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An MRI Magnet Charged by Multiple Flux Pumps: Construction and Test of the Prototype Magnets

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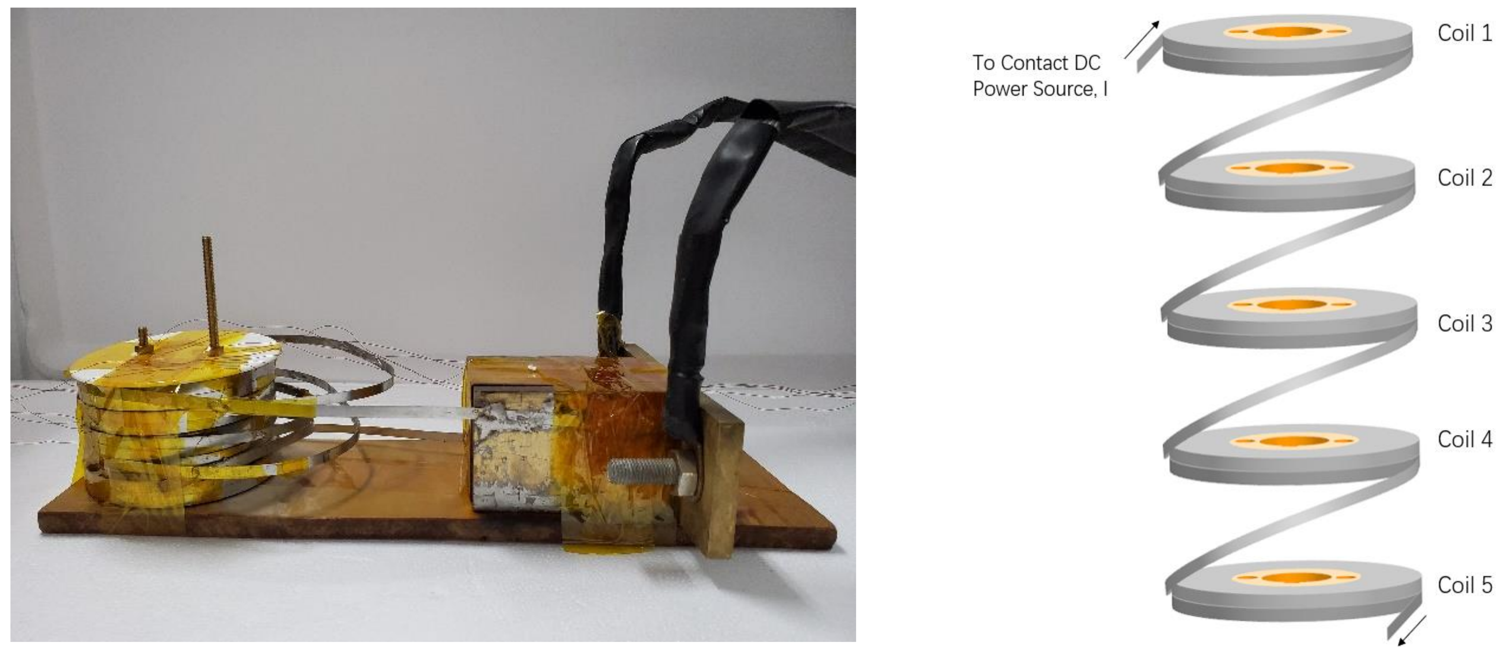
Introduction

The construction and test results of an MRI magnet charged by multiple rotating permanent flux pumps was presented in this paper. The magnet consists of 5 no-insulation (NI) double pancake coils (DPCs), whose inner diameter is 50 mm, outer diameter is about 92 mm, and axial length is 50 mm. In order to increase the magnetic field at the center of the magnet, 5 DPCs operated at 3 different currents, which were provided by 3 flux pumps. The effect of the charging sequence on the central magnetic field has also been studied. Compared to the magnet operating at single current, the magnet proposed in this paper can improve the central magnetic field by 32.65%.

