FIELD MEASUREMENT OF SPEAR3 MAGNETS AT IHEP

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Abstract

The SPEAR3 storage ring comprises a total of 292 magnets which has four types and eight different effective magnetic lengths.

The magnetic measurements of all the production magnets including 40 gradient dipoles, 102 quadrupoles with quadrupole modulation system (QMS) coils, 76 sextupoles with skew quadrupole trim coils and 74 dipole correctors combined H/V function, and their prototypes as well have been completed at IHEP successfully by the end of April, 2002.

This paper covers the development of the measurement systems as well as the results of the magnetic measurements for SPEAR3 magnets at IHEP.

1 INTRODUCTION

The Interlaboratory collaborative agreement between SLAC and IHEP including the design, fabrication and measurement of the magnets for the SPEAR3 project, a third generation synchrotron light source at SLAC, was approved in September, 1999.

Prototypes for all four magnet types were built and measured at IHEP. The gradient dipole pole end chamfer shapes were developed on the gradient dipole prototype to satisfy the integrated field quality requirements at IHEP.

Prototype measurements for the gradient dipole and H/V corrector were verified using SLAC measurement system integrates the coils with a wire system as well as using the duplicate rotating coils fabricated at IHEP for the quadrupole and sextupole at SLAC.

All the production magnets were built, measured and delivered from IHEP.

2 MAGNETIC MEASUREMENT DEVICES UPDATED AT IHEP

Four individual magnet measurement systems were developed and updated at IHEP for Spear3 magnet measurements. The details are described as follows.

2.1 Measurement Devices for Gradient Dipoles

The translating measurement coils machine with the positioning accuracy of ± 0.01mm and the positioning repeatability of $\pm 3\mu$ was designed and fabricated at IHEP. This machine can be used to translate one pair of measurement coils designed and fabricated at SLAC and duplicated for IHEP in order to develop the end chamfer shapes on the prototype and measure the integrated field quality of production magnets. The translating coils can be configured to measure the line integral of the magnetic field suppressing either the dipole or both the dipole and quadrupole fields so that it can measure the error fields with more precision.

This translating machine can be also used to position and carry Hall probes in order to measure the saturation behaviour and two dimensional field distribution of the Spear3 gradient dipoles.

2.2 Measurement Devices for Quadrupole and Sextupole

Two measurement systems, rotating coil measurement system and step current measurement system for measurement of harmonic contents and magnet - to magnet reproducibility of production quadrupoles, were updated at IHEP by using Labview software based on the previous data acquisition system.

Two compensated rotating coils were designed and fabricated at IHEP, which can be configured in two modes, compensated and uncompensated.

In the compensated configuration, the signals of two coils should be large compared to the ambient electrical noise and insensitive to both the fundamental field and the N-1 multipole in order to measure the error multipoles in a high sensitivity. Thus, the measurement is independent of the alignment of the coil assembly.

In the uncompensated configuration, the main coil can measure the transfer function and the magnetic center computed from the spill-down dipole field for the quadrupole and the spill-down quadrupole field for the sextupole.

The rotating coil assembly consists of an outer housing and a coil carriage form with embedded coil bundles, two side bearing pedestal and shaft etc. The outer housing should be indexed to the top poles of the quadrupoles and to the horizontal poles of the sextupoles by using the belts In order to maintain a common datum for the magnetic center measurement.

2.3 H/V Corrector

The driver elements and controller of the mapping field equipment was updated and used to map field for H/V prototype corrector. An uncompensated rotating coil was designed and fabricated at IHEP to measure the relative integral field deviations of H/V correctors.

3 MEASUREMENT RESULTS FOR PRODUCTION MAGNETS

3.1 Line integral uniformity for gradient dipoles

Spear3 gradient dipole is a straight magnet with 50 mm gap height and 1.42 Tesla field at the mechanical centre of magnet excited at the maximum current of 690 A. The field integral uniformity measurements were performed at 630 A and 690 A on all production dipoles, of which 30 are 145D (145 cm length) and 10 are 109D (109 cm).

The integral uniformity under operating current of 630A for 40 gradient dipole magnets is below the limit of $\pm 5 \times 10^{-4}$ in the good field region ($-47mm \le x \le 47mm$ for 145D & $-42mm \le x \le 42mm$ for 109D)

The average values of field uniformity of 40 gradient dipoles and their standard deviations below 1×10^{-4} in the good field region are listed in Table 3.1.

Table 3.1: Average Values of Field Uniformity

X(mm)	(dBL/BLo)ave.	S.D.
50	-9.13E-04	1.88E-04
45	2.59E-05	8.73E-05
40	3.05E-04	4.53E-05
35	3.35E-04	3.34E-05
30	2.71E-04	2.85E-05
25	1.82E-04	1.61E-05
20	9.93E-05	1.79E-05
15	3.15E-05	1.51E-05
10	-8.59E-06	1.42E-05
5	-3.76E-05	1.21E-05
0	-3.34E-05	1.23E-05
-5	-2.29E-05	1.24E-05
-10	-7.31E-07	1.18E-05
-15	3.82E-05	2.01E-05
-20	8.48E-05	2.53E-05
-25	1.38E-04	3.23E-05
-30	1.85E-04	4.14E-05
-35	2.13E-04	5.52E-05
-40	1.97E-04	7.56E-05
-45	1.05E-04	9.28E-05
-50	-1.73E-04	1.37E-04

The average curve of uniformity of 40 gradient dipole magnets is shown in Fig. 3.1

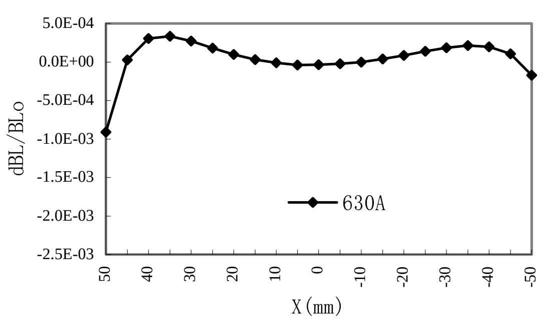

Figure 3.1: Average Cure of Uniformity

3.2 Field quality for quadrupoles

Spear3 production quadrupoles with 35 mm bore radius have four different lengths, 15 cm (15Q), 34 cm (34 Q), 50 cm (50Q) and 60 cm (60Q). The integrated multipole error distribution and the offset of magnetic centre were measured at eight currents on all production quadrupoles.

