MAGNETIC MEASUREMENTS OF THE ANKA STORAGE RING MAGNETS

D.Einfeld, A.Krüssel, M.Pont[1,2] Forschungszentrum Karlsruhe GmbH,
Projektgruppe Errichtung ANKA, Postfach 3640, D-76201 Karlsruhe, Germany

Abstract

ANKA is a 2.5 GeV storage ring under construction. The storage ring consists of 16 bending magnets with a maximum field of 1.5 T, 40 quadrupoles divided in five families with a maximum gradient of 20 T/m, 24 sextupoles with a maximum second order differential of 550 T/m^2, and 44 correctors with a maximum kick capability of 0.8 mrad. The production of all the magnets is now finished and the magnets have been mechanically and magnetically characterized to ascertain their excitation curves and field uniformity. For the dipoles a Hall probe has been used to map the magnetic field while for the quadrupoles and sextupoles a rotating coil system has been used to determine the magnitude of the high order multipoles. In this paper the analysis of these data is discussed and results for measured magnets are presented.

1 INTRODUCTION

The magnetic system of the ANKA storage ring [1] is summarised in table I. It consists of 16 bending magnets, 40 quadrupoles, divided in 5 magnetically different families and two families of sextupoles.

Table I

Magnet type	Name	Number	Max. magn
Bending	BEN	16	1.5 T
Quadrupole	Q320	8	18.1 T/m
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Quadrupole	Q320	8	18.1 T/m
Quadrupole	Q320	8	18.1 T/m
Quadrupole	Q390	8	17.9 T/m
Sextupole	SH	8	551 T/m^2
Sextupole	SV	16	482 T/m^2

There are 32 magnets of the Q320 type. They have been organised in families according to the magnetic measurements.

For each type of magnet a prototype was produced to test the expected magnetic performance. The results [2,3,4,5] indicated a performance comparable to what had been expected, therefore the magnets were produced with only minor modification from the prototypes.

2 THE MAGNETIC MEASUREMENTS

The magnetic measurements on the bending magnets have been performed using a Hall probe mounted on a bench that allows movement in three directions [6]. The resolution of the read-out is 1 μm in each axes, while the precision is smaller than 5 μm for the three axes. The Hall probe is calibrated against an NMR system to better than ± 1 G.

To characterise the quadrupoles and the sextupoles a rotating coil system has been used [7]. The system has a relative accuracy better than $\pm 2.10^{-4}$ for the main harmonic, and has a reproducibility better than $\pm 2.10^{-4}$ for the ratio of the high order components to the main component.

3 PRELIMINARY RESULTS FOR THE MAGNETIC MEASUREMENTS

3.1 Bending Magnets

Figure 1 shows the dependence of the normalised magnetic field with respect to the current for a typical magnet. At the nominal current (approx. 650 A) there is a saturation of 7 %.

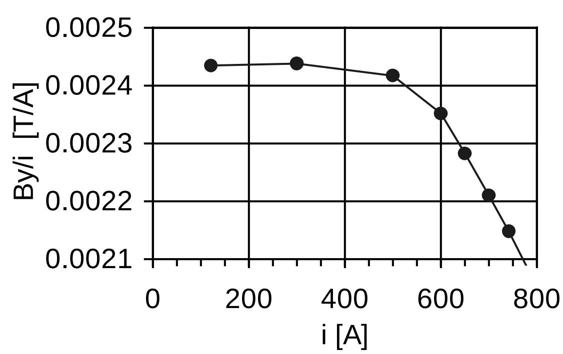

Figure 1 Normalised magnetic field versus current for a typical bending magnet

Figure 2 shows a typical field quality in the transversal direction at different currents. At the

[1] On leave of absence from IFAE-LLS, Barcelona , Spain
[2] Email: pont@anka.fzk.de

nominal current, one can clearly see a quadrupole component due to the magnetic forces in the pole gap. This quadrupole component is $1.34.10^{-2}$ T/m and the sextupole component is -0.8 T/m^2 according to a fit of the measured data in the centre of the magnet.