Experiment Configuration

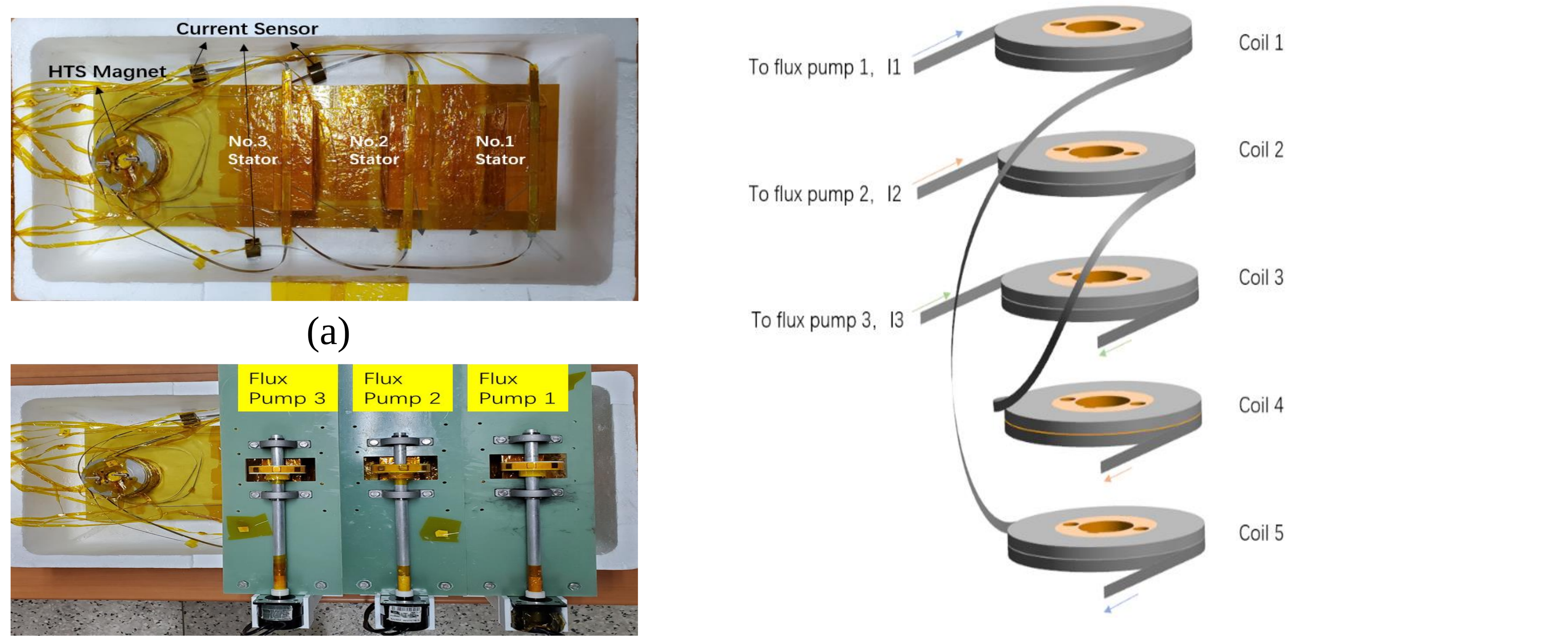


(a) (b)

Fig.1. (a) The experiment setup of single flux pump charging the magnet. The contact DC power supply charges five superconducting coils connected in series. The magnetic field at the center of the magnet was measured by the Hall element and the voltage across each coil was collected by twisted pair, which were recorded by Keysight 34972A. (b) Wiring diagram of five series coils. The flying wire of the lower pancake in coil 1 was connected to the flying wire of the upper pancake in coil 2, and coil 3, 4, and 5 coils are connected in the same way; the fly leads of the upper pancake in coil 1 and the lower pancake in coil 5 are connected to the two poles of the DC power source.

Single conventional power supply charges the series coil, and the experimental setup is shown in Fig.1. The E-I characteristics and center magnetic field of the magnet are shown in Fig.3. When the magnet is resistive, the current was defined as a critical current of 32A.

Multiple flux pump power supplies were charged for coils at different positions. The experimental setup is shown in Figure 2. The charging sequence can be adjusted as shown in Table 1. The stable current and center magnetic field are shown in Table 2.



