STATUS OF THE SUPERCONDUCTING MAGNET SYSTEM FOR THE J-PARC NEUTRINO BEAM LINE

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Abstract

Superconducting combined function magnets will be utilized for the 50 GeV, 750 kW proton beam line for the J-PARC neutrino experiment. The magnet is designed to provide a dipole field of 2.6 T combined with a quadrupole field of 19 T/m in a coil aperture of 173.4 mm at a nominal current of 7345 A. Construction of the magnet system is underway.

INTRODUCTION

A second generation of long-baseline neutrino oscillation experiments has been proposed as one of the main projects at the J-PARC [1], [2] and the construction of the facility is in progress. Superconducting combined function magnets, SCFMs, will be utilized for the 50 GeV, 750 kW proton beam line for the neutrino experiment. The magnet is designed to provide a dipole field of 2.6 T combined with a quadrupole field of 19 T/m in a coil aperture of 173.4 mm at a nominal current of 7345 A. A series of 28 magnets in the beam line will be operated DC in supercritical helium cooling below 5 K. Since the main accelerator will be operated at 30 GeV in the beginning, the SCFM was designed for proton beam energies of 30 to 50 GeV. A cross sectional view of the SCFM is shown in Fig. 1 and the main design parameters are listed in Table 1.

STATUS OF CONSTRUCTION OF THE MAGNET SYTEM

The detail of the magnet system development was reported in the previous reports [3]-[8]. This report focuses on the status of the construction of the magnet system.

Main SCFMs

The SCFM has a unique design feature of the left-right asymmetry of the coil cross section: current distributions for superimposed dipole- and quadrupole- fields are combined in a single layer coil. Another design feature is the adoption of glass-fiber reinforced phenolic plastic spacers for electrical insulation to reduce the labor and inspection costs. Beam optics calculations confirmed that the design magnetic field of the SCFM within a tolerance of 10^{-3} at a reference radius of 50 mm was sufficiently acceptable. The coil is mechanically supported by a keyed yoke made of fine-blanked iron laminations. The iron yoke also functions as a magnetic flux return.

The contract to build 32 production magnets and 16 cryostats was given to Mitsubishi Electric. Fabrication of the magnets was completed by June 2008 and the excitation tests for all magnets in liquid helium at 4.2 K in the vertical cryostat were carried out at KEK.

All magnets were successfully excited up to 7700 A corresponding 105 % nominal current at a ramp rate of 20 A/s without a spontaneous training quench. Firing tests of the quench protection heaters including a full energy dump test were successfully carried out for all production magnets.

Magnetic field measurements were performed with a 500 mm-long rotating printed circuit board. Figure 2 shows a typical measurement result: the field integrals of SCFMs at 7345 A compared with the field computation by Opera-3d. The magnetic field at a reference radius of 50 mm was analyzed so that average of the skew

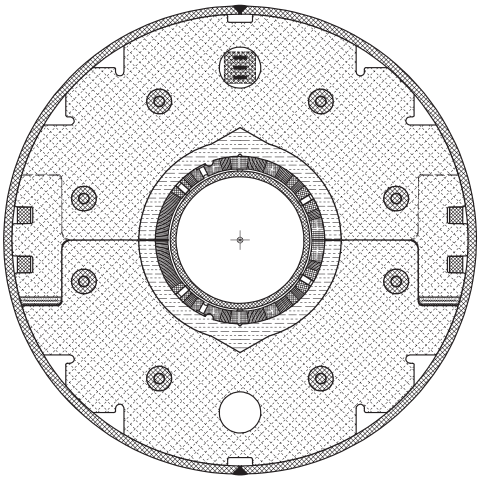

Figure 1: Cross sectional view of the superconducting combined function magnet, SCFM, for the 50 GeV proton beam line for the J-PARC neutrino experiment.

Table 1: Main Design Parameters for the SCFM

Physical & Magnetic Length	3630 & 3300 mm
Coil In. & Out. Diameter	173.4 & 204.0 mm
Yoke In. & Out. Diameter	244 & 550 mm
Shell Outer Diameter	570 mm
Dipole & Quad. Field	2.59 T & 18.7 T/m
Coil Peak Field	4.7 T
Load Line Ratio	72 %
Operational Current	7345 A
Inductance & Stored Energy	14.3 mH & 386 kJ

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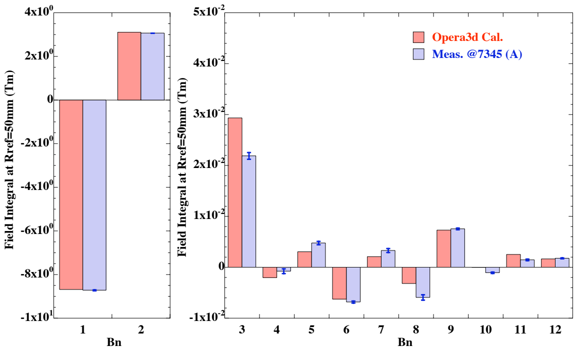

Figure 2: Field integrals of normal multipoles of SCFMs at 7345 A. Average over 32 SCFMs are compared with the field computation by Opera-3d.

quadrupole component along the magnet straight section was equal to zero. Measured normal field integrals fairly agree with the computation. Error bars indicate the standard deviation over 32 magnets and good reproducibility within 10^{-3} was confirmed in terms of the normal quadrupole component. The field qualities for all magnets were good enough to fulfill the specifications.

