FLUX METER FOR FIELD GRADIENT WITH PENDULUM

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In order to obtain the information of the field gradient, we have modified and improved the twin search coil system which was adopted in the field measurement of the Booster synchrotron magnet.[1]

When the excitation level of the field is specified, the quality of the magnets is judged by the relative value; the field gradient, the radial distribution of the effective length and the fluctuation of the field qualities from magnet to magnet. The information of the absolute value is necessary for the calcualtion of the transfer matrix of the magnets. The accuracy of these relative values can be much improved if following two conditions are satisfied;

(i) to suppress the lower order component, and

(ii) to perform simultaneous measurement with reference.

Displacement of the twin long coil by finite small length enables to satisfy those conditions. The second condition is also satisfied by the simultaneous measurement with search coil and reference coil. When these two conditions are satisfied, things become much easier. It is not necessary to worry about the stability or ripples of the power supply, the accuracy of the displacement of the twin coil and possible noises around the apparatus.

We take the right-handed coordinate, where s-axis is along the central orbit lying in the midplane (the xs plane) and z-axis is perpendicular to the midplane.

Nonlinear field

The quadrupole component is suppressed in the twin coils for measuring nonlinear fields. We perform the permutation and take the sum of the integrated outputs of the twin coils, then we get,

$$N^{twin} = \frac{f_0}{e_0}(A_1 + A_2)\frac{\partial^2 B(x)}{\partial x^2}\delta x \Delta x \tag{1}$$

where e_0 is the input full scale voltage, f_0 is the corresponding output frequency of the VFC, δx is the distance between the coils, Δx is the displacement length of the coils and A_1 and A_2 are the effective area of the coils respectively. Actually these parameters are designed to be; $A_1 = A_2 = 0.166$ m , $\delta x = \Delta x = 1 \times 10^{-2}$m.

Normalization of the multipole by the quadrupole at the central orbit is convenient to see the quantity of the deviation from the linear quadrupole field. The sum of the outputs of the single coils at the central orbit can be written as,

$$N^{single} = \frac{f_0}{e_0}(A_1 + A_2)\frac{\partial B(x)}{\partial x}\Delta x. \tag{2}$$

Then we obtain,

$$\frac{\dfrac{\partial^2 B(x)}{\partial x^2}}{\dfrac{\partial B(0)}{\partial x}} = \frac{1}{\delta x}\frac{N^{twin}}{N^{single}} \tag{3}$$

Effective length and fringing field

Distribution of the effective length is obtained by simultaneous displacement of the single long coil and the reference coil so as to satisfy the condition (ii) mentioned above. Following the similar procedure as above, we get

$$\frac{N}{N_0} = \frac{W}{A} \frac{\int_{-\infty}^{\infty} \frac{\partial B(x,s)}{\partial x} ds}{\frac{\partial B(x,0)}{\partial x}} = \frac{W}{A} \ell_G(x) \ , \qquad (4)$$

where N and N_0 denote the output of long and reference coils respectively, w denotes the effective width of the long coil and ℓ_G is the effective focusing length. Integrated nonlinear field along the orbit can be derived from the expression below,

$$\int_{-\infty}^{\infty} \frac{\partial^2 B(x,s)}{\partial x^2} ds = \frac{\partial \ell_G(x)}{\partial x} \frac{\partial B(x,0)}{\partial x} + \ell_G(x) \frac{\partial^2 B(x,0)}{\partial x^2} \ . \qquad (5)$$

Twin long coil enables to obtain the information of the non-linear field directly. The outputs of the twin long coils can be written

$$N^{twin} = \frac{f_0}{e_0} (W_1 + W_2) \int_{-\infty}^{\infty} \frac{\partial^2 B(x,s)}{\partial x^2} ds \ \delta x \Delta x. \qquad (6)$$

Examples of the data obtained is shown in ref.2. With this method, the accuracy is estimated to be a few times 10^{-4} for the quadrupole component. This amount of accuracy is enough for checking the mechanical accuracy of the pole profiles and the fluctuation among the magnets. And the improvement of the field quality of the magnet becomes easier by adopting this method.

References

1) M. Kumada, H. Sasaki, K. Takikawa, H. Someya, T. Kurosawa and Y. Miyahara: "The Magnetic field measurement of the Booster synchrotron magnet", to be published in KEK report.

2) M. Kumada, H. Someya, I. Sakai and H. Sasaki: "Wide aperture Q magnet with end cut shaping", contributions to this conference.