(a) (b) (c)

Fig.2. (a) The experiment setup of three flux pumps charging the magnet. The magnet consisting of five coils was connected to three stators, the gap between which and the flux pump was set as 1 mm. (b) The speed of the rotor was controlled by DSP microcontroller to regulate the charging current and the central magnetic field, which were collected by current sensors and Hall sensors and displayed on the panel in real-time; (c) Magnet circuit wiring diagram. Coil 1 was connected in series with coil 5 and then connected in parallel with the No.1 stator; Coil 2 and coil 4 were connected in series, and then in parallel with No. 2 stator. Coil 3 was connected in parallel with No. 3 stator.

Results and Discussion

TABLE II
STARTING SEQUENCE OF THREE FLUX PUMP POWER SUPPLIES

	Flux Pump 1	Flux Pump 2	Flux Pump 3
Sequence 1	3_{rd}	2_{ed}	1_{st}
Sequence 2	1_{st}	2_{ed}	3_{rd}
Sequence 3	3_{rd}	1_{st}	2_{ed}
Sequence 4	All Flux Pump Started at The Same Time		

TABLE II
STABLE CURRENT AND CENTER MAGNETIC FIELD OF FOUR SEQUENCE

	I_1 (A)	I_2 (A)	I_3 (A)	B_c (mT)
Sequence 1	22.9	31.4	36.6	390
Sequence 2	26.9	28.6	29.8	373
Sequence 3	25.0	29.8	31.4	377
Sequence 4	22.3	27.7	31.4	365

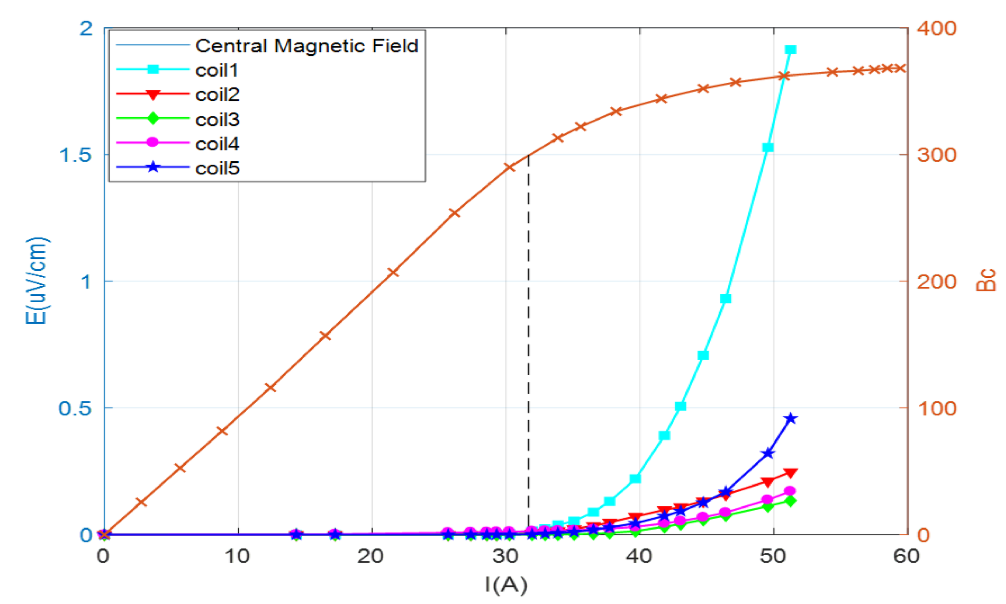


Fig.3. The E-I characteristic curve of each coil when the five coils are charged in series, and the correspondence between the central magnetic field of the magnet and the charging current. When the coil was resistive, with the magnet charging current of 32A, the relationship between the central magnetic field and the current became nonlinear.

Conclusion

A magnet with five coils connected in series has a center magnetic field of 294 mT with the charging current of 32 A. When the magnet the magnet connected in parallel as we proposed was charged in the charging sequence 1 with three flux pumps, the central magnetic field could reach 390 mT, which was increased by 32.65%.