ESTIMATION OF FRINGING FIELD OF THE DIPOLE MAGNET FOR TARN II USING TWO-DIMENSIONAL MAGNETIC PROGRAM TRIM

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ABSTRACT

Fringing field of bending magnet for TARN II was calculated using two-dimensional magnetic field analysis program TRIM. The results were compared with the field measurements by Hall-probe at low excitation current. The agreement was satisfactory.

INTRODUCTION

A synchrotron to accelerate heavy ion beams, named TARN II[1], is designed. The ring has six periods and in each cell four dipole magnets are placed. Designed specifications of the dipole magnet are listed in Table 1.

Table 1

Specifications of the Dipole Magnet (H-type Magnet)

Number	24		
Bending angle	15	deg	
Maximum field	1.8	T	
Core length	1000	mm	
Gap height	80	mm	
Overall width	988	mm	
Overall height	680	mm	
Effective length	1051	mm	
Good field width	±100	mm	
Total weight	8	ton	
	Main coil	Correction coil	
Number of turns	40	20	
Maximum current	4000	50	A
Average current	3429		A
Current density	8.58	1.7	A/mm^2
Temperature rise	30	35	deg
Pressure drop	4.6	---	kg/cm^2
Water flow	40	---	l/min
Coil weight	0.5		ton
Overall length	1490	1320	mm
Overall widtht	590	660	mm
Overall height	112	8	mm
Resistance	5.5	23.8	mohms
Average power	65		kW

The program for two-dimensional magnetic field analysis, TRIM[2 3], was used to study required Ampere-turns and field properties in the gap, taking into account a saturation effect in the iron yoke. Then, the same program was used to estimate the fringing field as a function of excitation current. The result was compared with a field measurement by Hall-probe at low excitation current.

ESTIMATION OF THE FRINGING FIELD BY TRIM

To have a constant structure of fringing field[4] for various field strength, the corners of the dipole magnet edge were cut off with three steps so as that the shape was close to the Rogowski's curve[5], which is represented as

$$Y = D\ (\ 1 + 2/\pi \exp(\ \pi/2D*(L-X))\ )\ ,$$

where D = Half gap height, 40mm,
X = Distance from pole edge,
L = Parameter.

To estimate the fringing field and the effect of the end cut, we have used the two-dimensional magnetic field analysis program, TRIM. To accomodate the configuration of yoke into the two-dimensional calculation, we have added a supplementary yoke to the magnet as shown in Fig. 1. The magnetomotive force in this calculation is produced by the coil, which is placed outside the edge of the magnet. Without this supplementary yoke, the magnetic field lines would have passed through the air around the coil. The resultant magnetic resistance would be so high that the magnetic field in the gap would become so small. With the supplementary yoke, magnetic resistance is reduced so as to reproduce a magnetic field as high as 18 kG in the gap at designed excitation current.

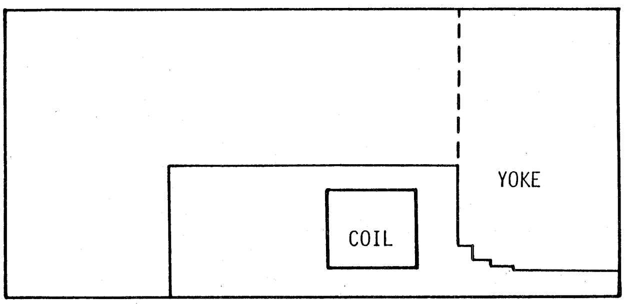

Fig. 1A Configuration of Magnet Yoke for Calculation by TRIM, Approximation by Step.

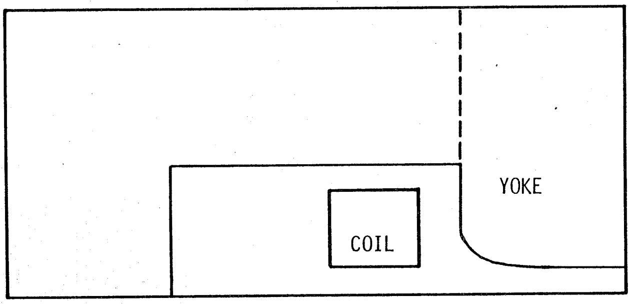

Fig. 1B Configuration of Maget Yoke for Calculation by TRIM, Rogowski's Curve L= 20mm.

We have calculated the end effect for the cut with three steps (Fig. 1A) and for the cuts by Rogowski's curve with several values of L = 15, 20, 25 and 40 mm.(Fig. 1B). The dimensions of the configuration are 90 cm in width and 44 cm in height. Number of mesh points is 82 x 43.

