Conceptual Design of a Bitter-like Superconducting Magnet stacked by REBCO Annular Plates and Magnetizd by Flux Pump

Xi Yuan[1],Yinshun Wang[1], Yanbing Hou[2],Changtao Kan[2], Chuanbing Cai[3] and Meijuan Sun[3]

1. State Key Laboratory for Alternate Electrical Power System with Renewable Energy Sources,North China Electric Power University, Beijing, China
2. Beijing Key Laboratory of High Voltage and Electromagnetic Compatibility, North China Electric Power University, Beijing, China
3. Shanghai Key Laboratory of High Temperature Superconductors, Physics Department, Shanghai University, Shanghai, China

NORTH CHINA ELECTRIC POWER UNIVERSITY

Background

Currently, all commercially available superconducting magnets are wound with (RE =rare earth) BCO coated conductors, low temperature superconducting (LTS) wires, NbTi, and Nb_3Sn conductors. REBCO pancake coils can operate in a higher magnetic field because of higher upper critical field limitations. This superconducting magnet was stacked of REBCO annular plates realizing the closed-loop operation of high temperature superconducting (HTS) without jointing, magnetized by flux pump.

Objectives

- ❖ A new conceptual design of a Bitter-like superconducting magnet stacked of REBCO annular plates, magnetized by flux pump, was proposed.
- ❖ The characteristics of induced field and magnetized by flux pump in the HTS magnet were analyzed and measured .

Conclusions

- ❖ A conceptual configuration of a Bitter-like HTS magnet stacked of REBCO annular plates and magnetized by flux pump was realized. A Bitter-like HTS magnet operated in mode of closed-loop without resistance was validated.
- ❖ The induced field of the HTS magnet were separately simulated and measured. Results show that both of them are good agreement. The maximum axial magnetic field B_z at the center of the HTS magnet is 24.5 mT.
- ❖ The conceptual configuration provides a new type of HTS magnet and hopefully has potential application in NMR (MRI) magnet, large scale magnet with high magnetic field.

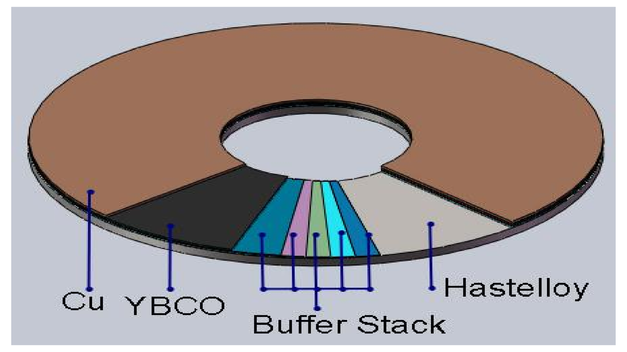
The HTS magnet

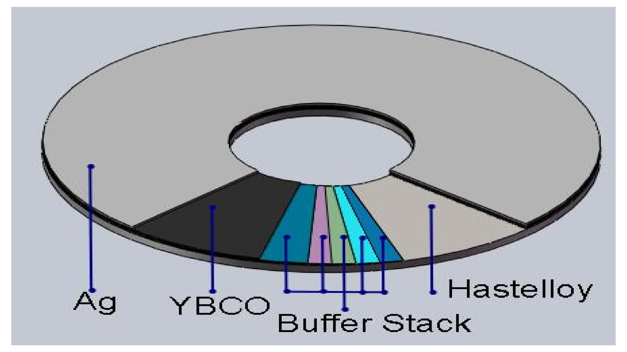
REBCO annular plates

The HTS magnet contains two types REBCO annular plates. Silver-plated REBCO annular and copper-plated REBCO annular plates have the same size, with outer diameter 12 mm and inner diameter 6 mm.

Silver-plated REBCO annular plates are composed of Hastelloy layer, Buffer layer, YBCO thin film, and silver layer.

