Eddy Field Measurement Using a Peaking-Strip

Yasumori KANAI, Toshikazu ADACHI*, Manabu FUJIOKA** and Yoshiharu MORI*

Department of Physics, Tohoku University,

Aramaki-Aoba, Aoba-ku, Sendai 980-77 JAPAN

*KEK High energy accelerator research organization

accelerator division

1-1 Oho,Tsukuba-shi Ibaraki-ken,305 JAPAN

**Cyclotron and Radioisotope Center, Tohoku University

Aramaki-Aoba, Aoba-ku, Sendai 980-77 JAPAN

Abstract

An eddy field in a bending magnet was measured along the longitudinal direction, when the magnet was excited by a sinusoidal current with a repetition of 49.73Hz. The measurement was performed by using a peaking strip[1]. It was found that eddy field generated in the edge plate made by stainless steel became larger as the position became closer to the magnet edge.

1. Introduction

In Japan, the JHF(JAPAN HADRON FACILITY) plan are being progressed. The JHF accelerator complex comprises the 200MeV linac, the 3GeV booster synchrotron and the 50GeV synchrotron.

The 3 GeV booster synchrotron is a rapid-cycling synchrotron with a repetition of 25 Hz. In the future, the repetition will be increased up to 50Hz, in order to obtain a beam power over 1MW. Although, in such a rapid-cycling synchrotron, the vacuum chamber used in the magnet is made of ceramics to avoid the field disturbance due to an eddy current, the eddy current is also induced in the magnet, which may disturb the magnet field. Especially, in a dipole magnet, a sextu-pole component of the eddy field must be considered in order to accelerate a high-intensity beam without beam loss.

Field measurement in a dipole magnet has been performed for the purpose of estimations of the field disturbance due to an eddy field. In this paper, the results obtained so far are described.

2. Field Measurement

A test magnet[2] for the B-factory was excited with the repetition of 49.73Hz using LC resonant circuit. Fig.1 shows a schematic view of the test magnet. The field measurement was performed along the longitudinal direction(y-axis) on the median plane.

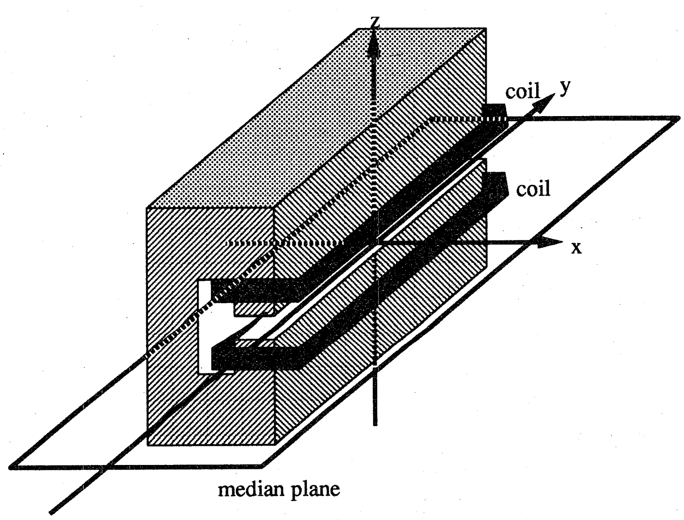


Fig.1. Schematic view of the test magnet.

Since the magnet is excited by a sinusoidal current, magnetic flux density(B) is given by

$$B=B_0\sin\omega t. \qquad (1)$$

Since an eddy current depends on $\dot{B}$, the eddy field is given by

$$B_{eddy}=B_1\cos\omega t. \qquad (2)$$

Then, total magnetic field (B_{tot}) is obtaind as

$$B_{tot} = B + B_{eddy} = \sqrt{B_0^{\ 2} + B_1^{\ 2}} \sin(\omega t + \delta),$$
$$\tan\delta = \frac{B_1}{B_0}, \qquad (3)$$

where δ is the phase difference between the main dipole field and the eddy field. Therefore, the amplitude of the eddy field can be obtained by measuring the phase difference (δ) and amplitude of the main dipole field (B_0).