Fig. 2-A shows the fringing field normalised by the central field strength $Bn = B/B_0$ at half the full excitation current $I = 0.5$. Fig. 2-B shows the comparaison of fringing field for different normalised excitation currents I. The central field strength B_0 at $I = 1.0$ is about 18 kG.

Fig. 3 shows the dependence of dispersion of the normalised fringing field on normalised excitation current I for different end cuts. The structure of the fringing field changed above $I = 0.6$.

Fig. 4 shows the position of the effective edge relative to the pole edge $\Delta L_B/2$ and its dependence on normalised excitation current I.

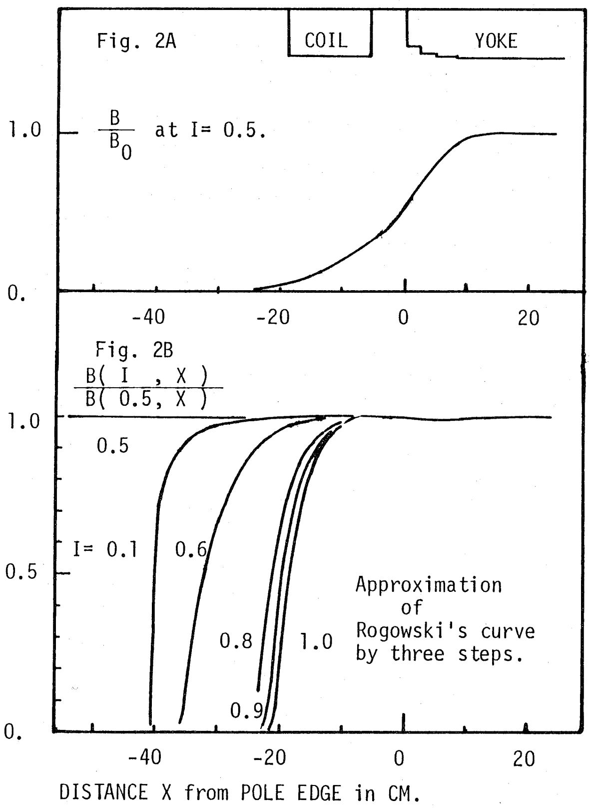

Fig. 2A Field Distribution at I= 0.5.

Fig. 2B Variation of Field Structure on Normalised Excitation Current I.

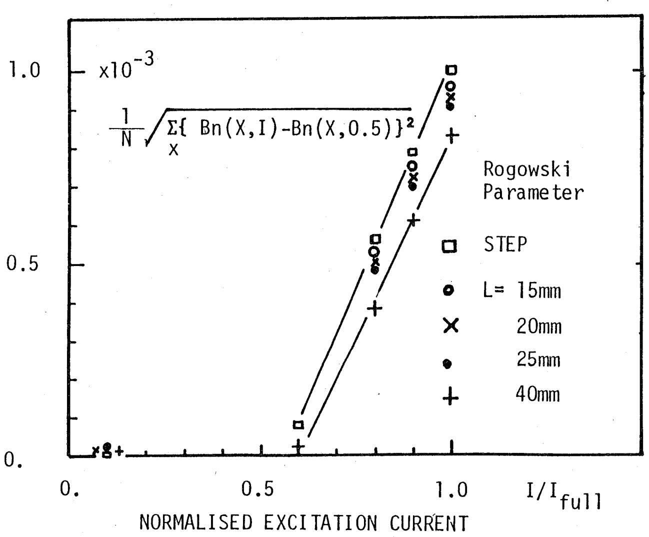

Fig. 3 Dependence of Dispertion of Field Distribution on Excitation Current.

FIELD MEASURMENT

To check the above calculation, we have performed a field measurement, using a Hall-probe (Siemens FC33) with computer-controlled positionning system[6]. As the power supply with full excitation current was not available yet, the measurements were performed at 400 A, i.e., 10 % of the full excitation. The central field strength was then 2.52 kG.

A resolution of pulse motors was 25μ m/pulse and the motors were driven only uni-directionally to avoid the backlash. Position error due to slip was less than 10 μm.

