MAGNET FIELD MEASUREMENT FOR KEK B-FACTORY

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Abstract

The KEK B-factory (KEKB) is a high-luminosity electron-positron collider scheduled to be commissioned in this fall. In the KEKB rings (LER and HER) will be installed 250 dipole magnets (half of which are recycled TRISTAN magnets), 192 wigglers, 900 quadrupole magnets (one-third of which are recycled TRISTAN magnets) and 200 sextupole magnets. The newly fabricated magnets were designed to satisfy high quality required for the KEKB. The recycled magnets were also overhauled in need. All the magnets were completed and precise magnetic measurements have been performed in parallel with production in order to check the quality of the magnets. Flip-flop coil systems are used to measure the dipole magnets and harmonic coil systems are used for the quadrupole, sextupole and wiggler magnets. The magnet system and the preliminary field measurement results will be presented.

1 MAGNET SYSTEM

The KEKB[1] is an asymmetric electron-positron collider to study B-quark physics. The KEKB has two ring, one is 3.5 GeV positron ring (LER) and the other 8.0 GeV electron ring (HER). The magnet system and the field measurements except some magnets near the interaction region will be presented. The KEKB accelerator has complex structure and many types of magnets are used properly according to their performance. More than 1600 magnets will be used for the KEKB besides correctors. More than 900 vertical and 820 horizontal correctors will be used in both rings. These vertical and horizontal correctors are produced in collaboration with IHEP and BINP respectively. Quarter of the main magnets are recycled from the TRISTAN electron-positron collider (TR)[2]. The main parameters of the LER and HER magnets are summarized in Table 1 and 2 respectively. All the magnets were newly fabricated for the LER. The LER magnets both dipoles and quadrapoles have wide aperture to reduce beam instabilities due to impedance of vacuum chambers. For the HER all the sextupoles and 30% quadrupoles were newly fabricated and the rest were recycled from TR.

Table 1 : LER Magnet Parameters

LER	g/2 or r_B (mm)	L_{eff} (m)	B, B', B" (T,T/m,T/m^2)	No. of mag.	current × turns	usage
Barc	57	0.76	0.848	134	1250A × 32	arc
Blc	57	2.1	0.52	26	1000A × 24	local corr.
Bv	55	1.2	0.2	4	500A × 18	vertical, block
Bs	57	0.3	0.21	3	500A × 20	trans-IR, block
wigg	55	0.75	0.77	192	944.4A × 36	wiggler
Qarc	55	0.4	10.2	414	500A × 25	arc, straight
Qrf	83	0.5	6.32	36	500A × 35	RF section
Qsk	105	0.2	0.73	8	200A × 16	skew Q
Sx	56	0.30	340	104	425A × 21	f, d
SxC	85	0.50	77.5	4	425A × 21	f, d

Table 2 : HER Magnet Parameters

HER	g/2 or r_B (mm)	L_{eff} (m)	B, B', B" (T,T/m,T/m^2)	No. of mag.	current	usage / recycle or new
B_{arc}	35	5.804	0.3	117	840A × 10	normal / recyc.
Bw	35	2.9	0.048	6	10A × 150	weak / recyc.
BsFL	35	1.14	0.214	1	500A × 12	short / recyc.
BsFR	57	0.76	0.339	1	500A × 32	same as LER.Barc
Q_S	50	0.5	12.7	80	500A × 26	arc, straight
Q_X	50	0.8	12.7	4	500A × 26	arc, straight
Qrf	83	1.0	6.32	43	500A × 35	RF section
Qsk	105 / 80	0.5 / 0.3	0.73 / 1.25	7 / 5	200A × 16	skew
Q_A	50	0.762	8.5	200	500A × 17	arc,straight / recyc.
Q_B	50	0.95	8.5	110	500A × 17	arc,straight / recyc.
SxF	56	0.3	340	56	425A × 21	f
SxD	56	1.0	348	48	425A × 21	d

All the cores except B_V and B_S are made by using laminated construction technique. The core material is 0.5 mm thick silicon steel having inorganic insulation layers at both sides. The required magnetic properties of the steel are shown in Table 3. The laminated core is welded to soft iron side plates and SUS 304 end plates. The quadrupoles and sextupoles have fixing bolts through pole to fix the laminated core tight. Accuracy of the punched sheet is 20 μm for pole face and some fiducial parts and is 50 μm for other parts. The assemble accuracy should satisfy 50 μm for bore diameter, minimum gaps and height between median and surveying planes and be 100 μm for other parts. The accuracy for length of the laminated core is 0.35 mm. The surveying planes must be also parallel with median plane within 0.1 mrad.

