ALBA STORAGE RING QUADRUPOLES AND SEXTUPOLES MANUFACTURING AND MEASUREMENTS

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Abstract

BINP has manufactured and measured 243 multipoles of 9 types for the ALBA storage ring. The magnets had severe requirements on the manufacturing tolerances and the alignment of their magnetic axes. The quadrupole magnets are made of 1mm laminated yokes with the bore diameter of 61mm. The sextupole magnets are made of 0.5mm laminated yokes with the bore diameter of 76mm. Rotating coils and Hall probes have been used for the magnetic measurements. The features of manufacturing and magnetic measurements are presented in this paper.

INTRODUCTION

ALBA is a 3rd- generation synchrotron light source to be built in Spain [1]. The facility consists of a 3GeV storage ring, a 100 MeV linac and a full-energy booster. The magnet system of the storage ring is composed of 32 dipole magnets, 112 quadrupole magnets and 120 sextupole magnets, plus a given number of spare magnets.

BINP has manufactured and measured 243 multipoles of 9 types for the ALBA storage ring [2] as given in the Table 1. These magnets include 5 pre-serial quadrupoles and 2 pre-serial sextupoles.

Table 1: The Types of Multipoles

Magnet type	Yoke length, mm	Total number
Quadrupole Q500CX	500	23
Quadrupole Q500OC	500	3
Quadrupole Q280CX	280	21
Quadrupole Q280OC	280	5
Quadrupole Q260CX	260	43
Quadrupole Q260OI	260	7
Quadrupole Q200CX	200	17
Sextupole S220	220	58
Sextupole S150	150	66

MAGNETS PARAMETERS

The quadrupole magnets have 1mm laminated yoke with the bore diameter of 61mm and have field gradient of 22 T/m at current of 200A. The sextupoles magnets have 0.5mm laminated yoke with the bore diameter of 76mm and have field gradient 700 T/m^2 at current of 200A. Steel type M1200-100A and M940-50A with a glue coating on both sides have been used. All quadrupole laminas have been punched with one stamp and 15 quadrupoles with the modified yoke for SR output have been machined after baking of the quadrants. Each sextupole has three sets of correction coils: horizontal, vertical and skew correction.

All coils have the own cooling circuit. The total outlet water flow is controlled by a flowmeters Eletta V1-GL15. Each main and correction coil is equipped with thermoswitches for the safe operation of the magnets.

The magnetic axis has to be aligned relative to the girder with the tolerance of ±50µm and the inclination better than ±0.2 mrad as per requirement. The requirement tolerance of the lamina profile is ±15µm.

ALIGNMENT

In order to meet the above mentioned requirement a special fixation of magnet to girder has to be done. The magnet axis height 400.00 mm and the inclination are adjusted by four legs in the support of the magnet. The leg consists of the fine-thread screw and the horseshoe-part between the girder and the screw. The screw and horseshoe part join as sphere on cone (Figure 1). The magnet is pressed to the girder with a stud-bolt through the screw. This structure provides an alignment of all four legs in one plane and a fast alignment of the magnetic axis of the magnet relative to rotating coil with the accuracy better than 30 µm and inclination better than 0.2 mrad. The horizontal position 225.00 mm of magnet axis from pins is adjusted by two lateral plates on the support by polishing or introducing foils under plates.

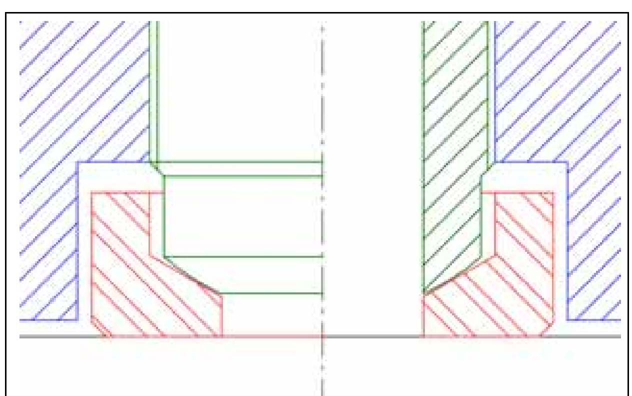

Figure 1: The leg consists of the fine-thread screw and the horseshoe-part.

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After alignment of magnets each leg has been fixed by additional nut and magnetic measurements by rotating coil at different current have been done.

