Mon-Af-Po1. 03-02 [24], Monday, August 28, 2017, 13:30 – 15:00

Transient Behaviors of a 3 T 100 mm Stainless Steel Cladding All-REBCO Magnet During Sudden Discharging

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MT25
The 25th International Conference on Magnet Technology
Amsterdam, the Netherlands
August 27-September 1, 2017
www.MT-25.org

✓ Introduction

➢ An international collaboration project whose goal is to develop a 400-MHz 64-mm room-temperature bore all-REBCO nuclear magnetic resonance (NMR) magnet has been embarked by the Korea Basic Science Institute (KBSI), Seoul National University, National High Magnetic Field Laboratory (NHMFL), SuNAM, Kunsan National University and Korea Institute of Machinery and Materials (KIMM).

➢ Prior to completion of the 400-MHz all REBCO NMR magnet, a 3 T 64-mm room-temperature bore all-REBCO magnet (with multi-width, stainless steel cladding no-insulation technique incorporated) was fabricated and tested to verify the feasibility of the stainless steel cladding technique. ➔ The magnet successfully reached its full field of 3 T at a operating current of 200 A.

➢ The magnet experienced unexpected power supply trips *twice* during its long-term field mapping experiment at the full field, after which the magnet was fully discharged in 5 seconds. ➔ . **The magnet survived without any damage after each trip of the power supply and is currently being operated normally without any performance degradation**.

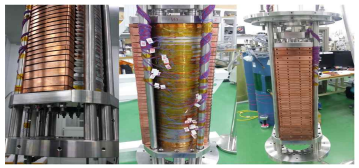
➢ This study reports the transient behaviors of the magnet in details during the sudden discharge events. And the results imply the self-protecting feature of the stainless steel cladding REBCO magnet, which has been experimentally demonstrated in a magnet level for the first time.

✓ 3 T 100 mm all REBCO magnet

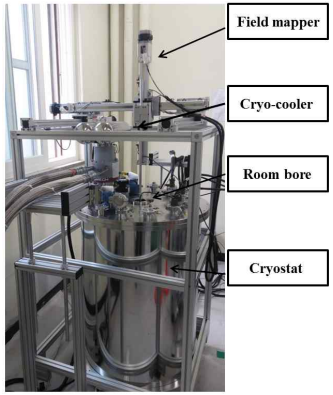
◆ Specification of the 3 T 100 mm magnet

Parameters	
HTS conductor	SuNAM ReBCO
Magnetic field	> 3.0 [T]
Operating temperature	< 20 [K]
Operating current	201 [A]
Inductance	0.465 [H]
Warm bore diameter	64 [mm]

◆ Fabrication of the 3 T 100 mm magnet



◆ Integration of the 3 T 100 mm magnet system



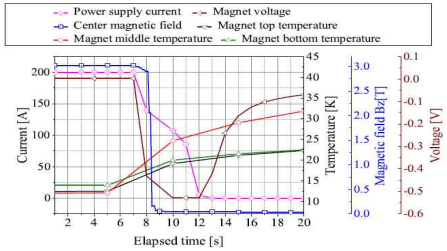
• The magnet is composed of the 32 double-pancake (DP) coils.

•Stainless steel layer surrounds the HTS tapes in a hermetic way to substantially reduce NI charging delay (Metallic-cladding)

•A two-stage pulse tube cryo-cooler was installed on the cryostat.

✓ Transient behaviors of the magnet during sudden discharge

◆Behaviors of the 3 T magnet after the power supply trip

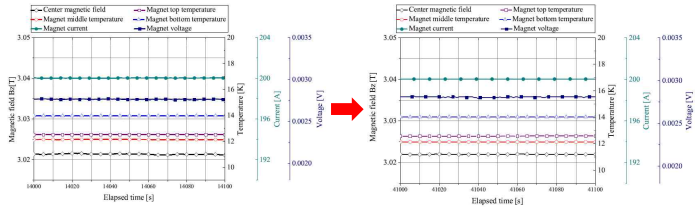


➢ The all-REBCO3 T magnet experienced sudden discharges at a operating current density of 353 A/mm^2.

➢ Note that the center magnetic field became zero before the magnet current dropped to zero.

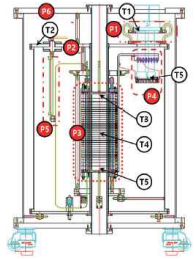
➢ An amount of power supply current leaks through the turn-to-turn contacts, which prevents local heating and consequent permanent damage of the magnet.
(Intrinsic behavior of an NI magnet was verified at the stainless steel cladding magnet.)

◆ Survival after a sudden discharge



[3 T magnet signal before the sudden discharge] [3 T magnet signal after the sudden discharge]

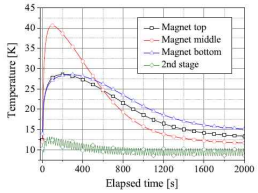
◆Temperature profiles of the 3 T magnet during the sudden discharge



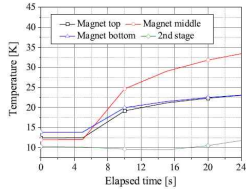
T1 ~ T6 : Temp. sensor

P1 : Cryo-cooler 1st stage (T1)
P2 : Radiation shield (T2)
P3 : HTS magnet (T3 ~ T5)
P4 : Cryo-cooler 2nd stage (T6)
P5 : Current lead
P6 : Vacuum chamber

[Location of temperature sensors]



[Temperature profiles during the sudden discharge]



[Enlarged view at 0 < t < 24]

➢ Adiabatic temperature analysis was carried out to estimate average temperature of the magnet, which is obtained by (1) with an assumption that all the stored magnetic energy is being converted to heat during sudden discharge.

$$\frac{E_m}{Vol} = \int_{13K}^{T_{av}} C_v(T)dT, \qquad (1)$$

➢ where *Em*, *Vol*, *Cv* and *Tav* are magnetic energy, total volume of the magnet, temperature dependent heat capacity and average temperature of the magnet after the sudden discharge, respectively.

➢ Assuming the magnet is composed of stainless steel and copper, average temperature rise of the magnet was estimated to be about 46.5 K

✓ Conclusion

➢ In this presentation, transient behaviors of the stainless steel cladding all REBCO magnet during a sudden discharge were introduced.

➢ The stainless steel cladding all REBCO 3T magnet survived after the sudden discharge without any degradation. An amount of power supply current leaks through the turn-to-turn contacts, which prevents local heating and consequent permanent damage of the magnet (Intrinsic behavior of an NI self-protecting magnet)

➢ The results imply a strong potential of the metallic (stainless steel) cladding magnet to be self-protecting.

This work was supported by a KBSI grant (D37611) so S.-G.L. funded by Korea Basic Science Institute (KBSI).