The ELETTRA Storage Ring Magnets

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Abstract

24 dipole magnets, 108 quadrupoles, 72 sextupoles and 82 steerers are needed in the storage ring. The very stringent requirements for the magnets field quality were met with the use of a combination of 2D and 3D magnetic design.

The dipoles are combined function elements with a field index n=13 and a maximum magnetic field of 1.5 T at the central orbit. The curved (R=5.5 m) pole profiles were obtained by machining the stacked laminations.

The quadrupoles and sextupoles are made by assembled pole pairs in a C shaped structure with the aperture on the outer side of the ring. To insert the vacuum chamber inside the magnets this structure allows a symmetric opening of the yoke.

The steerer magnets provide both horizontal and vertical magnetic fields; an inverted U shape with a 3D optimization of the vertical field coils sizes and positions was studied to provide space for the connection of vacuum pumps.

I. INTRODUCTION

A. General

Elettra has been designed to provide high brightness photon beams over a wide range of energies (10 eV-30 keV) from insertion devices in a low emittance 1.5-2.0 GeV electron storage ring. The machine is now being completed on the Carso plateau near Trieste. The commissioning is foreseen within 1993. The periodicity of the ring is 12, with dispersion free straight sections 6 m long to accommodate insertion devices. The magnets are all room temperature, DC magnets. For the steerer magnets a feedback controlled correction for frequencies up to 50 Hz can be superposed on the DC field controlled by a feedback system. The design of the magnets allows the insertion of the vacuum chamber horizontally from the outside of the ring. The yokes of all the magnets, including the steerers, have been made of low carbon steel laminations, adequately treated in order to keep the coercive force below 0.9 Oe. The dipoles, quadrupoles and sextupoles have been mounted with adjustable feet on a 20 mm thick iron plate, which was fixed to a concrete block well attached to the Carso rock in order to shield the magnets against external vibrations. The steerer magnets have been mounted on aluminum supports on which also the corresponding vacuum pumps are located.

B. Design method and tests

All the Storage Ring magnets have been designed by using both 2D (POISSON) and 3D (the Cern licensed TOSCA by Vector fields Ltd) packages. The results of the computer simulations have been compared to experimental measurements which have been made on prototypes [1]. To test the prototypes and to check that the units delivered by the contractors actually complied with the field requirements, two microprocessor controlled measuring systems have been designed and built [2].

II. DIPOLES

The 24 bending magnets (Figure 1) are C shaped, with a radius of curvature of 5.5 m and parallel end faces. The relevant main parameters are listed in Table 1.

TABLE 1. Dipole magnets main parameters

Number of units	24
Field @ 2.0 GeV	1.212 T
Field index	13
Nominal radius of curvature	5.5 m
Yoke length	1.37 m
Magnetic length	1.44 m
Overall length	1.57 m
Central gap	70 mm
Number of turns	48
Conductor dimensions	23x15-Φ5.5 mm
Maximum current (@1.49 T)	1950 A
Maximum excitation power	35 kW
Total weight	6 Tons

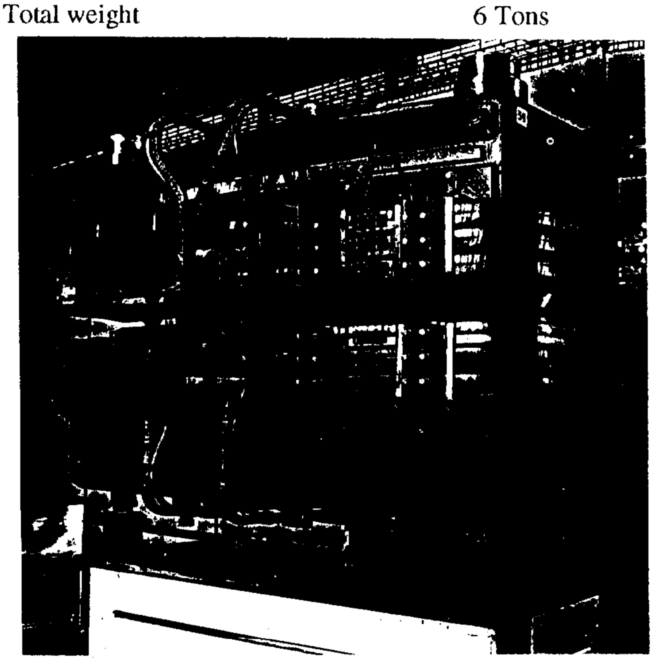

Figure 1. The Storage Ring Dipole on its support.

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The yoke is composed of a stack of 1.5 mm thick low carbon steel laminations ending with two 40 mm thick plates. The laminations are kept together by means of 11 longitudinal curved plates welded on its outside surfaces. The insulation between the laminations has been provided by plain blue-steaming.

Being supplied in series, all the dipoles must be as similar as possible to each other. This imposed tight tolerances on the magnetic length (±0.2 mm) and the filling factor (97%). Furthermore, each magnet has been constructed using laminations coming from all the melts, equally mixed. The magnetic properties and the content of impurities of the laminations has been monitored during the manufacture, the melts exceeding a value of coercivity higher than 1.9 Oe for the plates and 0.9 Oe for the sheets have been discarded.

