Field Measurement of the Magnets for COSY - Jülich

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Abstract

COSY-Jülich [1] is a synchrotron and storage ring accelerating protons from 40 MeV injection energy up to a maximum energy of 2500 MeV. The main magnet system consists of 24 dipole magnets bending the beam by 15 degrees each and a total of 56 quadrupole magnets. These quadrupole magnets are of two types the unit cell quadrupoles (MQU) in the circular part and the telescope quadrupoles (MQT) in the straight "telescope" sections differing only in the length of the iron.

The types of measurements for these magnets are described and some results are presented.

Bending magnets

The basic parameters of the bending magnets are given in table 1. All 24 dipole magnets are connected in series to one power supply. This requires that $\int Bdl$ is as identical as possible for all the dipoles. The requirement from theory is identity of $\int Bdl$ better than $2 \cdot 10^{-4}$. To achieve this identity the length of the bending magnets can be shimmed by means of removable pole endpieces.

Table 1:
Main parameters of the bending magnets

iron length	1755 mm
gap height	90 mm
induction	~ 0,13 - 1,58 T
max. current	5000 A
ramp rate	~ 1T/s

The measurements were done with sets of long coils integrating over the length of the magnet [2]. A set of coils consists of 4 coils. Seen in beam direction there are a long coil, two short coils located in the homogeneous part of the field and another long coil. The coils are imbedded in a rod made from carbon fibre to be mechanically stable. This coil support is driven across the aperture of the magnet by two 2-D tables located at the entrance and exit sides of the magnets. The absolute field inside the magnet can be determined by a coil flip. The voltages induced in the coils are integrated with Schlumberger 7061 integrating digital voltmeters. The reproducibility of the $\int Bdl$ measurement was found to be of the order of 10^{-5}. The shimming of the dipoles was done at a field level of 1T. Figure 1 shows the relative deviations of $\int Bdl$ of the individual magnets from the mean value. It shows up that the identity of $\int Bdl$ is better than the theoretical requirement of $2 \cdot 10^{-4}$. The mean excitation curve of all dipole magnets is given in Fig. 2. The excitation curves of the magnets are measured starting with a coil flip at 200 A to determine the absolute field value and then ramping up the current in steps of 200 A up to the maximum current of 5000 A integrating the induced voltage for each step.

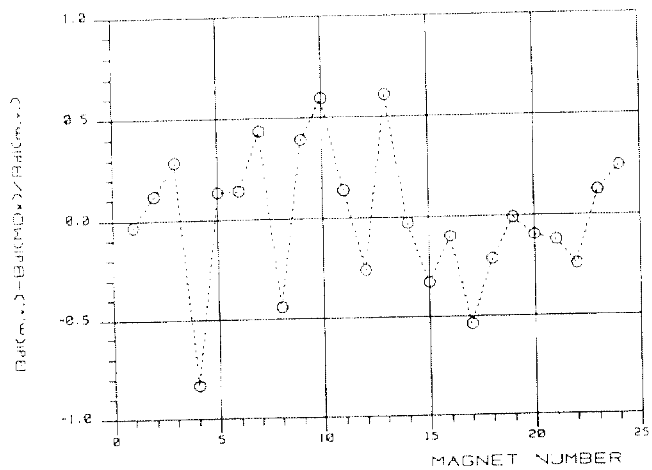

Figure 1:
Relative deviation of $\int Bdl$ of the individual dipole magnets with respect to the mean value of $\int Bdl$ of all the dipole magnets

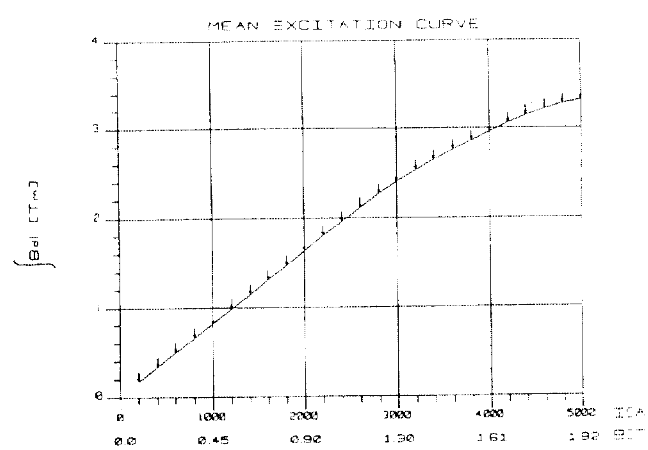

Figure 2:
Mean excitation curve for all the dipole magnets

The homogeneity of the field as well as the stray field were measured for one magnet with a 3 D-table and thermally stabilized hall probes measuring the 3 field components [3]. The homogeneity of the field at 1T is shown in Fig. 3. Up to this field level the homogeneity is approximately $2 \cdot 10^{-4}$.

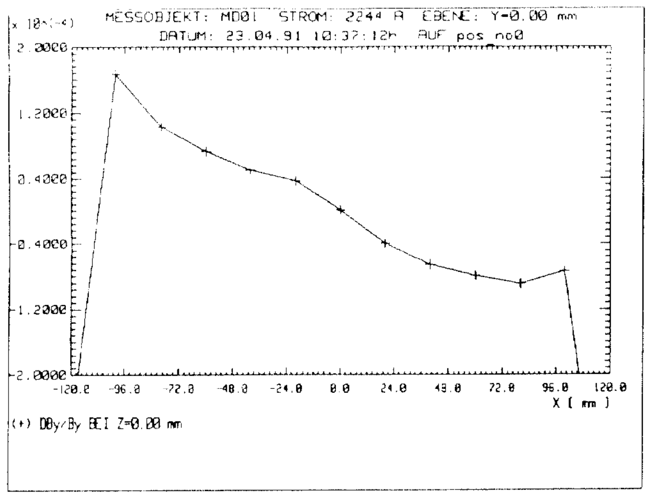

Figure 3:
dB/y/By in the midplane of the air gap measured across the gap in radial direction at an induction of ~ 1 T

Quadrupole magnets

The basic parameters of the quadrupole magnets are given in table 2.

