BENDING MAGNET AND QUADRUPOLE MAGNET FOR JKJ 50-GEV PROTON SYNCHROTRON

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Abstract

A bending magnet and a quadrupole magnet of the 50-GeV proton synchrotron for the JAERI-KEK Joint project (JKJ), the very high-intensity proton accelerator project, have been designed. The 50-GeV main ring consists of 96 bending magnets, 216 quadrupole magnets, 72 sextupole magnets and 192 steering magnets. The bending magnet is of a modified window-frame type, whose maximum field is 1.9 T. Field gradient of the quadrupole magnet is 18 T/m in peak and the bore radius is 65 mm, which was changed from the previous design of 63 mm.

This year, full-size prototype bending magnet and quadrupole magnet were constructed for R&D study.

This paper shows the design features and preliminary results of field measurements of both bending and quadrupole magnets.

1 50-GEV MAIN RING MAGNETS

The principal parameters of the bending magnet and the quadrupole magnet are summarized in Table 1.

Table 1. Main Parameters of JKJ 50-GeV Main Ring Magnets

Bending Magnet (BM1524)	
Magnetic Rigidity	12.76 - 170 Tm
Bending Radius	89.381 m
Field	0.143 T (for 3 GeV)
	1.9 T (for 50 GeV)
Useful Aperture (horizontal)	120 mm
	($\leq \pm 5 \times 10^{-4}$ at injection)
Gap Height	106 mm
Core Length	5.85 m
Quadrupole Magnet (11 families) (QM2102)	
Field Gradient	1.35 T/m (for 3 GeV)
	18 T/m (for 50 GeV)
Aperture	130 mm$^{\phi}$
Useful Aperture (horizontal)	132 mm
	($\leq \pm 5 \times 10^{-4}$ at injection)
Core Length	0.86 m ~ 1.86 m
	(7 kinds)

The bending magnet was designed with the code of POISSON. The maximum ampere-turn is 93617 AT for the field of 1.9 T. The turn-number of the coil is 30 turns/pole. The coil resistance and inductance are 45 m-ohm and 101 mH, respectively.

The maximum field gradient and its ampere-turn of the quadrupole magnet are 18 T/m and 38600 AT, respectively. The turn-number of the main coil is 24 turns/pole. In addition to this, a correction coil is also equipped to each pole, whose ampere-turn is equivalent to 5 % of that of the main coil. The 216 quadrupole magnets, having the same cross sectional shape, are divided into 7 groups according to the length.

2 DESIGN FEATURE OF MAGNETS

The bending magnet and the quadrupole magnet are excited up to very high field region and used in the environment of very high radiation level during operation. Then, the special cautions are paid on choosing a core material and insulation resin of the coil.

2.1 Bending Magnet

The cross sectional view of the bending magnet (BM1524) is shown in Fig. 1. The type of magnet is of window-frame and sector type with the bending radius of 89.381 m.

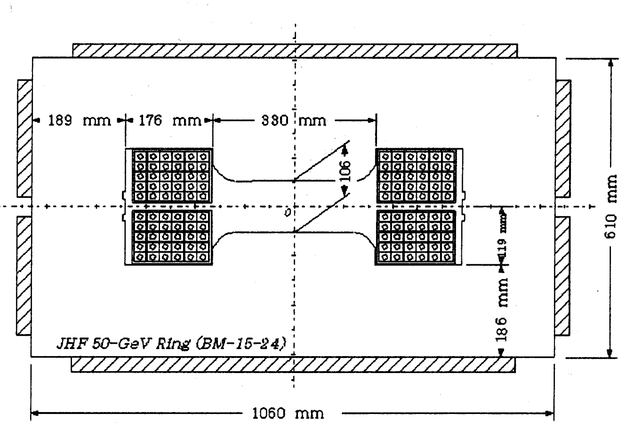


Fig. 1. Cross sectional view of the bending magnet

The magnet core is made of laminated silicon steel with inorganic insulation, whose code name is 65A1600 in JIS standard. The thickness is 0.65 mm. This core material is chosen from the view points of the high stacking-factor of magnet core, the high permeability at the high field region of about 2 T in the iron and the high resistivity abainst radiation.

Using this material, the field computation results show that the good field region (B/Bo $\leq$ 0.1 %) at 1.9 T is remarkably improved and the total electric power loss is reduced by about 6 % (~ 1 MW or more for 50-GeV main ring), comparing to the case of using a usual material such as 50A800.

The magnet ends are cut with the Rogowski curve being approximated with 8 steps. The Rogowski curve is described as $z/d = 1+(2/\pi)\exp(\pi x/2d)$, where d is the half length of the gap and x is the position of the longitudinal direction of the magnet.