Phase difference was measured by two peaking strips, each of which generates a voltage pulse by detecting a zero-crossing timing of a dynamic field. A phase gap was measured between the signal of peaking strips and zero cross timing. But it was very small. The amplitude of the main field was measured by a seach-coil method[3].

3. Experimental Results

Fig.2 shows a block diagram of the measuring system. Here, peaking strip1 was fixed at the center of the magnet. Peaking strip2 and the seach-coil were moved along the longitudinal direction. Signals of two peaking-strips were sent to an osilloscope, and phase difference was measured. A signal of the seach-coil was integrated for the interval between instants givinig the minimum and maximum field, so that the amplitude of the main field was obtained. The time interval for integration was determined by a signal of the back-leg winding.

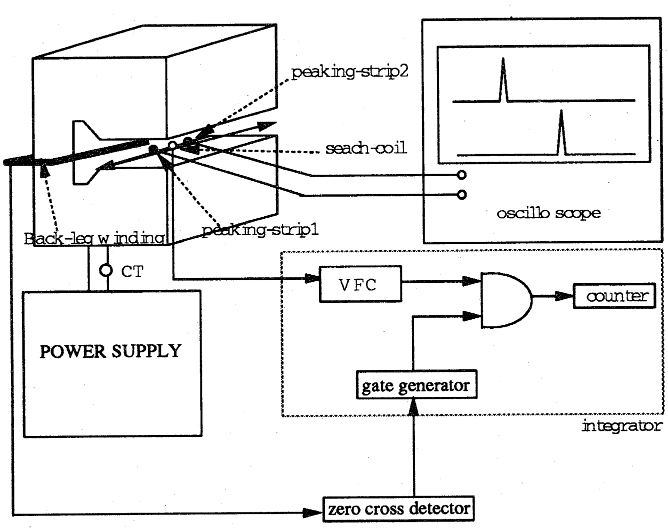


Fig.2. Block diagram of the measuring system.

The eddy field was measured along the longitudinal direction on the median plane. At first, two peaking-strips were set at the center of the magnet, in order to confirm the coincidence of two peaking timings. As shown in Fig.3, two peaks coincide with each other. Here,a little difference is seen between two signal tails due to a difference of inducance of a pick-up coil for each peaking-strip.

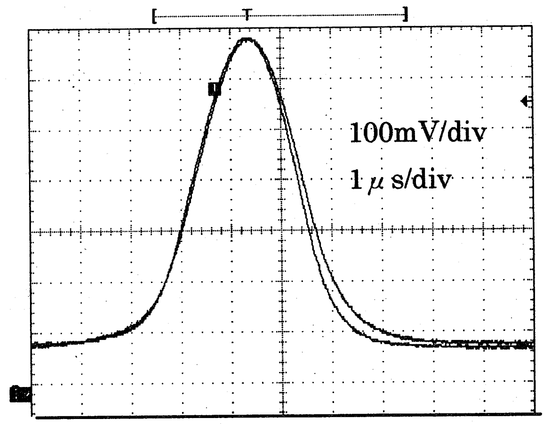


Fig.3. Signals of two peaking-strips which were placed at the center of the magnet.

The phase difference becomes larger as the position of the peaking-strip2 goes far away from the magnet center. Fig.4 shows typical phase difference where the peaking-strip2 was set at the end of the magnet core. In this case, the time difference is 29.2 μs. Since the operation frequency is 49.76Hz, the phase difference amounts to 0.00913rad.

The amplitude of the main dipole field at this point was measured by the seach-coil. Therefore, the normalized amplitude of the eddy field(B_{eddy}) is obtained in terms of the following formula:

$$B_{eddy} \equiv \frac{B_1(y)}{B_0(y=0)} = \tan\delta \frac{B_0(y)}{B_0(y=0)}. \qquad (4)$$

In this case, the normalized amplitude is 0.00364. Fig.5 shows the position dependence of the normalized amplitude of the eddy field, together with the magnet cross-section cut by the y-z plane at x=0.