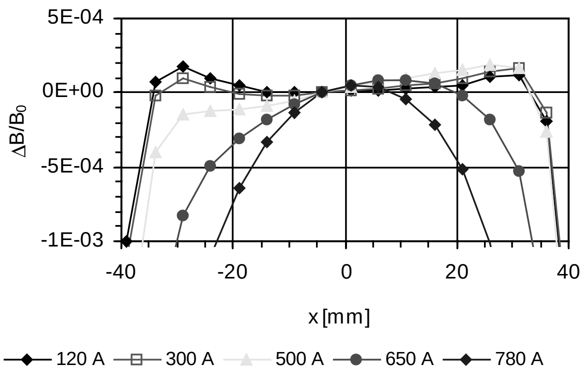

Figure 2 Transversal field quality for a bending magnet

Magnetic field maps have been measured in the midplane of the bending magnet at three different currents; injection (0.5 GeV; 125 A), at mid-energy (1.6 GeV; 400 A) and at nominal energy (2.5 GeV; 650 A). The electron trajectory has been calculated from the field maps and the field integral has been determined from the trajectory.

Figure 3 shows the relative difference from the mean integrated field for the magnets that have been measured up till now at nominal current. The relative difference is below ± 2.10^{-3}, which corresponds to a kick of ± 0.8 mrad, representing a deterioration of the close orbit deviation, that can be easily suppress using the corrector magnets distributed around the ring and an appropriate sorting procedure.

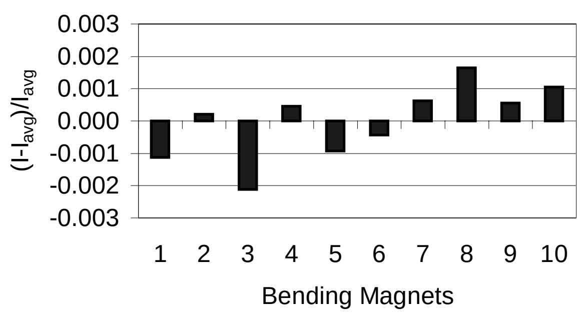

Figure 3 Relative deviation from the mean field integral for the up-to-now measured bending magnets at 650 A

3.2 Quadrupole Magnets

Quadrupoles Q320 will work at an approximate current of 350 A at nominal energy, while for the same energy quadrupoles Q390 will work at a current of 300 A. The difference between the measured gradient and the ideal gradient is below 5 % for both magnets.

Figure 4 (see next page) shows the relative difference between the measured integrated gradient and the mean integrated gradient. For the 32 Q320-quadrupoles, $\Delta g/g$ stays below ± 5.10^{-3}. These 32 quadrupoles are further divided in 4 groups of 8 magnets. Once this is done the relative difference to the mean is below 1.10^{-3} for three groups and only for one set of magnets it goes up to ± 3.10^{-3}, which is within specifications. The tune shifts induced are below ± 10^{-4} and the beta beat is below 2% in both planes, once the magnets are properly sorted as has been shown by calculations done with MAD.

The main high order multipoles present are the allowed n=6 and n=10 components and the non-allowed components n=3 (normal and skew) and n=4. The non-allowed components are due to mechanical errors. Typically the systematic components are the same for all the quadrupoles, while the non-allowed components vary from quadrupole to quadrupole. Nevertheless the largest high order component is still below ± 5.10^{-4} (ratio of the high order component to the main component), which has been shown not to have any detrimental effect on the dynamic aperture of the machine.

In order to understand the presence of the non-allowed multipoles we have performed extensive mechanical measurements. The aperture diameter is for all the magnets 70±0.04 mm. In the interpole distances there is a larger variation, 22.78±0.06 mm. However, there is no clear correlation between the interpole distances and the presence of the non-allowed sextupole and/or octupole components.

For the quadrupoles Q390 the same measurements have been performed. Figure 5 shows that the relative deviation of the measured integrated gradient is below ± 4.10^{-3}. Again the high order multipoles are characterised by the allowed n=6 and 10 and the non-allowed sextupolar and octupolar components.