In order to check the alignment of magnets on the girder a special plates with fiducial marks has been installed on the top of the magnets. Although the dimensions of the quadrupole and sextupole yokes differ, the plates are aligned at the equal height 760 mm from the girder.

For this purpose, the polished double-tee-iron ruler was aligned relative to the girder on two supports (Figure 2). The position of the double-tee-iron relative to the girder was measured with the accuracy better than 0.02 mm using the calibration magnet. The plate with the pins inserted into the holes for the alignment marks was pressed to the base surfaces of the ruler. Then the plate was fixed with steel corner to the magnet using epoxy compound. After the polymerization of the compound, the magnet was placed on the girder and the positions of the holes were measured. In that way, the holes were aligned relative to the girder with a tolerance better than 0.1 mm. The holes positions were measured relative to the girder with the accuracy better than 0.03 mm.

Figure 2: The alignment of the plates for the alignment marks on a quadrupole.

THE MEASURING SYSTEM

To perform the magnetic measurements on the ALBA multipoles BINP has designed and built the Rotating Coil System (RCS). Similar RCS was used for the measurements of PSI multipoles [2] and Diamond sextupoles. The position of the magnetic axis, the roll angle relative to girder surfaces and the harmonic coefficients were measured with a high accuracy. Figure 3 shows a sextupole on the RCS at BINP.

In the described system two coils of 10 turns each and a 26 mm radius are wound in one plane on a woven glass-fiber arbor. The length of each coil is equal to the half of the arbor length. Thus, by measuring the coils separately, the magnet input and output could be aligned relative to the axis; and by summing the signals from both coils, the harmonics of integral field can be measured at 815 mm length. The girder and the arbor have basic surfaces for placing the level. The arbor is aligned with the level relative to the girder always with the same inclination. A slight (~1 mrad) constant deviation of the coil planes from the level of the girder is checked from time to time by 180-degree rotation of the magnet or of the arbor relative to the vertical axis.

The arbor with windings was rotated with angle steps of about 3.2º. The measurement procedure was made at each steps and total circle measuring time was about 7 minutes. The measurement of the fields by the coils and the calculation of the harmonics are carried out without deduction of the main harmonic.

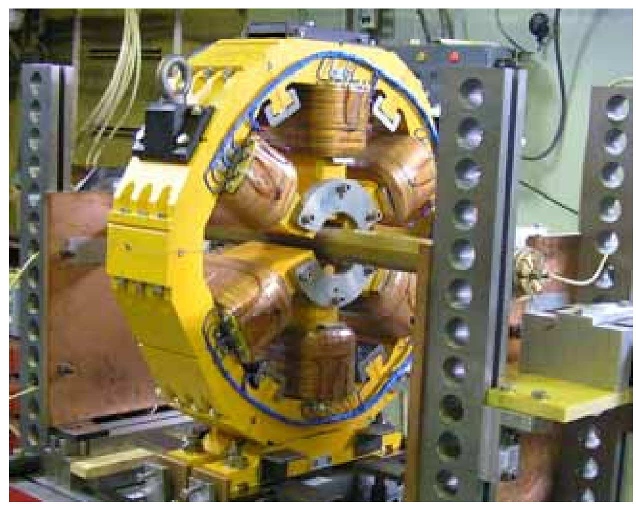

Figure 3: Rotating Coil System (RCS).

The resulting harmonic coefficients A_n and B_n were calculated by using the Fast Fourier Transform method (FFT) to expand the angle dependent function at the normalization radius of 25 mm.

$$\frac{\int H_{\varphi}(\varphi)dl}{Leff} = \sum_n \left(A_n \sin(n\varphi) + B_n \cos(n\varphi)\right)$$

$$\frac{\int H_{r}(\varphi)dl}{Leff} = \sum_n \left(-A_n \cos(n\varphi) + B_n \sin(n\varphi)\right)$$

The computer control program sets the multipole current, the combination of the measured signals, and the parameters of the rotation. The program reads the main signals, the angular position of the unit and records it as a digitized voltage. After the measurement the program is used to analyze the data: to calculate the harmonic coefficients of the magnetic field, the position of the magnetic axis and roll angle of the multipole.