The required tolerance of the pole profile was very high (±20 μm). To meet this requirement the manufacturer suggested to machine the profiles of the assembled yokes on a vertical numerically controlled lathe . Unfortunately the result of the machining was not as homogeneous as expected, and two groups of magnets were obtained, ten magnets with a very satisfactory integrated gradient uniformity, and the other magnets with an unacceptable spread (Figure 2). After several attemps the problem was finally solved by adding shims close to the pole ends (gradient and sextupole correction) and by radially displacing the magnets on the ring as needed for field correction [3].

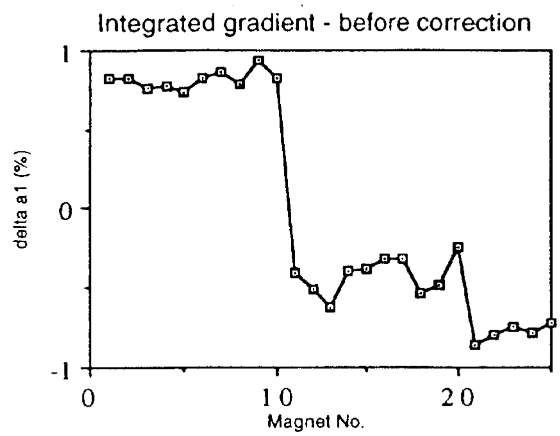

Figure 2. Dipole magnets integrated gradient along the central trajectory before adding the pole-face shims.

Each coil is made by three double pankakes following the curvature of the pole with 24 turns per pole. The coils are insulated with glass tape and radiation resistant epoxy resin. The electrical and hydraulical connections between the pankakes and toward the power leads and the water distribution are made in the center of the coils in order to achieve a good longitudinal symmetry of the magnet.

For alignment two sockets for Taylor Hobson spheres have been fixed on the magnets with a 3D machine with a precision of ± 0.02 mm with respect to the magnet reference marks which have been used for the magnetic measurements and for the pole profile machining.

All the dipoles are presently installed and aligned in the Storage Ring.

III. QUADRUPOLES AND SEXTUPOLES

The quadrupoles (Figure 3) and sextupoles (Figure 4) are C shaped magnets with the aperture toward the outer side of the ring, made with the same steel as that of the dipoles. The iron poles are assembled from precision-punched laminations, stacked between two thick end plates and held together by bolts and longitudinal welds on the outside of the stack. The poles are then assembled in independent pairs in order to allow the symmetrical opening of the yoke for the insertion of the vacuum chamber by a horizontal displacement. The opening of the quadrupoles is obtained by a hinge-like rotation, that of the sextupoles by a vertical displacement of the two outer pole pairs. To meet the field quality requirements tight geometrical tolerances have been imposed particularly on the pole surface profile and on the azimuthal position between the pole pairs (±70 μm along the whole length).

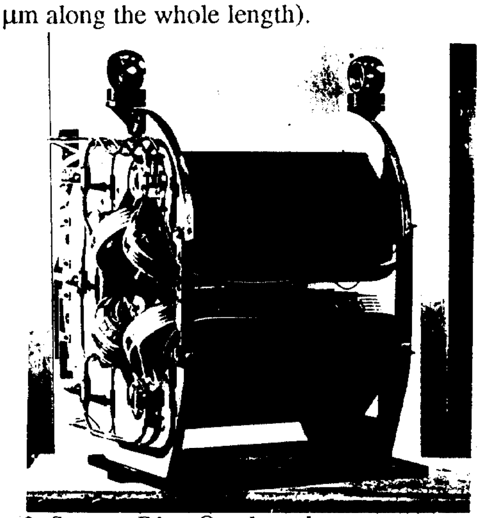

Figure 3. Storage Ring Quadrupole

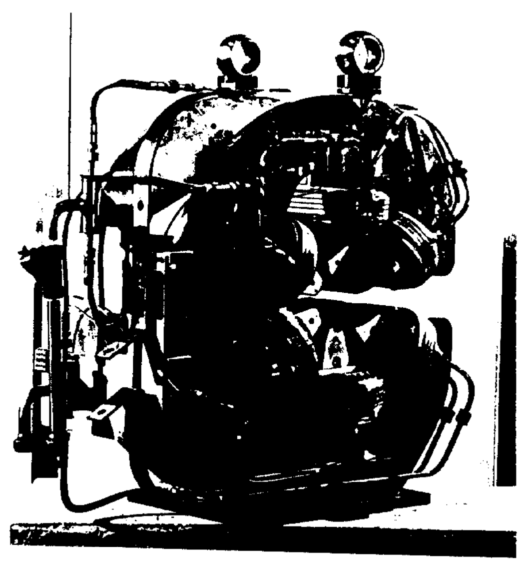

Figure 4. Storage Ring Sextupole

The quadrupoles (Table 2) have been made in three different lengths, the sextupoles (Table 3) in two. The results of the magnetic measurements made on the series production showed acceptable random and systematic harmonic errors (Figure 5 and Figure 6). The dodecapolar field component of the quadrupoles, due to end effects, was reduced by an appropriate chamfer on the end plates.