Copper-plated REBCO annular plates are composed of Hastelloy layer, Buffer layer, YBCO thin film, and copper layer.





Assembly of 80 REBCO Annular Plates

The HTS magnet is composed of 80 REBCO annular plates, including 40 silver-plated REBCO annular plates and 40 copper-plated REBCO annular plates, inserted insulating polypropylene laminated paper (PPLP) between adjacent REBCO annular plates.

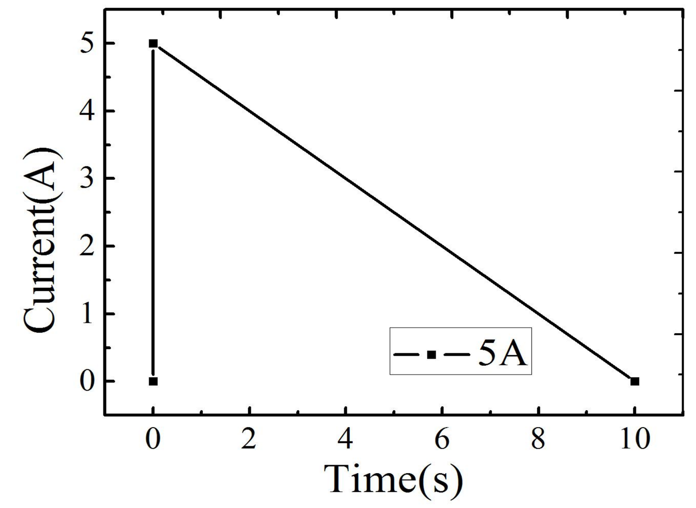
Five material components:

- Silver-plated REBCO annular plates;
- Copper-plated REBCO annular plates;
- PPLP insulating papers;
- Polyethylene insulation boards;
- Non-magnetic screws and bolts;

Flux pump

Pulse current

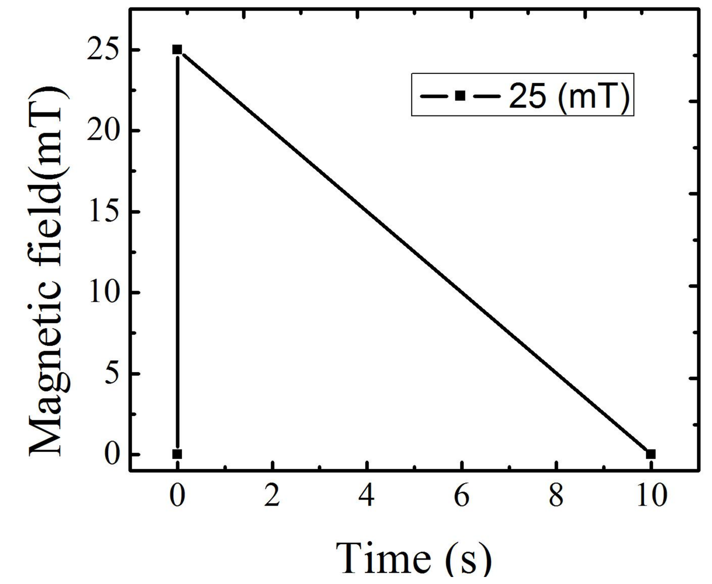
The peak value of pulsed current is 5 A. The rising edge of the pulsed current is 1 ms and falling edge is 10 s in one period. The dropping time is 100 times higher than the rise time.



Race-track coils excitation

Flux pump is composed of excitation coil and pulsed current power. The excitaton coils are placed outside of the HTS magnet. Copper excitation coils are wound into race-track coils provided pulse magnetic field for HTS magnet.

The magnetic field 25 mT of race-track coils is provided by the pulsed current. The period of the pulsed magnetic field is the same as that of the pulsed current. The pulsed current source keeps the pulsed magnetic field constant.

