THE DYNAMIC EFFECT OF THE VERTICAL FIELD CORRECTOR OF THE 1.8 T WIGGLER

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ABSTRACT

A wiggler W20 with 1.8 Tesla peak field was delivered to the Synchrotron Radiation Research Center (SRRC) at the end of 1994. The magnetic field of the W20 was measured at several gaps and the result was satisfactory. However, while the gap was in motion, an unexpectedly large first integral of the magnetic field occurred. The authors believe that this large field was mainly from the eddy current of the vertical field corrector of the wiggler due to a big changing rate of the magnetic flux during gap motion.

2 INTRODUCTION

The first insertion device (ID) W20 was fabricated by STI of Washington, U.S. After delivery, a series of intensive measurements on mechanics and magnetic field of W20/SRRC were performed as an acceptance test. All the results meet the specification quite well. Some parameters of this device are shown in the Table 1. Table II shows the main specifications of the magnetic field.

TABLE I
THE W20/SRRC 1.8 T WIGGLER PARAMETER

maximum field	1.85 tesla
minimum gap	22 mm
support structure	C-frame
magnets type	hybrid
period	20 cm
number of full strength poles	23
pole width	22 cm

TABLE II
THE MAIN SPECIFICATION OF THE WIGGLER

	normal (By)	skew (Bx)
1st integral (G-cm)	100	100
2nd integral (G-cm^2)	100000	100000
Dipole (G-cm)	100	100
Quadrupole (G)	100	100
Setupole (G/cm)	100	100
Octupole (G/cm^2)	10	10

The operation of the IDs may contribute to the instability of the synchrotron light source. In the commissioning phase, while the gap of the IDs are closed to workpoint, the field qualities at each gap position of them determine whether the electron beam can survive or not. In the operation phase, the photon beamlines and the work stations of the users are most sensitive to the movement of the gaps. To study the dynamic behavior of the w20/SRRC, in parallel with the acceptance test, we used a long loop coil to measure the magnetic field while the gap was in motion. We call this approach “Dynamic measurement”.

Usually, after an ID has been fabricated, a series of measurements are made to make sure that the magnetic field error is acceptable by the electron beam dynamics and photon beam spectrum analysis. Most of the magnetic field measurements are made with gap static. One can measure the magnetic field at as many gap changes as possible to learn the details of the field fluctuation at different gaps, but it is an absolutely different meaning from measuring the field continuously during the gap change.

In spite of the satisfactory results of the acceptance test, the data of the dynamic measurement were surprising. There was an abnormal behavior of the average first integral of the vertical field around the centerline in the middle plane of the wiggler gap. An unexpected peak occurred at 26 mm gap in the opening process and some peaks in the closing process. This performance is out of the specification defined for the static measurements.

On the other hand, while the commissioning of the wiggler and storage ring were performed as a whole, we found the electron beam which can be monitored by electron Beam Position Monitor (BPM) reflected this adverse effect.

There was a list of explanations[1]: the lag of the control process, the abnormal response of the mechanical system, the imperfect driving of the vertical field correctors (end correctors). We believe that the second one is most critical. The end correctors caused too much eddy current while they were moving with gap change and induced an unnecessary magnetic field. We will focus on end correctors in this paper.

Field Correctors are necessary in IDs for the correction of the electron beam, especially in the ones with high magnetic field. Nevertheless, one should design the end corrector carefully for the reasons described later.

2 THE W20 SYSTEM

2.1 Gap motion Mechanism

The gap motion mechanism assembly consists of the C-frame necessary to support the magnetic structure and the drive train to adjust the gap between the upper and lower beams of the magnet structure. The range of motion of the drive train allows for a minimum magnet gap of 22 mm for operation and maximum gap of 230 mm for maintenance and installation. The travel time from minimum to maximum gap is less than three minutes with full speed. The width of the gap was monitored by two independent linear optical encoders.

2.2 The End Correctors

The first integral of magnetic field in the good field region of the gap space can be eliminated by the correction magnets on both ends. The vertical field correctors are electromagnets with solid iron yokes and a great number turns of copper wires to excite a large correction field. Mechanically, the end correctors are moved with magnet beams so that the steering powers decrease with gap increase. The settings of the correction current to excite the correction field are functions of gap. Moreover, the settings, which are different in opening and closing the gap, reflect some hysteresis of the mechanical and the magnetic material. Fig. 1. shows the setting of correction currents of end correctors. It is an iterative process of measurement and calculation to find the settings of a finite set of gaps. With the settings of the finite gaps one can interpolate the current needed to all the other gaps. At 22 mm Gap, the total steering power of the end correctors is about 26 Gauss-cm per mili-Ampere. From the Fig.1, one can tell that there is a large first integral field of 3000 Gauss-cm if the correctors are turned off.

