FULL SIZE PROTOTYPE MAGNETS FOR HEAVY ION SUPERCONDUCTING SYNCHROTRON SIS100 AT GSI: STATUS OF MANUFACTURING AND TEST AT JINR*

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Abstract

The SIS100 synchrotron is designed for acceleration of high intensity beams with a pulse repetition rate of 1 Hz. The use of superferric Nuclotron-type dipoles, quadrupoles and corrector magnets is planned in the accelerator magnetic system. The magnet coils are made of hollow NbTi composite cable cooled with two-phase helium flow at 4.5 K. The lattice comprises 108 dipoles, 168 quadrupoles and necessary set of steerer and multipole corrector magnets. We present recent results from the design and optimization of the SIS100 magnetic elements parameters. The manufacturing status of the full size magnets is presented. The essential features of the magnets production are discussed.

INTRODUCTION

The FAIR facility at GSI in Darmstadt is a world famous project aimed at substantial development of experimental base for study of intrigue problems in nuclear, atomic and plasma physics with the use of high intensity relativistic heavy ion and antiproton beams. The required upgrade of the existing GSI accelerator facility was discussed elsewhere [1]. The new accelerator complex will consist of 2 synchrotrons in one tunnel, SIS100 and SIS300 (100 Tm and 300 Tm rigidity respectively), and several storage rings. In the beginning of 2006 the FAIR parameters were actualized within the Baseline Technical Report (FBTR) [2]. According to this status the SIS100 lattice and magnet basic parameters were specified and the design of full-size model magnets was started. It was decided to construct three dipoles, two straights and one curved, and one quadrupole. One of the straight dipoles and the quadrupole are being manufactured at JINR. This work was additionally included in the EU FP6 program within the frame of the project: DIRAC secondary Beams. The first results of this work have been presented at EPAC'06 and MT-20 [3,4]. Completion of the work program is scheduled for January 2009.

MAGNET PARAMETERS

The SIS100 superconducting magnetic system is based on improved versions of fast cycled, superferric magnets, similar in design to the Nuclotron magnets in Dubna [5]. The collaborative JINR/GSI R&D on improvement the magnets, namely: reduction of the total AC power losses at 4.5K, were completed by the end of 2005. The losses were reduced by a factor of 2.2 and 2.8 for the dipole and the quadrupole respectively in comparison with the original Nuclotron magnets. [6,7]

The magnet parameters, fixed for the design and construction at JINR, are presented in Table 1.

Table 1: The SIS100 FBTR magnet parameters

Parameter	Quadrupole PQP1	Dipole PDP1
Maximum dipole field, T		2.11
Quadrupole gradient, T/m	27	
Effective length at 4.5 K, m	1.300	2.756
Beam pipe aperture, mm^2	135 x 60	130 x 60
Dipole yoke window, mm^2	180 x 66	
Pole inner diameter, mm	100	
Ramp rate, T/(m·s; T/s	54	4

Substantial difference between the Nuclotron and SIS100 dipoles is the magnets length and aperture size. This necessitates modernizing the existing facilities for coil and yoke fabrication. Moreover, it was supposed from the beginning that the magnet manufacturing technology and necessary tools should be suitable to apply them further to the series fabrication and to save production cost.

BASIC TECHNOLOGICAL FEATURES

Several conceptual conditions were fixed as basis for the design, namely: 1) the new dipole and quadrupole should be fitted to the Nuclotron cryostat despite of it's larger cross sections; 2) the technology should be changed to manufacture 3m long coil winding; 3) the process of lamination preparation should be made as much automatic as possible.

a. Dipole yoke manufacturing

View of the Dubna SIS100 full size straight model dipole is shown in Figure. 1.

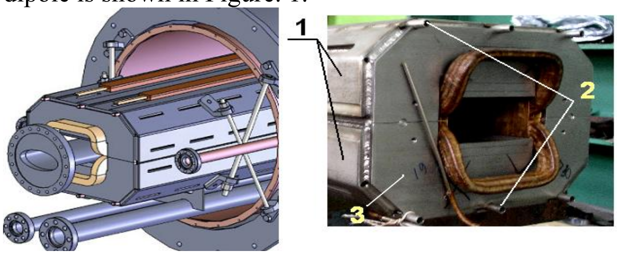

Figure 1. Artistic view of SIS100 full size dipole fitted in the Nuclotron cryostat (left) and the manufactured magnet (right): 1 – stainless steel brackets, 2 – yoke cooling tubes, 3 – stainless steel end plate .