Table 2:
Main parameters of the COSY quadrupole magnets

	MQU	MQT
iron length	300	570 mm
aperture diameter	170	mm
max. gradient	7,6	T/m
max. current	520	A

The quadrupole magnets are measured on a measuring bench with slowly rotating coils [4]. The quadrupole as well as the dipole component are compensated by a bucking coil. The radii of the main and the bucking coils are according to a design of K-Halbach [5] giving maximum sensitivity for harmonics with n $\geq$ 3. The supression of the quadrupole term achieved is ~ 10^{-3}. The measuring "coil" consists of 3 sets of compensated coils. One long set integrates over the whole length of the magnet the other two are integrating at the entrance and exit sides of the magnet from inside the magnet to the field free region. The "coil" is rotating in air bearings and driven by a dc motor. The angular position of the coil is controlled by an 15 bit absolute optical encoder. The voltage induced in the coils is integrated for 256 angle steps during one revolution of the "coil". The harmonics are calculated by fast fourier transform of the flux sum. The main aim of this machine and the reason for the 3 sets of coils is to align the quadrupole magnets with respect to their magnetic axis. The magnets can be aligned to a distance between coil axis and magnetic axis of less than 0.02 mm. The displacement between coil axis and magnetic axis is caluclated from the ratio of the dipol-component to the quadrupole component of the uncompensated signal. After this alignment of the magnet on the bench optical targets on top of the magnet are placed with respect to a laser beam that is aligned parallel to the "coil" axis. These targets are then used for the alginment of the magnets in the accelerator tunnel.

After aligning the magnet on the measuring bench the excitation curve the harmonic content as well as the gradient are measured for a number of currents. The gradient is deduced from the difference between the long coil and the two short coils.

The pole edges are chamferred with an angle of 45 degree. The depth of the chamfer was decided after measurement of the harmonic content of the prototype magnets. The criterion for the depth was to minimize the n=6 (dodecapole) component.

The measurement of the series magnets has been finished at the beginning of march and the analysis of the data is still under way. Figure 4 shows an example of an excitation curve. The relative deviation of $\int$gdl of the individual magnets from the mean value of $\int$gdl at a current of 350 A for all the MQT magnets is given in Fig. 5. Magnet no. 1 was the prototype magnet. For a few magnets the deviation is larger than would be expected from the mechanical tolerances. This could be due to instabilities of the power supply.

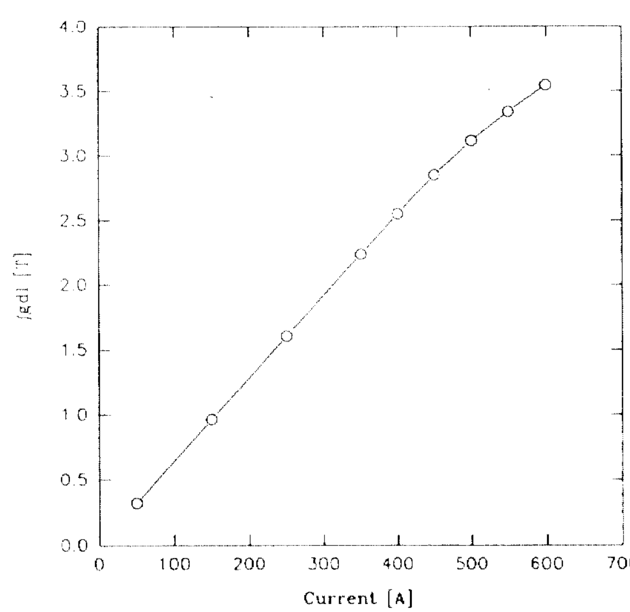

Figure 4:
Excitation curve of unit cell quadrupole MQU 7

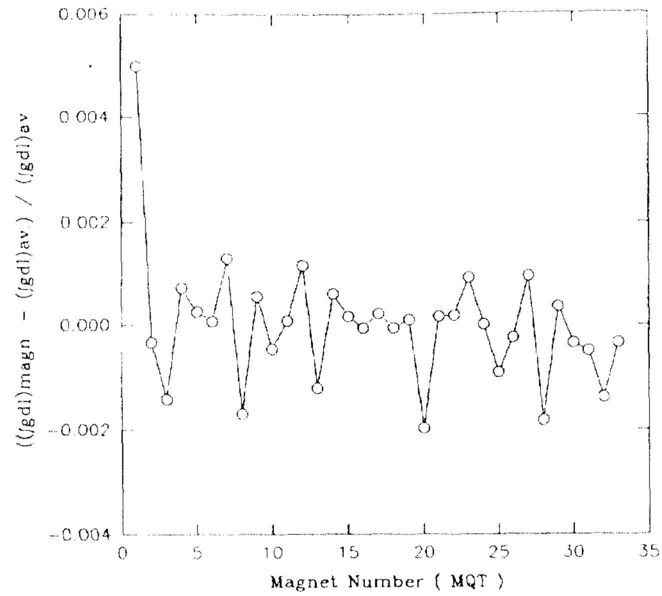

Figure 5:
Relative deviation of $\int$gdl of the individual quadrupole magnets MQT with respect to the mean value of $\int$gdl of all the quadrupole magnets MQT

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