Magnet System of SPring-8 Booster Synchrotron

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Abstract

Manufacture of all magnets for the SPring-8 synchrotron have been finished on July in 1995. To suppress horizontal COD, we discussed sorting of bending magnets based on the field measurement. The COD comes from the field error of bending magnets could be reduced to about 1/7.

Five power supplies were manufactured. The excitation current of all magnets were increased by eight times simultaneously. It was confirmed that the figure of output current of all power supplies was agreed within 10^{-4} accuracy.

1. Introduction

The SPring-8 synchrotron has a circumference of 396.124 m with a FODO lattice of 40 unit cells. It is required to accelerate the electron or positron beam from the linac of 1 GeV up to the full energy of the storage ring of 8 GeV. The repetition time is 1 sec. The excitation pattern of the magnet system is designed to be a trapezoid one, and the lower constant excitation of the magnetic field (call flat-bottom) is corresponding to 1 GeV and upper one (call flat-top) is corresponding to 8 GeV. Each period of the flat-bottom and flat-top is 150 msec, and the ramping and falling times are 400 msec and 300 msec, respectively.

The synchrotron contains 64 bending, 80 quadrupole (focus 40, defocus 40) and 60 sextupole (focus 30, defocus 30) magnets. Field measurements were performed for all magnets. Based on this results, we discussed sorting of bending magnets to suppress horizontal closed orbit distortion (COD). Five power supplies were manufactured for above mentioned five types magnets. These are designed that the output currents are proportional to a reference value and the trapezoid pattern of the output currents are realized with the fast feedback method following to a reference pattern.

2. Magnets

Integrated field was measured at 3 excitation currents (1,4 and 8 GeV equivalent) by means of long-flip coil for all bending magnets. The coil has 12 mm width, 3600 mm length and 3 turns. It takes 5 ~ 20 seconds to flip the coil 180 degrees. Since the measurement was performed for a half year, a reference magnet was used to keep long term stability. The deviation from the average for all magnets were obtained as an instrumental error. The instrumental error was less than $\pm 8 \times 10^{-4}$ at three excitation currents. An example at 1 GeV was shown in Fig.1.

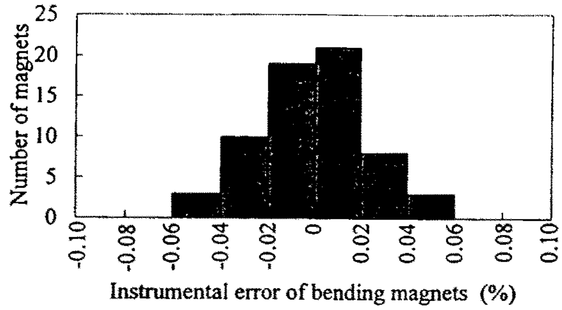

Fig.1 Histogram of the instrumental error of integrated fields.

Horizontal COD is generated by the field error of bending magnets. The instrumental error is equal to the field error of bending magnets. Let the direction of electron beam as the s coordinate axis, the COD x(s) is shown as, [1]

$$x(s)=\frac{\sqrt{\beta(s)\,\beta(s_1)}}{2\sin\pi\nu}\cos\{\pi\nu+\mu(s)-\mu(s_1)\}\,(\Delta B/B)\theta \quad (1)$$

where, s_1 the position of the field error, $\beta(s)$ the betatron function (m), $\mu(s)$ the phase advance (rad), ν the horizontal tune (=11.73), $\Delta B/B$ the field error and θ the bending angle (rad). To cancel the COD, two magnets with same error were arranged at distance equivalent to $\mu(s) = \pi$ (rad). The COD is canceled except for the region between two magnets. For this region, a pair of magnet with opposite sign of the error were put to cancel remained COD Electron beam size is maximum at 1 GeV and become minimum at 8 GeV.[2] To suppress the COD at 1 GeV, 64 magnets were arranged based on the result at 1 GeV.

The COD was calculated at the upstream point of every quadrupole magnet (location of monitor) by code "RACE TRACK". The COD against the monitor number was shown in Fig.2 by the solid line. Maximum and r.m.s. of the COD were 0.35 mm and 0.10 mm, respectively. For comparison, the COD was also shown in Fig.2 by the dotted line when the magnets were put according to the order of production of magnets. In this case, maximum and r.m.s. of the COD were 1.71 mm and 0.69 mm, respectively. These results show that the COD was reduced to about 1/7 by this discussion.

