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SERIAL MAGNETIC MEASUREMENTS OF THE NICA COLLIDER TWIN-APPERTURE DIPOLES. THE MAIN RESULTS

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Abstract

NICA Collider includes 80 dipole twin-aperture superconducting magnets. Totally 80 main and 6 spare magnets were manufactured and tested by a specially designed magnetic measurement system (MMS). Dipole magnets were tested at the ambient and operating (4.5 K) temperatures. This paper contains the main results of magnetic measurements of the NICA Collider twin-aperture dipoles.

INTRODUCTION

NICA (Nuclotron-based Ion Collider fAcility) is a new acceleration-storage complex. It is under construction in JINR. Collider includes 80 dipole twin-aperture superconducting magnets [1]. The operating energies for the Collider are 1.0, 3.0, and 4.5 GeV / nucleon, which correspond to the magnetic fields of 0.4, 1.2 and 1.8 T, respectively. Manufacturing of 80 main and 6 spare magnets is finished now. The main parameters of the dipoles were checked:

- Field in the center of the dipole ($B_1(0)$).
- Effective length (L_{eff}).

$$L_{eff} = \frac{1}{B_1(0)} \sum_{i=1}^{3} B_{1,i} S_i \quad (1)$$

- Median plane angle.

$$\alpha = -arctg \frac{A_1}{B_1} \quad (2)$$

- Relative harmonics up to 10th.

Dipoles were tested at the ambient and operating (4.5 K) temperatures. Maximal operating current at operating temperature is 10.44 kA.

MAGNETIC MEASUREMENTS SYSTEM

Magnetic measurements were completed using the rotating harmonic coil method. Special MMS (see Fig. 1) were designed and manufactured for those tasks. This MMS consists of 3 blocks. Blocks locate in lodgement. Each block (see Fig. 2) includes 3 harmonic coils produced by PCB (printed circuit board) technology. Each coil consists of 400 turns (20 layers of 20 turns) [2,3]. Six MMS were produced and used for the magnetic measurement procedures: 2 for tests at the ambient temperature and 4 for the operating temperature. The basic views (front and rear) of the dipole magnets include MMS are shown in Fig. 3 (before connection with feed box).

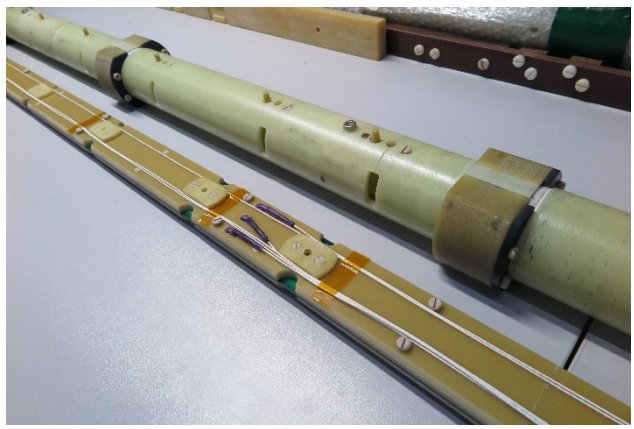

Figure 1: Magnetometer (lodgement and measuring shaft).

Figure 2: Block of the PCB harmonic coils.

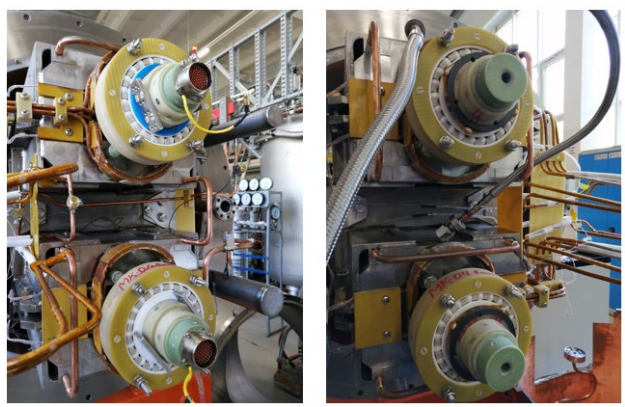

Figure 3: The basic views of dipole magnets.