For the insulation material of the coil, pre-impregnated tape with polyimide resin and boron-less glass is chosen instead of epoxy-resin, because polyimide resin shows very high resistivity against radiation, namely a few-ten times stronger than epoxy resin.

2.2 Quadrupole Magnet

The cross sectional view of the quadrupole magnet (QM2102) is shown in Fig. 2.

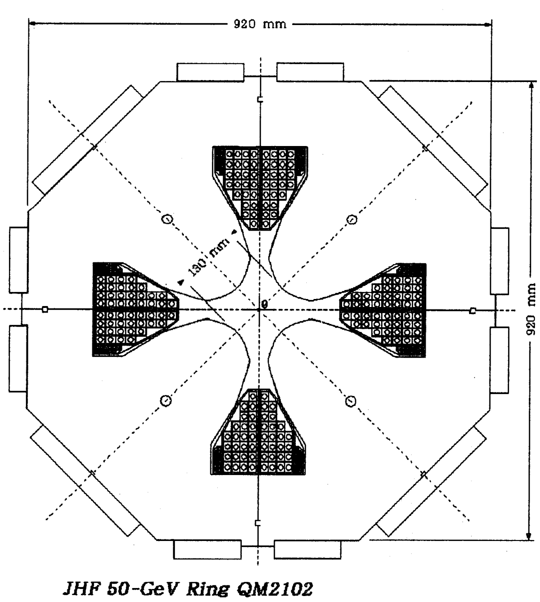


Fig. 2. Cross sectional view of the quadrupole magnet

The core material and the insulation material of the quadrupole magnet are also adopted the same ones as those of the bending magnet. The magnet ends of each pole are cut with the straight slope being approximated with 7 steps. The depth and height of each step is 2.6 mm and 5 mm, respectively.

3 R&D STUDY OF THE MAGNETS

3.1 Bending Magnet

Figure 3 shows the full-size R&D bending magnet being under field measurement. Total length and weight are 6.3 m and 32.4 tons, respectively.

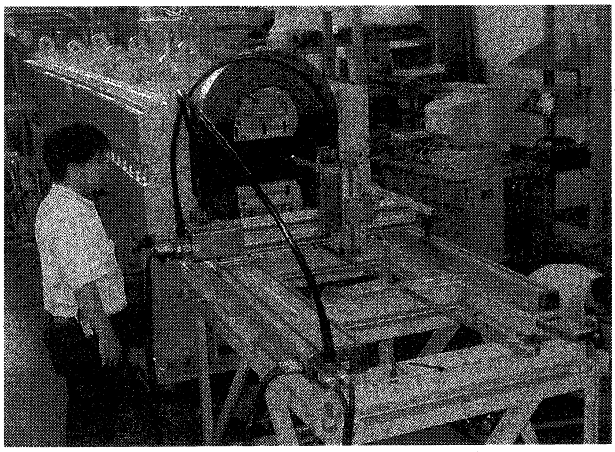


Fig. 3. R&D bending magnet under field measurement

The stacking factor of the magnet core was achieved to be 0.995 with the stacking pressure of 20 kgf/cm^2.

Figure 4 shows the excitation characteristics measured with an NMR probe. The measurement result is very consistent with the calculation result (open circle).

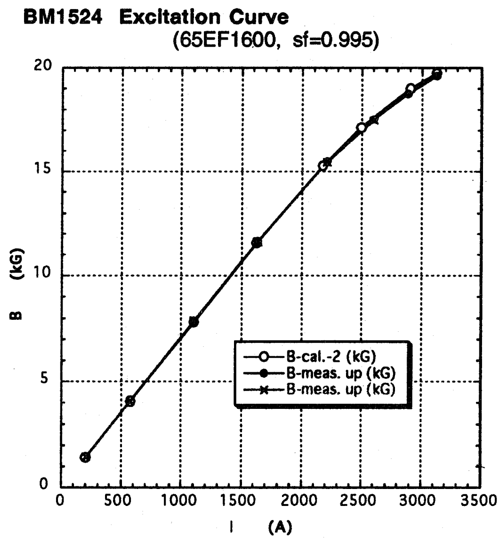


Fig. 4. Excitation characteristics of the bending magnet

Figure 5 shows the measurement results of the field distribution up to 1.15 T (corresponding to 30 GeV operation) measured with a Hall probe.