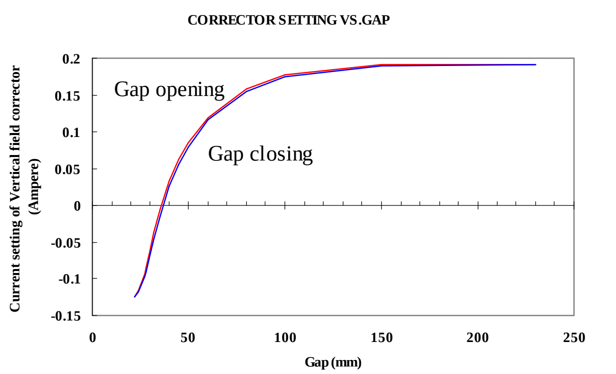

Figure: 1 The current setting of the vertical field corrector. There is a minor difference between the closing and the opening gap process.

3 The Dynamic measurement

3.1 The monitoring of the magnetic field

We modified a long coil system which was originally used for the first integral and high harmonic component measurements in acceptance test. In the static measurement, after the upper and lower beams of the magnets have reached certain gaps with everything at rest, we rotate the long coil and measure the induced voltage by a digital integrator. Nevertheless in the dynamic measurement, we keep the coil static while the magnet beams are moving and measure the induced voltage by a digital voltage integrator.

By moving the gap at different speeds, we can identify the speed dependency of the field.

While running the long loop measurement we suffer from the terrible drift of the voltage integrator because it takes two or three minutes to move the gap and takes more time in low speed mode. On the other hand, the measurement is an open loop process which means we have no close point for reference adjustment. Fortunately one can define three boundary conditions from the field slope (vs. time) at beginning and the end as well as the zero field of the beginning of the measurement. Then we can subtract the terms not higher than quadratic one. It works in high speed mode but cannot fit the lower speed mode at all.

3-2 Direct Observation of the Beam Position.

The electron trajectory is the most direct response of the magnetic field. We installed four BPMs on the upstream and downstream of the wiggler in the storage ring. With these BPMs, we can gain the angle and the trajectory of the electron beams. Fig. 2 shows an example of the BPM result. Beside some tragic variation in the moving range, there is an irreversible position change of the beams. It will be inconvenient to the users working on the beam lines if we can't develop a feedback system to cure this variation.

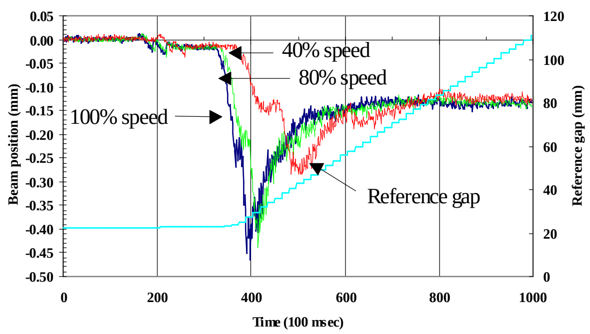

Figure: 2 The speed dependence of the position deviation of electron beam. We focus on the gap range under 120 mm so as to observe the detail near the minimum gap.

Note that in gap-closing case, even the trajectory looks strange, the deviation is tolerable from the specification point of view. In gap open procedure the trajectory can be much worse. As shown in Fig. 6 the maximum deviation is 0.45 mm which is triple as the specification.

We find that there is a reversible shift after the gap movement both in long loop measurement and beam position.

4. DISCUSSION

From the results of the dynamic measurement of the magnetic field and the tracing of the position of the electron beam one can see that the signs of the induced magnetic field are different from opening to closing gap and the amplitudes are speed dependent. The effect is evident at small gap. While the gap and the end corrector are moving, any pair of the end correctors at one end will induced an eddy current to each other and alter the steering power of field correction. The exact calculation of the eddy current and induced field may be complicated but one can estimate it roughly[2]

From Fig. 2. we can also tell the irreversible shift of beam position is speed independent. Someone may suggest that the electrons find a new close orbit after going through the big lump of field deviation but it sounds more strange.

Since the long loop has a finite area, the physical meaning of flux will not be the same with one which electron beam real see.

REFERENCES

[1] T. C. Fan et al., “The Dynamic Measurement of the Magnetic Field of the SRRC 1.8T Wiggler”, SRRC-mmg-030,1995.

[2] P.J. Bryant. “Proceedings, CERN Accelerator School - Magnetic Measurement and Alignment, 16-20 March, 1992, p. 53.