IMPROVEMENT OF FIELD SIMILARITY OF PULSE BUMP MAGNETS

T. Ohshima*, SPring-8, Hyogo, Japan

Abstract

Top-up operation is planned at SPring-8 from this autumn. It is important to reduce the oscillation amplitude of stored beam during beam injection. Deviation form similarity in magnetic field of pulse bump magnets is one of the perturbation sources. The old bump magnets were composed of stacking the thin electromagnetic steels, which were supported by metallic end plates. The eddy currents induced at the end plates mainly contributed to this deviation. So, we replaced the pulse magnets to new ones, which have non-metallic end plates to suppress the effect of eddy current. The field patterns measured by using a search coil were improved and the reduction of beam oscillation was observed by beam test.

INTRODUCTION

The SPring-8 is a synchrotron radiation source of third generation. It consists of 1 GeV linac, 8 GeV booster synchrotron and 8 GeV storage ring. Top-up operation will be introduced at SPring-8 in this autumn. This operation mode reduces the change of heat load of optical elements such as mirrors of monochrometers. The top-up operation mode also enables to use high current bunches which have short beam lifetime. To make top-up mode in use for experiments there are many hurdles to overcome. The reduction of oscillation of stored beam caused by the injection bump orbit is one of them. The sources of the oscillation are (1) imperfection of similarity of four bump magnets and (2) non-linear effects from sextupole magnets located in the bump orbit. The detail on the latter topic will be reported in another letter [1] and here we concentrate on the former topic.

We use four pulse magnets to produce the injection bump orbit. The pole of the magnet consists of a stack of 0.1mm thick electromagnetic steels. The turn number of the coil is two. The gap is 56mm. There are two types of magnets; long pole type one (BP1 and BP4) and short pole type one (BP2 and BP3). Table 1 shows the main parameters of them. The designed waveform of magnetic field of the bump magnet is half sine whose width is about 8μs. Actual waveforms of magnets have slight differences from each other but they satisfied the specification designed at construction stage of the SPring-8. These small differences however shake the stored beam and cause problem at top-up operation. To reduce the differences the current waveform were firstly adjusted. The values of charging capacitors and matching inductors were carefully selected. The transmission cables from power supplies to magnets were replaced to same type of coaxial ones with same length in summer of 2001. But there still remained some differences in waveforms. In this paper we present how we measure the field and how we improve the similarity of magnetic fields.

Table 1: Parameters on bump magnets

Magnet	**L @ 1kHz**	**Dimension of pole (mm^2)**	**βx (m)**	**kick (mrad)**
BP1	5.6μH	320*110	4.1	-2.33
BP2	4.8μH	170*130	22.9	-0.65
BP3	4.8μH	170*130	22.9	-0.55
BP4	5.6μH	320*110	3.7	-2.35

MEASUREMENT OF MAGNETIC FIELD

We measured the magnetic field distribution using a small search coil whose diameter is 10mm at the test bench. The coil was mounted on movable x-y-z stages. The output of the coil is also connected to a twisted cable and to the probe of the oscilloscope. The bandwidth of the scope is 300MHz and the sampling ratio is 500Ms/s. A personal computer is used to take data from the oscilloscope and to control the xyz-stages. The magnetic field is obtained by numerically integrating the output voltage of the search coil.

To measure the integrated magnetic field along z-axis (beam axis), two long coils are used. The widths of the coils are 1.27mm. The lengths of the coils are 350mm for the long pole magnet and 220mm for the short pole magnet. This coil is also used to measure the magnetic field of each bump magnet at the actual position in the storage ring. The output of the coil is connected to twisted cable and to the probe of the oscilloscope.

RESULT OF FIELD MEASUREMENT

Figure 1 shows an example of field pattern in time domain taken for the BP1 magnet. A line with filled circles shows the output voltage of search coil and a line with triangles shows the integral of the output voltage. Typical rms errors in measurement are about 2% in the peak amplitude and about 7ns in timing at peak value of the magnetic field B. The measured field distributions along z-axis (beam axis) and x-axis (perpendicular to z-axis in a horizontal plane) are shown in figure 2 for the BP1 magnet. We could find the field is decreased to about 1/10 of maximum value at a distance of the gap length.

*ohshima@spring8.or.jp

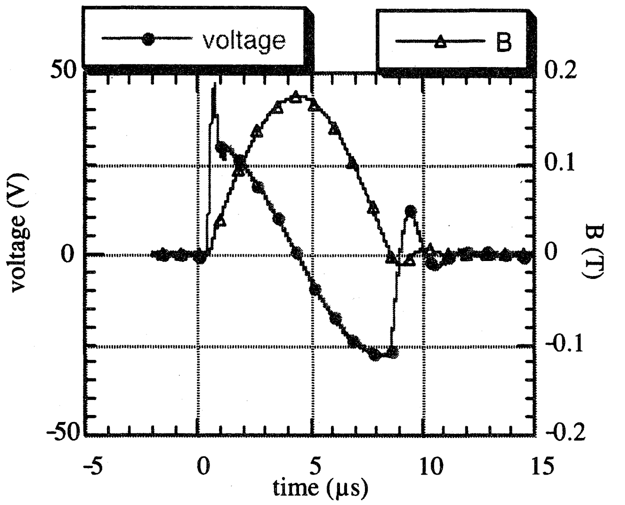

Figure 1. Example of output signal from the search coil and its integral.