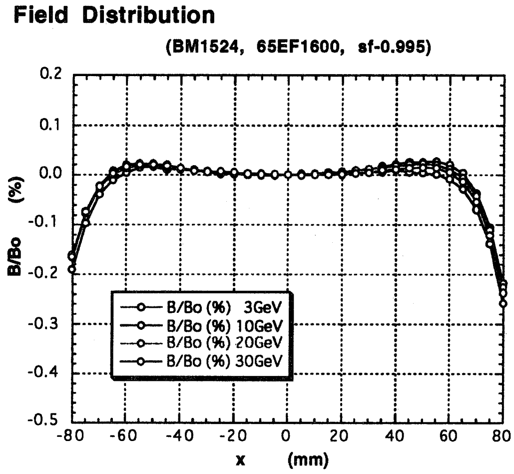


Fig. 5. Field distribution of the bending magnet

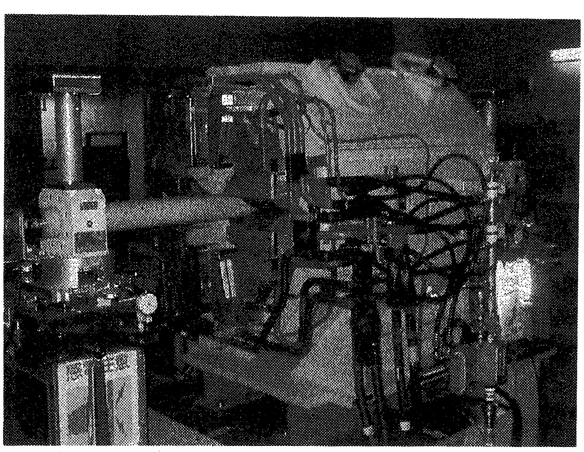
The measurement results also agreed with the calculation results very well. As seen from the figure, the good field region (B/Bo $\leq \pm 5 \times 10^{-4}$) more than ± 60 mm of the radial direction is obtained.

Measurement of field distribution up to 1.9 T is now in progress.

3.2 *Quadrupole Magnet*

Figure 6 shows the full-size R&D quadrupole magnet. The total length of the magnet is 1.2 m, which is the shortest one in 7 groups. The bore radius of the R&D magnet is 63 mm basing on the previous design (QM2007). Now, it has been changed to 65 mm, described above.

The stacking factor of four magnet core blocks were 0.993~0.994 with the stacking pressure of 15 kgf/cm^2.



Fir. 6. R&D quadrupole magnet under field measurement

At present, field measurement of the R&D quadrupole magnet is done with temporary system, whose rotating coil radius is only 46.5 mm. New rotating coil system for the 50-GeV quadrupole magnet is under construction.

Figure 7 shows the saturation curve normalized at the current of 724 A.

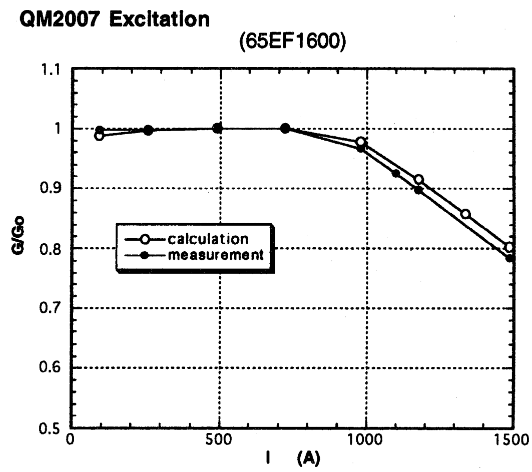
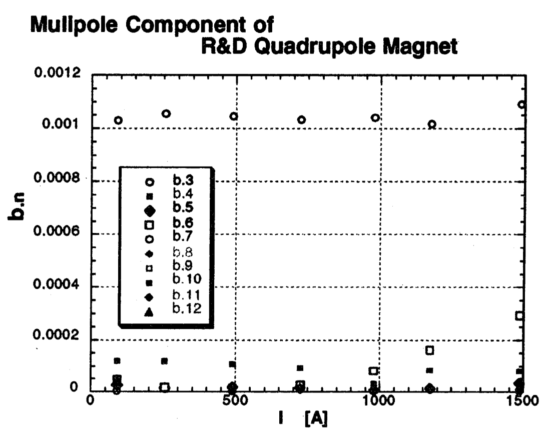


Fig. 7. Saturation curve of R&D quadrupole magnet

Figure 8 shows the multipole component of the R&D quadrupole magnet.



Fir. 8. Multipole component of R&D magnet

The figure shows that the sextupole component (b.3) is constantly higher than others regardless of the level of excitation current. This suggests that it is due to some mechanical errors, not due to electrical reason. The detailed cause is now under investigation.

4 ACKNOWLEDGEMENTS

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