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Magnetic Measurements of the 12-Pole Trim Magnets for the 200 MeV Compact Synchrotron XLS at the National Synchrotron Light Source

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Abstract

Magnetic measurements performed on the 12-pole trim magnets is described including Hall probe measurements to verify symmetry of the field and, rotating coil measurements to map the multipoles. The rotating coil measurements were carried out using a HP Dynamic Signal Analyzer. Excited as a quadrupole the dominant error multipole is the 20th pole and excited as a sextupole the dominant error multipole is the 18th pole. Reasonable agreement was found between the Hall probe measurements and the rotating coil measurements.

I. Introduction

The 12-Pole trim magnets used in this study are based on the ones used in the Daresbury Synchrotron[1] . These are located at the two ends of the two 180°, 1.1 Tesla, bend magnets of the 200 MeV Compact Synchrotron operational at the National Synchrotron Light Source since August 1990. These magnets were wound to produce trim quadrupole and trim sextupole fields. Situated at the ends of the dipoles they also serve as clamps to the dipole fringe fields. We describe herein magnetic measurements using both rotating coil and Hall probes to obtain the field gradients as well as to check the symmetry of the fields.

II. Description of the Magnets

The magnets have an aperture radius of 50mm and the magnetic structure is built up from 12 identical pieces held together mechanically. The quadrupole windings are distributed on the circular structure(backleg) formed from the 12 sector pieces and the sextupole windings are placed on the inside region of the magnet on alternate sectors. Eight out of twelve outer coils are used to produce the quadrupole fields and six inner coils produce the sextupole field. As used in this ring the quadrupole and sextupole windings are excited from independent power supplies differently from to the way they are excited in the Daresbury Synchrotron.

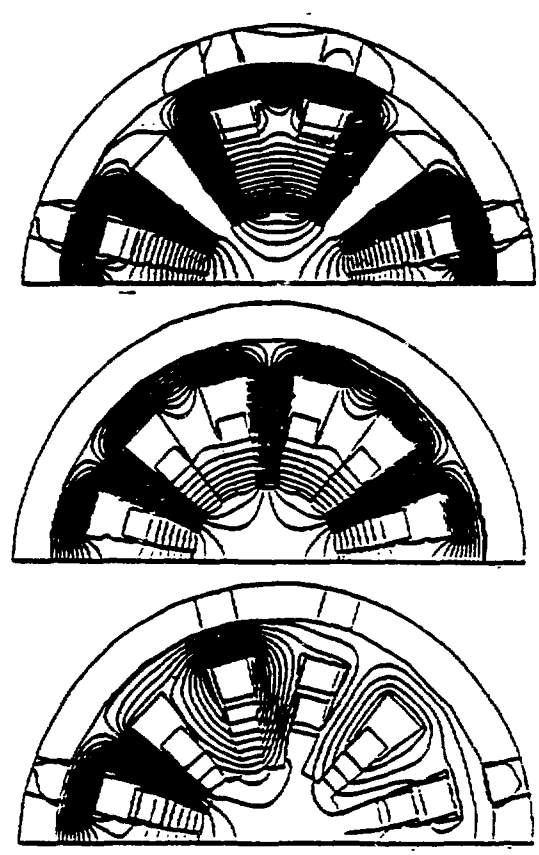

Figure 1. Poisson field plot of the magnets:(top to bottom) in Quadrupole, Sextupole, and Combined excitations
POISSON field plot of the magnet excited in two different ways is shown in Figure 1.

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DISCLAIMER

III. MAGNETIC MEASUREMENTS

A. General

Hall probe measurements to determine the longitudinal distribution along the Z(along the direction of the electron trajectory) and X axes of the magnet were carried out. In the very early stages of these measurements it was found that the mechanical assembly was not rigid enough and it contributed to the asymmetry of the field. Another factor which dictated the modification of the magnet was the question of reproducible assembly of the magnets over the synchrotron ring after the measurements. The original design consisted of 12 independent pieces held together in place, produced a magnetic structure with poor mechanical rigidity due to significant play. After two modifications,in its final version the magnet can be taken apart in two rigid halves which may be reassembled in a reproducible manner.

B. Hall probe measurements

A F.W.Bell HTR-0608 transverse Hall probe held in a brass fixture attached to a table (capable of motion in the X and Y axes)was used to monitor the field. The table was mounted on a carriage parallel to the Z-axis of the magnet. Using linear encoder signals the Z and.X coordinates could be set to within 0.001mm in a reproducible fashion. Magnet current was measured using a precision shunt and the current drift over a period of 45 minutes was less than 0.01%.

For each magnet and after each modification the symmetry of the field was checked by folding the Z-axis distribution about the symmetry plane. This was checked for several X axis positions. The X-axis(horizontal plane) distribution at the center of the magnet was similarly checked(from x=-43mm to x=43mm) by a folding procedure for both quadrupole and sextupole excitations.

