Ultra-high field NMR superconducting magnet design with conduction-cooled cryostat system

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Introduction

Nuclear magnetic resonance (NMR) system is a powerful tool in the material composition analysis, identification of chemical functional group, inspection of molecular steric configuration, etc., which has exerted a profound impact on the human recognition. The development of NMR technique keeps as an on-going topic on the high-tech science. The NMR signal resolution is closely related to the magnetic field intensity and the augmentation of the magnetic field of NMR magnet will elevate NMR spectrum resolution significantly, resulting in more accurate explanation of material microscopic structure.

Method

The 7T conduction-cooled NMR superconducting magnet adopts a design scheme of radial current classification with a reduction of the wire cost. Several types of wire gauges were used to wind the primary long solenoids. However, the magnetic field homogeneity of solenoid cannot meet the magnet design requirement. Compensating coils are necessary to offset the unwanted inhomogeneous components. Therefore, a magnetic field superposition strategy was used for the homogeneity optimization and also the stray field shielding, as diagramed in Fig. 1

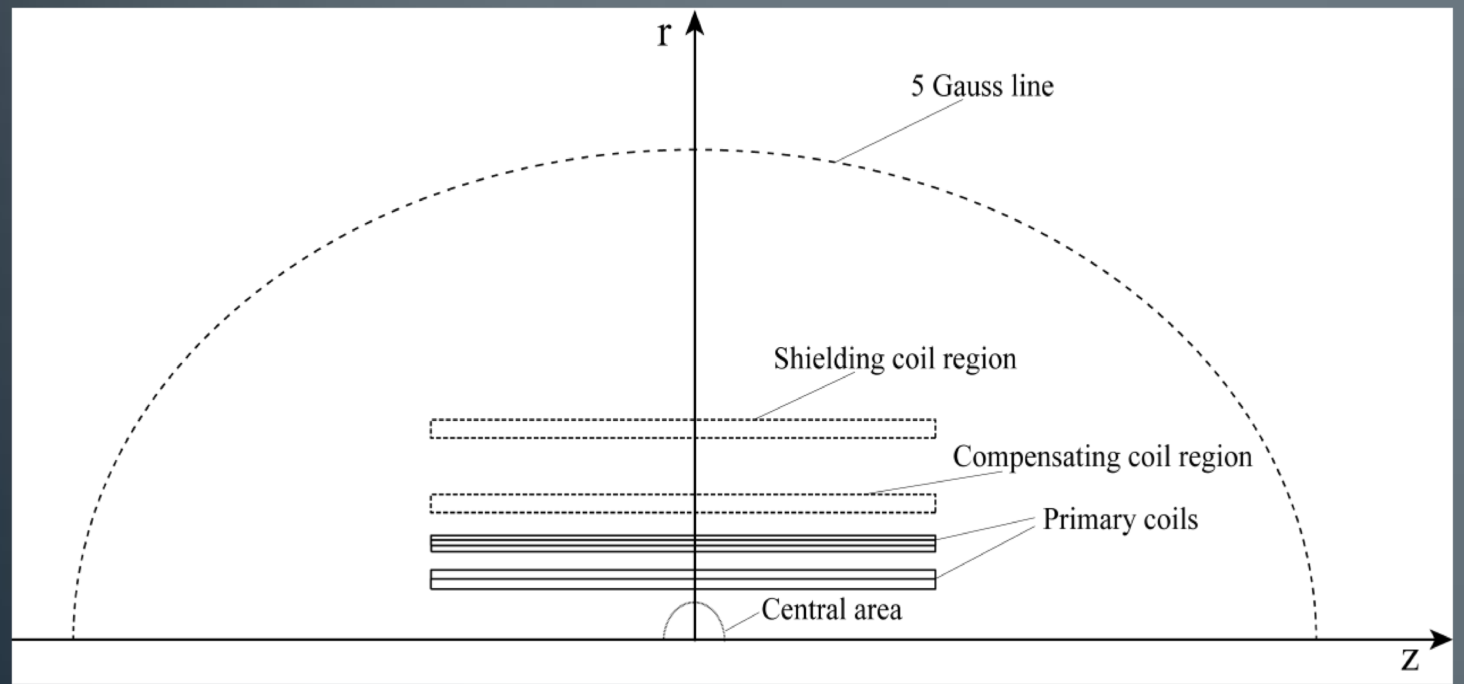

Fig.1 Diagram of the compensating field method for high-field superconducting magnet design