During the measurements of the series magnets the coils and the measuring system have been regularly checked. For this purpose, several quadrupoles and sextupoles have been chosen as calibration magnets. These testing with reference magnets show that magnet axis alignment have many month reproducibility better than 15µm.

Hysteresis of the pre-series magnets has also been measured with the Hall-probe matrix. For sextupoles also the set of measurements with the RCS were fulfilled for each set of corrector coils.

After delivery the multipoles to the ALBA all seven pre-serial magnets and 8 serial magnets have been additionally measured at SOLEIL.

THE MAGNETIC MEASUREMENTS RESULTS

All magnets have been aligned at current of 150A. The statistical results of alignment on all 114 serial quadrupoles and all 122 serial sextupoles are presented in Table 2. The general results of magnetic measurement with RCS are presented on Figures 4 and 5.

Table 2: Statistical Results of Alignment

	Quadrupoles	Sextupoles
Horizontal position, mm	1 ± 13	2 ± 15
Vertical position, mm	7 ± 11	5 ± 10
Roll angle, mrad	0.0 ± 0.1	0.0 ± 0.1

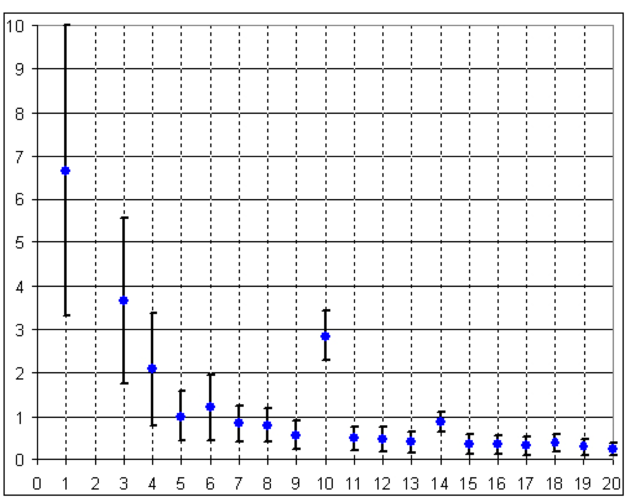

Figure 4: The statistical results of $\sqrt{A_n^2 + B_n^2} \Big/ \sqrt{A_2^2 + B_2^2}$ for the first twenty harmonics on 114 serial quadrupoles at 150A. In units 0.0001.

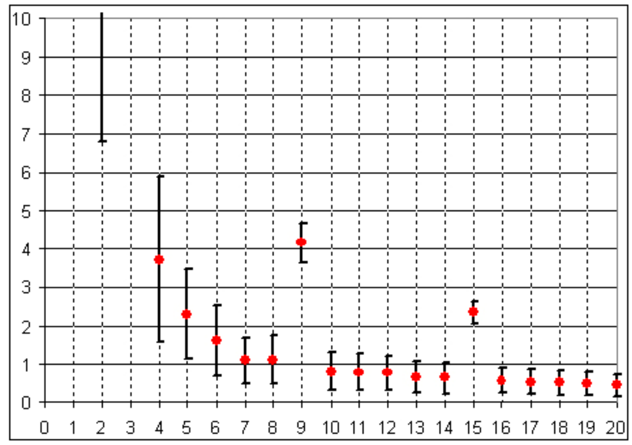

Figure 5: The statistical results of $\sqrt{A_n^2 + B_n^2} \Big/ \sqrt{A_3^2 + B_3^2}$ for the first twenty harmonics on 122 serial sextupoles at 150A. In units 0.0001.

CONCLUSION

The multipoles for the ALBA synchrotron were manufactured precisely and magnetic measurements were carried out by BINP. The specially designed Rotating Coil Systems have provided the accurate magnetic measurements of the ALBA multipoles at BINP. The more detailed information about the measurement results will be presented at the MT-21 conference. The first girders with magnets have been installed in the ALBA tunnel in beginning of April 2009.

Figure 6: The magnets on the girders. April 2009.

REFERENCES

[1] http://www.cells.es
[2] D. Einfeld "Status of ALBA", PAC'07, TUPMN066.
[3] E.I. Antokhin at all, "Multipoles of the SLS Storage Ring: Manufacturing and Magnetic Measurements", MT-17, IEEE Transactions on Applied Superconductivity, March 2002, Volume 12, No.1, pp.51-54, MOPO1A1.