The Z-distribution can yield information on the effective magnetic length of the magnet. The Z-distribution is fit to a polynomial and the polynomial is then integrated from the beginning of the fringe field to the peak field to yield the effective length of the magnet[2]. Also using the X-scan distribution of the field, the multipole values for both quadrupole and sextupole excitations at one longitudinal position,namely at Z=0.0 was determined.

C. Rotating Coil Measurements

The theory of rotating coil measurements for evaluating multipole components of magnets is well documented[2]. The rotating coil consists of 4 strands of very fine wire (5/1000" in diameter)with each strand consisting of 43 conductors. The 172 insulated turns so formed are wound in a 2m long slot(0.185"x 0.047") cut on the surface of a 90mm nominal diameter G-10 tube.These conductors at the surface return through the center of the tube and the two ends of the coil are brought to slip rings for external connection. The magnet was energized with a constant current DC source and the current delivered to the magnet did not fluctuate more than 0.01% during measurement.The rotating coil was run at 1/3Hz using an AC motor. The angular position of the coil was optically encoded and was used to trigger HP 3562A Dynamic Signal Analyzer as shown in Figure 2 to sort out the various harmonics representative of the multipoles present in the magnetic field using Fourier analysis of time captured signals. These were used to calculate,the gradient values using relevant equations of electromagnetic induction.

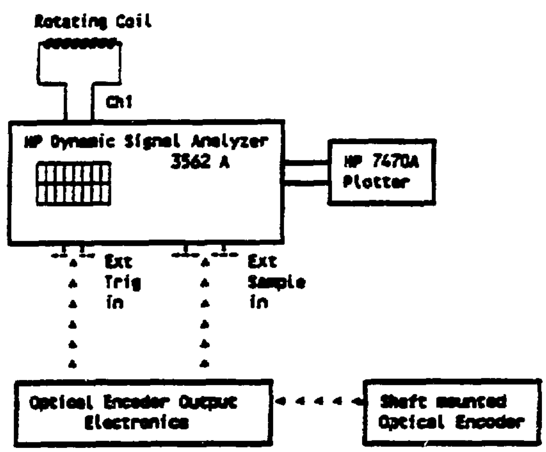

Figure 2. Instrument set up for multipole measurements

IV. RESULTS AND CONCLUSIONS

Figure 3 shows the Hall probe longitudinal scan for one of the magnets in quadrupole excitation. Figures 4(a)and4(b) show the transverse scan in the aperture of the magnet for quadrupole and sextupole excitation of the magnet. Some asymmetry in the longitudinal scan was observed on an axis passing through the magnetic center which did not exceed 10% of the peak field value. The symmetry was better for longitudinal axes passing through points away from magnetic center. After each modification the symmetry of the field improved. The two curves of Figure 3 are for longitudinal axes passing through(x=-7mm,y=0) and (x=+7mm, y=0) with one of the curves shown in reflection about the horizontal axis. Polynomials fit to Figures 4(a) and 4(b) indicated that the good field of the quadrupole and the sextupole did not exceed a radius of ~30mm as evidenced by the sharp features at the ends of the magnet. The effective length of the magnet from Z-distribution was within 10% for the quadrupole and 20% for the sextupole from their design values of 0.1m and 0.08m respectively. The transverse distributions were used to determine the gradients of the magnets at a peak current of

6.5 amps. A global average of 0.98 tesla/meter for the quadrupole and ~16 tesla/meter^2 for the sextupole were obtained.

