experimental results of measured line-average contact resistances as a function of average distance between strands. The experiment indicates two important things. One is the resistances through the SUS rap surrounding the last sub cable are quite large compare to the values between strands both inside the rap. The epoxy is supposed to get in the void between the laps and to have an influence on the current path. The other is the most important, the effect of epoxy impregnation to the strand locations is negligible inside the rap.

According the results, the strand trace measurement have no problem, which gives us just the difference of bending strains for both straight and curved CICCs to discuss about the adaptability of R&W method for large helical magnet design.

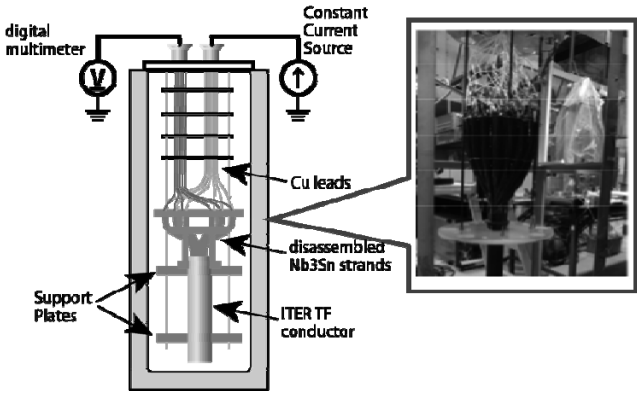

Fig. 1. Experimental setting of inter-strand contact - resistance measurement for the conductor with epoxy impregnation or without the impregnation.

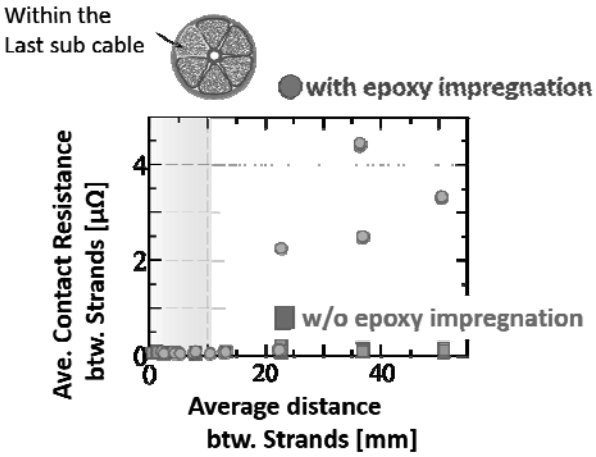

Fig. 2. Experimental results of contact-resistance measurement. The resistances are identical in the last sub-cable region surrounded by SUS lap.

1) Yagai, T.et al.: IEEE Trans Appl. Supercond. **16** (2006) 835.
2) Natsume, K. et al.: Abstracts of CSJ Conference **86** (2012) 105.