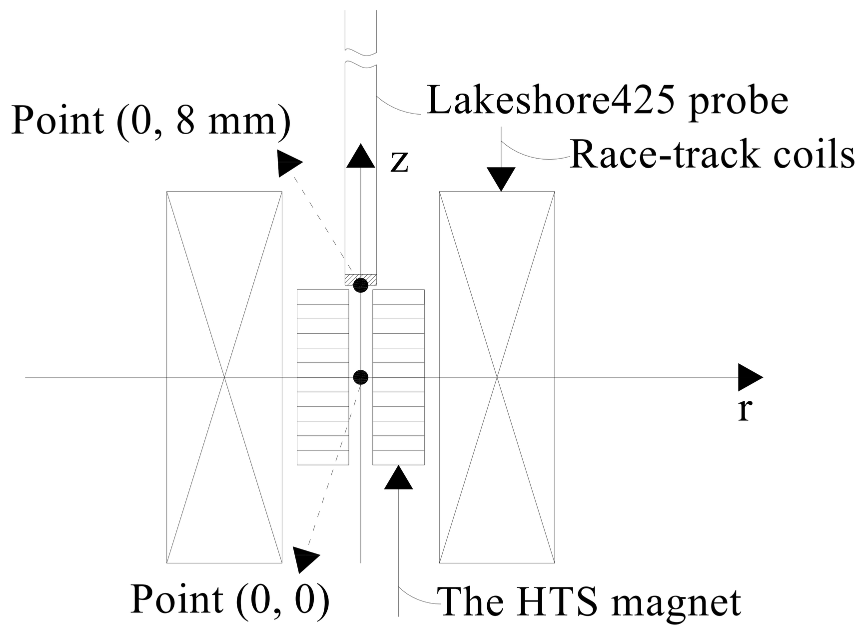


Results

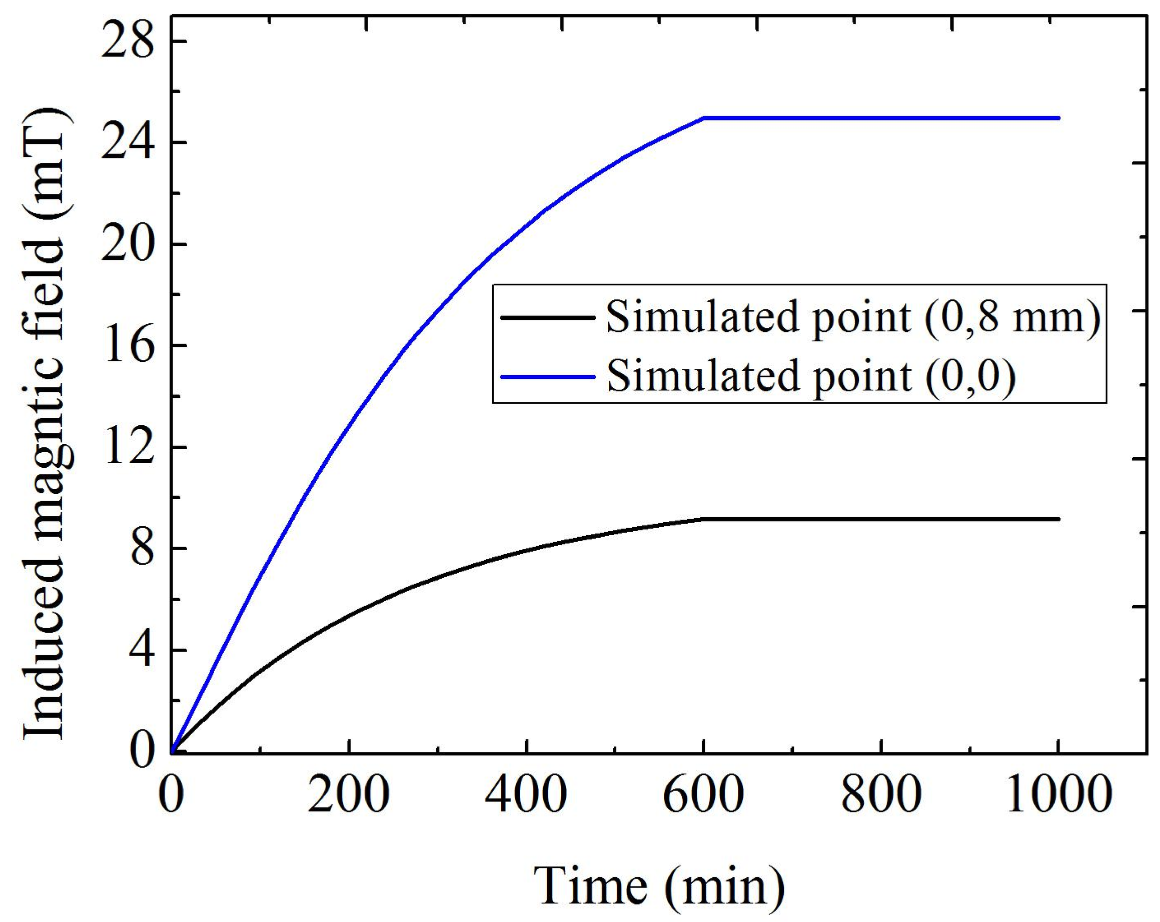
Simulation Results

The whole experimental facility was soaked in LN_2 (77 K) styrofoam cryostat. The coordinate origin is based on the geometric center of the HTS magnet. It is implicitly assumed that the problem is perfectly axisymmetric with homogeneous and isotropic material properties. The central point (0, 0) and the upper point (0, 8 mm) of the HTS magnet were simulated by COMSOL 5.0 respectively.

