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A Concentrically Arranged Joint-less HTS Coil System for Persistent Current Mode Operation

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1. Introduction

- ✓ We proposed HTS magnet with no joints by using **the joint-less winding technic** with 2G HTS tape conductor.
- ✓ In order to improve the homogeneity of the center magnet flux density, **two concentrically arranged solenoid magnets were connected in series with a perfect closed loop** were fabricated , so that we could avoid unfavorable gap near the magnetic center of the coil from the previous work.
- ✓ The prototype magnet was operated at the temperature of 77 K by LN2 cooling and **charged up with a persistent current switch which** was also a part of the perfect superconducting closed loop.

2. The joint-less HTS magnet

a) HTS joint-less magnet concept

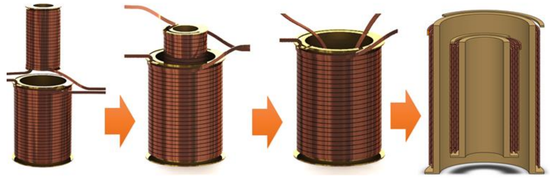

Fig.1. Concentrically arranged HTS joint-less magnet method

b) Design of HTS Joint-less magnet

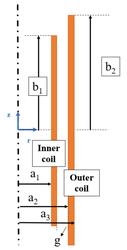

Fig.2. Design of the magnet

Table 1. specifications of the joint- less model magnet

Parameter		Value
a_1		35 mm
a_2		50 mm
a_3		50.36 mm
b_1		96 mm
b_2		138 mm
g		14.28 mm
No of turns	Inner coil	32 turns X 4 layers = 128 turns
	Outer coil	46 turns X 2 layers = 92 turns

c) Make an HTS Joint-less magnet and PCS

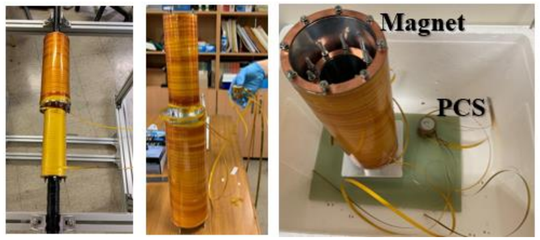

Fig.3. Winding process of the joint-less magnet and PCS

3. Experimental setup for the magnet with PCS

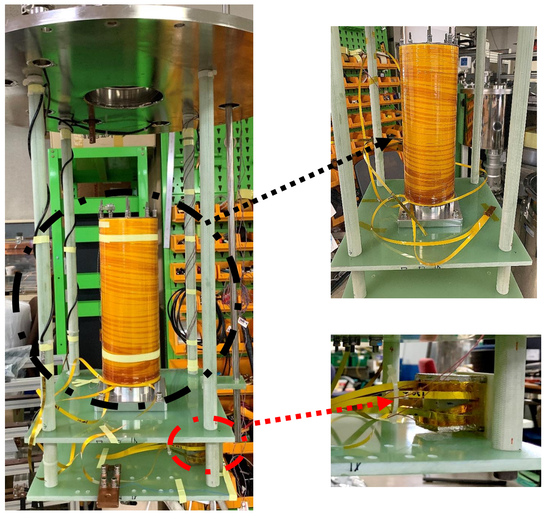

Fig.4. Magnet charging system with PCS

Table 2. specification of the magnet and PCS

HTS magnet	
Conductor	12 mm, Stabilizer free (SuNAM)
Coil type	Nested coil
Magnet constant	0.00117971 T
Inductance	1 mH
Conductor Length (wide 6 mm)	Superconductor : 60 m

PCS part	
Conductor	12 mm, Stabilizer free (SuNAM)
Coil type	Double pancake
Inner Diameter	30 mm
Number of Turns	Total 36 Turn (sus and superconductor co-winding)
Conductor Length (wide 6 mm)	Superconductor : 3.9 m S/S heater : 4 m