Two-in-One Structure Cryostats

Figure 3 shows top and side views of the cryostat with support structure of the magnets. Design of the cryostat was based on the LHC arc dipole magnet [8]. Dimensions of cryostat are 0.94 m in outer diameter, 10 m in length and it weighs 22 tons. It consists of two vacuum vessels and one connecting part in-between, forming one united cryostat. The cryostat has mechanical bending angle of 2.88 degree at the center to accommodate the beam bending. Two GFRP support posts from the vessel, as shown in Figure 3, support each magnet. The post at the end has slide mechanism to cope with thermal shrinkage of the magnet along the longitudinal direction (z-axis) of the cryostat. They are designed so that the magnetic center sits on the designed location when the magnets are cooled down to 4.5 K, taking into account thermal shrinkage.

Cooling down test of the prototype cryostat was carried out and the cryostat was successfully cooled down to 4.5 K. In this test, cryostat performances such as mass flow rate of supercritical helium, heat loads and magnet displacement due to cooling down were experimentally evaluated [8].

So far, 14 out of 16 production cryostats have been built. Lowering the cryostat down to the neutrino beam line tunnel was started in February 2008 and 10 cryostats have been already installed at the final position by the end of June, as shown in Figure 4.

Interconnect Cryostats

The superconducting neutrino beam line has 13 interconnect regions between main cryostats. We decided to develop following 3 types of "interconnect cryostats": 5 cryostats for the primary proton beam monitors, 3 ones for the superconducting corrector magnets, 4 ones for ones for the quench relief valve units for main magnets (and 1 vacancy). This concept leads to standardization of the main cryostat.

The superconducting corrector magnets for the beam steering were built by BNL and supplied to KEK as a US in-kind contribution to the J-PARC neutrino experiment. The magnet with a copper bobbin consists of a 2-layer normal dipole over a 2-layer skew dipole, and the coils can be independently energized to generate the field integral of 0.1 Tm at 50 A. The coils are wound by using "direct winding technology" with a serpentine coil pattern. The corrector magnet will be operated under the conduction cooling: thanks to a huge cooling power of the supercritical helium line, the corrector magnet can be operated at the temperature below 6 K. The corrector

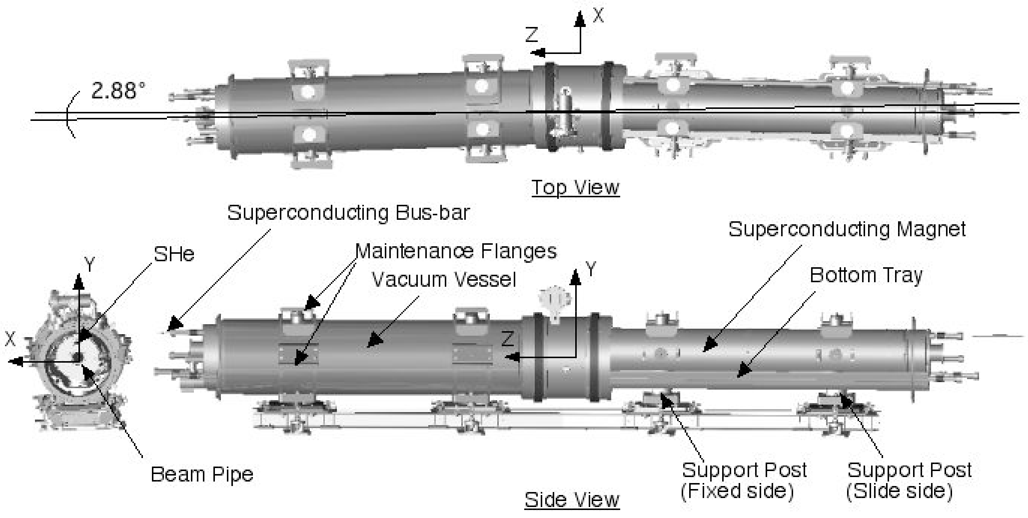

Figure 3: Top and side views of "Two in One structure" cryostat. Right half of the views show inside of the vacuum vessel and radiation shield to describe support structure in the vessel.

magnet cryostats were assembled at KEK, as shown in Figure 5.

All interconnect cryostats were completed and 9 of them have been installed in the neutrino beam line. Interconnect work such as pipe welding, soldering of superconducting bus lines for the main magnets and beam tube connection is underway.

SUMMARY AND SCHEDULE

Following success of the R&D program for the superconducting magnet system for the J-PARC neutrino beam line, the production magnets and cryostats have been fabricated by Mitsubishi Electric since 2005. All magnets showed excellent excitation performance and good field qualities fulfilled the specification. Magnet installation in the beam line tunnel was started at February of 2008 and will last until the autumn. The hardware commissioning will be carried out from December of 2008. The neutrino experiment is anticipated at April of 2009.

Figure 4: Installed superconducting magnet system in the J-PARC neutrino beam line.

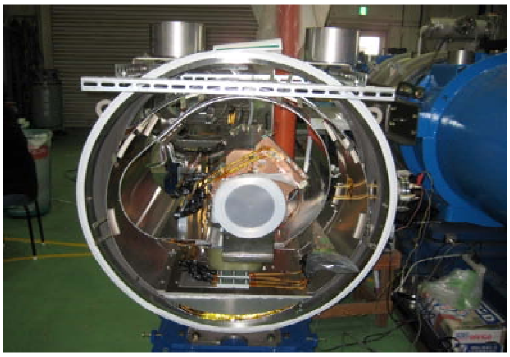

Figure 5: Interconnect cryostat containing a superconducting corrector magnet for beam steering.

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