The total simulation time is 1000 minutes. The axial magnetic field B_z reaches a stable state for 700 minutes, and attenuation time is 300 minutes. The point (0, 0) axial magnetic field B_z at the center of the HTS magnet is 24.5 mT. Additionally, the point (0, 8 mm) axial magnetic field B_z at the upper of the HTS magnet is 9.18 mT.



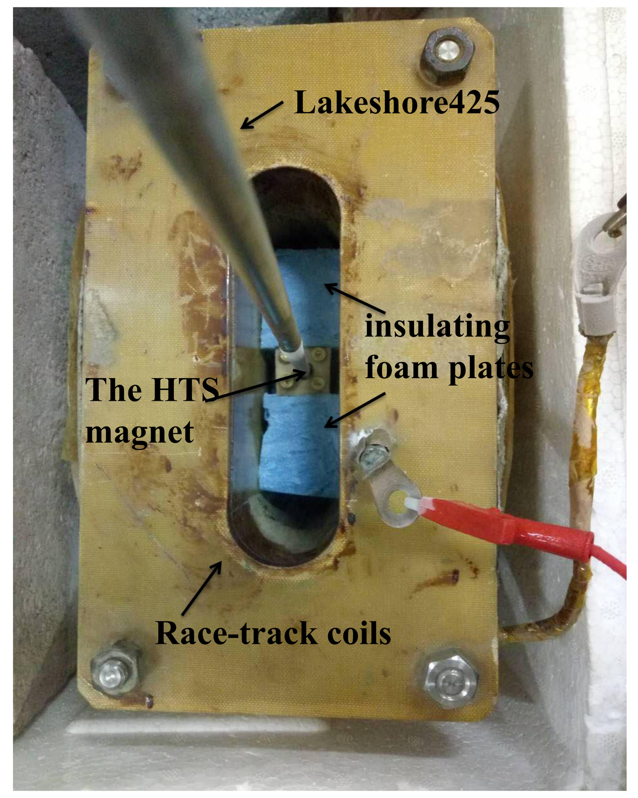
At first, the induced axial magnetic field B_z increases rapidly. With time going on, the B_z grows slowly and reaches a steady state. In the simulation process, the B_z will not decrease.

