DESIGN OF MODEL SECTOR MAGNET FOR THE RIKEN SUPERCONDUCTING RING CYCLOTRON

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Abstract

The construction of two superconducting ring cyclotrons, SRC-4 and SRC-6, has been proposed at RIKEN as post accelerators of the existing ring cyclotron. In this report we describe a design of a model sector magnet for the superconducting ring cyclotron SRC-6.

1 INTRODUCTION

An RI-beam factory based on the projectile fragmentation method has been proposed as an extension of RIKEN Ring Cyclotron(RRC).[1] In this project we plan to build two superconducting ring cyclotrons (SRC) as post accelerators of RRC. The first SRC we call SRC-4 is a 4-sector ring cyclotron and its mean injection and extraction radii are taken to be 2.37 m and 3.56 m, respectively. The second SRC called SRC-6 consists of six superconducting sector magnets whose sector angle is 25 degrees and maximum magnetic field is 4.2 T. Its mean injection and extraction radii are taken to be 3.56 m and 5.36 m, respectively. These two SRC's boost 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. Such capability of heavy ion beams would enable efficient production of RI beams using projectile fragmentation.

Design studies of the SRC are reported in these proceedings.[2,3] The present paper reports on a design of a model superconducting sector magnet for the SRC-6.

2 DESCRIPTION OF MODEL SECTOR MAGNET

We plan to build a full-scale model so that the design of the sector magnet can be made sure under the condition as close to the real one as possible. This would be particularly important to see if the huge magnetic force due to the high magnetic field and current density[3] can be properly supported. The model magnet aims at generating a magnetic field higher than 4.2 T that is required in the current design of the SRC-6[2].

Figure 1 shows a schematic drawing of the model magnet. The cold-pole method has been adopted as described in ref. [3]. The pole pieces are separated from an iron yoke and cooled down together with main coils in a cryostat. The coil vessel that accommodates the main coil is attached to the side of the pole piece. The upper and lower pole pieces are linked each other. Such an arrangement allows the pole pieces to support the magnetic force exerted on the main coils. Furthermore it enables to reduce the magnetic force expanding the main coil, since the main coil can be placed very close to the pole[3]. Several support links are shown in Fig. 1; the horizontal ones support the shifting force and the vertical ones the weight of pole pieces and main coils.

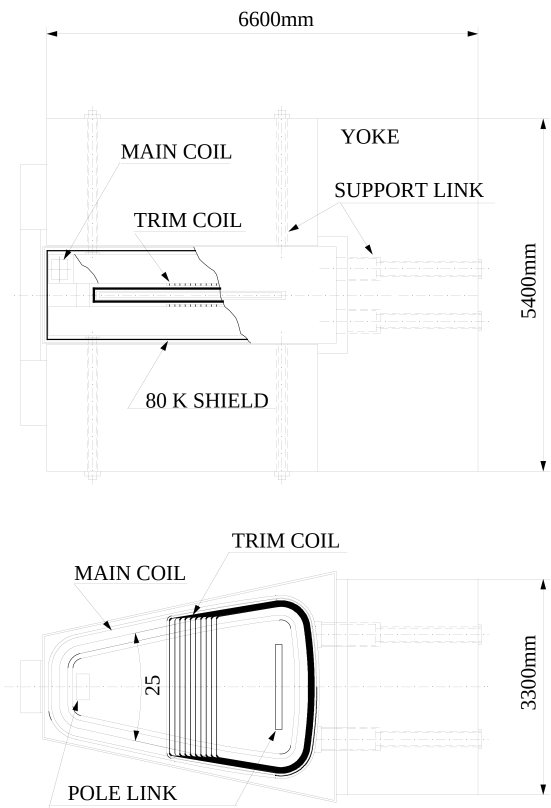

Fig. 1 A schematic drawing of the model sector magnet: a side view(upper); a top view(lower).

Figure 2 shows some details of the main coil and the cold pole. The coil vessel made of stainless steel is fixed to the side of iron pole. We plan to use screw bolts to do so instead of welding, considering the difference of thermal contraction between the stainless steel and the iron. The pole gap is taken to be 380 mm, considering the size of trim coils[2,3] and magnets for injection and extraction[4] that are installed in the gap. The cold-mass weight and the total magnet weight are estimated to be about 60 and 680 tons, respectively.

