Magnetic Leakage Shield of Septum Magnet for SPring-8 Synchrotron

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Abstract

This paper describes magnetic field measurements of the prototype septum magnet and countermeasure for reducing the leakage magnetic fields in the incidence and the extraction parts of the SPring-8 synchrotron[1]. We studied and developed "*leakage magnetic shield*" on the basis of the tests data got in these measurements. Consequentially, it succeeded in reducing effects of the leakage field to about 50% by installing the shield board in the magnet main body. Then, it was possible to manufacture the magnet which sufficiently held the effect of the leakage field for the electron and positron beam.

In this examination, we confirmed the reproduction with the magnetic field distribution of the magnet measured in the manufacturer. We developed and produced of the septum magnets which were carried out determination of the shapes of the magnetic shielding.

1 Introduction

In the SPring-8 synchrotron, pulsed magnets[2] were respectively installed at incidence division and extraction part. The fast pulse response of septum magnets[3] are also required at the microsecond order. The countermeasure of magnetic leakage field was examined on the septum magnet with the characteristic structure. Consequentially, it succeeded in reducing effects of the magnetic field to about 50% by installing the shield board in the magnet main body.

Therefore, all septum magnets has finished very high-performance, and again, in the compact magnets.

2 Pulsed Magnets for Injection

Figure 1 shows the configuration of the magnets for the injection system [2]. This system is composed of two kicker magnets and two septum magnets. An electron/positron beams are accelerated from $1GeV$ using the linac to $8GeV$ by the synchrotron with through of the injection system.

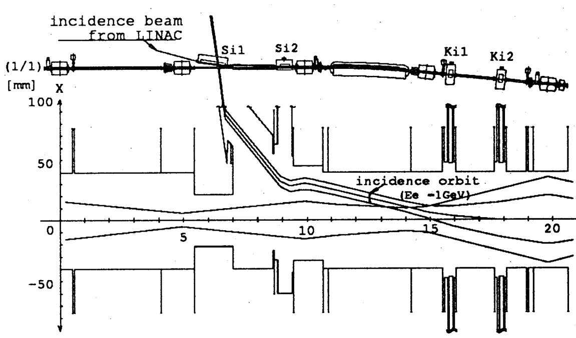

Fig. 1 The synchrotron injection system. It is a layout drawing of the magnet in the top. The bottom shows the horizontal orbit of the beam. It shows the beam which came from the linac in the continuous line, and shows incidence orbit. The dotted line is reference orbit.

3 Pulsed Magnets for Extraction

The extraction system is composed of three kicker magnets[4], four septum magnets and four bump magnets. The electron/positron beam accelerated to $8GeV$ by the synchrotron does be ejected in eleven pulse magnets to the storage ring. Figure 2 shows the configuration of the magnets for the extraction system [2].

4 Experiment

The third septum magnet which is prototype, it is necessary to consider effect of the leakage field for the beam orbit. The first septum magnet for the incidence and the forth septum magnet for the extraction has done the structure equal to the third septum magnet for extraction in a standard type (cf.Table 1). It must be a structural reason of the magnets. The magnetic field measurement was carried out on the third septum magnet. Then whether it might install "*leakage magnetic*

Table 1
Characteristics of the septum magnets

	1st Septum*	2nd Septum**	3rd Septum**	4th Septum**
Effective length $[m]$	1.0000	0.4000	1.1105	1.4047
Number of turns	4	1	4	4
Current wave form	half-sinusoid	half-sinusoid	half-sinusoid	half-sinusoid
Septum $[mm^2]$	$h30.9 \times w7.8$	$h11.3 \times w1.5$	$h30.9 \times w7.8$	$h30.9 \times w7.8$
Pulse width $[ms]$	2.5	0.1	2.5	2.5
Magnetic field strength $[T]$	1.000	0.344	1.225	1.440
Leakage magnetic field $[T]$	3.0×10^{-5}	3.0×10^{-5}	2.0×10^{-4}	4.0×10^{-5}
Deflection angle $[mrad]$	$271(at0.9T)$	$4.95(at0.33T)$	$45.78(at1.1T)$	$63(at1.2T)$
Shield Material	iron	copper and iron	iron	iron
Resistance $[m\Omega]$	13.3	1.8	16.1	18.6
Inductance $[\mu H]$	109	2.1	107	147