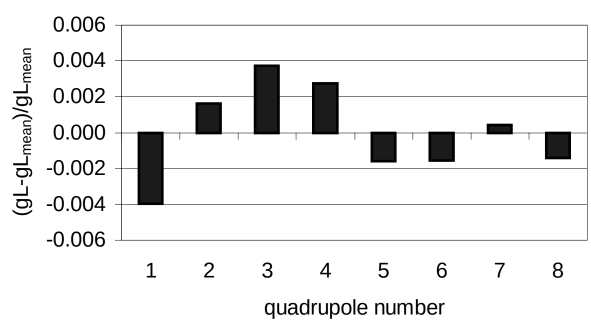

Figure 5 Relative deviation from the mean integrated gradient for the Q390 quadrupoles at 300 A, nominal current

3.3 Sextupole Magnets

Measurements on the vertical acting sextupoles SV have not yet started and those on SH are now under way, therefore only preliminary results will be here presented.

The sextupoles SH and SV will work at a nominal current of approx. 200 A with a saturation smaller than 2 %. The main high order harmonics present are the allowed n=9 and n=15. For all magnets the contribution of these high order harmonics to the main component is smaller than 5.10^{-3}.

Figure 6 presents the relative deviation from the mean integrated sextupolar component for the sextupoles SH at 200 A.

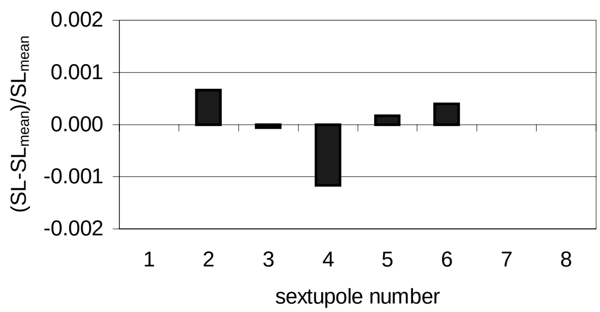

Figure 6 Relative deviation from the mean integrated sextupolar component for the SH sextupoles at 200 A

4 SUMMARY

The measurements of the ANKA magnets are well advanced. The 40 quadrupoles measured are within specifications. The relative spread in integrated quadrupole strength amongst the different families is below ± 3.10^{-3}. The high order multipoles do not have any detrimental effect on the behaviour of the machine. The measurements performed up to now on the dipoles and sextupoles indicate also magnets within the magnetic specifications.

5 REFERENCES

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Acknowledgements

The authors want to thank BESSY-II, specially D.Krämer, for lending us the rotating coil on which the measurements of the quadrupoles and sextupoles have been performed, also we would like to thank the LLS team for performing the measurements on the bending magnets.

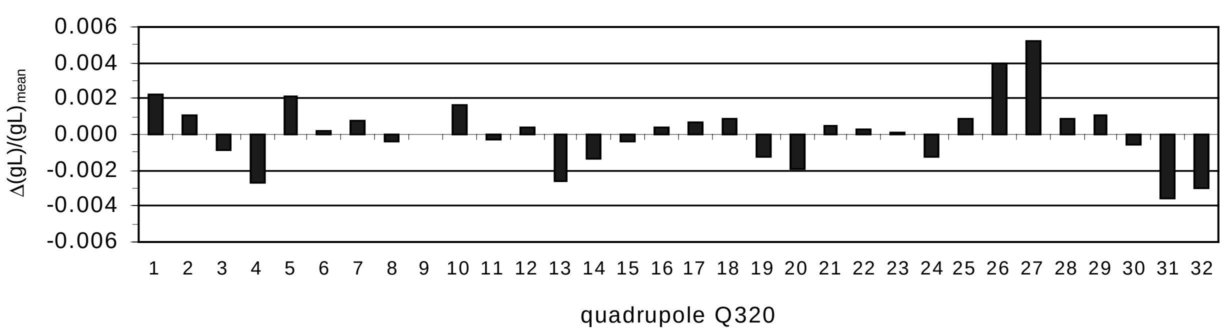

Figure 4 Relative deviation from the mean integrated gradient for the quadrupoles Q320 at 350 A, approximately nominal current