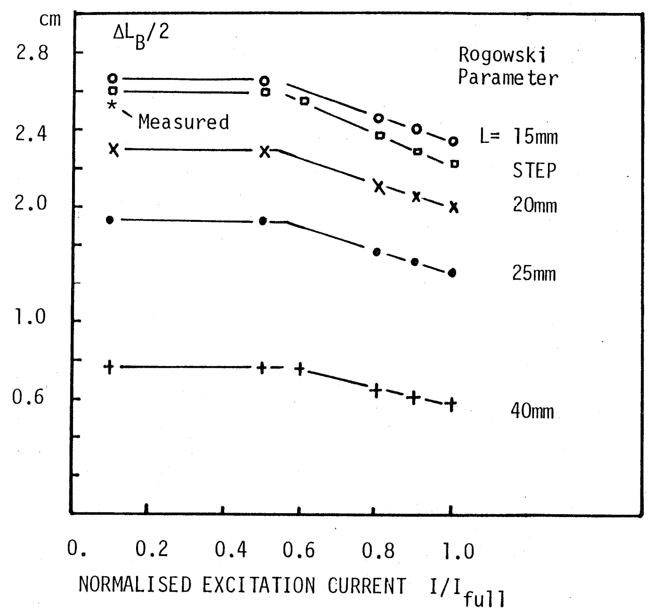

Fig. 4 Position of Effective Edge relative to Pole Edge and its Dependence on Excitation Current.

The interval of the mesh points for the measurement was 10 mm. Stability of the field was monitored by NMR and the voltage across shunt impedance of DC power supply and was less than 3×10^{-5}.

A feed back circuit controlled a temperature of the Hall probe at 50 ^{0}C within accuracy of $\pm$0.1 ^{0}C.

To allocate the Hall probe correctly relative to the magnet, iron blocks (Pararel gauge) with 6 and 8 mm thichnesses were located precisely in the central region of the magnet gap, and the field distribution was measured. Sharp peaks which corresponded to the blocks were observed and the position of the Hall probe was measured within an accuracy of $\pm$0.3 mm.

Fig. 5 shows the dipole magnet and the Hall-probe contained in a copper box fixed at the end of a 80 cm long SUS 316L pipe.

Fig. 6 shows the result of field measurement together with the calculation by TRIM at normalised excitation current I = 0.1.

Results of field measurement showed somewhat steeper fringing field. Position of effective edge from field measurement is $\Delta L_B/2$=2.55 cm and is also shown in Fig. 4. A discrepancy of about 0.5 mm resulted from the fact that the fringing field by TRIM at lower field region is higher than that of the field measurement.

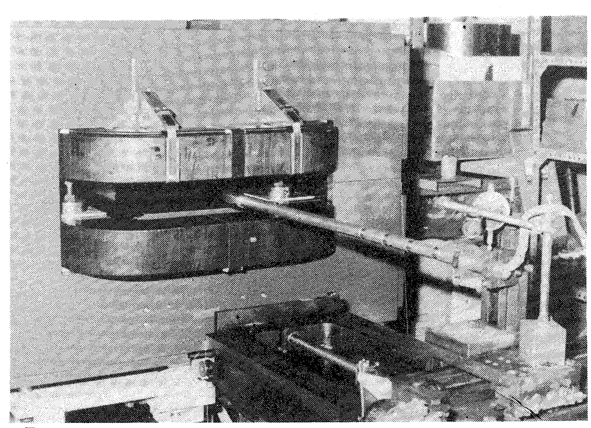

Fig. 5 Dipole Magnet and Hall-Probe.

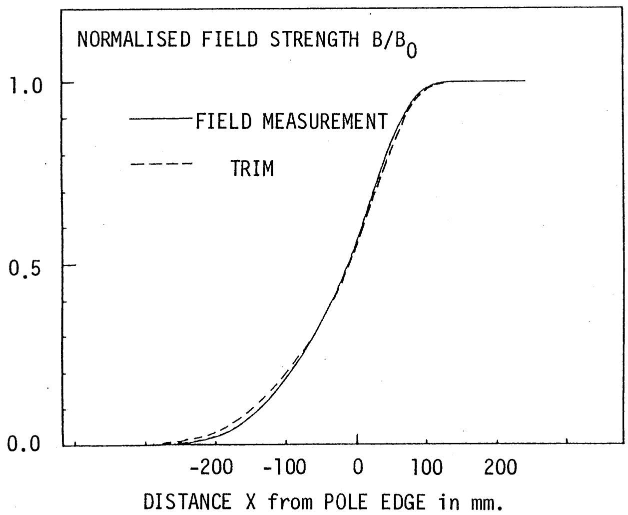

Fig. 6 Comparaison of Field Measurement and Calculation by TRIM at 400 A.

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Field calculation by TRIM was performed with M-180-II AD computer at INS.