PRELIMINARY RESULTS OF MAGNET MEASUREMENTS FOR THE KEK B-FACTORY QUADRUPOLE MAGNETS

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Abstract

The KEK B-factory rings (LER and HER) will have about 900 quadrupole magnets. One-third of them are recycled TRISTAN magnets and two-thirds are newly-fabricated magnets. The magnets are measured in parallel with production and rapid feedback is given to the factory production line if a magnet fails to satisfy the specifications. A couple of examples of spotting bad magnets are shown. A unique problem regarding the recycled TRISTAN magnets is also presented. Preliminary results from the quadrupole magnet measurements are summarized in the table at the end.

1 THE MEASUREMENT SYSTEM

A harmonic coil system is used for the field measurements. A schematic diagram of the system is shown in Figure 1. The analog signal from the coil is brought to the integrator (PDI5025) and digitized. A Fourier Transform is performed on the waveform to obtain the multipole components of the field. The accelerator control system EPICS, which is also used in the control system for the KEK B-factory[1], is used as the data acquisition software.

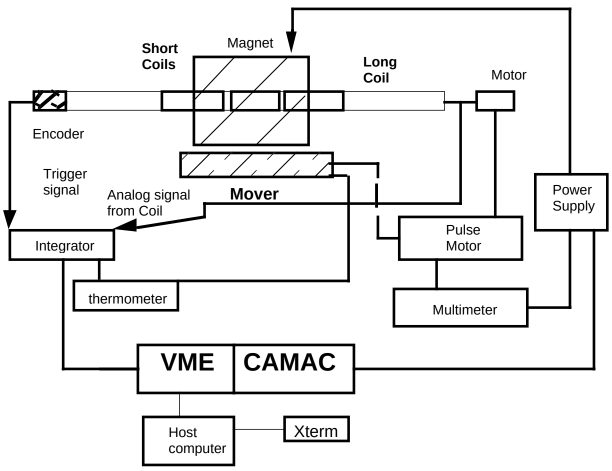

Figure 1: Schematic diagram of the field measurement system. A mover is used for adjusting the magnet position with respect to the measurement system (not shown).

The integrated field strength along the beam axis is measured at 6 different currents (100,200,300,400,500 and 0A) by a long harmonic coil for each magnet. There are also three short harmonic coils along the beam axis. The dipole components measured by the short coils are used to calculate the transverse offset between the physical and magnetic centers. A typical series measurement scenario is shown in Figure 2. Note that the magnets are all measured at the same polarity (focus), unless mentioned otherwise.

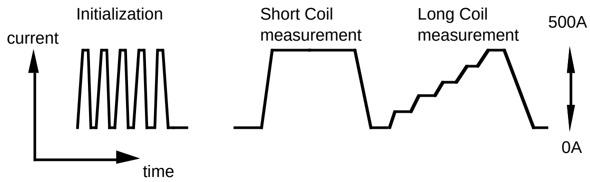

Figure 2: A typical scenario for series measurements.

2 QUALITY CHECK OF THE NEWLY-FABRICATED MAGNETS

Table 1 gives the basic parameters of the newly-fabricated quadrupole magnets. Dimensional checks are carried out on each magnet at the production line. However, a magnetic field measurement is also done for each quadrupole magnet as it is a more direct and accurate way to check the magnet quality. Some problems have been found by the field measurements.

Mag. name	r (mm)	L (mm)	B' (T/m)	# of Mag.
Qarc(LER)	55	0.4	10.2	416
Qrf(LER)	83	0.5	6.32	42
Qarc(HER)	50	0.5	12.7	82
Qrf(HER)	83	1.0	6.32	44

Table 1: Parameters of the new quadrupole magnets. Bore radius, lamination length and the field gradient are represented by r, L and B', respectively.

Figure 3 shows an example of a bad magnet found among the Qarc(HER) magnets. The main quadrupole amplitude was ~0.4% smaller than the average. The same magnet showed a larger sextupole component which indicates an unbalanced field. Electrical tests performed later showed that one of the coils was partially shorted. It was found that the coils were wound manually for the first ~10 magnets resulting in uneven winding, which is suspected as a cause of possible damage during transportation from the factory to KEK.

An example of a different problem is shown in Figure 4. The Qrf(LER) main amplitude distribution shows a current dependence. Three groups appear at 500A due to iron permeability differences at high magnetic field. This problem was accounted for by assigning magnets from the same group to the same power supply.