The magnet cold mass together with the thermal shield is fitted to the external vacuum jacket of 630 mm diameter. The shape of the brackets (1) is designed to minimize the overall cross section, to guaranty good heat distribution around the lamination package and to limit the number of the different yoke elements. Upper and lower parts of the yoke are aligned with respect to each other and fixed with alignment pins. It is supposed that the yoke halves will be welded together using stainless steel plates on both sides of the yoke.

The yoke lamination was manufactured from Russian steel type 3413ET 0.5 mm thick. The total mass of the laminations is about 1600 kg. The sheets are prepared using a precise laser cutting machine. The precision was defined by special test measurements at the Eclipse measuring device of the Zeiss company, an accuracy of 5 microns is guaranteed. The measured difference between the specified sizes of two arbitrary chosen sheets did not exceed 20-30 microns. There are several specific technological problems for manufacturing the SIS100 dipole yoke, in particular: 1) About eleven thousand lamination sheets are required for one SIS100 dipole yoke, thus special tooling to prepare the sheets before assembling the half - yoke packages is required to perform this work within reasonable time, 2) There are three types of lamination sheets in the yoke package: regular lamination i.e. sheets without slits and the end part sheets, sheets with narrow horizontal (0.1-0.15 mm width) slits to minimize eddy current loss in the yoke at 4 K level. Two different types of sheets with slits are used. Preparing these sheets and forming the yoke lamination end packages requires also an additional technological stage. Some preparatory stages of the yoke fabrication are illustrated in Figures 2 and 3. Even if the laminations were stamped, the slits can only be cut by a laser cutting machine, thus the sheets surface needs to be cleaned.

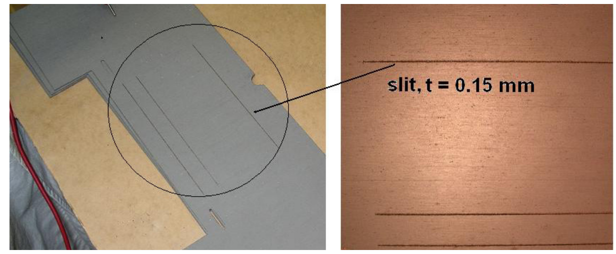

Figure 2. Lamination sheet with narrow slits used for the dipole yoke end-packages.

Figure 3. Dipole half yoke assembled before welding.

b. Dipole coil manufacturing

A new technology of winding 3m long coils was proposed and realized at the Laboratory. The basic idea was to separate the winding process into two stages, namely: 1) winding of a 2D quasi-racetrack coil and 2) formation of a saddle-shaped coil by bending the whole coil end at once. The process is illustrated in Figure 4. The coil form shaping tool (2) is installed on a rotating table (1) connected to the driver. The cable (3) from the cable bobbin is fixed to the form (2) and the winding process is starting. The designed form and other tools make it possible to wind the coil from one cable piece, nevertheless, for the first time it was decided to wind the coil from two halves. The ends of the wound coils are shown: the first stage -5 and the second stage – 4.

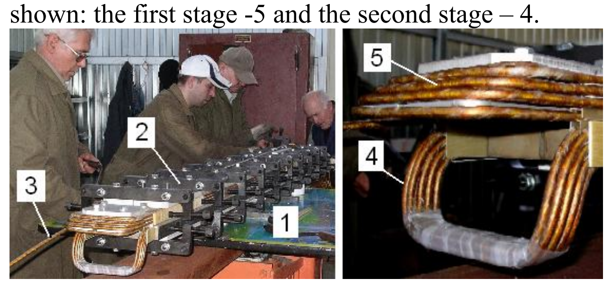

Figure 4. Dipole coil winding process.