Figure 3 shows the time evolutions of the magnetic field for four bump magnets measured by using the long coil. The peak values are normalized to one. We could find field deviations near starting point (A in the figure) and end point (B) of the half sine wave. The deviation at the point (A) may be caused by the difference in operation parameters of the thyratron in the power supply. The deviation at the point (B) may be caused by the difference in effect of eddy current at somewhere the magnetic field is strong. Two 20mm thick SUS plates were used to support the stacked electromagnetic steels. The coils were wound including these end plates. It is probable that the time varying magnetic field generates eddy current on the SUS end plates, which change the shape of magnetic field at the point (B). The effect of eddy current is stronger in the short pole magnet than the long pole magnet because the ratio of the endplate-length to the pole-length is larger in the former than the latter.

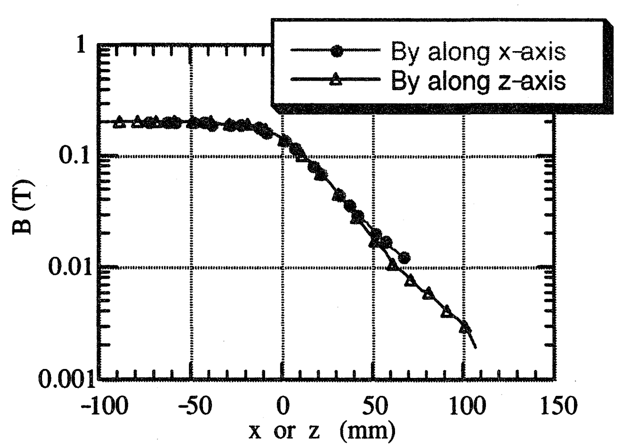

Figure 2. Distribution of the peak field of BP1 along x-axis and z-axis.

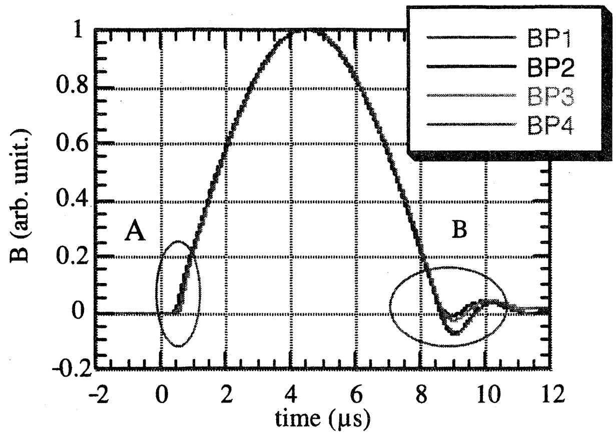

Figure 3. Time evolution of magnetic fields of old bump magnets: BP1, BP2, BP3 and BP4.

IMPROVEMENT OF FIELD SIMILARITY

We made new magnets to reduce the effect of eddy current at the end plates. The material of end plates is changed from SUS metal to glass-epoxy-mat, which is non-conducting material. Figure 4 shows the measured inductance for the old and new bump magnets. New bump magnets show larger inductance at high frequency.

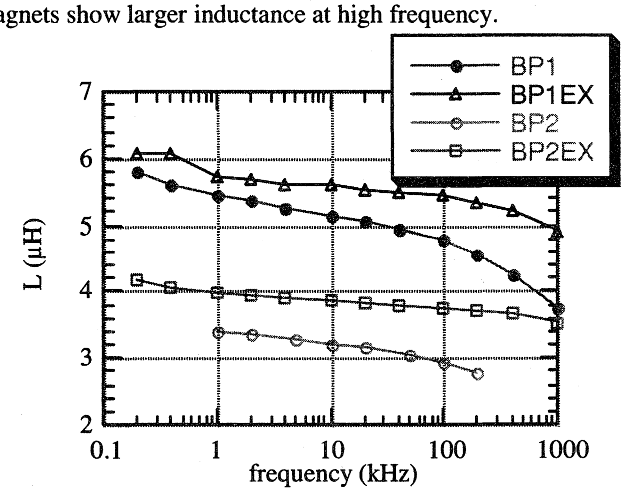

Figure 4. Inductance of old magnets (BP1, BP2) and new ones (BP1EX, BP2EX).

