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DESIGN OF MAGNETS AND POWER SUPPLIES OF 3 GEV BOOSTER FOR JAPAN HADRON PROJECT

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Abstract

Magnets and power supplies of 3 GeV Booster for Japan Hadron Project (JHP) have been designed. This paper describes design concepts and the parameters of the magnets and the power supplies.

1. Introduction

3 GeV Booster for Japan Hadron Project (JHP) is a rapid-cycling synchrotron with a repetition rate of 25 Hz. The repetition rate will be revised up to 50 Hz when an rf acceleration system is completely installed. The Booster supplies 3 GeV proton beams into 50 GeV Main Ring, a neutron facility and a meson facility. It comprises 48 bending magnes and 48 quadrupole magnets. The optics of this machine is described elsewhere in this proceedings. In addition, two bending magnets and two quadrupole magnets are needed to measure magnetic field, which is used by a current feedback system.

Magnets are classified into three groups in accordance with their functions such as bending, focussing and defocussing. Each group is exicited using an independent resonant network:

-BM Network (for Bending Magnets),
-Qf Network (for Focussing Magnets Qf),
-Qd Network (for Defocussing Magnets Qd).

Each network contains a resonant capacitor and a choke transformer for feeding a dc current. Using the resonant network, magnetic field is obtained by a superposition of the dc current and the resonating ac current or sinusoidal current.

Two kinds of feedbacks are needed in this magnet system. One is a current feedback in order to maintain a stable magnetic field. The other is a phase feedback for 'tracking' which fixes phases of oscillating currents of four resonant networks.

A total power of 6 MW was estimated including power dissipation of resonant capacitors and choke transformers.

2. Magnet Design

The requirements of the 3 GeV Booster to magnets are summarised in Table 1. Here, we intend to use the same quadrupole magnet for focussing and defocussing magnets.

Table 1
Requirements of the 3 GeV Booster to magnets

-Proton Kinetic Energy	(GeV)	0.2 ~ 3.0
-Repetition Rate	(Hz)	25
-Bending Magnet		
Radius of curvature	(m)	13.369
Magnetic Field	(T)	0.161 ~ 0.954
Magnetic Length	(m)	1.75
Good Field Region	(mm)	280
-Quadrupole Magnes		
Magnetic Length	(m)	0.5
Radius of Good Field Region	(mm)	110
Field Gradients	(T/m)	
Focussing Magnet Qf		0.911 ~ 5.400
Defocussing Magnet Qd		0.692 ~ 4.100

2-1 Bending Magnet

An aluminium stranded conductor of $30 \times 30\ mm^2$ is used as a coil conductor of the magnet in order to reduce eddy loss. A stranded conductor comprises a stainless pipe in the center and thin aluminium wires. Fig. 1 shows plan view of the bending magnet. Supposing field homogeneity of $\pm 5 \times 10^{-4}$, a shim was optimized by an arc (D ~ E) and a line (B ~ C ~ D). The parameters of the bending magnet are listed in Table 2.

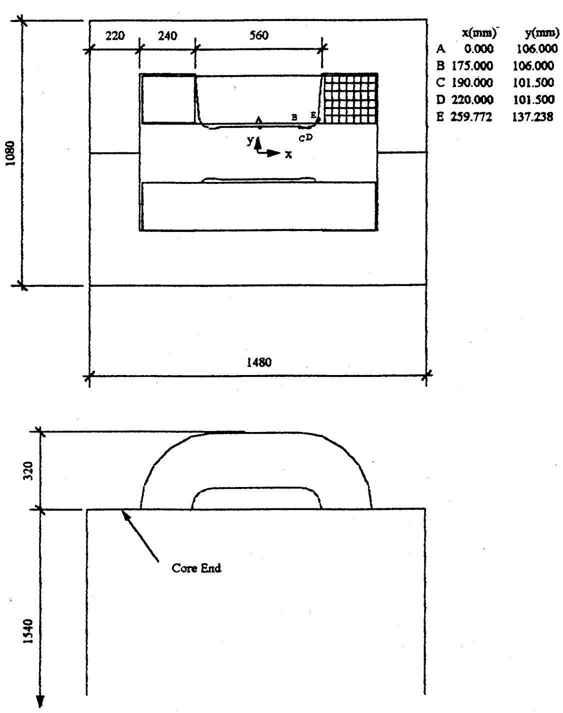

Fig. 1 Plan view of the bending magnet.

