**HTS-WISE conductor and magnet impregnated with low-melting point metal**

S. Matsunaga¹, Y. Narushima¹,², Y. Onodera², Y. Terazaki², J. Miyazawa¹,², N. Yanagi¹,²

¹The Graduate University for Advanced Studies(SOKENDAI), ²National Institute for Fusion Science(NIFS)

Contact to us: matsunaga.shinnosuke@lhd.nifs.ac.jp

---

**Abstract**

The several types of High-Temperature Superconducting (HTS) large-current capacity conductors to be applied to the LHD-type heliotron heliotron fusion reactor have been investigated in NIFS. Recently, J. Miyazawa et al. invented an unique winding technique, called “Wound and Impregnated Staked Elastic tapes (WISE).” The HTS-WISE conductor has been considered as one of the candidate conductors for the next generation heliotron fusion device. This poster reports the results on the first trial making of the HTS-WISE conductor/magnet and its testing.

**INTRODUCTION**

**HTS-WISE concept**

Stacked HTS tapes are inserted into a flexible metal tape to form an assembled conductor, and wound onto a coil frame. In the flexible metal tape, each tube naturally deforms so as to minimize strain. Flexibility of this type of conductor allows easy coil winding even if a coil has a complex shape like helical coils. Then a coil is impregnated using low-melting point metal in liquid state, as it eliminates voids between tapes. (J. Miyazawa et al., Japanese Patent, Application No. 2017-232731., 2017)

**SAMPLE FABRICATION AND EXPERIMENTAL SETUP**

Fig. 1 Impregnation container

Fig. 2 Impregnation using low-melting point metal U78 Sn, after impregnation, produced by Arai Metal Co., Ltd. (19, 2007-19, 2007)

**Measurement setup**

- Terminal voltages of all taps
- Current flow through the coil (Hall probe)
- Magnetic field at the center of the bore of the coil (Hall probe)

**RESULTS AND DISCUSSION**

**EXPERIMENT**

Charging test before impregnation

- As most of induced voltages are evaluated to be 0.3 mV with the ramp-rate of 10 A/s, the inducance of the sample coil can be estimated to be ~30 pH.

Charging test after impregnation

- Both the magnetic field and induced voltages behaved like those observed in Non-Insulation (NI) coils (2).
- Time constant of the delay with the magnetic field was found to be ~7.5 s, and the characteristic resistance is calculated to be ~4 Ω at first cooling.
- Thermal cycles made the damage in tapes from the second cooling.
- Achieved a central magnetic field of 0.16 T @ 800 A (15 Am²/m²) in steady-state.
- Thermal runaway occurred at a current of 850 A in the steady-state operation.

**DISCUSSION AND CONCLUSION**

- By fabricating a WISE solden coil sample, it was shown that WISE is a smart winding method to make a multi coil having even complex 3D shapes.
- In this first test, thermal cycles damaged the 2G HTS tapes impregnated with U78. To solve this problem, optimizations of the impregnation process, the investigations of the mechanism, and the usage of some other HTS tapes and low-melting point metal are desirable to be examined.
- Even with some degradation, the WISE coil sample demonstrated an outstanding thermal stability; it allowed about ten times the typical voltage criterion of critical current (0.1 mV/6kV) for stable operation. In order to apply the WISE conductor/magnet in some applications having complex shapes like heliotron fusion reactors, the optimizations are expected.
- After the experiment, the sample was examined by x-ray diffraction. Fig. 17 shows the cross sectional view of the cut surface. Some voids are observed at some locations as a flexible metal tube. In order to improve the impregnation, we had better consider the vacuum pressure impregnation (VPI) process to completely fill up the coil case.

---


---

MT26-Wed-MoPo3.02-05