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**COMPUTER CALCULATIONS
OF DIPOLES AND QUADRUPOLES
BASED ON PERMANENT MAGNETS**

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Расчеты на ЭВМ диполей и квадруполей из постоянных магнитов

Излагаются результаты применения двумерной программы POISSON для расчета диполей и квадруполей из постоянных магнитов.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1978

Ilyushchenko V.I.

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Computer Calculations of Dipoles and Quadrupoles
Based on Permanent Magnets

The results of application of the two-dimensional POISSON code in calculations of dipoles and quadrupoles based on permanent magnets are presented.

The investigation has been performed at the Laboratory of High Energies, JINR.

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Dubna 1978

INTRODUCTION

Recently the development of new hard magnetic materials based on rare-earth compounds, e.g., SmCo_5 ^{/1/}, has substantially enlarged the possibilities of application for permanent magnet dipole and quadrupole systems. Permanent magnet dipoles are used, e.g., to calibrate NMR magnetometers^{/2/}. Permanent magnet quadrupole lenses can be effectively utilized in linear accelerator drift tubes^{/3/}.

Model dipole and quadrupole magnets with SmCo_5 pole tips have been developed at the High Energy Laboratory, JINR.

The magnetic field distributions for these magnets have been calculated with a CDC-6500 computer using the two-dimensional Poisson code^{/4/}.

COMPUTATIONAL MODEL

Recently the code PANDIRA more complex in comparison with POISSON has been used to calculate the quadrupole lenses with disk poles made of barium ferrite, alnico and SmCo_5 ^{/3/}. The method for solving the difference equations in PANDIRA is similar to that used in the RF cavity field code SUPERFISH^{/5/}. The basis for the physical model of permanent magnet description taking into account the anisotropy is presented in a paper of H.Zijlstra^{/6/}. In this model an actual magnet is represented by the sum of its elementary crystallites and described by four parameters.

In our case a more simple model was used in which M_0 was replaced by a current sheet of filaments and any $M(H)$ dependence was ignored. In the nearest feature it is supposed to perform calculations taking into account the anisotropy.

DIPOLE ANALYZER FOR NMR MAGNETOMETER ^{/2/}

A hard magnetic dipole of the "window frame" type has a steel yoke with zero gap outer dimensions of $16.4 \times 10.8 \times 3.6 \text{ cm}^3$. SmCo_5 prisms $3.5 \times 3.6 \times 1.0 \text{ cm}^3$ in size with $(BH)_{\text{max}} \sim 18 \text{ MG} \cdot \text{Oe}$ were used as pole tips. The magnetic field strength in a 0.6 cm gap was 6500 Oe . The accuracy of measurements by a film Hall probe $0.1 \times 0.3 \text{ cm}^2$ in size amounted to 10^{-3} with the NMR calibration.

The magnetic field distributions for different gap widths and pole dimensions were calculated using the POISSON code under the assumption of equivalent substitution of permanent magnets by current sheets (fig.1).

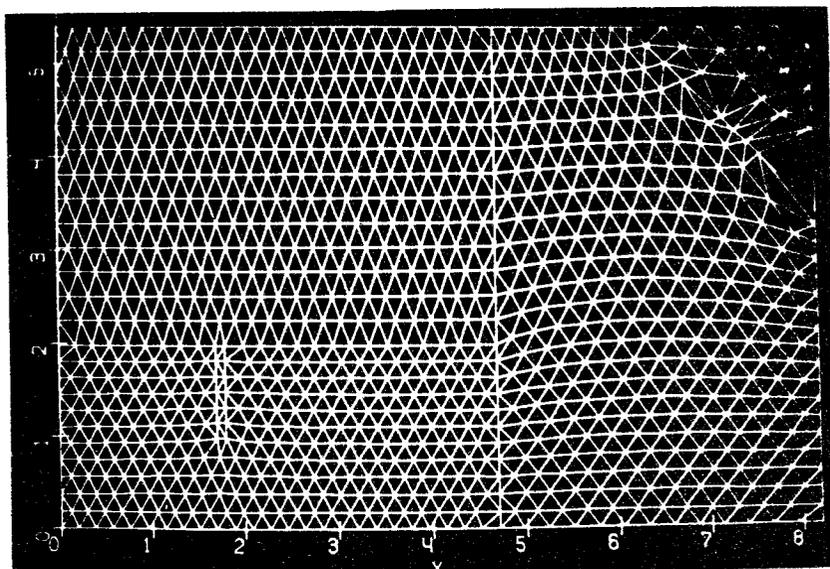


Fig. 1. Computer mesh for the NMR dipole.

