MAGNETIC MEASUREMENT SYSTEM FOR THE NICA COLLIDER DUAL DIPOLES

M. Shandov, V. Borisov, A Bychkov, O. Golubitsky, H. G. Khodzibagiyan, S. Kostromin, M. Omelyanenko, A. Schemchuk, Veksler and Baldin Laboratory of High Energy Physics, Joint Institute for Nuclear Research, Dubna, Russia

Abstract

NICA collider magnetic system consists of 80 dual-aperture dipole superconducting magnets. Measurement of magnetic field parameters is assumed for each collider's magnet. This paper describes magnetic measurements methods and developing of dedicated system.

INTRODUCTION

NICA (Nuclotron-based Ion Collider fAcility) is a new accelerator complex presently under construction at the Joint Institute for Nuclear Research (JINR) in Dubna, Russia to study properties of dense baryonic matter. NICA booster and collider composed more than 250 superconducting (SC) magnets [1]. These magnets will be assembled and tested at a new test facility in the Veksler and Baldin Laboratory of High Energy Physics (VBLHEP) JINR. The program for magnets testing includes warm and cold magnetic measurements (MM). The some of the details for measuring system for carrying out MM of a twin-aperture dipole magnet of collider is made and tested. Full-scale prototype of measurement shaft and plain bearing with teflon liner were tested in cold MM of quadrupole lens of NICA and sextupole lens SIS100. The basis of design laid down to magnetic measurement system for dipole magnets of NICA booster [2].

TWIN-APERTURE (DUAL) DIPOLE MAGNET FOR THE NICA COLLIDER

The Nuclotron-type design based on a cold (4.5K) window frame iron yoke and a saddle-shaped SC winding cooled with a two-phase helium flow has been chosen for the NICA booster and collider magnets. Main characteristic of the NICA twin-aperture dipole collider magnets are given in [1]. The twin-aperture dipole collider magnets with installed magnetic measuring system (MMS) is shown in Fig. 1. The general view of magnet is shown in Fig. 2.

Reference Magnet Field

Each magnet has an additional winding (see Fig. 1 Pos. 6) consisting of 4 conductors located in the corners of magnet yoke. This winding generate the reference magnetic field, directed parallel to the magnet poles, which used for positioning of measuring coils of separate sections relatively each other and magnet median plane.

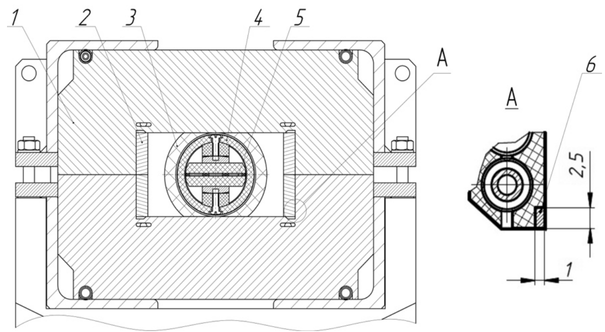

Figure 1: Cross-section view of dipole magnet for the NICA collider with MMS: 1. Yoke, 2. Main coil, 3. Plain bearing of measurement shaft, 4. Measurement shaft, 5. PCB with harmonic coils, 6. Reference coil.

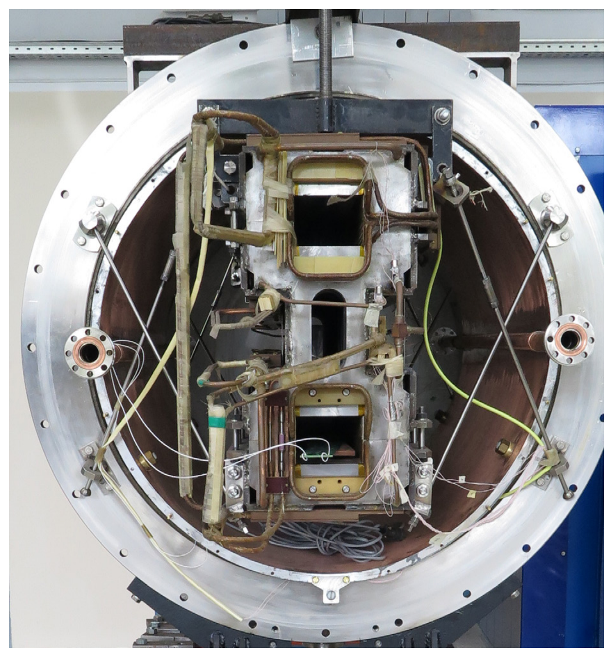

Figure 2: The twin-aperture dipole magnet mounted in a cryostat.

THE MAGNETIC MEASUREMENT SYSTEM

According to the technical specification the following parameters of dipole collider magnet have been measured:

- field at the center of magnet;
- magnetic field integral;
- effective length;

ISBN 978-3-95450-181-6

- angle between magnetic and mechanical median plane;
- integrated harmonics of a magnet field up to the 7th.