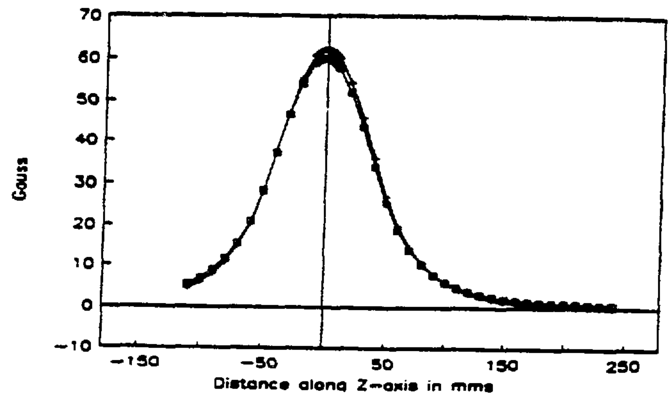

Figure 3. Longitudinal scan for quadrupole excitation

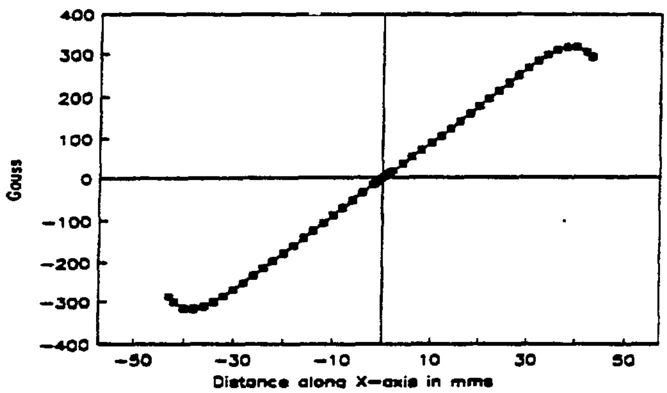

Figure 4(a). Transverse scan for quadrupole excitation

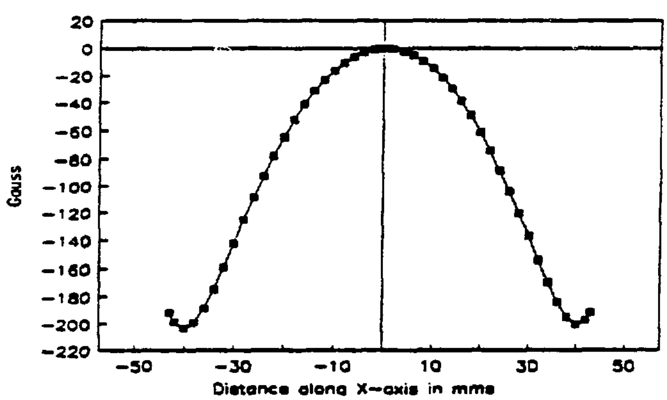

Figure 4(b). Transverse scan for sextupole excitation

The harmonic components in the magnets excited in the quadrupole and sextupole schemes are as shown in Figures 5(a) and 5(b). In quadrupole excitation the main components were quadrupole and 20-pole while in sextupole excitation the dominant terms were the sextupole and the 18th pole.These are expected from symmetry considerations-[1]. The sextupole component in quadrupole excitation was very small. The various modifications improved the picture for the main field component and reduced the magnet to magnet variation from above 2% to 1%. The remnant field varied depending upon its previous history of excitation requiring 4 to 5 conditioning runs to obtain reproducible results.The quadrupole gradient averaged for the magnets was ~0.99 tesla/meter and for the sextupole, 16.9 tesla/meter^2. These compare reasonably with those of the Hall probe measurements. The gradient values for the quadrupole are only 50% of the Poisson calculations and is probably due to the reluctance of 12 airgaps between the 12 pieces which forms the magnetic core not included in the model.

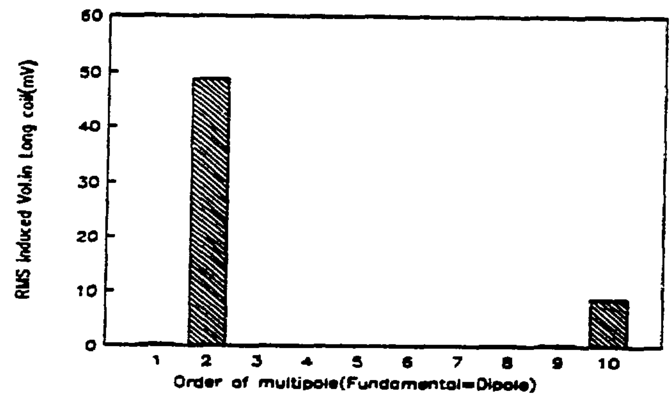

Figure 5(a). Harmonics in quadrupole excitation

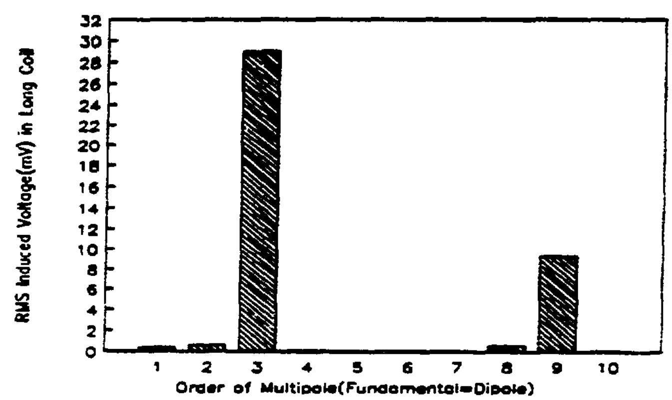

Figure 5(b). Harmonics in sextupole excitation

V. References

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[2]. C.Haddock, G.Smith, and J.S.C.McKee, "A Microcom puter-Controlled, Magnetic Field Measurement and Analysis System", Nuclear Instruments and Methods in Physics Research, A294,397-410,(1990).

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