The proposed technology makes it possible to manufacture easily long enough coils of hollow superconducting cable. Our first experience in this direction was positive enough although the tooling for the bending the ends needs to be improved further. The other equipment necessary for manufacturing the SIS100 coil was also designed, manufactured and tested. It was used for fabricating the SIS100 full-size dipole coils in the beginning of May. The comparison between the SIS100 and the Nuclotron dipole coil is shown in Figure 5. A preassembly of the cold mass is shown in Figure 6. We are planning to finish vacuum tests of the coil and to finally assemble the magnet by the end of June. The first cryogenic and current tests will be performed after that.

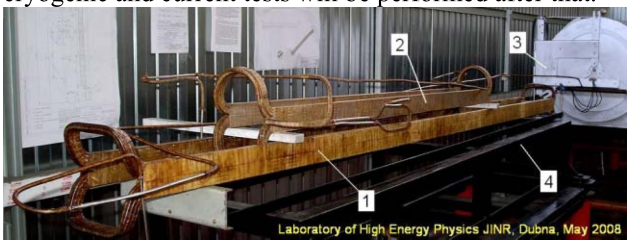

Figure 5. SIS100 (1) and Nuclotron (2) straight dipole superconducting coils at the new JINR manufacturing facility. The other elements are: 3 – oven and 4 – moving platform for installation coil package into the oven.

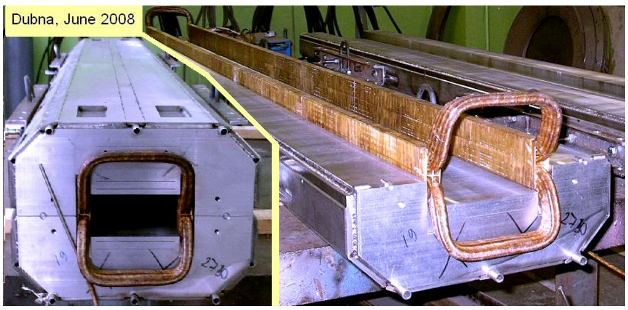

Figure 6. Pre-assembled SIS100 full size dipole.

c. Manufacturing the quadrupole

The basic outer configuration of the PQP1 yoke is similar to that of PDP1. The lamination sheets are produced from the same steel as are those of the dipole. Stainless steel brackets, with longitudinal cuts, and the end plates provide stacking of the laminations of each quarter of the yoke. Narrow slits are used to suppress the eddy currents induced by the longitudinal component of the fringe field. The coil is manufactured from the same superconductor and hollow cable as the dipole and contains 6 turns per yoke pole. The maximum operating current is 4580 A at G = 27 T/m. Manufacturing of the quadrupole is scheduled for July-September 2008.

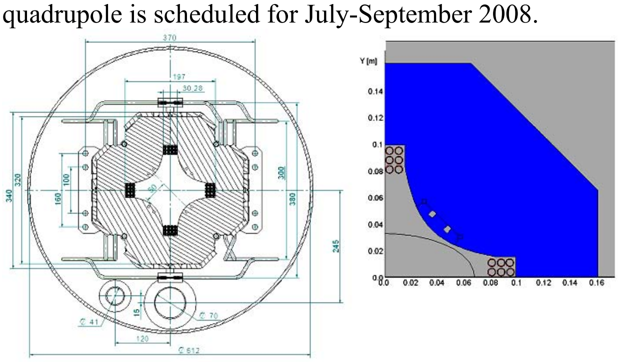

Figure 7. Schematic front view of the PQP1 cold mass (left) and one quarter of the lamination and the coil cross section.

OUTLOOK

Work on manufacturing the SIS100 full-size dipole and quadrupole magnet is close to completion. The next stage in the FAIR project realization is series production of the systems and elements of the accelerators and storage rings. It is supposed that this work will be performed based on the Expression of Interests (EoI), which have been formulated by the countries participating in the project [8]. For further realization of the SIS100 superconducting magnetic system JINR proposed to participate together with International Consortia of different Laboratories and Companies. We are looking forward and will continue our collaborative work.

ACKNOWLEDGEMENT

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