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MAGNETIC FIELD MEASUREMENTS FOR THE NICA COLLIDER MAGNETS AND FAIR QUADRUPOLE UNITS

A. V. Shemchuk†, V. V. Borisov, I. I. Donguzov, O. M. Golubitsky, H. G. Khodzhibagiyan, B. Kondratiev, S. A. Kostromin, D. I. Khramov, A. V. Kudashkin, T. Parfylo, M. M. Shandov, E. V. Zolotykh, D. A. Zolotykh,
JINR, Dubna, Moscow Region, Russia

Abstract

The magnetic system of the NICA collider includes 86 quadrupole and 80 dipole twin-aperture superconducting magnets. The serial production and testing of the dipole magnets was completed in the summer of 2021. The tests of the quadrupole magnets of the collider and the quadrupole units of the FAIR project have successfully entered the phase of serial assembly and testing at the Joint Institute for Nuclear Research (VBLHEP JINR). One of the important testing tasks is to measure the characteristics of the magnetic field of magnets. The article describes the state of magnetic measurements and the main results of magnetic measurements of NICA collider magnets, quadrupole units of the FAIR project, as well as plans for measuring the following types of magnets of the NICA project.

INTRODUCTION

NICA (Nuclotron-based Ion Collider fAcility) is a new acceleration-storage complex[1]. It is under construction in JINR. In parallel with the NICA project, the FAIR project is being implemented in Darmstadt, Germany, of which the SIS100 accelerator is a part [2]. The SIS100 accelerator includes 166 quadrupole units of various configurations. For quadrupole units, it is necessary to measure these parameters of the magnetic field:

- Integral of the mainl field component (GL).
- Effective length (L_{eff}).
- Roll angle (α).
- Position of magnetic axis (dz, dy).
- Relative harmonics up to 10^{th}.

At the moment, 25 units have successfully passed cryogenic tests.

Collider includes 86 quadrupole and 80 dipole twin-aperture superconducting magnets. Manufacturing of 80 main and 6 reserve magnets is finished now. To carry out magnetic measurements, the method of rotating harmonic coils, described in articles [3], [4] was chosen. It is necessary to measure the parameters of the magnetic field such as:

- Field in the center of the dipole ($B_1(0)$).
- Effective length (L_{eff}).
- Magnetic field angle (α).
- Relative harmonics up to 10^{th}.

Dipoles were tested at the ambient and operating (4.5 K) temperatures. Maximal operating current at operating temperature is 10.44 kA for NICA collider and 11.5 kA for SIS100 quadrupole units.

MAGNETIC MEASUREMENTS SYSTEMS (MMS)

Figure 1 shows the progress of magnetic measurements. For serial magnetic measurements, 4 stands are used, 3 for measurements at room temperature, 1 for measurements in cryogenic conditions. The total number of magnetometers is 15 pcs.

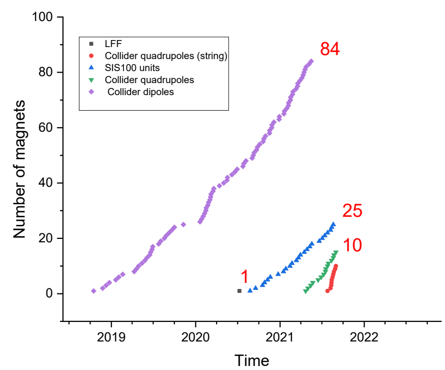

Figure 1: The progress of magnetic measurements.

For measurements of quadrupole magnets of both the NICA and FAIR projects, in addition to the method of rotating harmonic coils, the method of a vibrating string is used.

MMS for NICA Collider Dipoles

During the measurements, 6 serial magnetometers (see Fig. 2) were created to measure the collider dipole magnets. 2 magnetometers are used in the area of warm magnetic measurements, and 4 magnetometers on the cryogenic stand. A detailed description of the measurement system and design of the magnetometer is presented in [5].

The statistics of parameters of magnetic field are presented in the results (see Fig. 7, Fig. 8, Fig. 9).

† shemchuk@jinr.ru

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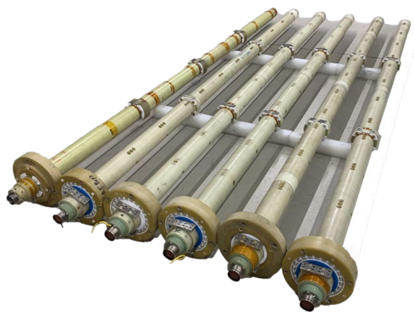

Figure 2: Serial magnetometers for collider dipole magnets.