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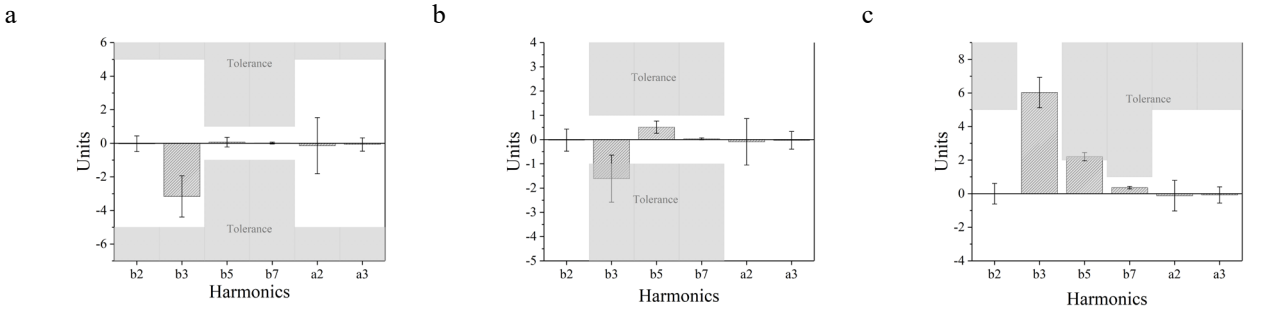

Figure 4: Relative harmonics for 2.3 kA (a), 6.89 kA (b) and 10.44 kA (c).

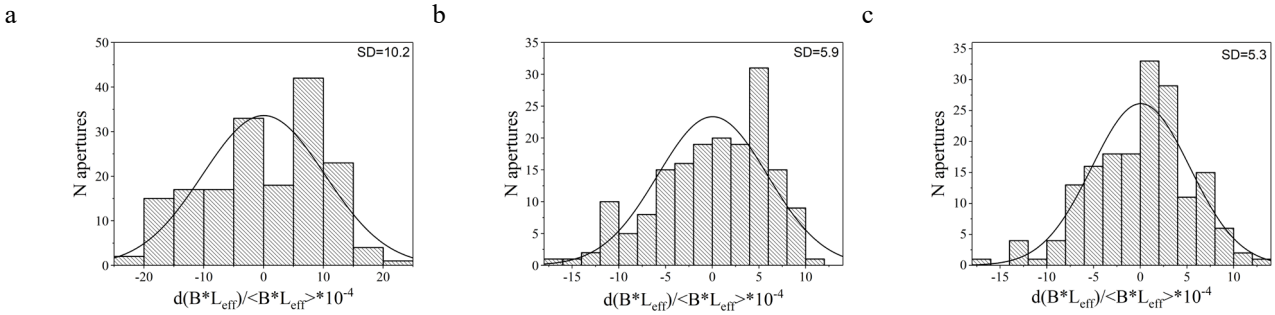

Figure 5: Distributions of relative deviation of the magnetic field integral for 2.3 kA (a), 6.89 kA (b) and 10.44 kA (c).

THE MAIN RESULTS

The procedure of the magnetic measurements of dipole magnets includes «warm» (at the ambient temperature) and «cold» (@ 4.5 K) tests. «Warm» magnetic measurements allow to detect defects of magnets and check build quality of magnets. «Cold» magnetic measurements allow to define the main characteristics of magnets at maximal operating current [4].

The procedure of magnetic measurements at the ambient and operating temperatures consists of 3 steps:

- 1: measurements of «reference» magnetic field (for definition of initial phase).
- 2: measurements of the main field (in the center of magnet) and the effective length.
- 3: measurements of the compensated field (relative harmonics).

Each step was measured clockwise and counterclockwise using step-by-step method.