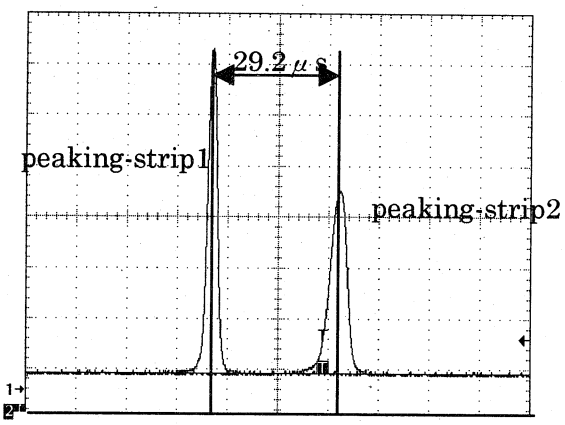
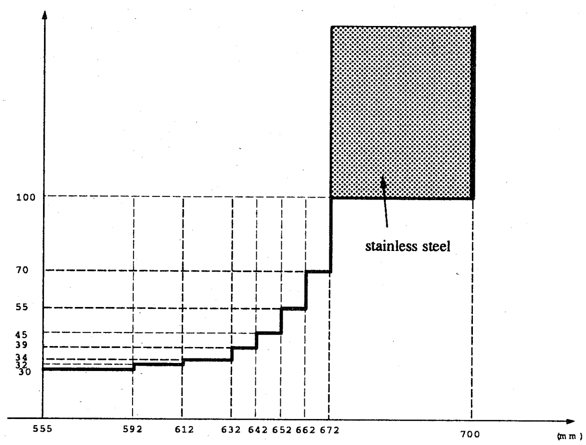


Fig.4. The typical phase difference of peaking strips



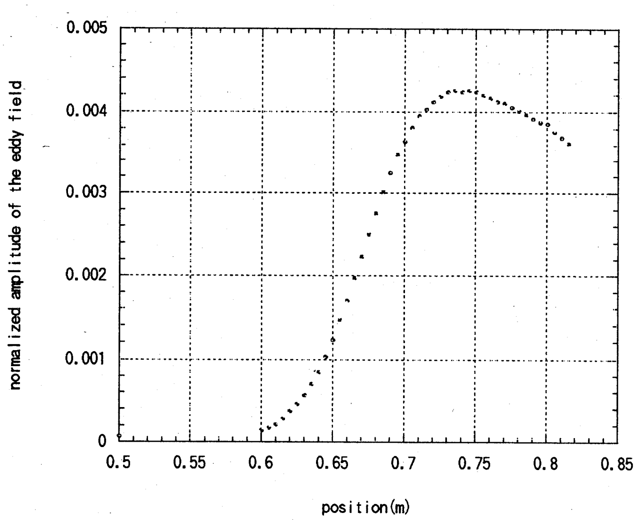


Fig.5. Position dependence of the eddy field.

As shown, the eddy field becomes larger as the position becomes closer to the end plate of stainless steel. This result implies that the eddy current induced by the main field can not be ignored aroud the end plate made by stainless steel.

4. Conclusion

An eddy field in a bending magnet was measured along the longitudinal direction on the median plane, when the magnet was excited by a sinusoidal current with a repetition of 49.76Hz. The field disturbance due to the eddy field was found to be large around the magnet end part, and amounts to 0.4% of the main dipole field at the magnet center.

The transverse distribution of the eddy field is necessary in order to estimate an effect of the eddy field to a circulating beam in a synchrotron. In addition, a 3-dimensional simulation code for a dynamic field is also being prepared in order to compare the experimental result with the simulation. When the simulation code is confirmed, it gives a guiding principle in design of a magnet for a rapid-cycling synchrotron.

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