Key features of magnetometers:

- The production time of 1 magnetometer: 60 days.
- Each magnetometer is relative calibrated on a reference magnet.
- The assembly is carried out under the control of a control measuring machine (0.050 mm).
- The accuracy of the measuring system does not exceed the TK tolerance.

MMS for NICA Collider Quadrupoles

At the moment, 6 serial magnetometers are taking part in the measurements. Each magnetometer is equipped with a hall sensor for measuring correctors, which are mounted on a quadrupole magnet.

Figure 3 shows a stand of warm (I=100 A) magnetic measurements. The concept of magnetometers, as well as the control and data acquisition system, is similar to that used in [3] and [5].

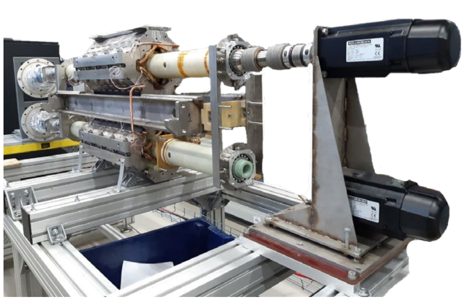

Figure 3: Warm magnetic measurement stand.

The key features of the magnetometer are similar to those for collider dipole magnets.

MMS for FAIR Quadrupole Units

The design of a magnetometer for quadrupole units is based on the design of magnetometers for collider quadrupoles. The main differences are:

- The production time of 1 magnetometer: 90 days.
- The magnetometer is equipped with a system for monitoring the position of the axis of rotation.
- 4 ceramic bearings. 2 of them are double-row self-aligning.

Figure 4 shows a 3D model of a quadrupole unit with an installed magnetometer.

The statistics of parameters of magnetic field are presented in the results (see Fig. 11, Fig. 12).

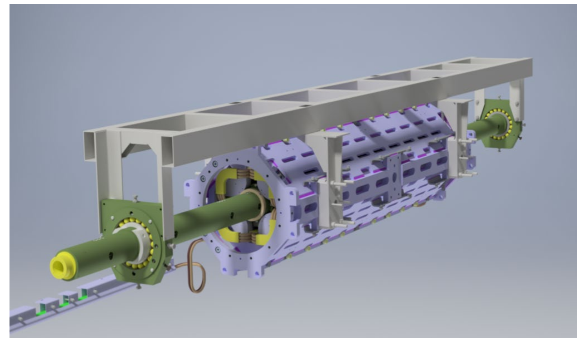

Figure 4: Serial magnetometer for FAIR quadrupole units.

POLE GEOMETRY CONTROL SYSTEMS

Since the field for magnets for the NICA and FAIR projects is formed by an iron yoke, the exact measurement of the geometry of the poles and their mutual position is of particular interest.

Pole Gap Measurement System for NICA collider dipoles

The system (see Fig. 5) was developed and assembled at JINR. It allows measuring the interpolar gap of the collider two-aperture dipole magnets with an accuracy of no worse than 0.005 mm.

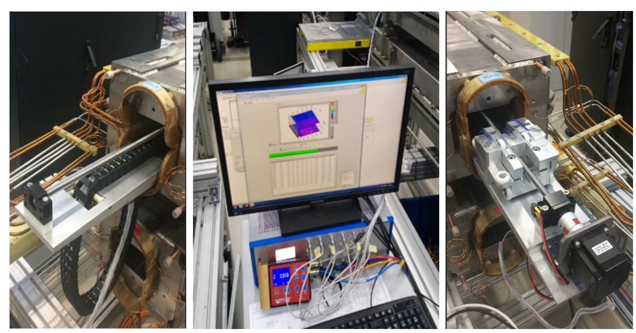

Figure 5: PCB harmonic coils for FAIR qadrupole untit magnetometer.

The main element of the system is 6 MicroEpsilon capacitive sensors with a measurement range of 0 - 1.2 mm.

Thus, by measuring the geometry of the poles, it is possible to carry out a comparative analysis of the results of measuring the geometry of the poles and the results of magnetic measurements.

Hyperbolic Profile Measurement System for FAIR Quadrupole Units

The concept of the system is similar to that described above. The measuring card contains 20 capacitive sensors, which allow measuring the hyperbolic profile of a quadrupole unit with an accuracy of no worse than 0.005 mm.

The main elements of the system are shown in Fig. 6. The statistical measurement results are shown in Fig. 10.