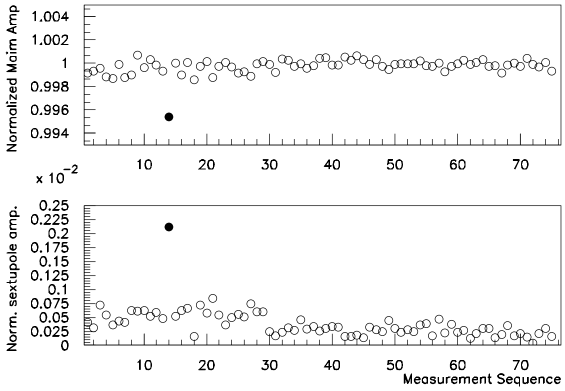

Figure 3: The main amplitude and the normalized sextupole component are plotted against the magnet measurement sequence. The solid circle in each plot (the 14th magnet to be measured) corresponds to the short-layered magnet.

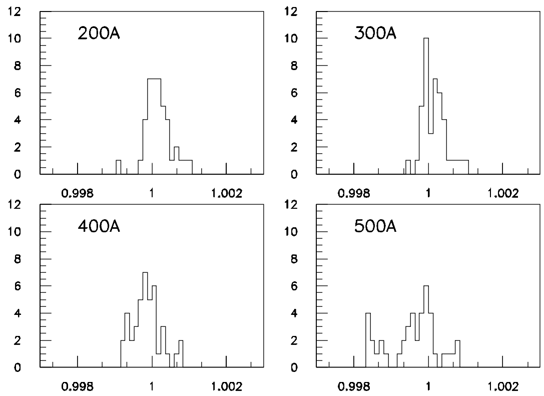

Figure 4: Qrf(LER) main quadrupole amplitude distribution at various currents. Three groups appear at 500A due to iron permeability differences.

3 HYSTERESIS OF THE RECYCLED TRISTAN MAGNETS

One-third of the HER quadrupole magnets are recycled TRISTAN magnets[2]. They were used as either focusing (F-type) or defocusing (D-type) lenses at a maximum current of 1500A during TRISTAN operation. These magnets were never demagnetized when they were later removed from the tunnel. At the KEK B-factory the recycled TRISTAN magnets will be powered by 500A-capacity power supplies. The recycled magnets were measured under the same conditions as the new magnets. Figure 5 shows the main amplitude distribution at 500A. There are two clear peaks; the TRISTAN F-type magnets form the upper peak and the D-type magnets form the lower peak, due to hysteresis. The difference between the former F-type and the D-type magnets has a current dependence, as shown in Figure 6. The effect of historical polarity is measured to be as large as 0.2%. An attempt was made to evaluate and reduce the hysteresis effect with the available 500A power supply. A TRISTAN D-type magnet was initialized with F- and D- connections alternately. The field was measured at each connection to monitor the demagnetization process. Figure 7 shows the main amplitude after initialization at each polarity. The hysteresis effect, i.e. the difference between the F- and D-connections, is slightly reduced after a few initialization cycles at alternating polarity. However the amplitudes at F- and D-connection never converge to a common value. There still remains a significant dependence on the polarity. Thus it has been decided that TRISTAN F-type and D-type magnets should not be connected to the same power supply.

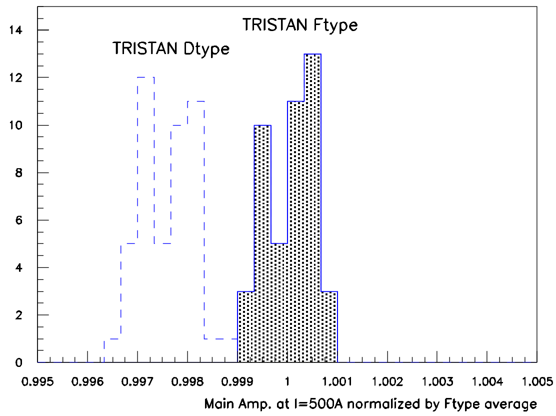

Figure 5: The main amplitude (normalized by the TRISTAN F-type average) distribution at I=500A. TRISTAN F-type and D-type magnets correspond to the upper and the lower peaks, respectively.

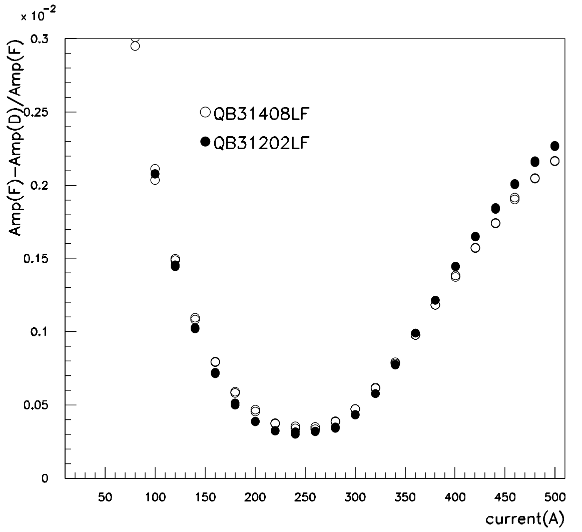

Figure 6: The main amplitude difference between the F- and D-connections is plotted as a function of current for two TRISTAN F-type magnets. The hysteresis effect has a minimum at around 250A.