Table 3 : Magnetic Properties of the silicon steel

$B_{50} > 1.6$ T	$\Delta B_{50} / B_{50} < \pm 1$ %
$Hc^{15} < 70$ A/m	$\Delta Hc^{15} / Hc^{15} < \pm 5$ %

The main coil is made of O_2 free Cu hollow conductor. Each magnet has correction coil with about 1 % ampere-turns compared to main coil and also has 1 turn coil per pole for magnetic flux monitor.

For the recycled magnets, some special cares have been taken. The outer insulation of the coils which had got heavy radiation damages have been repaired. The damaged or badly rusted surveying planes have been overhauled. Some recycled magnets had to be reassembled in order to satisfy the above requirements.

2 MEASUREMENTS

The KEKB accelerator needs very high luminosity. Hence the KEKB magnets are required to have good field quality. The tolerances of higher multipole errors are given in Table 4. Each magnet is designed to satisfy these tolerances by itself or by applying end shim correction. Three flip coil systems, a simple harmonic coil and two harmonic coil systems were used for the measurement of the KEKB magnets.

Table 4 : Tolerances of systematic multipole errors

	Tolerance at 50 mm radius
Dipole magnets	B3 / B1 < 0.12 %
	B5 / B1 < 0.45 %
Quadrupole magnets	B6 / B2 < 0.12 %
	B10 / B2 < 0.14 %

2.1 Dipoles and Wigglers Measurement

All the dipoles except B_V were measured by the flip coil systems. The LER B_{arc} were measured by a newly constructed flip coil. The LER B_{lc} for chromaticity correction and the HER B_{arc} were measured by 3.6 m and 6.6 m flip coils recycled from TR respectively. Each probe is a few turns coil wound on glass epoxy cylinder. At each system, a pair of test and standard dipoles are facing each other and the probe moves horizontally between two dipoles. The integrated magnetic field BL (integrated along beam direction) can be obtained to measure the induced voltage by flipping the probe in dipole field. MetroLab high precision integrators (PDI5025) are used to digitize the induced voltage. The BL's are measured along transverse direction at several different currents. After measuring test magnet, the probe comes back to the standard magnet and measure it to eliminate system errors. The measurement accuracy of relative BL is about a few $\times 10^{-5}$. The whole measurement is performed automatically by a personal computer. The typical measurement results of LER B_{arc}, HER B_{arc} and LER B_{lc} are shown in Fig.1, 2 and 3 respectively.

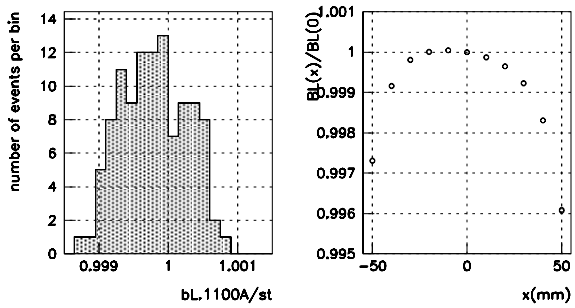

Figure 1 : Normalized integrated field histogram and an example of its transverse distribution for LER B_{arc}

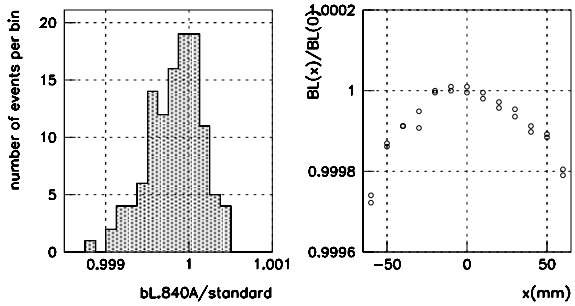

Figure 2 : Normalized integrated field histogram and an example of its transverse distribution for HER B_{arc}

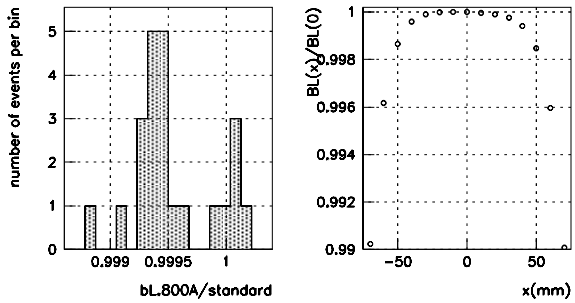

Figure 3 : Normalized integrated field histogram and an example of its transverse distribution for LER B_{lc}

The LER wigglers were measured by the simple harmonic coil mounted in aluminum cylinder. This harmonic coil has one long coil and two half coils. The residual Δ[BL] is obtained by the long coil and the BL for each pole is obtained by each half coil. The measurements were performed by using a spectrum signal analyzer HP3562A. The results are shown in Fig. 4.