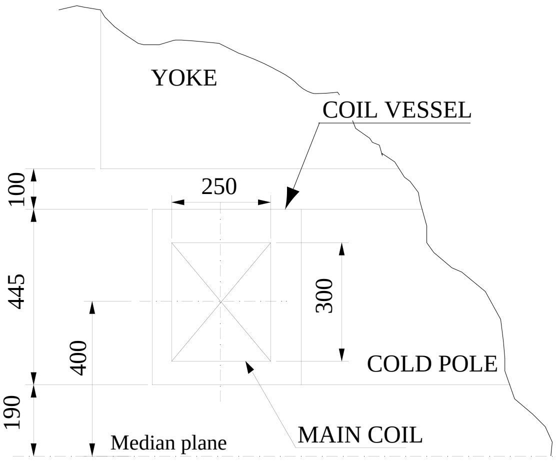

Fig. 2 Some details of the main coil and cold pole.

It is planned to use a cryogenically-stabilized superconductor (based on Maddock's criterion) in order to prevent the main coil from quenching.[3] The cooling is made by the liquid-helium bath-cooling method. The conductor to be used has a cross-sectional size of 7.5 mm x 14 mm and consists of a Rutherford-type NbTi cable and a stabilizer housing. The stabilizer material will be either copper or aluminum. The conductor is designed to be stable up to 6000 A when the magnetic field applied is 6 T and the cooling efficiency is assumed to be 50%. However we plan to excite the main coil with currents lower than 5000 A, because the deterioration of cooling may happen in some parts of the coil. The current density at 5000 A is estimated to be about 40 A/mm2, taking account of conductor gaps for the liquid helium and the insulation. The maximum stable current will be checked in the test operation of model magnet. The number of turns is taken to be 1200 so that the maximum ampere-turn can be 6 MA.

Figure 3 shows median-plane field distributions along the central line of sector magnet which were calculated by the code TOSCA[5]. The solid line in the figure shows the distribution when the ampere-turn is 6 MA. The field is found to be around 4.7 T, which is well above the value required for the SRC-6. The maximum field in the main coil is calculated to be about 6 T, which is smaller than the stabilization limit of the conductor at 5000 A. The stored energy has been calculated to be 80 MJ. The dotted line in the figure shows the distribution at the ampere-turn of 5.25 MA where the magnetic field required is achieved.

The total heat load has been estimated to be about 120 W at 4.5 K. We plan to purchase a liquid-helium refrigerator with a capacity of about 200 W at 4.5 K.

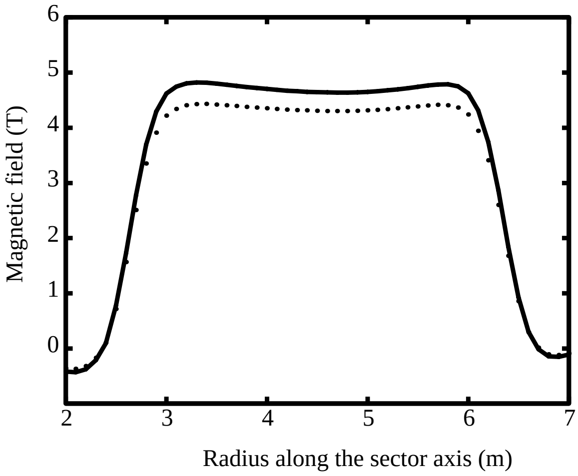

Fig. 3 Calculated median-plane field distributions along the central line of sector magnet. The solid and dotted lines show the distributions at the ampere-turn of 6 and 5.25 MA, respectively.

3 SCHEDULE

We plan to first make only the cold mass and cryostat because of the limitation of budget and accommodation space. The iron yoke will be added later. The model magnet will be operated without the yoke for a while. Without the yoke it is calculated that the median-plane field is reduced by 20 to 30 %. However the field strength in the main coil does not decrease that much. The decrease rate is calculated to be 5 to 10 %. So the operation without the yoke would give us some useful information.

We plan to test a prototype of superconducting trim coil by installing it onto the pole surface as shown in Fig. 1. The cryogenically-stable cooling will also be applied to the trim coil. We also plan to install and test a prototype of superconducting magnetic channel which will be used for the beam injection or extraction.

The fabrication of the model magnet (without the yoke) is scheduled to start early in the next year and complete by its end.

REFERENCES

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[4] H. Okuno et al.: 'Design Study of Injection System of the RIKEN Superconducting Ring Cyclotron', These proceedings.

[5] Vector Fields Limited, Oxford, England.