IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 55, January, 2024

Development of the First Tesla Class Iron-based Superconducting Coil Tested in 20 T Background Magnetic Field

Hangwei Ding[1,2], Hang Zhao[1,2], Pengcheng Huang[1], Lei Yu[1,2], Jianyuan Xu[1,2], Zhen Fang[1], Zhiyou Chen[1], Dongliang Wang[3,4], Xianping Zhang[3,4], Wenge Chen[1*] and Yanwei Ma[3,4*]

[1]High Magnetic Field Laboratory, Hefei Institutes of Physical Science, Chinese Academy of Sciences, Hefei, China
[2]University of Science and Technology of China, Hefei, China
[3]Key Laboratory of Applied Superconductivity, Institute of Electrical Engineering, Chinese Academy of Sciences, Beijing, China
[4]University of Chinese Academy of Sciences, Beijing, China

*E-mail: wgchen@ipp.ac.cn and ywma@mail.iee.ac.cn

Iron-based superconductors, which were discovered in 2008, represent a new high-temperature superconductor family and have garnered significant attention from the global scientific community [1]. Plenty of studies have been conducted to enhance the critical current density of this superconductor and to optimize the manufacturing process of superconducting wires [2]. In 2017, the Institute of Electrical Engineering, Chinese Academy of Sciences (IEECAS) successfully produced the first 100-m class iron-based superconducting wire, which is an important step from the laboratory towards practical use of iron-based superconductors [3].

In 2019, the first performance test of iron-based superconducting coils made of long wires was conducted in a 24 T background field [4], which demonstrated the high current carrying capacity of coils in high fields. The high-performance 100-m long wires were further verified through the testing of an iron-based superconducting racetrack coil in 10 T, showing an 86.7% of critical current of the short samples [5]. Other studies on pancake coils and solenoid coils also strongly suggest that iron-based superconductors exhibit a bright future for large-scale high-field applications [6-11]. However, besides the high current carrying property of the coils, the strength of magnetic fields generated by them is also an important parameter, especially in high-field regions. Thus, further research into superconducting coils is necessitated to fully show the practical potential of iron-based superconductors.

Recently, the High Magnetic Field Laboratory, Chinese Academy of Sciences (CHFML) and IEECAS combined iron-based superconducting long wires with high-field insert coil technology, and successfully developed an iron-based superconducting coil that generated 1 T of field in a background field of 20 T. Three 100-m iron-based superconducting wires were utilized to construct nine large-sized double pancake coils (DPC). The performance of all double pancake coils was tested at 4.2 K, and seven double pancake coils with superior performance were selected to assemble into an insert coil as shown in Fig. 1. Charge experiments for the insert coil were conducted at 0 T, 10 T, and 20 T background magnetic fields, respectively. All experiments achieved the design objective, with the iron-based superconducting insert coil generating above 1 T magnetic field at the background field of 0 T, 10 T, and 20 T, respectively. The test results were shown in Fig. 2. Critical performance testing also demonstrated that the insert coil has a critical current of approximately 84 A in the 20-T background field, surpassing all previously reported performance tests of iron-based superconducting coils. More details can be found in reference [12].

The successful development of the first Tesla class iron-based superconducting insert coil was regarded as an iconic achievement that indicates iron-based superconductors have joined the practical high-field magnet family, and iron-based superconducting wires are needed to be seriously considered as one of the candidates to be used for large-scale superconducting magnets [13].

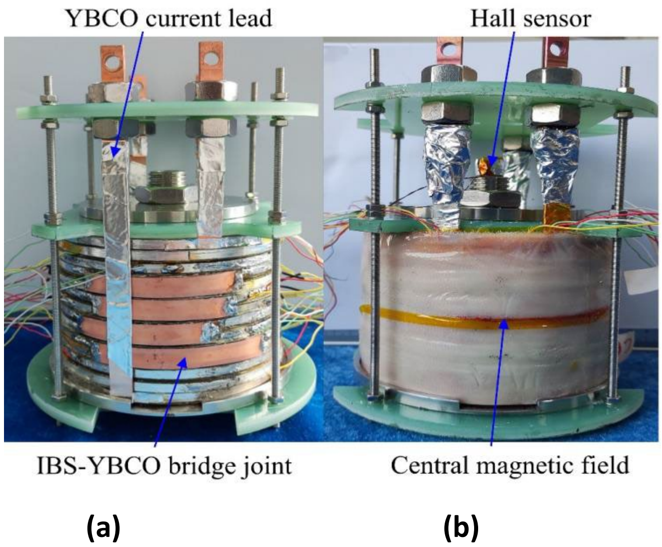

Figure 1. Iron-based superconducting high-field insert coil (a) before reinforcement, (b) after reinforcement.