In order to check the performance of new magnets at the actual setting, we replace the old bump magnets in the storage ring to new ones and we measured the magnetic field using the long coil. The shapes of field patterns were improved and the deviations at the point B were decreased from 7% to 2%. The remained small deviations may be caused by the difference of environment such as different shape of ceramics chambers, different geometry of electric shield made of aluminium plates and so on. We insert a field cramp made of a stack of electromagnetic steels with 0.1mm thick. The cramp absorbs the filed leaked from the pole gap and reduce the effect of eddy current produced by the vacuum chamber next to the ceramics duct or the aluminium electric shield. The similarity of the field is improved by the cramp and the result is shown in figure 5.

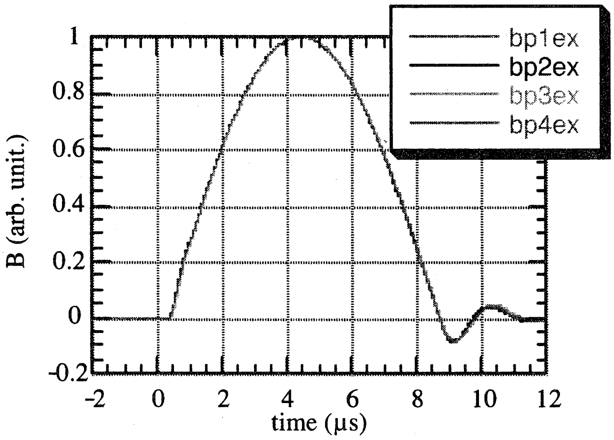

Figure 5. Time evolution of magnetic fields of new bump magnets: BP1EX, BP2EX, BP3EX and BP4EX.

The beam test was performed to verify the effect of these improvements. The oscillation amplitude of the stored beam was measured by using a turn by turn monitor. Figure 6 shows the result. Horizontal axis shows the time after beam injection with an offset of 4.5μs. Vertical axis shows the rms oscillation amplitude of stored beam. A line with filled circles shows the oscillation amplitude with old bump magnets. A line with triangles shows the amplitude with improved new bump magnets. The peaks at 2μs and 7μs are due to non-linearity effect of sextupole magnets in the bump orbit. Since the revolution time is 4.8μs, the shape of the oscillation after 10μs repeats in the duration of 4.8μs and this amplitude is damped with the damping time of 8ms. A large peak at 9μs before improvement is produced by the field irregularity at the end of the waveform ((B) in the figure 5) and this amplitude is reduced to 1/10 after the improvement.

CONCLUSION

By using new bump magnets with non-metallic end plates, we could reduce the effect of eddy current. This results in improvement of the similarity of the field shape for four

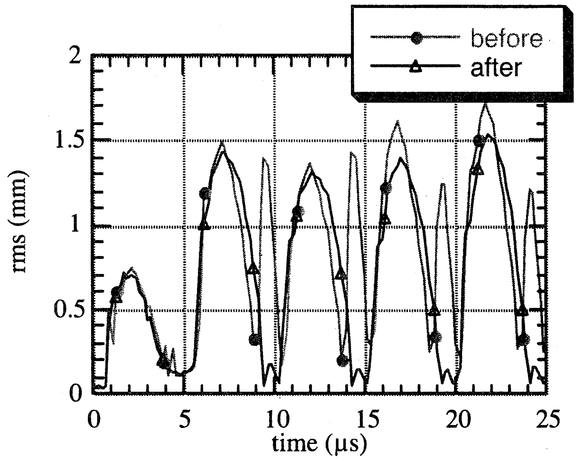

Figure 6. Oscillation amplitude of stored beam before and after replacement of bump magnets.

bump magnets. The amplitude due to the field deviation at the end point of the waveform was reduced to about 1/10. Further efforts will be made to improve the similarity of field shape such as model calculation for matching of the power supply and the magnet, precise measurement of the effect on the magnetic field shape form the aluminium shielding plates etc. We also observe the vertical kick by the bump magnets at a beam test. We are now preparing a remote controlled height adjuster and we will adjust the tilt of the magnet to minimize the vertical kick. The effect from non-linearity of sextupole magnets will be reduced by adjusting the strength ratio of sextupole families. The detail of this method will be shown in another paper.

ACKNOWLEDGEMENT

The author thanks to H. Tanaka, S. Nagasawa and M. Yosioka for their help during the width adjustment, K. Kajimoto for his help in programming data acquisition system. He thanks to S. Matsui, K. Soutome, M. Takao and H. Ohkuma for their supports. He thanks to K. Kumagai for helpful information. He thanks to H. Kanazawa of Nishishiba Electric co. LTD. for his effort during production of new bump magnets. He also thanks to N. Kumagai who suggested initial idea to exchange the end plate to non-metallic material.

REFERENCES

[1] H. Tanaka et. al. , to be published.