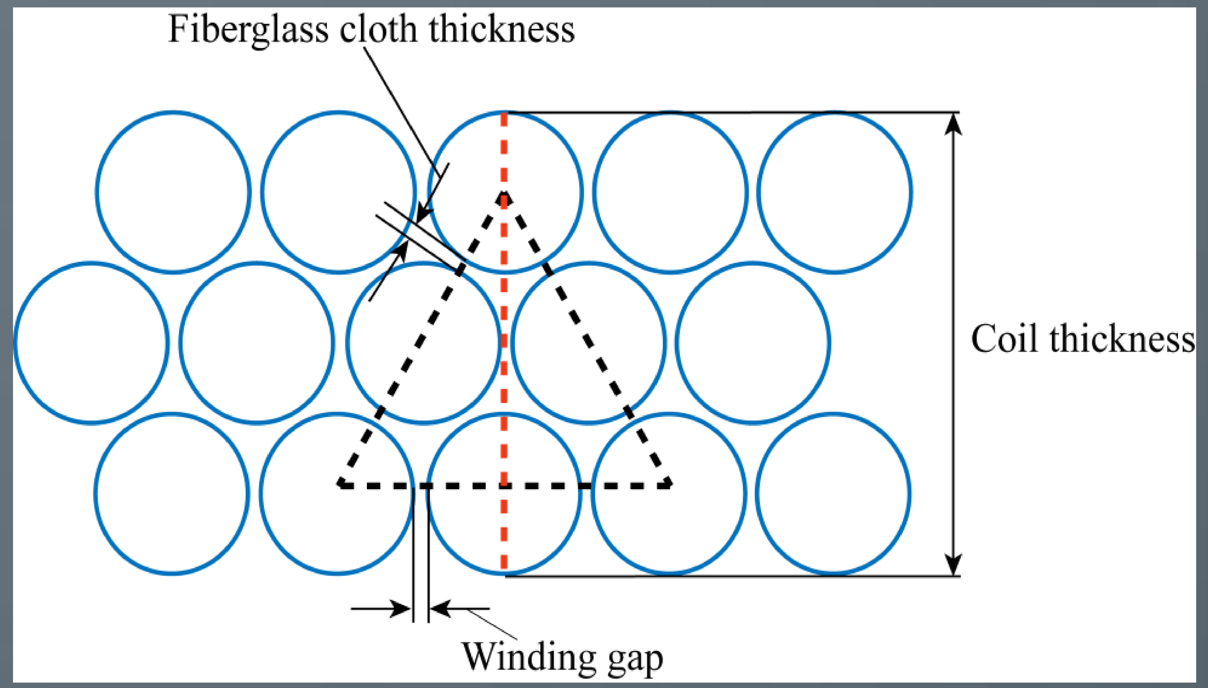

Fig. 2 A sketch map of the round superconducting layout in a NMR magnet coil.

Result

The magnet coil pattern is shown in Fig. 3, where there are totally 14 coils, including 12 magnet coils and 2 EIS coils. Coils 1-5 are the primary solenoid coils, 6-9 are the compensating coils, 10-12 are the shielding coils and 13-14 are the EIS coils. The shielding efficiency of the EIS coil on the incident interference magnetic field is 37.7.