4. Persistent current mode operation of the joint-less HTS magnet

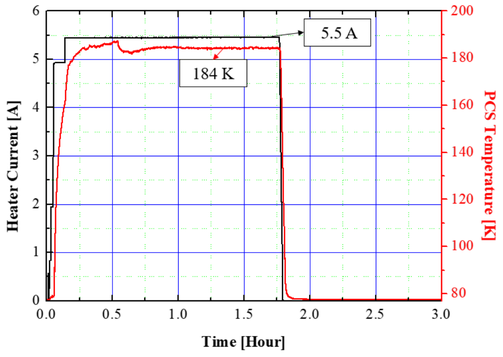

Fig.5. PCS temperature by heater current

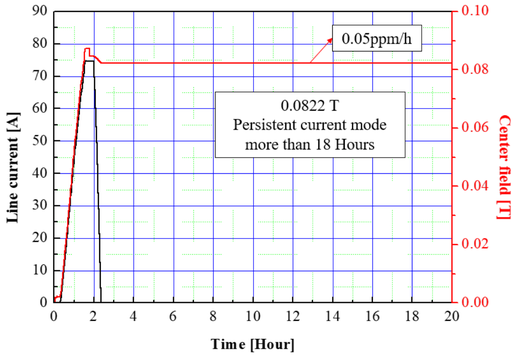

Fig.6. Persistent current mode result at 77 K

- ✓ The PCS test at 77 K confirms that **persistent current mode operation is possible**.
- ✓ The prototype Jointless magnet immersed in a LN2 vessel was charged up to 0.0822 T with the PCS with heater current of 5.5 A.
- ✓ **The center magnetic field of 0.0822 T** with the persistent current of **72.4 A** was **maintained for more than 18 hours**.
- ✓ The temporal stability of the center magnetic field after 18 hours operation was **0.05 ppm/hour**.

5. Field mapping of the joint-less HTS magnet

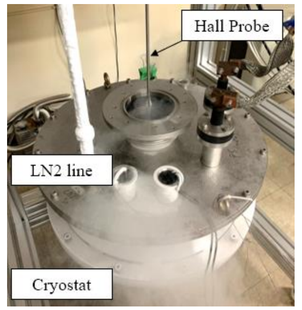

Fig.7. Magnet Field mapping system

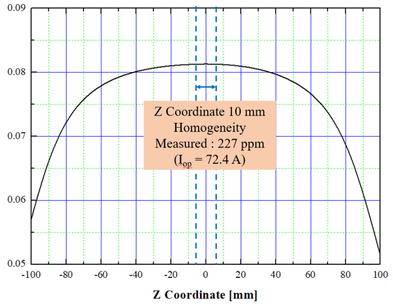

Fig.8. Magnet homogeneity at z coordinate

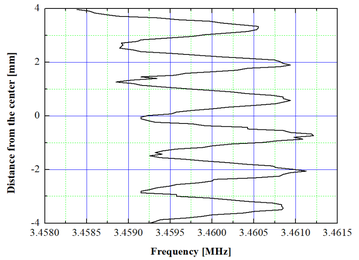

Fig.8. Cylindrical mapping result

Table 3. Harmonics analysis

Field gradient	Values (Hz)
Z0	346.20534040
Z1	-0.06734685
X	0.21908360
Y	-0.07321368
Z2	-0.30173351
ZX	0.05065190
ZY	0.02171259
C2	0.03039777
S2	0.00730840

- ✓ We carried out a **mapping of the magnetic field along the spiral path around the magnet center** after 18 hours persistent current mode operation of the prototype joint-less HTS magnet.
- ✓ The measured spatial homogeneity for **the DSV of 10 mm was 227 ppm**.

6. Conclusion

- ✓ We fabricated and tested a prototype of **the concentrically arranged Joint-less HTS magnet** wound by the joint-less winding technique. The experimental results showed the possibility of **the persistent current mode operation of the HTS magnet**.
- ✓ Although the measured spatial homogeneity of the center magnetic field was not good enough for the NMR applications, **it could be improved by applying longer HTS conductor and the passive shimming**.
- ✓ The prototype HTS magnet was operated at the temperature of the LN2. Our next targets are to; **1) design and fabricate a bigger magnet using longer HTS conductor, 2) operate at the lower temperature like 20 K by cryocooler, 3) suggest a proper PCS for dry magnet, 4) try to charge up the joint-less HTS magnet with a flux pump, 5) try the passive shimming, and 6) get an NMR signal**.