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THE TECHNOLOGY BEHIND THE PRODUCTION OF DIFFERENT NICA COLLIDER MAGNETS

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Abstract

The NICA collider magnetic system includes 70 quadrupole and 80 dipole superconducting (SC) magnets. The serial production and testing of these magnets are near to completion at the Veksler and Baldin Laboratory of High Energy Physics of the Joint Institute for Nuclear Research (VBLHEP, JINR). Manufacturing and assembly technology directly affects the quality of the magnetic field. The article describes the technology behind the production of different type of the NICA collider magnets.

INTRODUCTION

NICA (Nuclotron-based Ion Collider fAcility) is a new acceleration-storage complex. It is under construction in JINR. Collider includes 80 dipole and 70 quadrupole twin-aperture superconducting magnets [1]. The collider is designed to work with operating energies 1.0, 3.0, and 4.5 GeV / nucleon, which correspond to the operating fields of dipole magnets 0.4, 1.2 and 1.8 T, respectively. Serial Production of these magnets started at JINR in 2013 [2]. The magnet includes a cold (4.5K) window frame iron yoke and a SC winding made of a hollow NbTi composite SC cable cooled with a two-phase helium flow.

SC MAGNET PRODUCTION STAGES

The magnet production begins from the fabrication of the SC cable, which show in Fig. 1.

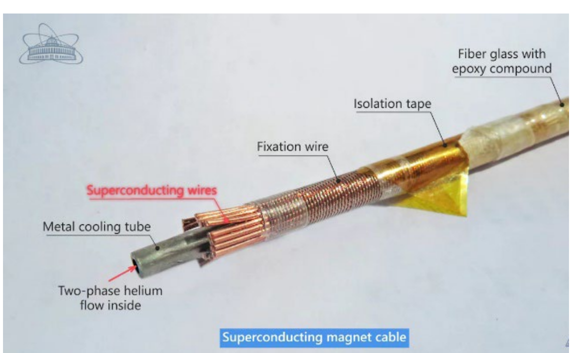

Figure 1: View of the hollow SC cable.

Superconducting wires are wrapped on a cooper- nickel tube and have with cooling tube reliable thermal contact provided by means of fixation wire. The cable is electrically insulated with Kapton tape and fiberglass tape impregnated with epoxy compound. Each SC wire contains 12600 Nb-Ti filaments of 8 microns in a copper matrix. This wire is made in Joint Stock Company "Chepetsk Mechanical Plant". The production of SC cable takes place in LHEP on a special cabling machine (see Fig. 2) when, in one pass, all SC cable components are wind.

Figure 2: Cabling machine for the manufacture of a hollow composite SC cable.

The wet cable is coil on a bobbin and is ready for SC winding production. The wet SC cable on a special rotary table is manually placed in the coil structure and wrapped with prepreg show in Fig. 3.

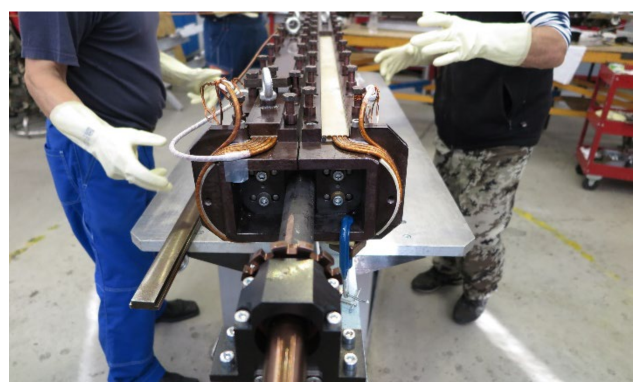

Figure 3: Equipment for baking the SC winding for the NICA collider dipole magnet.

The entire assembly is sent to an oven for baking at a specific temperature regime so that the epoxy compound polymerizes. After baking, the winding is ready for further tests, namely checking the electrical parameters and checking the geometric dimensions.

The iron yoke of the magnet consists of three parts that are bolted together. The yoke is fabricated of the laminated isotropic 0.65 mm thick electrical steel M 530. The laminations are compressed with specific pressure of 5 MPa and clamped together with stainless steel side plates 10 mm thick. The side plates are welded with laminations and 20 mm thick stainless steel end plates. After assembly and welding, yoke is processed on a high-precision machine,

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the manufacturing accuracy is 0.02 mm. All yokes are manufactured by «Stroytekhprogress» Open Joint Stock Company. The yoke of the magnet is received from the manufacturer, after which its basic geometric parameters are checked. Further, the coil and yoke go to the assembly area, where the coil is installed in the yoke. The yoke parts are pulled together with a certain moment, the magnet strapping is mounted. The next step the magnet undergoes warm (at room temperature) magnetic measurements, rotating coil sensors show in Fig. 4.

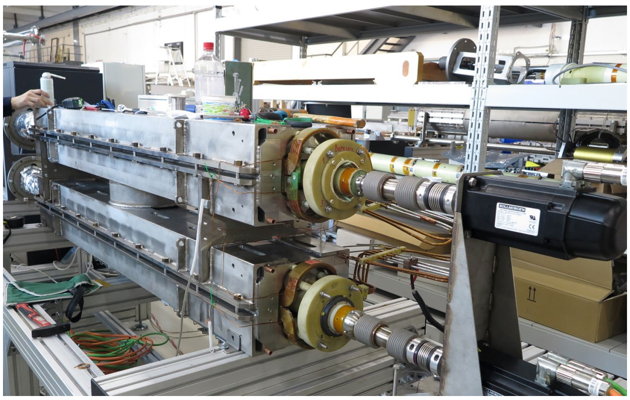

Figure 4: View of the magnetic measurements at room temperature.