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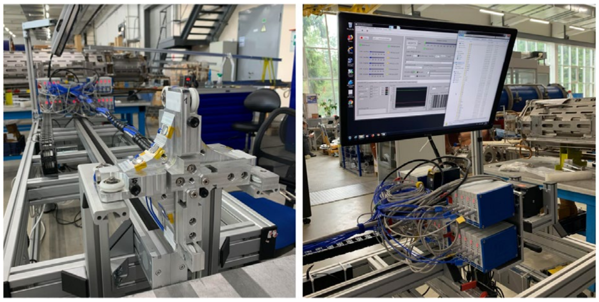

Figure 6: Hyperbolic profile measurement system for FAIR quadrupole units.

RESULTS

Below are the results of magnetic measurements for dipole and quadrupole magnets of the NICA project, as well as measurements of the interpole gap of dipole magnets.

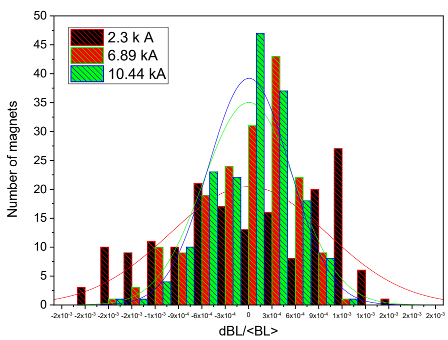

Figure 7: Relative spread of the integral of the magnetic field for dipole magnets of the NICA project.

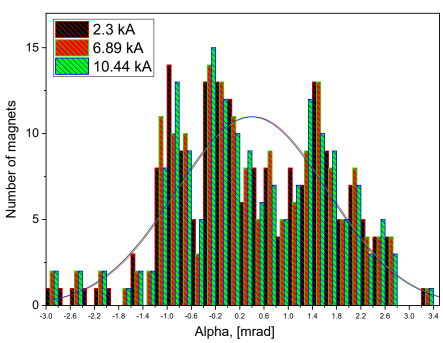

Figure 8: Integral angle of the magnetic field of the dipole magnets of the NICA booster

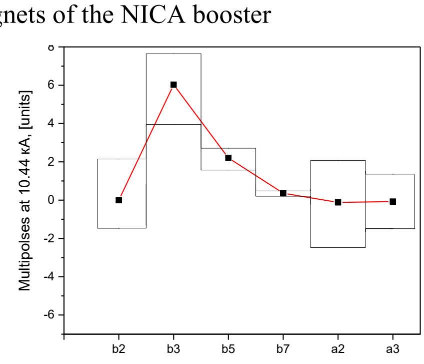

Figure 9: Multipoles for dipole magnets of the NICA project.

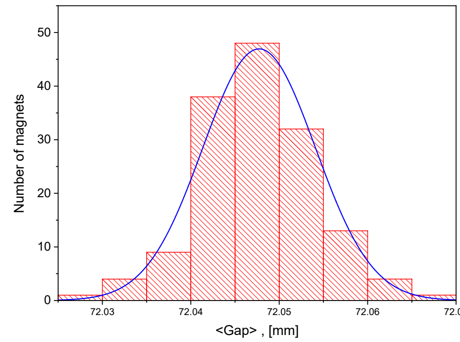

Figure 10: Interpolar gap for dipole magnets of the NICA project.

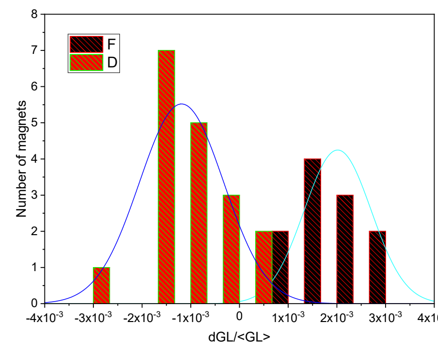

Figure 11: Relative spread of the integral of the magnetic field for quadrupole magnets of the NICA project.

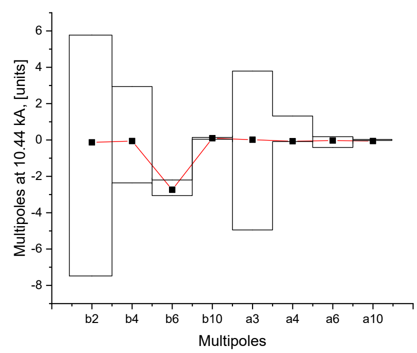

Figure 12: Multipoles for quadrupole magnets of the NICA project.

CONCLUSION

Magnetic measurements performed:

- 100 % collider dipole magnets.
- 35 % collider quadrupole magnets.
- 15 % SIS100 quadrupole units.

Total created magnetometers:

- 16 serial magnetometers of various configurations.

Measuring stands put into operation:

- 6 stands for measuring magnetic field parameters.
- 2 stands for measuring the geometry of magnets.

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