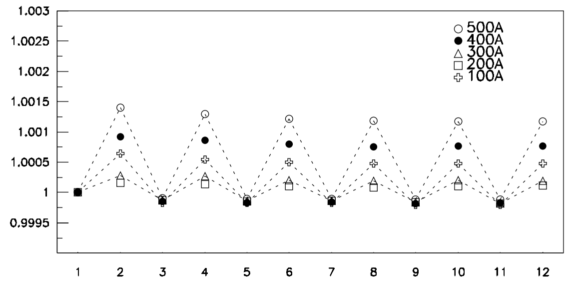

Figure 7: An attempt to reduce the hysteresis effect by alternating the polarity of the initialization. A TRISTAN D-type magnet was used. Even numbers on the horizontal axis indicate that the magnet was connected as D (the same polarity as in TRISTAN), while odd numbers indicate F (the reverse polarity). The amplitude is normalized by the amplitude of the first F-connection for each current. Since the magnet was originally operated as a D-type magnet at a maximum current of 1500A, it retains the D-type hysteresis. The effect could not be removed by the usual 500A initialization loop.

4 SUMMARY

95% of the quadrupole magnets have been measured. The field measurements have successfully spotted magnets with problems. Rapid feedback has been given to the production line and the problems have been solved. The quality of both the newly-fabricated magnets and the TRISTAN recycled magnets has been checked and is summarized in the table below. The r.m.s. of the normalized (by the mean value) integrated field of the recycled TRISTAN magnets is calculated for each peak in Figure 5. It is found to be consistent with the original measurements[3]. Both new and recycled magnets satisfy the requirements[4] for the r.m.s. of ΔX, ΔY (transverse field offsets) and the normalized main amplitude.

	ΔX(μm)	ΔY(μm)	Norm.amp
Requirement	≤100	≤100	≤1.0e-03
Qarc(LER)	40	40	6.0e-04(500A)
Qrf(LER)	30	30	4.0e-04(300A) 6.8e-04(500A)
Qarc(HER) (recycled)	60	60	4.8e-04(500A)
Qrf(HER)	Not yet		

Table 2: .ΔX and ΔY are r.m.s. of the transverse offset between the physical and magnetic centers. The last column shows r.m.s. of the normalized main amplitude.

The requirements for the higher order multipoles are also satisfied for all types of quadrupole magnets. Shim corrections have been made for certain types of magnets in order to reduce the multipole component. Figure 8 shows the normalized multipole amplitudes evaluated at r=50mm for Qarc(LER)magnets. The 6th multipole, the lowest allowed higher multipole, has been reduced after the shim correction.

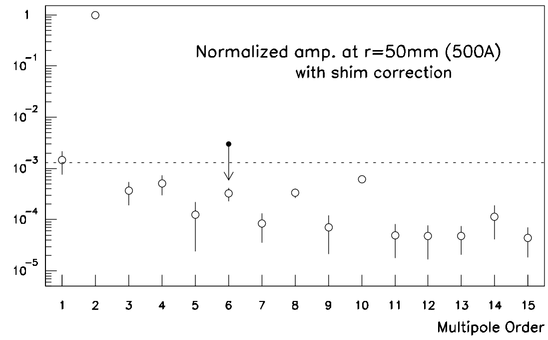

Figure 8: Normalized multipole amplitude plotted as a function of multipole order for Qarc(LER) magnets. The solid circle indicates the 6th multipole before the correction. The requirement for the lowest allowed multipole (n=6) is indicated by a dotted line. The error bars indicate one standard deviation of each multipole.

The recycled TRISTAN magnets presented a hysteresis problem, coming from the fact that a proper demagnetization process was not undertaken upon removal from the TRISTAN tunnel. Some hysteresis was expected, but not as large as what has been observed by the field measurements. It has been decided to group them separately with respect to the KEKB power supplies. About 50 recycled TRISTAN magnets were measured with the same polarity as the new magnets (F-connection), independent of the original TRISTAN polarity. However, the later measurements of about 250 TRISTAN magnets have been performed with the KEKB polarity, in order to avoid any additional error due to switching polarity between the measurement bench and the KEKB tunnel.

The remaining work, such as the evaluation of the absolute value of the magnetic field and the effective length, and the study of the interference between neighboring magnets, etc., will follow the series measurements.

5 ACKNOWLEDGMENTS

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6 REFERENCES

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[4]KEKB B-Factory Design Report 95-7