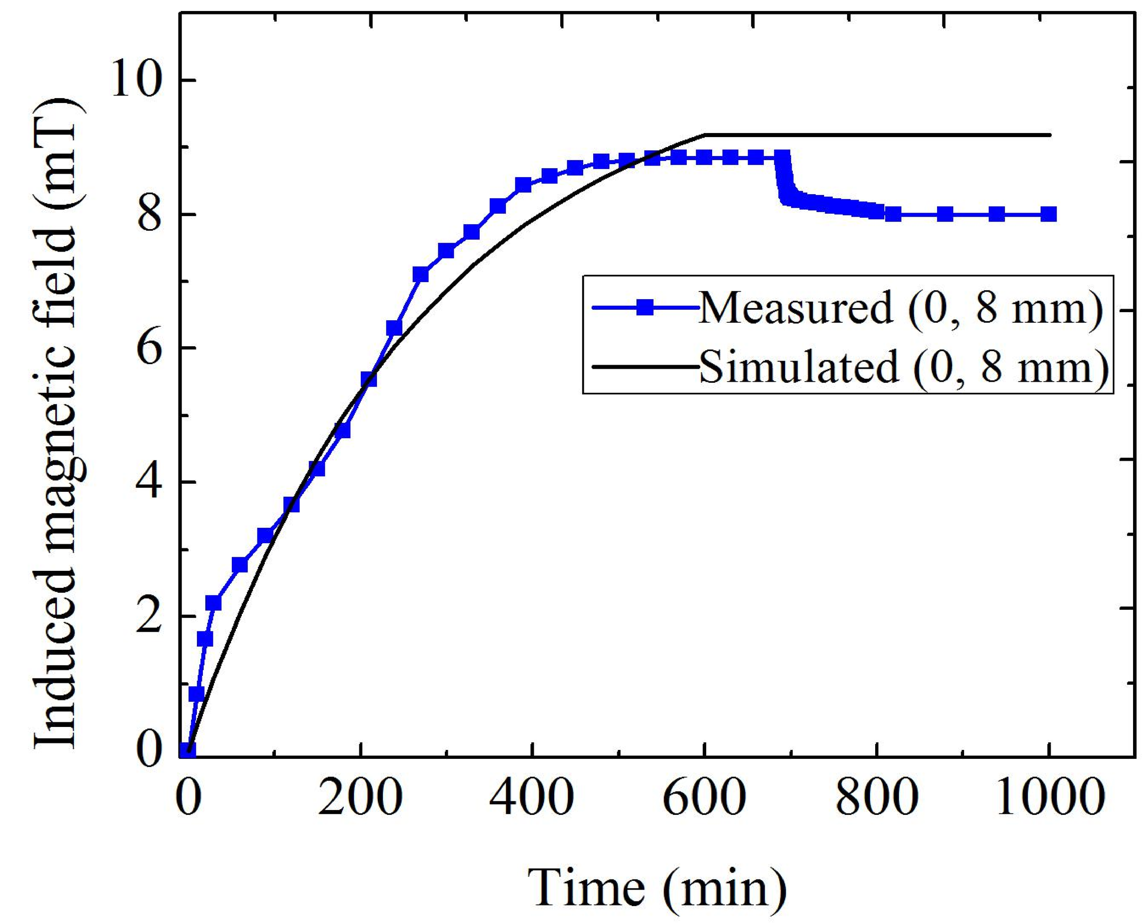


Experimental Results

The point(0, 0.8 mm) of the experiment result was 8.84 mT and simulation result was 9.18 mT, error of both 0.34 mT (3.8%). The point (0, 8 mm) B_z attenuates during the actual measurement.

The axial magnetic field B_z decreases from 8.84 mT to 8 mT, reduced 9.5%. The point (0, 8 mm) B_z begins to decay faster and the slope of the attenuation is larger at first. The slope of attenuation decreases with time, and finally reach a steady state. At last, the axial magnetic field B_z is not decrease and keeps 8 mT constant.





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