*It is for the incidence part
**It is for the extraction part

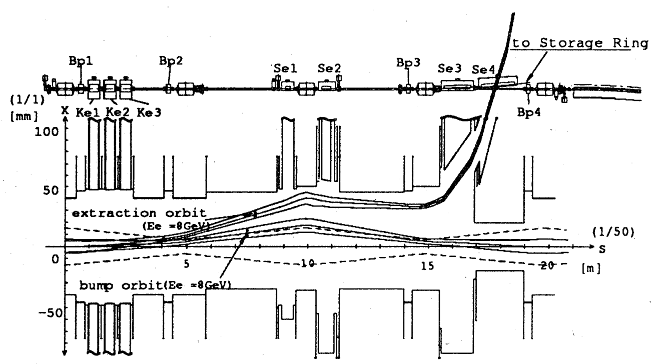

Fig. 2 The synchrotron extraction system. The continuous line shows extraction orbit and bump orbit.

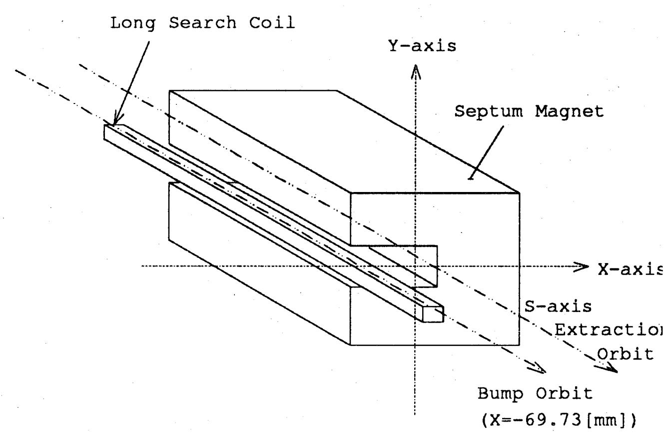

Fig. 3 It is conceptual scheme of the search coil installation. The origin of the x, y and S axis shows just outlet of the magnet. The arrow direction of the axis is the positive direction.

shield" of what kind of shape or installing existence was decided.

4.1 set up

In the magnetic field measurement, we used short search coil and long search coil [3]. Figure 3 shows a measurement coordinate system. The setup of the long search coil was also installed in incidence orbit in the magnet gap or parallel position in it and reference orbit and on the bump orbit. The search coil was respectively set to the inlet and exit side of the magnet. This search coil used PEW line ($\phi = 0.23[mm]$).

Figure 4 shows a picture of the installing shield and the non-shield. By changing shape of the shield with 6 types, an effect of the leakage field is measured. We chose the iron (SPCC) as a material of the leakage shield with the conductivity. The iron is popular, and handling is also a simple material. In the beam inlet side, the reference orbit is $x = -36.2mm$ and $x = -69.73mm$ in the beam exit side from the incidence orbit. Then, we measured the magnetic field of the incidence and the extraction orbit.

5 measurements

The measurement contents are as follows, the current wave form, the pulse wave form of 1 pulse $[/sec]$ operation, the output differential wave form from the search coil and the magnetic field wave form which are integral wave form of the search coil output voltage. The oscilloscope is made to output 4 points of the above. Figure 5 shows the measurement wave form of the typical septum magnet.

5.1 The effects of "leakage magnetic shield"

The BL product measurement of x axis direction and bump orbit in the case that "*leakage magnetic shield*" was installed and it is not added is carried out in the leakage magnetic field region, $y = 0mm$, $x = -35.0 \sim -69.73mm$, in the x axis direction. In