The measurement system consists of two measurement shafts, each comprising three identical sections, fixed on plain bearings on the bottom yoke and driven by two servomotors. Detailed description of the magnetic measurement technique is presented in [3]. Warm magnetic measurements allow to detect defects of magnets and check build quality of magnets. The main goal of the warm magnetic measurements is assessment of the quality of the magnetic field in the gape of the magnet.

Figure 5: Preparation the magnet to cryogenic test.

After magnetic measurements, the magnet again enters the assembly site for assembling and brazing helium cooling channels of the winding and bus bars. Brazing takes place with an acetylene-oxygen torch using high-temperature solder show in Fig. 5 After brazing the helium lines, the hydraulic resistance of the helium cooling channels is measured.

The next step is to check the vacuum tightness of the cooling channels. The magnet is placing in a vacuum shell and pumped to 10^{-2} Pa. Then helium is supplied to the helium lines at a pressure of 30 bars. In the case of vacuum tightness of helium lines, the magnet is moved to the cryogenic testing area, where the thermometry and the voltage taps are mounted. Then the magnet is mounted in a vacuum shell and prepared for cryogenic tests show in Fig. 6.

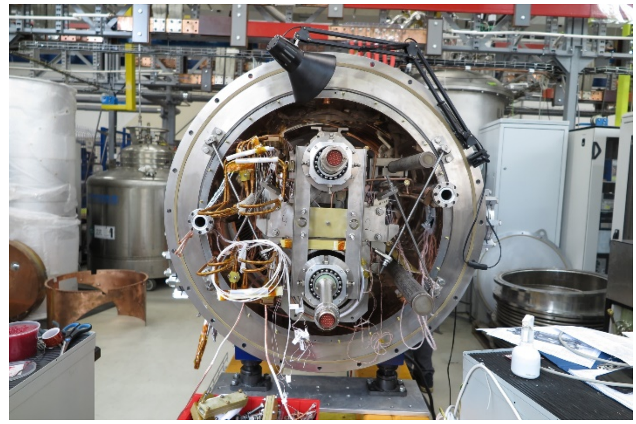

Figure 6: Assembly on a test cryostat for cryogenic testing.

After assembly on a cryogenic stand, tests of the SC magnet are started, "cold" (at 4.6 K) magnetic measurements make it possible to determine the main parameters of the SC magnets at the maximum operating current. These tests are carried out at the operating temperature of the SC magnet and maximum currents. After successfully passing the tests, the magnet is demounted from the vacuum shell and it enters the assembly area. The magnet is completely disassembled, for mounted the High-Vacuum beam pipes. Beam pipes are mounted using measuring equipment Romer Absolute Arm, preliminarily checking the geometric parameters of the beam pipe and its further installation in a SC magnet show in Fig. 7.

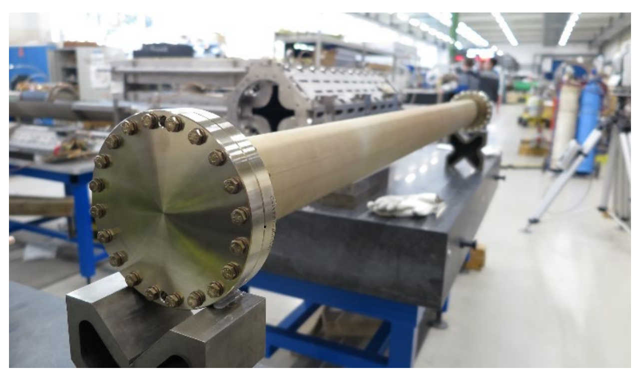

Figure 7: Checking the geometric parameters of the beam pipe and its further installation in a SC magnet.

Precision of the beam pipe mounting in magnet yoke is 0.1mm. The next step is assembling and repeat brazing of helium lines and bus bars. Brazing takes place with an acetylene-oxygen torch using high-temperature solder. After brazing is finished checking the hydraulic resistance of the helium lines of the SC magnet is measured. Again, SC magnet is placed in a vacuum shell and pumped to 10^{-2} Pa, and helium is supplied to the helium lines at a pressure of

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30 bars. After successful vacuum tests, the thermometers and the voltage taps are mounted on the magnet, and the magnet is put in a vacuum shell show in Fig. 8.

Figure 8: Assembly and preparation of magnets for shipment to the ring.

After all the checks and final tests, a conclusion is made about the suitability of the magnet and its further sent to the collider tunnel.

CONCLUSION

Manufacturing of the dipole magnets was finished. All of the dipole magnets have successfully passed the cryogenic tests and waiting for arrangement in the tunnel of the NICA Collider. 17 collider lenses are assembled and tested, it remains to test 29 lenses, 12 doublets of quadrupole lenses and produce 12 final focus lenses and 8 magnets for the beams vertical separation.

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