The total number of triangular mesh points was 980. For a current sheet 0.07 cm thick and 1.0 cm high the equivalent current density is $j = 6.1 \times 10^4 \text{ cm}^2$ which is comparable to that in superconductors.

The calculated distribution of the equipotential lines inside the dipole is presented in fig. 2.

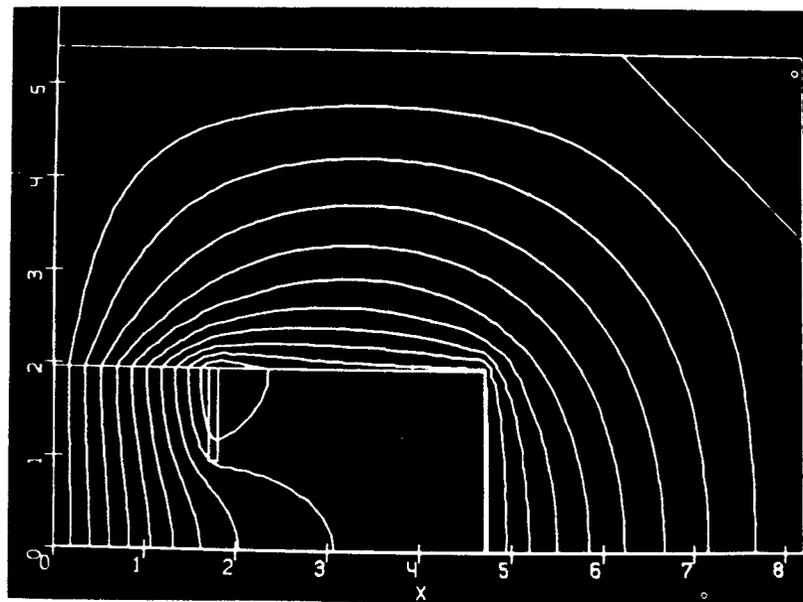


Fig. 2. Distribution of equipotential lines for the dipole.

The measured and calculated magnetic field distributions $H = H(x)$ along the median plane and the gap width $d = 1.9 \text{ cm}$ are shown in fig. 3 for comparison.

From the data given it follows that when calibrating the computed curve at the dipole center point according to the measured field strength $d = H(x)$, which is by $\sim 3\%$ higher than the experimental one at a distance of $x = 2.0 \text{ cm}$ from the dipole center. This systematic trend may be due to a two-dimensional character of the POISSON code as the yoke width is only about 3.5 cm , i.e., it is comparable to the gap width.

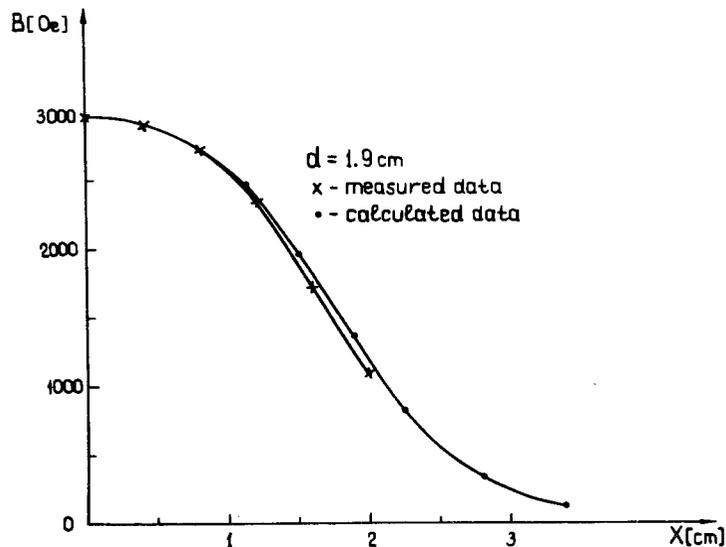


Fig. 3. Measured and calculated magnetic field distributions.

HARD MAGNETIC QUADRUPOLE LENS FOR A LINEAR ACCELERATOR^{7/}

A model quadrupole lens with a yoke 8.2 cm in outer diameter and 2.0 cm wide has been developed for a linear accelerator. SmCo₅ pole tips 1.6x1.6x0.8 cm³ in size with (BH)_{max} = 18 MG·Oe were placed in the 3.6x3.6 cm² square cross section aperture.

The magnetic field distributions were also measured by Hall probes.

Magnetic field gradients of 4.7 kOe/cm were realized inside the 2.0x2.0 cm² aperture. The calculations were performed by the POISSON code.