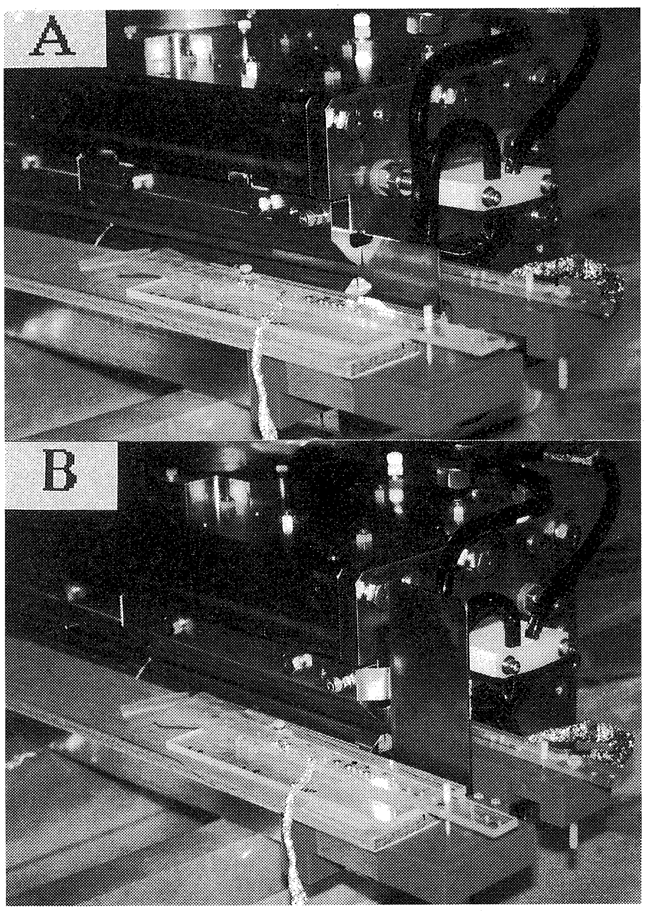

Fig. 4 The beam exit side of the magnet, it is a photograph in the case in which the shield was installed and case in which the shield is not done. The photograph "A" is not installing the shield, and the "B" is installing the shield. The search coil has been attached to the reference orbit side of the magnet.

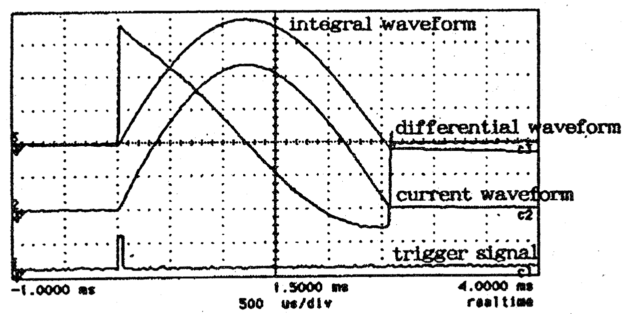

Fig. 5 The oscilloscope has 4 channels, $2GSa/s$ and 8 bits. The x axis is $500\mu s/div$, and the vertical line is $2.0V/div$ on $C1$ and $C3$. $C2$ is $5.0V/div$, The integral wave form is $1.2mV/div$.

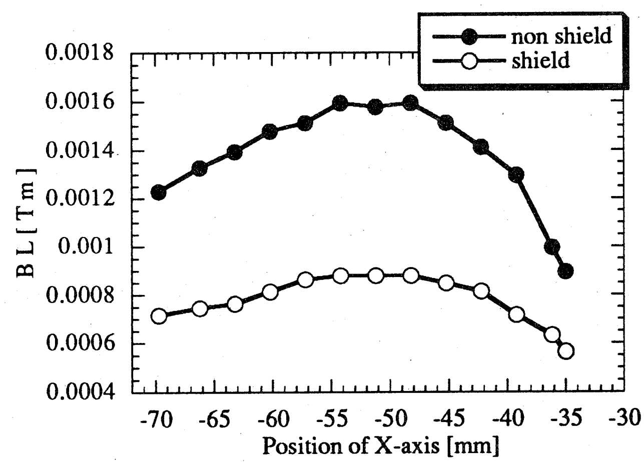

Fig. 6 The BL integral cloth of x axis direction ($x = -35 \sim -69.7mm$). It shows the peak of the leakage field at $x = -51.2mm$. The reduction in 50% leakage field was achieved in the existence of the shield.

the bump orbit, $y = 0mm$, $x = -36.2$ and $-69.73mm$ were respectively measured. The shield size is $65mm \times 200mm \times t2mm$ that time.

5.2 The leakage field of the shield shapes or sizes

The magnetic field distribution was measured on the bump orbit in the beam exit side. The measuring ranges are $x = -69.73mm$, $y = 0mm$, $S = -30$ and $+40mm$. We measured the magnetic leakage fields distribution using the shield of six types ($65 \times 200 \times t2$, $80 \times 200 \times t2$, $80 \times 300 \times t2$, $140 \times 200 \times t2$, $140 \times 300 \times t2$ and non-shield) and the thickness of the shields. The shield thickness is changed from $t = 0$, the shield is not installed, to $4mm$. The thickness interval is $t = 1mm$.