Relative harmonics spectrums for the operating currents 2.3, 6.89 and 10.44 kA are shown in Fig. 4 (a, b, c). The magnetic field quality of most magnets is within specification. b_3 harmonic at a current of 6.89 kA and b_5 at a current of 10.44 kA slightly exceed the specification for some of the magnets.

The distributions of the relative deviation of the magnetic field integral are shown in Fig. 5 (a, b, c). The dependence of the mean value and standard deviation of the magnetic field normalized integral at the operating currents is shown in Fig. 6. The standard deviation dependence of magnetic field integral on the current is shown at Fig. 7. From the existence of such a dependence, it follows that one of the factors causing the spread of the field integral decreases with increasing magnetic field induction.

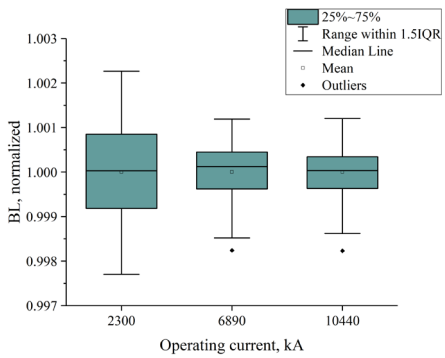

Figure 6: Normalized integral of magnetic field vs. operating current.

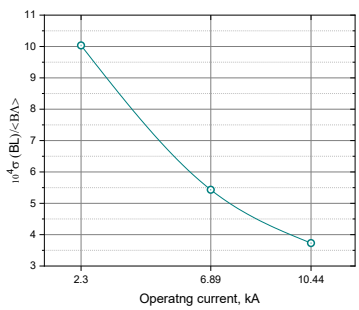

Figure 7: Standard deviation of magnetic field integral vs. operating current.

For the dipole magnets b_3 increases because of iron saturation. In case of the dipole magnets b_3 is allowed. The dependence of b_3 harmonic (mean value) on operating current and standard deviations are shown in Fig. 8.

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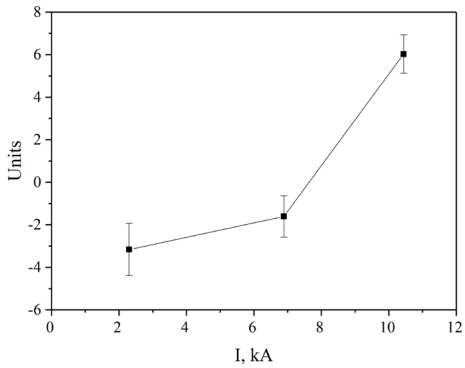

Figure 8: Dependence of b_3 mean value on current.

Relative deviation of integral of the magnetic field on magnets (for blue and red apertures separately) is shown in Fig. 9.

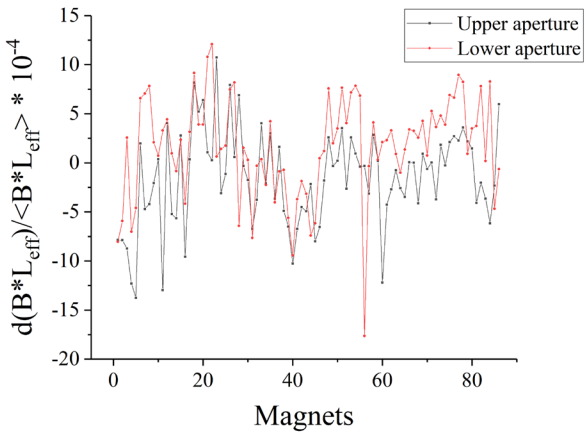

Figure 9: Relative deviation of integral of the magnetic field on magnets.

Specified values were received by relative calibration procedure of all magnetic measurement probe to one.

CONCLUSION

Manufacturing and test 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. Absolute calibration of all of the dipole MMS and results of hall probe measurements will be carried out later.

ACKNOWLEDGMENT

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