It is necessary to meet the following requirement by the developed system:

- system is designed for serial measurements and will be used for all magnets of this type;
- cold measurement of all parameters for each aperture must be carried out at one cooling session;
- small size of aperture (120×70mm) precludes the use of anti cryostat.

Mechanical Design

Measurement system for warm MM (Fig. 3) consist of two measurement shafts (Fig. 4), each comprising three identical section, fixed on plain bearings on the bottom yoke and driven by two servomotor.

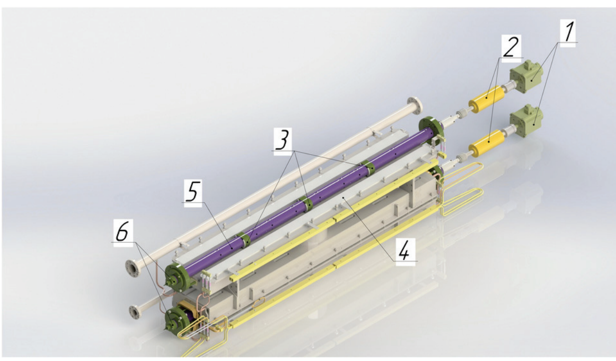

Figure 3: Layout of equipment for warm MM: 1. Servomotor, 2. Slip rings, 3. Plain bearings with teflon liner, 4. Bottom part of yoke, 5. Measurement shaft, 6. Angle encoder.

Measurement shaft composing three identical section, glued together. To eliminate the relative rotation of parts, pins are also installed in the place of gluing. Each section – glas-cloth-base laminate cylinder with an installed frame with a mounted multilayer printed-circuit measurement coil (Fig. 6).

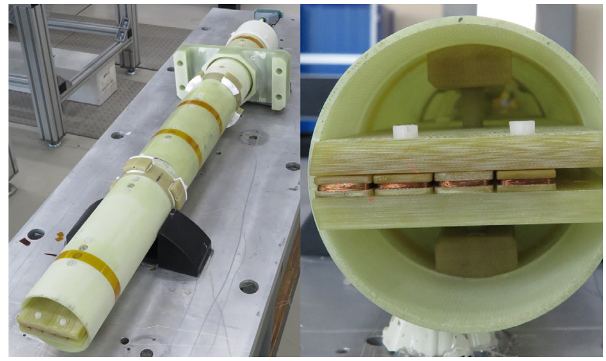

Figure 4: Measurement shaft (prototype).

Plain bearing includes housing from glas-cloth-base laminate and teflon liner. After assembly, the teflon liner connect to the housing by screws to avoid displacement. In the bearing seat on the shaft applied the epoxy resin layer, which reduce friction.

Precision fabrication of a yoke pole surface, plain bearings and base frame determines the accuracy of positioning of measuring system in a magnet aperture. For the connection of the signal cable used sliding connectors (slip rings) with 18 contacts. From the one side the system via the coupling connect to servomotor shaft, from the other side – connect to angular encoder (system accuracy is 5 arc. sec.).

Design of measuring system for cold MM (Fig. 5) is slightly different by location of main assembly parts. This is due to the fact that minimum operating temperature of slip rings is -40°C, angle encoder is -20°C and therefore it is necessary to place the devices in front of a nitrogen-screen. Also, organized additional insulation of devices and supply of heat through the mounting bracket.

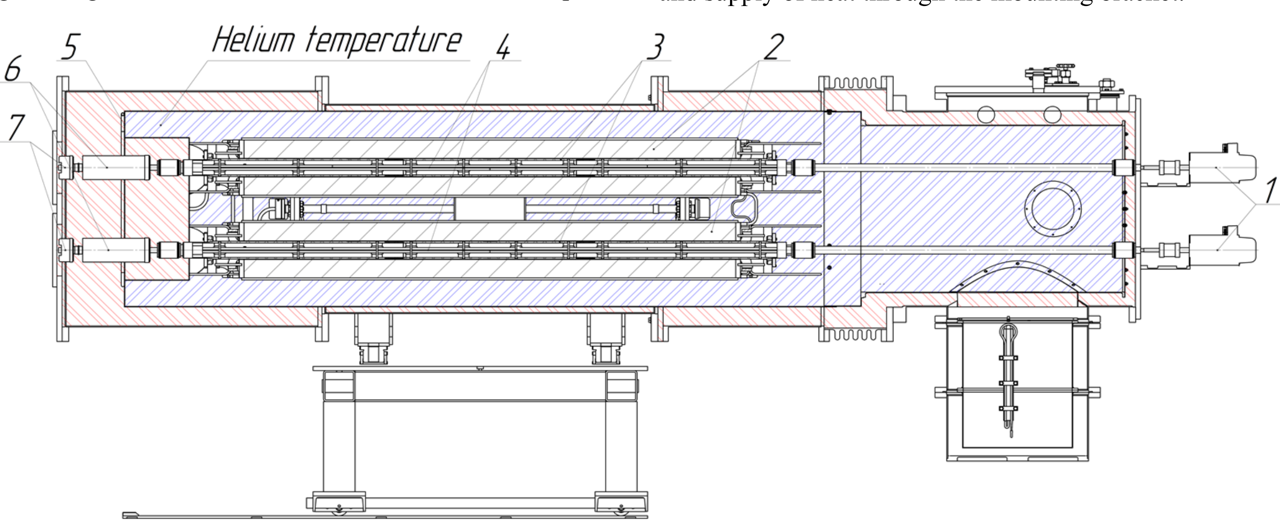

Figure 5: Layout of equipment for cold MM: 1. Servomotor, 2. Magnet, 3. Measurement shaft, 4. PCB, 5. Nitrogen-screen, 6. Slip rings, 7. Angular encoder.