6 Results and Discussions

Figure 6 shows the result of magnetic leakage field measurement using the search coil. In the case in which the magnetic shield was installed and it is not so, the reduction of the BL product of largest 50% was able to confirm it.

Figure 7 shows how shapes or sizes of the magnetic leakage shield are effective for the leakage field. The leakage field does be saturated it in to some extent size on the magnetic shielding. However, it is possible to hold the leakage field quantity in 1/10, in the existence of the shield. Therefore, the "type 2" shield size was chosen as a shielding material.

Figure 8 shows the relationship between thickness and leakage field of the shield board. How much it could reduce the leakage field, when the thickness of the shield is changed, was examined. Consequentially, though the leakage field can be reduced even in $t = 1mm$ thickness. However, the leakage field is not sufficiently held in the distribution of $S = -30mm$. It is possible to hold the leakage field, when the thickness of the board exceeds $t = 2mm$, and it is well proven that the shield hoard sufficiently reduces the leakage field, because the distribution becomes a saturation state. However, it may

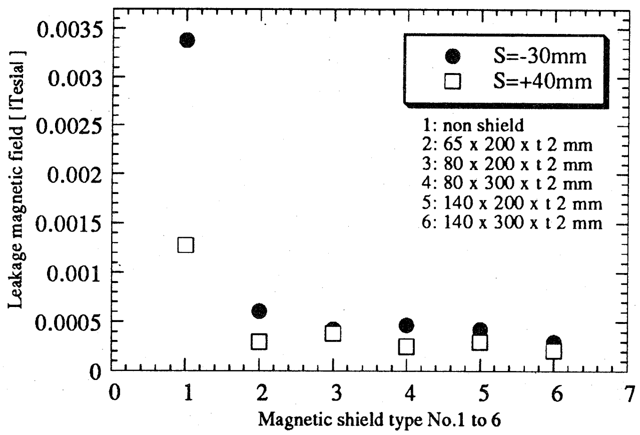

Fig. 7 The leakage field distribution in using each shields. By dividing the x axis many types of the shield to $No.1 \sim 6$, it is displayed. Therefore, the line was not connected, because each plotting is separate.

interfere in the bump orbit, if $t = 4mm$ thickness of the magnet it is structural are installed. Besides, the magnetic leakage shield was also decided in choosing $t = 2mm$ thickness, because the shield already installed is the same thickness.

The calculated value of tolerance for the leakage field of the BL product is $2.1 \times 10^{-3}[Tm]$, and the leakage field B is $1.9 \times 10^{-3}[T]$. The experimental value is 8.8 $\times$ $10^{-4}[Tm]$ or less, maximum value of the graph which shielded plots, in the BL product for it. The magnetic field B got the result of $4.2 \times 10^{-4}[T]$ (see Figure 8, $t = 2mm$ value of thickness at $S = -30mm$ plotting). Actual leakage field considerably fell below the tolerance. Realistically, it can be concluded that there is completely no problem in kick broth to the injection orbit.

7 Conclusion

There were very few research in this field yet, very rich data and worthwhile result were obtained.

Then, all pulsed magnets also makes the data except for this paper to be a reference, and it carries out the adjustment.

References

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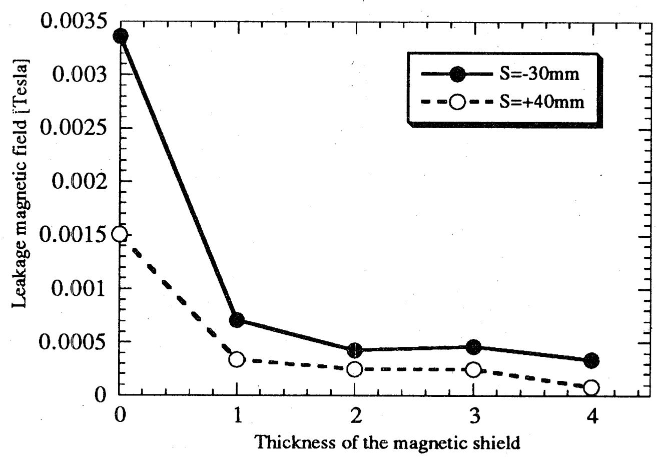

Fig. 8 The thickness of the shield was made to change to $t = 0 \sim 4mm$. Then, the effect of the leakage field by the thickness was viewed. The x axis is thickness t mm of the magnetic shield which uses iron (SPCC:$65mm \times 200mm \times t$ mm)