DESIGN OF A MODEL SECTOR MAGNET FOR THE RIKEN SUPERCONDUCTING RING CYCLOTRON

T. Kubo, T. Kawaguchi, T. Mitsumoto, T. Tominaka, S. Fujishima, J.-W. Kim, Y. Tanaka, K. Ikegami, N. Sakamoto, S. Yokouchi, T. Morikawa, A. Goto and Y. Yano
The Institute of Physical and Chemical Research(RIKEN)
2-1 Hirosawa, Wako, Saitama 351-01, Japan

Abstract

A six-sector superconducting ring cyclotron is to be built in the RIKEN RI-beam factory project as one of post accelerators of the existing K540 ring cyclotron. This paper reports on a full-scale model sector magnet for the superconducting ring cyclotron.

1 INTRODUCTION

In the RIKEN RI-beam factory project, it is planned to build two new ring cyclotrons as post accelerators of the existing K540 ring cyclotron [1]. The first new cyclotron we call IRC has a K-value of 950 MeV, consisting of four normal-conducting sector magnets. Its mean injection and extraction radii are designed to be 2.77 m and 4.15 m, respectively. The second one we call SRC is a superconducting ring cyclotron with a K-value of 2,500 MeV, consisting of six superconducting sector magnets whose sector angle is 25 degrees and maximum field is 4.3 T. Its mean injection and extraction radii are designed to be 3.56 m and 5.36 m, respectively. The cascade operation of these cyclotrons boosts energies of heavy ion beams up to: e.g. 400 MeV/nucleon for light heavy ions like carbon, 300 MeV/nucleon for krypton ions, and 150 MeV/nucleon for uranium ions.

Here we report on a design of a model superconducting sector magnet for the SRC. The design of the SRC is reported elsewhere in these proceedings [2, 3].

2 MODEL SECTOR MAGNET

A full scale model is to be built so that we can make sure the design of sector magnet under the condition as close to the real one as possible. Figure 1 shows a schematic drawing of the model sector magnet. The cold pole method has been adopted to support the huge electromagnetic force due to the large magnetic field and coil current [3]. Figure 2 shows some details of the main coil vessel and cold pole.

2.1 Cold Pole and Main-coil Vessel

As seen from Figs. 1 and 2, the iron pole pieces are separated from the iron yoke and are cooled down together with the main coils in the cryostat. Two coil vessels that accommodate the main coils are attached to the side of the upper and lower pole pieces, which are linked each other by pole links. This arrangement allows the pole pieces to work as a mechanical support against the huge force excerted on the mail coils or the coil vessels.

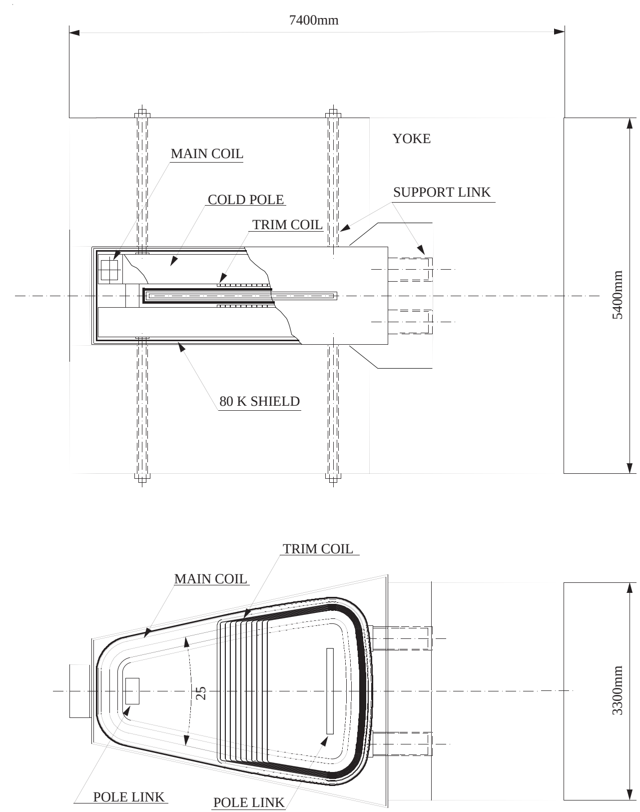

Fig. 1. Schematic drawing of the model sector magnet: a side view (upper figure); a top view (lower figure).

The pole gap is designed to be 380 mm, considering sizes of the trim coils and of the magnets for injection and extraction to be installed in the gap space. The cold-mass weight is estimated to be about 50 tons. The coil vessels are made of stainless steel. One of the important issues in the design is how to fix the coil vessel to the side of pole piece. Figure 3 shows two alternative methods that we considered. The scheme shown in the upper part of Fig. 3 uses sort of “hook” to fix the coil vessel to the pole. The coil vessel and the “hook” are assembled by welding. The second scheme shown in the lower part of Fig. 3 uses screws to fix the coil vessel to the pole as well as to assemble the coil vessel. We plan to adopt the former scheme for the upper coil and the latter one for the lower coil, and to examine in the test operation of model magnet which scheme is better.

