MT 2021
TUE-PO1-705-11

The Influence of Metal Plates on Quench Protection of High Temperature Superconducting Pancake Coils

Zhen Lu, Wenbo Xue, Yutong Fu, Yawei Wang, Zhiyong Hong, Zhijian Jin
School of electronic information and electrical engineering, Shanghai Jiao Tong University, Shanghai, China

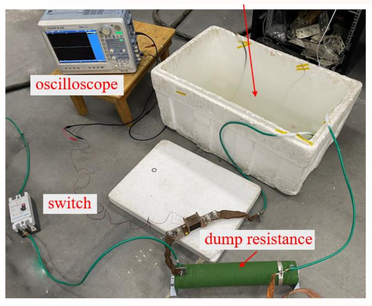
Introduction

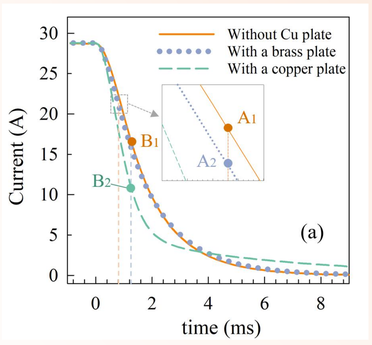
1) In HTS magnets, metal plates are originally used to provide conduction cooling and mechanical support for the coil. During fast discharging operations, the metal plates can rapidly absorb part of magnetic energy stored in HTS coils through electromagnetic coupling, which may be very helpful for the quench protection. Previous researches are all based on copper plates.
2) This paper is to study the influences of metal materials on the discharging behavior of HTS coils coupled with metal plates. Several different metal materials are analyzed: stainless steel 304L, Al 6061-T6, Ag, Au, Al (RRR = 30), Cu (RRR = 30) and Cu (RRR = 300).

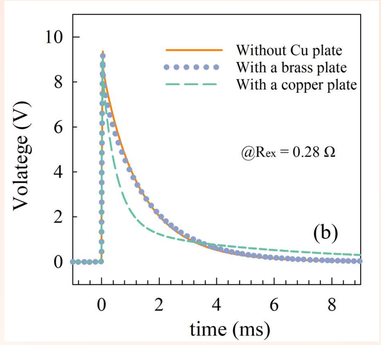
Experiments

1) The coil tested is an insulated double pancake (DP) coil wound by HTS tapes. Three discharging tests are performed on the coil: without metal plate, with a brass plate and with a copper plate. The dump resistance is 0.28 Ω, and the initial transport current is 28.8 A, which is 30 % of the critical current of the HTS coil. The thickness of both plates is 1 mm.

Results The maximum difference between the current of coil without and with brass plate is only 4.03 % of the initial transport current 28.8 A. The maximum difference happens between the current of coil with and without copper is 20.28 % of the initial transport current, which is 5 times of that with brass plate.





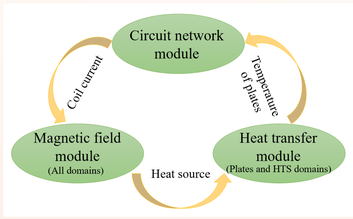


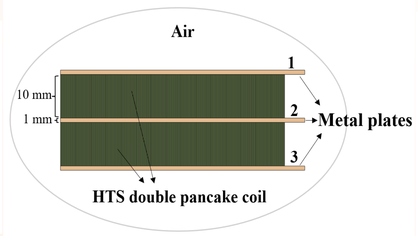
Conclusions

1) The effects of copper plate is much better than brass plate. And the effects of different metal plates on accelerating coil discharge are rank as: SS 304L < Al 6061-T6 < Al (RRR = 30) < Cu (RRR = 30) < Au < Cu (RRR = 300) < Ag.
2) The higher the electrical conductivity of metal plates, the better effect on accelerating the coil discharging process. Higher electrical conductivity can lead to more energy absorbed by the metal plates. However, the more significant the current rebound, the less the energy absorbed by metal plates. So, the Cu (RRR = 300) plates can absorb more energy than Ag plates.

Simulations

1) A 2D axisymmetric multi-physics model is developed for this study, which couples a magnetic field module with A-formulation, a heat transfer module and a circuit network module. An industry-scale HTS DP coil with larger size and more turns is studied in this section, which is for a 25 T all-HTS magnet.
2) The initial temperature is 4.2 K in this study, the initial transport current is 300 A, and the dump resistance is 0.5 Ω.





Results

1) The coil with Ag plates shows the fastest current drop at the early stage, which is up to 95 % of the initial current at t = 50ms. Its rebound is also the highest one, which is 30.6 % of the initial current at t = 404ms.
2) During the discharging process, metal plates can absorb energy from the coil through electromagnetic coupling and convert it to joule heat. The definition of parameter η is as:

$$\eta = \frac{Q_{plate}}{Q_{total}} \times 100\%$$

3) The plate with lower resistivity can absorb more energy from the HTS coil. The higher the energy absorbed by metal plates from the coil, the more favorable for the quench protection of HTS coils.

TABLE II
ENERGY PARAMETERS OF DIFFERENT METAL PLATES

Metal materials	Q_{plate}	Energy ratio η
SS 304L	2.4 J	0.04 %
Al 6061-T6	82.2 J	1.4 %
Al – RRR=30	1070.9 J	18.6 %
Cu - RRR=30	1510.3 J	26.3 %
Au	1844.6 J	32.1 %
Cu – RRR=300	3441.6 J	59.9 %
Ag	3076.3 J	53.5 %