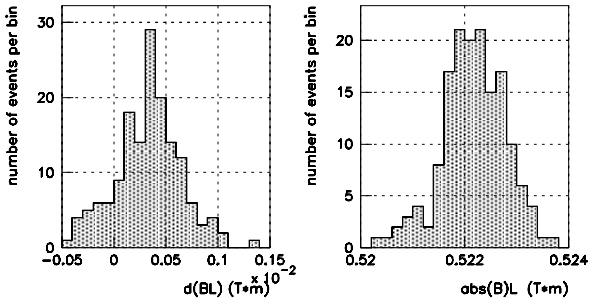

Figure 4 : Δ[BL] and |B|L histograms of the wigglers

2.2 Quadru- and Sextupoles Measurement

All the quadrupoles and sextupoles are measured by two harmonic coil systems, one for the LER magnets and another for the HER magnets. Each system is equipped with a remote controlled mover which can adjust magnet position to the measuring probe within a few ten μm.

Each measuring probe made of aluminum-epoxy cylinder contains a single turn long coil for measuring integral field along beam direction, a center short coil (short B) and two end coils (short A, C) for measuring the central field and each end field respectively. The measuring probe is supported at both ends by non-magnetic frictionless aerostatic bearings, which ensure a rotation concentricity of better than 0.02 mm. The support systems of the probe have adjusting knobs to align the prove better than 0.01 mm. The angular position of the probe can be monitored by a precise angular encoder (65536 pulses/rotation). The induced voltage during rotation of the probe is measured by PDI5025 Integrator. The amplitude and phase of each multipole is obtained by performing Fourier Transformation to the measured wave form stored in computer. Effective length of the magnetic field is obtained by using both long and short-B coils. The magnetic axes are determined by the ratio of the first lower multipole to main one using short-A and -C coils. One magnet for each type is selected as a standard magnet and has been measured about once a week through all the measurements for system check.

The measurement results of the newly fabricated LER Q_{arc} and the recycled HER QA are shown in Fig.5 and 6 respectively. The details on the quadru- and sextupole measurements are presented in another contribution to EPAC98 [3].

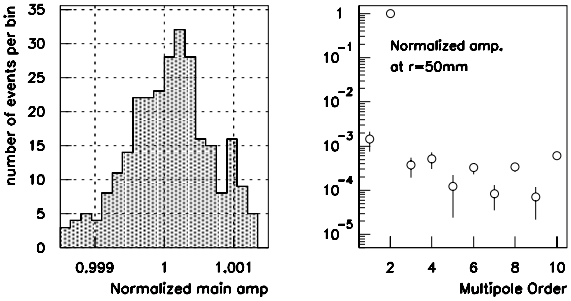

Figure 5 : Normalized integrated field gradient (left) and normalized multipole amplitudes plotted as a function of multipole order (right) for LER Q_{arc}.

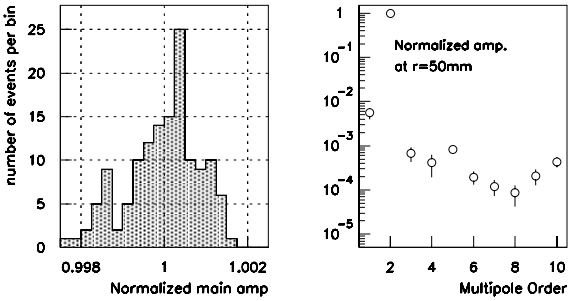

Figure 6 : Normalized integrated field gradient (left) and normalized multipole amplitudes plotted as a function of multipole order (right) for HER QA.

3 SUMMARY

All the KEKB magnets except several magnets near the interaction region were completed and the series measurements have been performed and finished in this May. Further measurements such as field mapping and absolute value measurements are being prepared. These fine measurements will be performed for one or two magnets by each type. Interference of magnetic field between adjacent magnets and environmental effects (air temperature, cooling water flow and its temperature, etc.) on magnetic field will be also studied before the start of commissioning.

4 ACKNOWLEDGMENTS

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REFERENCES

[1] KEKB B-Factory Design Report 95-7
[2] 'TRISTAN electron-positron colliding beam project', KEK Report 86-24 March 1987
[3] 'Preliminary results of the KEKB quadrupole magnet measurements', Contribution to EPAC98