Table 2
Parameters of the bending magnet

Gap Height	(mm)	212
Number of Turn	(turn/pole)	42
Maximum Current (A)		1916
Minimum Current (A)		323
dc Current	(A)	1119.5
ac Current	(A)	796.5
series resistance	(m Ω)	25.6
series inductance	(mH)	58.1
Power dissipations		
dc loss	(kW)	32.1
ac loss	(kW)	12.3

2-2 Quadrupole Magnet

As mentioned above, we use the same quadrupole magnet for two kinds of quadrupole magnets which are required by the optics in this machine. The magnet parameters were optimized with respect to the specification of the Qf. Fig. 2 shows plan view of the quadrupole magnet. The shape of the pole is a hyperbola and a shim was optimized by an arc (A - B), supposing the homogeneity of the field gradient of $\pm 5\times 10^{-3}$. In Table 3, the parameters of the quadrupole magnet are listed.

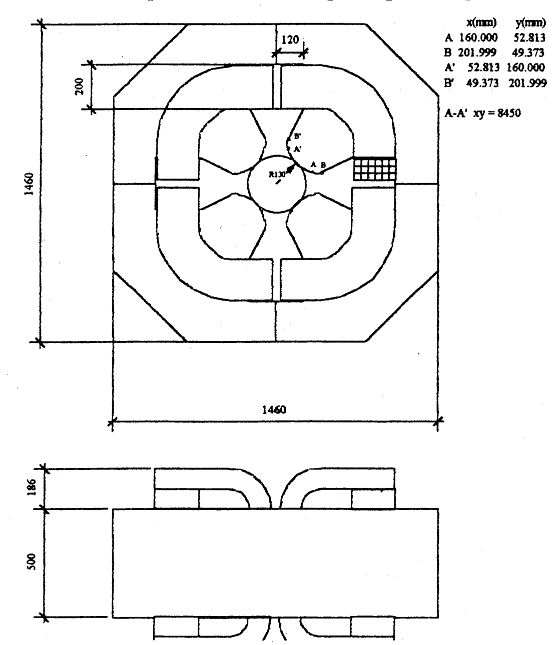

Fig. 2 Plan view of the quadrupole magnet.

Table 3
Parameters of the quadrupole magnet

Bore Radius (mm)		130	
Number of Turn (turn/pole)		18	
Maximum Current (A)		1914 (Qf)	1453 (Qd)
Minimum Current (A)		323 (Qf)	245 (Qd)
dc Current	(A)	1119 (Qf)	849 (Qd)
ac Current	(A)	796 (Qf)	604 (Qd)
series resistance	(m Ω)	9	
series inductance	(mH)	8 9	
Power dissipations			
dc loss	(kW)	11.3 (Qf)	6.5 (Qd)
ac loss	(kW)	4.5 (Qf)	3.0 (Qd)

3. Resonant Network

As mentioned above, magnets are grouped in accordance with their functions. Each group is excited using an independent resonant network:

-BM Network (for Bending Magnets),
-Qf Network (for Focussing Magnets Qf),
-Qd Network (for Defocussing Magnets Qd).

The resonant network comprises magnets, resonant capacitor and a choke transformer for feeding a dc current. Fig 3 shows the BM Network. Here, Lch is inductance of the choke transformer, C is the resonant capacitor and Lm is inductance of the magnets. The number of magnets included in Lm is restricted by an allowable ac voltage. In our case, such a voltage is 10 kV. It is easily proved that Lch, C and Lm form a parallel resonant circuit. The number of such a circuits is called a mesh number. For example, BM Network is 25-mesh resonant network and Lm includes two bending magnets. The parameters of resonant networks are listed in Table 4. Here, repetition frequency was supposed to be 25 Hz.

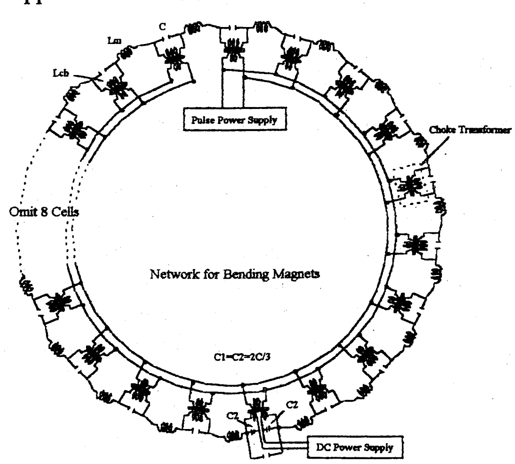

Fig. 3 Schematic view of the BM Network.