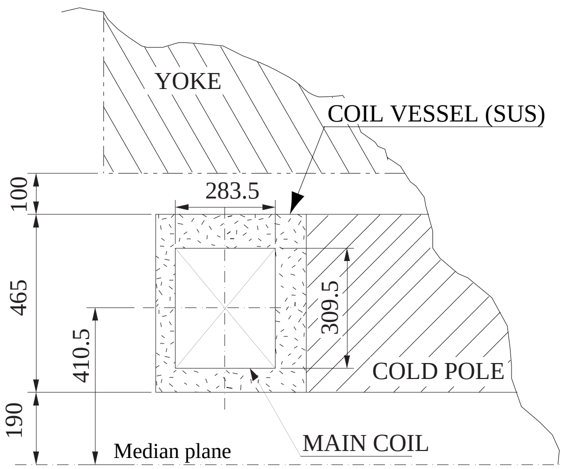

Fig. 2. Some details of the main coil and cold pole.

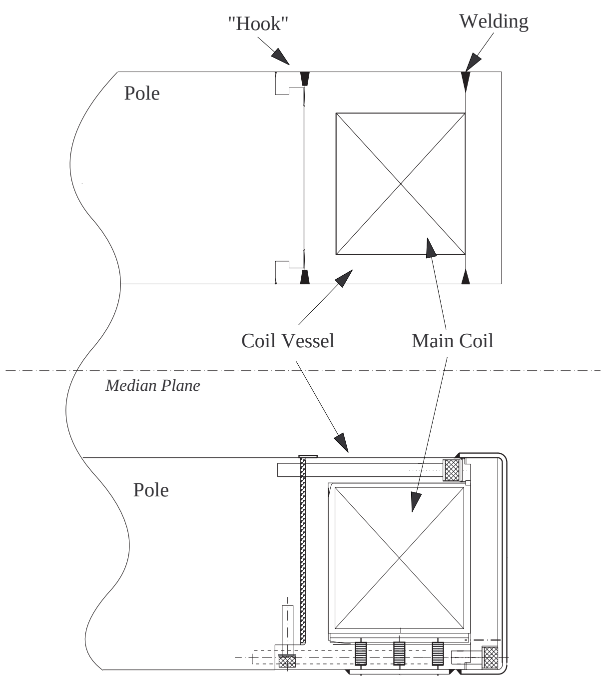

Fig. 3. Two alternative schemes to fix the coil vessel to the cold pole.

2.2 Main Coil and Conductor

A cryogenically-stabilized superconductor has been designed based on Maddock's criterion, and is used for the main coil in order to prevent it from quenching. The conductor has a rectangular shape, consisting of a Rutherford-type NbTi cable located at the center of conductor and a stabilizer housing. The conductor's cross-sectional sizes are horizontally 8 mm and vertically 15 mm. The Rutherford-type cable is composed of ten NbTi superconducting wires of 1.25 mm diameter and 1.05 Cu/SC ratio. The diameter and twisting pitch of the filaments contained in each wire are 27 and 18 mm, respectively. Critical currents of the wire at 4.3 K is greater than 14,500 A at 5 T, 11,500 A at 6 T, and 8,500 A at 7 T. The Rutherford-type cable has a rectangular cross-section of 2.35 mm x 6.35 mm and has a twisting pitch of 55 mm. The stabilizer material has been chosen to be pure aluminum with a residual resistivity ratio greater than 500. The condition of the stabilizer surface is flat. The Al:Cu:SC ratio of the conductor is 17 : 1.05 : 1. The conductor is cryogenically stable up to a current of 6,000 A when the applied magnetic field is 6 T and the cooling efficiency is assumed to be 50%.

The main coil is cooled by the liquid-helium bath cooling method. Cross-sectional area of the main coil is 283.5 mm x 309.5 mm, as shown in Fig. 2. The number of turns is 600 for each coil. The main coil is wound by the solenoid winding method in such a way that it has 30 layers in the horizontal direction and 20 turns in the vertical direction. The conductor length is estimated be 6.4 km/coil. The cooling gaps in horizontal and vertical directions are chosen to be 1.5 mm and 0.5 mm, respectively. A heat-flux measurement has shown that these gap-widths are large enough to achieve the designed heat flux. The spacers of FRP (Fiber Reinforced Plastic) are placed in the gaps in such a way that 50 % of conductor surface is exposed to the liquid helium. We plan to excite the main coil with currents lower than 5,000 A, considering deterioration of cooling which may happen in some parts of the coil. The current density at 5,000 A is estimated to be about 34 A/mm^2. The total ampere-turn is 6 MA at 5000 A, which is large enough to generate the design field strength of the sector magnet.

2.3 Test Trim Coils

Test trim coils, which correspond to a part of real trim coil, are to be fabricated and installed in the pole gap space as shown in Fig. 1. The conductor of trim coil has been designed to be cryogenically stable, based on Stekly's criterion. It is a rectangular conductor whose cross-sectional sizes are horizontally 2.9 mm and vertically 3.6 mm, and consists of a stabilizer housing of pure aluminum and a superconducting wire located at the center of conductor. The superconducting wire is the same as that used for the Rutherford-type cable of main-coil conductor. The cooling gaps of trim coil are taken to be 0.25 mm. The cooling efficiency is estimated to be 40 % considering the spacers placed in the gaps. The trim coil is stable up to 550 A at 6 T. We plan to excite it with currents lower than 500 A for safety. The current density at 500 A is estimated to be about 41 A/mm^2. The trim coil vessel is connected in series to the main coil vessel, so that the trim coil can be cooled by liquid helium provided by a common refrigerator.

3 SCHEDULE

Fabrication of the conductors has been finished this March. Fabrication of the model magnet will be soon placed an order with manufacturers. The cold mass and cryostat will be completed in a year.

REFERENCES

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