ISBN 978-3-95450-181-6

Structure of Harmonics Coil

Measurement coils sets are made as the multilayered printed-circuit board (PCB). PCB contains three identical radial coils. Coils consist of 400 turns created from 20 layers, each of which contains 20 turns. Parameters of PCB are specified in the Table I. Print PCB are made to order in China. The central coil is symmetric to a rotation axis, i. e. is the dipole one. The sample coils of shorter length, were tested 50 times thermo cycled by cooling down to the LN2 temperature. The sample wasn't destructed.

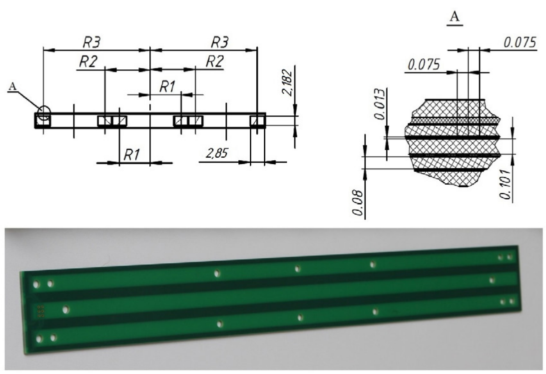

Figure 6: Cross section view of PCB with harmonics coils and photo of PCB.

Table 1: Main Parameters of the Harmonics Coils

Length, mm	730
Width, mm	53.4
Height, mm	2.4
R1, mm	7.325
R2, mm	10.325
R3, mm	24.975
Number of turns	400

Data Acquisition

The data acquisition system (Fig. 7) is developed on the basis of the hardware NI PXI platform and the environment of LabVIEW system. The form and parameters of operating signal for power supply generate in NI PXI 4461 DAC channel. Servomotor control is carried out by NI cRIO-9031. Measured signals from harmonic coils and magnet current sensor are digitized in NI PXI 4464 blocks with sample rate 204.8 kS/s [3]. Software in the LabVIEW environment is developed for acquisition data processing.

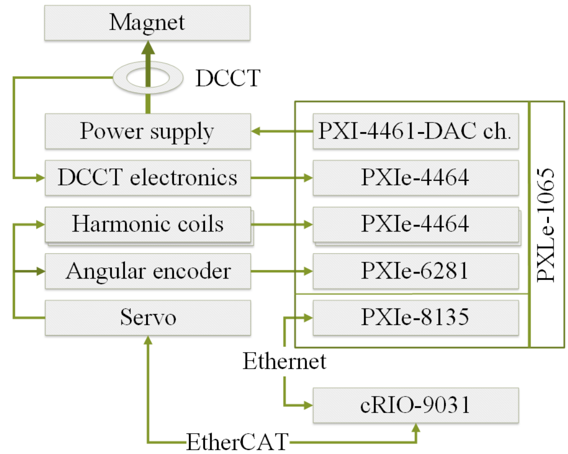

Figure 7: Data acquisition and controls schematic diagram.

Analyze of Raw-Data

Each measurement consist of reading of a reference, main and compensated signals delivered by rotating coils over complete forward and backward rotation. The coils angular position is read by angular encoder. Measurement cycle consist of: start rotation; generation of an operating signal for power supply; digitization of signals of EMF, from DCCT and angular encoder; data recording; stop rotation.

The main and reference signals are obtain from the reading of a single coil, and is used for determination of the main field component. The compensated signal is obtained as a combination of the signals of different coil and used for determination of the field errors.

Further is used the procedure for standard analysis of measurements taken with constant current in the measured magnets [4].

CONCLUSION AND FUTURE PLANS

The previous experience got in the establishing and operating of MMS for magnets of NICA booster was taken into account in the development of the MMS. Next our steps are executing of first warm testing, cold MM with full current, calibration of MMS, development of MMS for quadrupole magnets of NICA collider.

REFERENCES

[1] H. G. Khodzibagiyan et al, "Superconducting magnets for NICA accelerator-collider complex", IEEE Trans. Appl. Supercond, 3 (2014), 4001304.

[2] V. Borisov et al, "Series magnetic measurements of NICA booster dipoles", RuPAC'16, this conference.

[3] http://www.ni.com

[4] A. K. Jain, "Measurements of Field Quality Using Harmonic Coils", US Particle accelerator school on superconduction magnets 2001.

ISBN 978-3-95450-181-6