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Magnet design of a 7 T animal MRI scanner

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Introduction

Animal magnetic resonance imaging (MRI) is a useful tool on preclinical scientific research due to its superior soft-tissue imaging capability and functional MRI characteristics. Some early medical experiment has to be conducted on mouse, monkey or other animals which have similar gene feature with human beings. Compared with whole-body medical MRI system of similar field strength, animal MRI generally has smaller imaging bore and system volume, lighter weight, less construction cost, etc. Therefore, animal MRI has a broad market on modern biomedical exploration.

Method

For ultra-high field superconducting MRI magnet design, for example 7T or higher, long solenoid coils plus compensating coils are the commonly-used design strategy, since the maximum magnetic field intensity in long solenoid coil is approximate to the central field intensity, thus increasing the current margin. The 7T magnet applied the magnetic field compensating method. Two long solenoid coils were initially set as primary coils with designated wire gauges and compensating and shielding coils were optimized with a consideration of the preset primary magnetic field. Fig. 1 is a diagram of the design method.

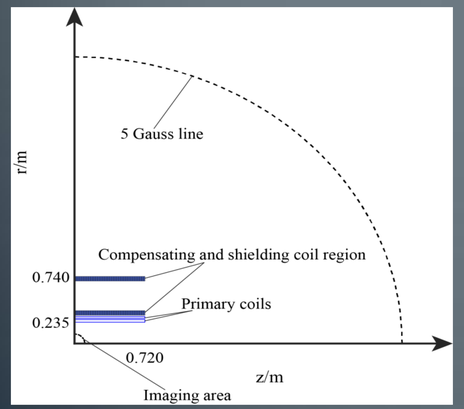

Fig.1 Diagram of an actively-shielded 7T animal superconducting magnet design using a compensating field strategy on long solenoid coils.

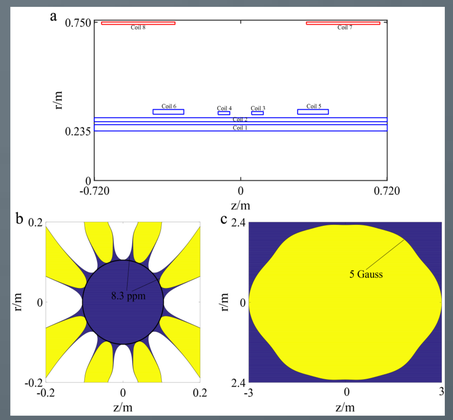

Fig. 2 Adjustment optimization result after coil discretization into wire turns: (a) magnet coil positions, (b) magnetic field homogeneity contour over the imaging area and (c) 5 Gauss line at the stray field distribution.

Result

Fig. 2 shows the final optimization result. The magnet include 2 long solenoid primary coils, 4 compensating coils and 2 shielding coils in total. The warm bore is designed to be 400 mm.

Table I Magnet design parameters of a 7T superconducting animal MRI system

Magnetic field strength	7 T
DSV	210 mm
Magnetic field homogeneity	8.3 ppm
Stray field range (5 Gauss line)	3 m×2.4 m (r×z)
Operating current	180.86 A
Peak field	7.33 T
Maximum hoop stress with binding	138 MPa
Inductance	415.8 H
Storage energy	6.8 MJ
Conductor length	124.9 km

The magnet design parameters were concluded in Table I. The magnet consumes a total wire length 124.9 km and owns a storage energy 6.8 MJ when energizing to 7T.

Conclusion

An actively-shielded 7 T superconducting magnet was designed for use in an animal MRI system. The warm bore diameter is estimated at 400 mm. The magnetic field has a peak-peak homogeneity 8.3 ppm over a 210 mm imaging sphere and the 5 Gauss stray field was constrained in a range with 3 m at axial direction by 2.4 m at radial direction. Both the magnetic field and mechanical performances of the magnetic coils were presented. The selected superconducting wire has a current margin 14.71% at liquid helium temperature and the maximum hoop stress is 138 MPa. The critical design parameters meet the NbTi superconductor requirement. Further work needs to be conducted on the mechanical structure design, liquid helium dewar design, shimming coil design, etc.