TABLE 2. Storage Ring Quadrupoles main parameters

	Short	Medium	Long
N. of units	60	24	24
Inscribed diameter	75 mm	75 mm	75 mm
Maximum gradient	19.6 T/m	19.6 T/m	19.6 T/m
Maximum current	300 A	300 A	300 A
Length of iron	230 mm	380 mm	470 mm
Total length	400 m	550 mm	640 mm
Total weight	425 kg	580 kg	700 kg

TABLE 3. Storage Ring Sextupole main parameters

	Short	Long
N. of units	24	48
Inscribed diameter	90 mm	90 mm
Maximum strength	280 T/m^2	280 T/m^2
Maximum current	300 A	300 A
Length of iron	125 mm	240 mm
Total length	310 mm	425 mm
Total weight	280 kg	450 kg

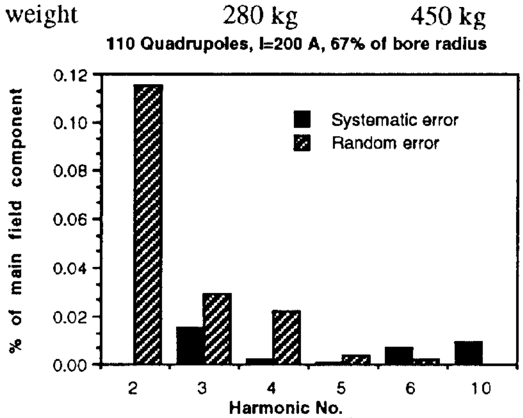

Figure 5. Harmonic measurements on the quadrupoles.

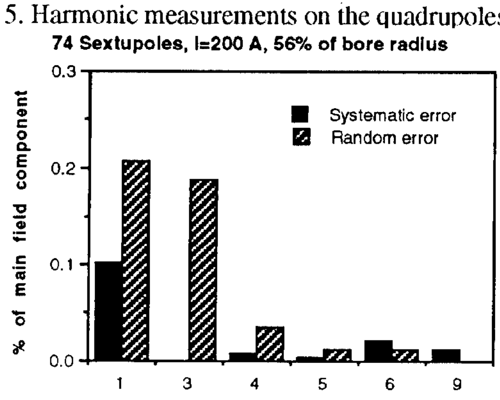

Figure 6. Harmonic measurements on the sextupoles

IV. STEERERS

The Steerer magnets (Figure 7) provide both horizontal and vertical magnetic fields. The limited longitudinal space available and the need of a complete aperture on the bottom of the magnets in order to allow the connection for the vacuum pump required a detailed 3D design leading to an inverted U shape with an optimisation of the current density distribution in the vertical field coils. An external ferromagnetic screen has been added to shield the lateral fringing field.

TABLE 4. Storage Ring Steerer magnets main parameters.

Number of units	82
Length of iron	150 mm
Total length	220 mm
Horizontal free aperture	110 mm
Maximum magnetic field	500 Gauss (both H and V)
Maximum integrated field	15000 Gauss·cm
Maximum current	16 A
Total weight	60 kg

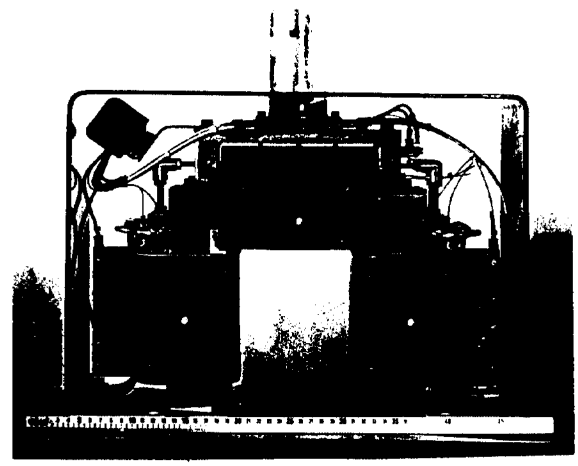
Figure 7. The storage ring steerer magnet.

V. CONCLUSIONS

All the storage ring magnets have been delivered and have been individually measured [3,4].The installation and alignement of the magnets are nearly completed, the commissioning of the Storage Ring will start in September 1993.

VI. REFERENCES

[1] G.Petrucci et al., "Magnetic measurements of the ELETTRA Storage Ring Prototype Magnets", Proc. of the 3rd EPAC, Berlin, March 24-28, 1992.
[2] G.Petrucci et al., "The calculation and Measurements of the ELETTRA Magnets", Proc. of the 2nd EPAC, 1990.
[3] R.P.Walker and D.Zangrando, these Proceedings.
[4] D.Zangrando and R.P.Walker, these Proceedings.