The computational mesh with current filaments is presented in fig. 4 for a single lens quadrant. The current at 7 points on the pole boundary is I = 770 A.

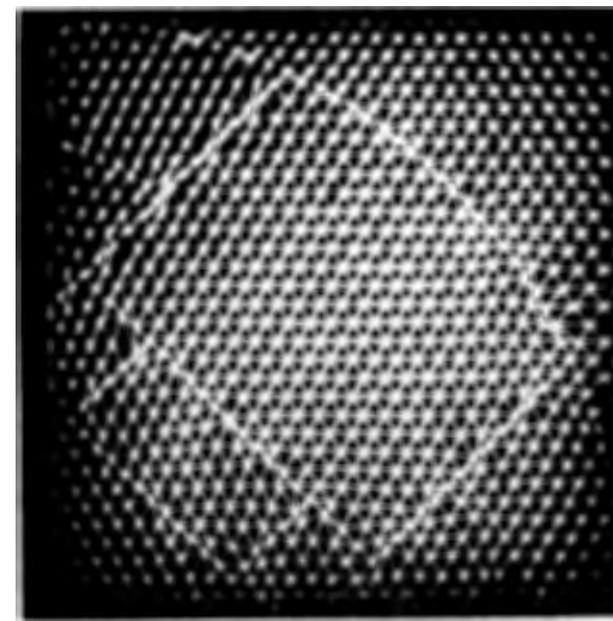


Fig. 4. Computer mesh for the quadrupole lens.

The equipotential distribution inside the lens aperture is presented in fig. 5.

Finally the comparative data have been obtained for measured and computed magnetic field gradients $G_r = G(r)$. The observed discrepancies between the experimental and computed points are of systematic origin as in the dipole case.

CONCLUSION

The POISSON calculations of magnetic field distributions in hard magnetic dipoles and quadrupoles with the ratio of the yoke width to the aperture diameter equal to ~1:1 achieve an accuracy of a few per cent. To improve the accuracy, three-dimensional GFUN3D codes should be used and the model should incorporate an anisotropy effect.

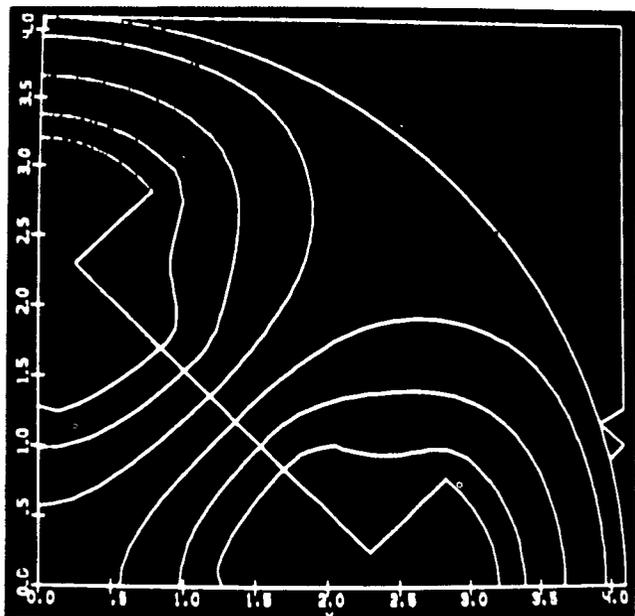


Fig. 5. Distribution of equipotential lines for the quadrupole lens.

The most effective case for application of these codes is to determine optimum dimensions of a magnetic yoke at a minimum volume of permanent magnet poles of the given $(BH)_{\max}$.

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1. Mishin D.D., Grechishkin R.M., Ilyushchenko V.I. Proc. VI Int. Conf. Magnet Techn. (MT-6), 1978, v.II, p.992.
2. Ilyushchenko V.I., Karpunin A.V., Kulikov Yu. V. JINR, 10-10970, Dubna, 1977 (in Russian).

3. Swenson D.A. et al. Proc. X Int. Conf. High Energy Accel., 1977, v.1, p.295.
4. Halbach K., Holsinger R., Magyary S. Proc. V Int. Conf. Magnet Techn. (MT-5), 1975.
5. Halbach K., Holsinger R.F. Particle Accel., 1976, 7, p.213.
6. Zijlstra H. Proc. I Int. Conf. Comp. Mag. Fields (COMPUMAG-1), Oxford, 1976, p.164.
7. Ilyushchenko V.I. et al. JINR, P9-11422, Dubna, 1978 (in Russian).

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