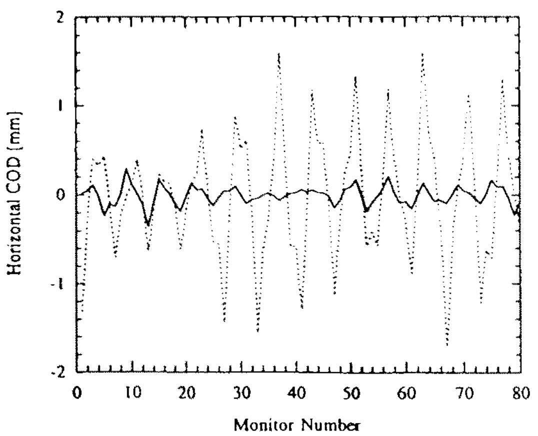

Fig.2 Horizontal COD against the monitor number. Number 1 indicates the position of the inlet of first quadrupole magnet from the injection point. The solid and dotted lines indicate the COD for the arrangement with and without consideration of the phase of betatron oscillation, respectively.

3. Power supplies

In order to obtain a stable beam, the tracking error of all power supplies were designed within 10^{-4} accuracy. Block diagram of the power supply for bending magnet (PS-BM) is shown in Fig.3.

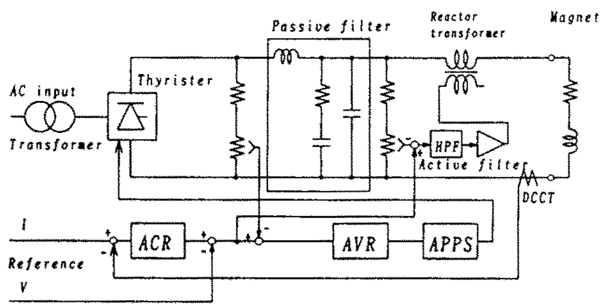

Fig.3 Block diagram of PS-BM. ACR and AVR : Automatic Current and Voltage Regulator, APPS : Automatic Pulse Phase Shifter, HPF : High Pass Filter.

Thyrister converter method with a active filter was selected. DC-voltage ripple produced in the thyrister converter is suppressed by the passive and active filters. The active filter excites inverse voltage of the ripple voltage of the passive filter. Current regulation is realized with a proportional-integral regulation and the voltage signal of the regulation is taken in the feedback circuit directly without some filter to keep the high responsibility of the regulation circuit.

Output current stability, reappearance and ripple were measured at the flat-bottom and top for all power supplies. It was confirmed that these current instability were less than 10^{-4} in comparison with reference current. For the PS-BM, deviation between the reference pattern and the output current was shown in Fig.4. The deviation at the ramping part was obtained to be 7.8×10^{-4}. However, it decreases as delay time of the reference increases and it become $< 5 \times 10^{-5}$ at 300 μsec of the delay time. Since the delay time for each power supplies is able to adjust individually with 100 μsec step, tracking ability of all power supplies will be obtained to be $< 5 \times 10^{-5}$.

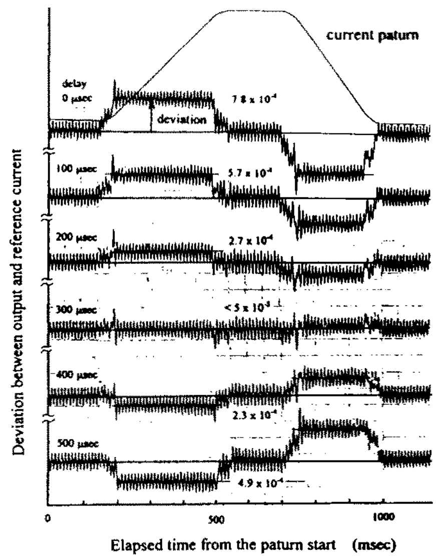

Fig.4 Current pattern and deviation of PS-BM; uppermost figure shows the output current of the ramping pattern. Lower 6 figures show the deviation between the reference pattern and the output current according to the delay time of the reference pattern.

4. Conclusion

Integrated field were measured for all bending magnets of synchrotron. The variation of integrated field was less than $\pm 8 \times 10^{-4}$. We decided the arrangement of bending magnets based on the result to suppress horizontal COD The power supplies for magnets were completed with $< 10^{-4}$ precision of output current.

References

[1] OHO '88 (1988) pIII-2.
[2] JAERI-memo 04-289 (1992).