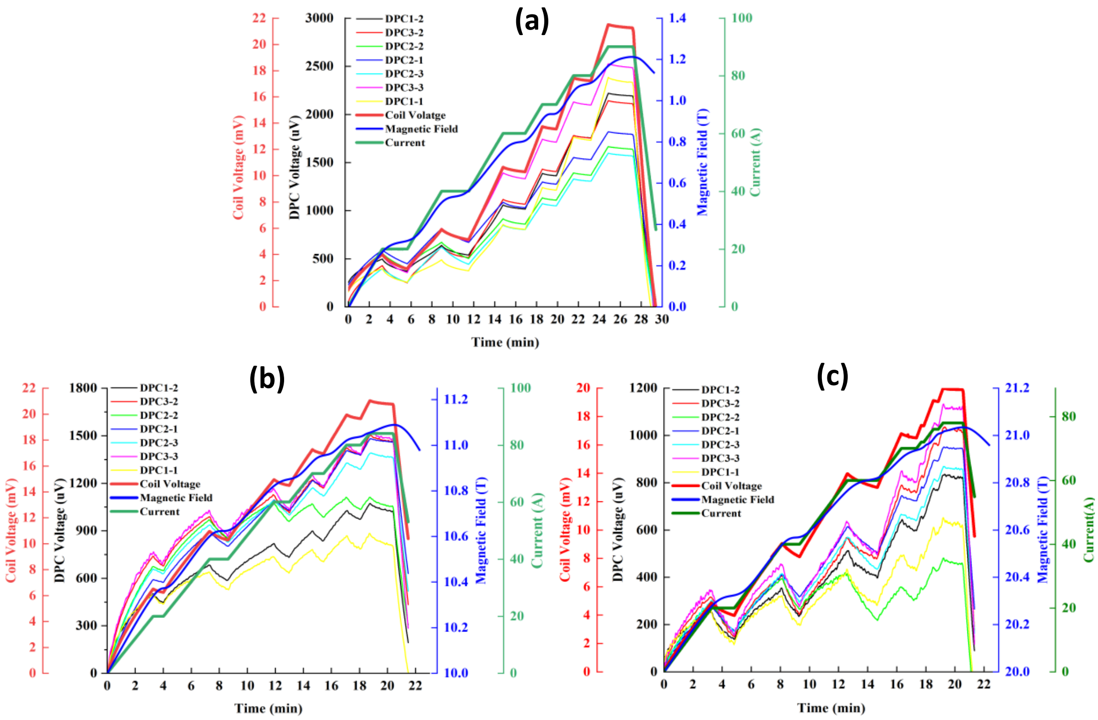

Figure 2. The insert coil charge test results in (a) 0 T (b) 10 T (c) 20 T background.

Acknowledgements

This work is supported by the National Key R&D Program of China (Grant No. 2018YFA0704200), the Strategic Priority Research Program of Chinese Academy of Sciences (Grant No. XDB25000000), the National Natural Science Foundation of China (Grant No. U1832213).

This work is also supported by the Key Program of Research and Development of Hefei Science Center CAS (Grant No.2019HSC-KPRD002) and the National Natural Science Foundation of China (Grant No. U2032216)

References

[1] Kmihara Y, Watanabe T, Hirano M and Hosono H 2008 Iron-based layered superconductor $La[O_{1-x}F_x]FeAs$ (x = 0.05-0.12) with T_c =26 K *J. Am. Chem. Soc*. 130 3296-7

[2] Hosono H, Yamamoto A, Hiramatsu H and Ma Y W 2018 Recent advances in iron-based superconductors toward applications *Mater. Today* 21 278–302

[3] Zhang X P, Oguro H, Yao C *et al* 2017 Superconducting Properties of 100-m class $Sr_{0.6}K_{0.4}Fe_2As_2$ Tape and Pancake coils *IEEE Trans. Appl.* 27 7300705

[4] Wang D L, Zhang Z, Zhang X P *et al* 2019 First performance test of 30 mm iron-based superconductor single pancake coil under 24 T background field *Supercond. Sci. Technol.* 32 04LT01

[5] Zhang Z, Wang D L, Wei S Q *et al* 2021 First performance test of the iron- based superconducting racetrack coils at 10 T *Supercond. Sci. Technol.* 34 035021

[6] Qian X X, Jiang S L, Ding H W *et al* 2021 Performance testing of the iron-based superconductor inserted coils under high magnetic field *Physica C Superconductivity and its Applications* 580 1353787

[7] Zhang Z *et al* 2020 Fabrication and Test of Diameter 35 mm Iron-Based Superconductor Coils *IEEE Trans. Appl. Supercond.* 30 4602404

[8] Wei S Q *et al* 2023 First performance test of $FeSe_{0.5}Te_{0.5}$-coated conductor coil under high magnetic fields *Supercond. Sci. Technol.* 36 04LT01

[9] Pyon S *et al* 2022 Fabrication of multi-filament $(Ba,A)Fe_2As_2$ (A: Na, K) HIP round wires and a small superconducting coil *Supercond. Sci. Technol.* 36 015009

[10] Tamegai T *et al* 2023 Fabrication of Small Magnets Using Mono-and Seven-Core $(Ba,A)Fe_2As_2$ (A: K, Na) HIP Round Wires *IEEE Trans. Appl. Supercond.* 33 6900104

[11] Li C *et al* 2024 Development of metal-insulated iron-based superconducting coils and charging tests under high magnetic fields up to 32 T *Supercond. Sci. Technol*. 37 015001

[12] Ding H W *et al* 2023 Development of the first Tesla class iron-based superconducting coil for high field application *Supercond. Sci. Technol.* 36 11LT01

[13] Tamegai T 2024 Iron-based superconductors have joined the practical high-field magnet family *Supercond. Sci. Technol* 37 010501