Table 4
Parameters of the resonant networks

BM Network		
Number of Mesh		25
Number of Magnets (/mesh)		2
Lm	(mH)	29.05 †
Lch	(mH)	58.1
C	(mF)	2.09
dc Current	(A)	2239
ac Current	(A)	1593(magnet)

		2389.5(capacitor)
Peak Voltage (kV)		7.27
dc loss	(kW)	3210
ac loss	(kW)	1665
Qf Network		
Number of Mesh		5
Number of Magnets (/mesh)		5
Lm	(mH)	44.5
Lch	(mH)	89.0
C	(mF)	1.37
dc Current	(A)	1119
ac Current	(A)	796(magnets)
		1194(capacitor)
Peak Voltage (kV)		5.56
dc loss (kW)		565
ac loss (kW)		232
Qd Network		
Number of Mesh		5
Number of Magnets (/mesh)		5
Lm	(mH)	44.5
Lch	(mH)	89.0
C	(mF)	1.37
dc Current	(A)	849
ac Current	(A)	604(magnets)
		906(capacitor)
Peak Voltage (kV)		4.22
dc loss (kW)		325
ac loss (kW)		154

† In order to reduce an ac voltage, coils of the bending magnet are connected parallel so that the inductance Lm is reduced to one-fourth.

4. Power Supplies

4-1 dc Power Supplies

Ratings of dc power supplies are listed in Table 5.

Table 5
Ratings of dc power supplies

Name of Network		BM	Qf	Qd
-Power	(kW)	3210	565	325
-Voltage	(V)	1433	503	382
-Current	(A)	2239	1119	849

4-2 Pulse Power Supplies

A schematic view of a pulse power supply is shown in Fig. 4. Parameters of the elements shown in the figure are listed in Table 6.

Table 6
Parameters of elements of pulse power supplies

Name of Network		BM	Qf	Qd
-Power	(kW)	1665	232	154
-Vs	(V)	909	1390	1060
-Cf	(mF)	34.5	2.04	2.37
-Lf	(mH)	18.8	317	273
-Lp	(mH)	0.13	2.20	1.90
-Choke Stepup Ratio		8	4	4

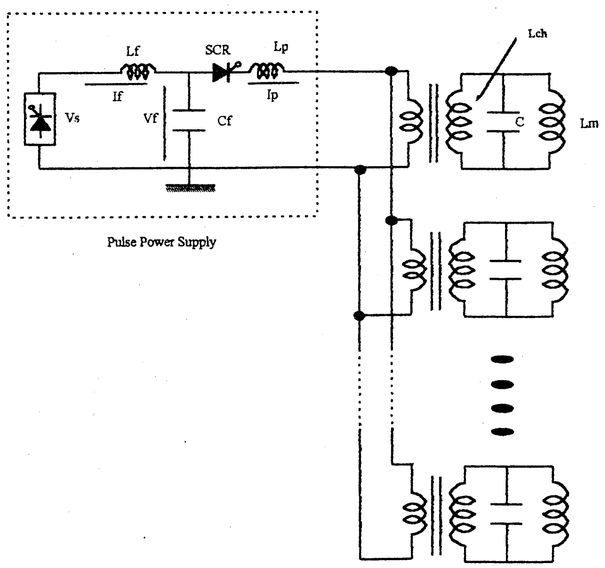

Fig. 4 Schematic view of the pulse power supply.

Concluding Remarks

In order to realize the magnet and power supply system of the 3 GeV Booster, there are many problems to be solved. At first, magnet size is very huge, which makes accurate stacking of thin iron plates so difficult. Therefore, large-scale and accurate stacking method must be established. An aluminium stranded conductor of 30×30 mm^2 is used as a coil conductor. Since a stranded conductor requires a larger radius for bend than a radius of a hollow conductor, a free space between magnets may be shortened. This problem, however, is solved by using a stranded conductor with smaller size.

Concerning the power supplies, the most important problem is to establish a feedback method. Especially, there is no established method by which large-scale and independent resonant networks are operated synchronously. Now we are preparing an R & D in order to fix a feedback method by which phases between two resonant networks are adjusted.