The relative integral allowed & unallowed multipole errors at r=32 mm are below the required limit of 5×10^{-4} & 3×10^{-4} at the operating current of 81A for 34Q, 50Q and 60Q excepting 15Q, shorter magnets, whose allowed multipole errors are more than the requirements.

The average values of the relative multipole errors of 46 quadrupoles (34Q) at 81A are listed in Table 3.2 and shown in Fig. 3.2. Their standard deviations are less than 1×10^{-4}.

Table 3.2: Average Values of Spectrum

Har.n	(Bn/B2)ave.	S.D
3	1.40E-04	6.53E-05
4	1.03E-04	7.31E-05
5	3.08E-05	1.76E-05
6	2.31E-04	4.05E-05
7	1.98E-05	1.32E-05
8	2.61E-05	1.51E-05
9	1.80E-05	9.27E-06
10	5.65E-04	2.08E-05
11	1.23E-05	8.83E-06
12	1.23E-05	8.76E-06
13	1.58E-05	9.68E-06
14	3.79E-04	1.22E-05
15	1.49E-05	1.37E-05
16	1.76E-05	1.58E-05
17	2.92E-05	1.45E-05
18	6.89E-04	1.83E-05

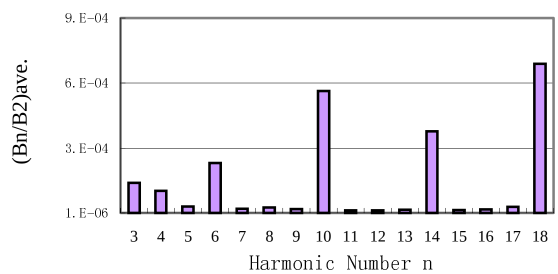

Figure 3.2: Spectrogram of 46 Quadrupoles

3.3 Field quality for sextupoles

Spear3 production sextupoles with 45 mm bore radius have two different lengths, 21 cm (21S) and 25 cm (25S).

The relative integral allowed & unallowed multipole errors at r = 32 mm are below the limit of 4.4×10^{-3} & 1.2×10^{-3} at the operating current of 154A for 21S and 187A for 25S respectively.

Table 3.3: Average Values of Spectrum

Har.n	(Bn/B3)ave.	S.D
4	6.67E-04	3.06E-04
5	1.38E-04	7.59E-05
6	1.57E-04	1.06E-04
7	1.27E-04	7.90E-05
8	2.79E-05	1.71E-05
9	7.74E-04	2.75E-05
10	4.35E-05	2.49E-05
11	1.72E-05	1.38E-05
12	3.20E-05	1.79E-05
13	5.94E-05	3.42E-05
14	8.93E-05	3.43E-05
15	3.21E-03	1.38E-05
16	4.01E-05	1.69E-05

The average values of the relative multipole errors of 30 sextupoles (25S) at 187 A are listed in Table 3.3 and shown in Fig. 3.3. Their standard deviations are less than 1×10^{-4} excepting unallowed multipole error n = 4.

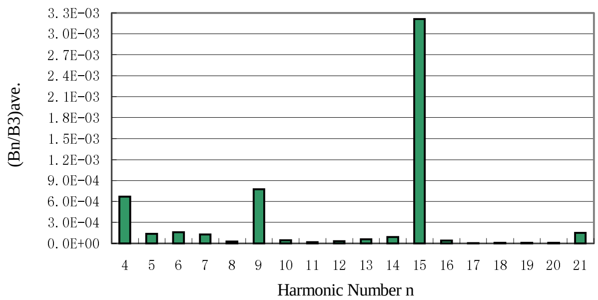

Figure 3.3: Spectrogram of 30 Ssextupoles

3.4 Field Quality for H/V Correctors

The integral field deviation normalized to the center field for 74 H/V correctors is below the limit of ± 2 % in the good field region (- 10 mm ≤ x ≤ 10 mm & - 4 mm ≤ Y ≤ 4 mm) with and without shielding when coils are excited at ± 15 A, ± 20 A, ± 25 A and ± 30 A.

4 CONCLUSION

Total 292 production magnets plus their four prototypes and total 9799 measurement files in 14 batches have been completed and shipped successfully by the end of April, 2002.

Review of the production magnet magnetic measurements, made at IHEP and verified at SLAC, indicate that all the received magnets have either met or exceeded the required magnetic performance specifications [1].

For dipole field uniformity measurement, those results showed that the IHEP measurement data is consistent and reliable and SLAC inspection using different measurement system - wire measurement system duplicated the result of IHEP measurement data.

SLAC has repeated rotating coil measurement on some randomly selected quadrupoles and sextupoles. Those data matched the IHEP measurement result very well [2].

5 ACKNOWLEDGMENT

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6 REFERENCES

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[2] T. Elioff and R. Boyce, "SPEAR3 Magnet Measurement Work Certificate", SLAC, April, 2002.