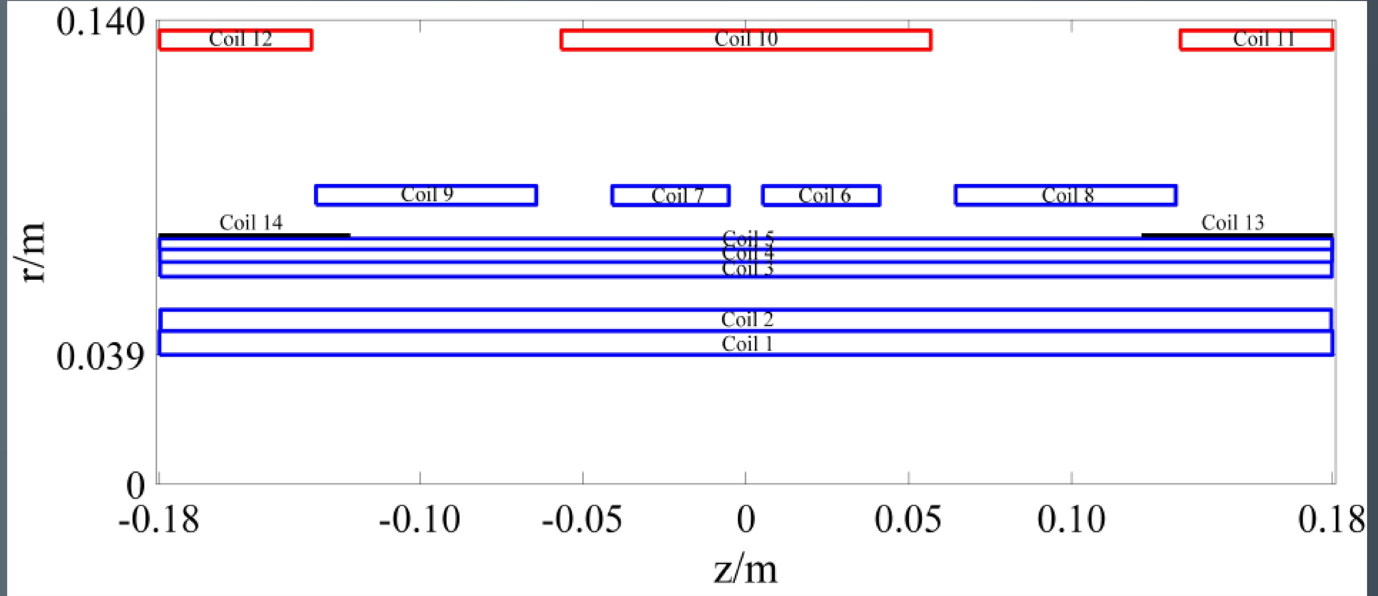

Fig. 3 Coil pattern of a 7T conduction-cooled NMR superconducting magnet

Table I Design parameters of the 7T NMR superconducting magnet

Magnetic field strength	7 T
DSV	50 mm
Magnetic field homogeneity (peak to peak)	8 ppm
Stray field range (5 Gauss line)	0.65 m×0.4 m (z×r)
Operating current	115.44 A
Peak field	7.02 T
Maximum hoop stress with binding	120 MPa
Inductance	13.8 H
Storage energy	91.8 kJ
Conductor length	14.7 km

The magnet design parameters were concluded in Table I. The magnet consumes a total wire length 14.7 km and owns a storage energy 91.8 kJ when energizing to 7T.

Conclusion

A compact 7T conduction-cooled NMR superconducting magnet design was presented in this work. The coil optimization considered the winding gap, fiberglass cloth layout, and round wire clustering pattern, etc., so as to reducing the design deviation. The ultimate magnet pattern includes 12 magnet coils and 2 EIS coils. The magnetic field homogeneity has peak-peak 8 ppm and 5 Gauss line is restricted in a range with 0.65 m at the axial direction by 0.40 m at the radial direction. The maximum hoop stress resides at the middle shielding coil, reaching 120 MPa. The operating current is 115.44 A with a current margin 21.36% and temperature margin 1.45 K in terms of the selected superconducting wire. Low-temperature system will be dedicatedly designed in the future to make an integral NMR magnet.