Dynamic Measurement of Magnet Array Phase Position in an APPLE Type Undulator

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Abstract

The closed orbit distortion (COD) of an electron beam induced by the periodic movement of permanent magnetic arrays of the undulator needs be corrected dynamically. For correction, we must excite steering magnets in accordance with the phase position at any instant of time. In this paper, experimental methods to measure dynamically the phase position of magnetic arrays and its results are discussed.

1. Introduction

We are studying machine characteristics of a double array undulator of the APPLE (Advanced Planar Polarized Light Emitter) type. This undulator was installed at the cell number 23 in the SPring-8 storage ring in February, 1998. Our trial in constructing this light source is to produce any kinds of X-ray polarization (horizontally and vertically linear, circular and elliptical) by changing mechanically the phase position of two pairs of permanent magnet arrays. The period of the undulator is 120 mm, and its total length is 1.92 m. At a given gap distance (variable from 36 mm to 300 mm) of the undulator, phase-shift (relative longitudinal distance between two magnet arrays) can be altered from -120 mm to 120 mm, and also it can be driven periodically (designed period is 2 sec) in a pre-determined movement pattern by controlling two servo-motors for the arrays.

The closed orbit distortion (COD) of the electron beam induced by the phase movement is corrected by one pair of long-steering magnets (for Bx and By magnetic field) which surround the arrays of the undulator. The current intensity supplied to these long-steering magnets are altered in accordance with the gap distance and phase-shift since the field strengths integrated along the beam axis are different. We prepared an excitation table for COD correction based on magnetic field measurements (off-site test) as a function of gap distance and phase-shift, and then adjusted the table by on-beam machine study so as to reduce the COD as small as possible. The table adjustment was performed step by step at fixed gap distance and phase-shift. This table is also used to determine current intensity of the long-steering magnets by interpolation at a given phase-shift during periodic movement of phase. In order to suppress an additional COD during the periodic movement, the relation between the phase position and the exciting current for the steering magnet should be precisely in accord with the table at any instant. Thus, we needed to measure the phase position at a given instant of time in order to match the phase position with the corresponding current intensity. The eddy current field induced by the periodic motion in the vacuum chamber placed in the undulator was numerically calculated to be negligibly small. In this paper, we present two experimental methods to measure dynamically the phase position of permanent magnetic arrays. Some results are also discussed.

2. Experiments

2.1 Methods

The time-dependent phase position of the magnetic arrays was measured with two methods using a potentiometer and a rotary-encoder.

In the first method, the electrical resistance of a linear potentiometer (300 mm long and 5000 Ohm of resistance) was directly read out. The potentiometer was fixed at one end of magnet array in such a manner that the axis of potentiometer elongates and shrinks when the arrays move periodically. The electrical resistance was read by a digital multimeter (Keithley, model 2001) which was triggered by 100 Hz pulse from an external source (Function Generator of Hewlett-Packard, model 33120A). The GP-IB control program was written in BASIC with the master computer NEC-9821. The multimeter has 32 kilo-byte memories, which limited the number of readings up to 1300 consecutive readings. This method is simple to carry-out and efficient, but it has a disadvantage to push and pull the potentiometer axis at a rather high frequency with some mechanical load.

The second method using a rotary-encoder is a little complicated to integrate the measurement system. It consists in reading a pair of 10 bit Gray binary code output from rotary-encoders (Koyo-Denshi Co., absolute-type, 0.36 degree of precision) attached to the ends of upper-phase and lower-phase magnet arrays. The pair of 10 bit encoder signals was transmitted to a high scanning speed programmable controller (Yokogawa Electric Co., model FA-M3). An internal clock (0.01 sec) of programmable controller makes a sampling of readings at a time interval of 100 Hz, and then converts the Gray binary code to an ordinary binary code. A GP-IB control program was also prepared to obtain a set of 5000 consecutive readings per each test run.

2.2 Test Condition

Table 1 shows test condition of the magnet array movement in the measurements.

Table 1. Test condition of undulator for the array phase position measurement

Test Parameters	Method of potentiometer	Method of rotary-encoder
gap distance (mm)	38.0	38.0
phase-shift (mm)	40.0	32.0
hold time (sec)	1.4	1.4
maximum velocity (pulse/sec)	30,000	30,000
minimum velocity (pulse/sec)	1	1
time-step to change velocity (microsec)	30	30

The gap distance of 38.0 mm and phase-shift of 32.0 mm (or 40.0 mm) indicated in Table 1 were chosen for the measurements because a circularly polarized light is generated around these condition at a light energy about 400 eV. Phase-shift D is defined as “upper-phase position” minus “lower-phase position ”, so D=32.0 mm represents the situation where upper-phase is 16.0 mm and lower-phase -16.0 mm. When upper-phase is -16.0 mm and lower-phase 16.0 mm, D is -32.0 mm. Hold time of 1.4 sec at D=32.0 mm or -32.0 mm is the minimum time which we can set in the present control system.

The maximum velocity of 30,000 pulse/sec in Table 1 indicates servo-motor parameter meaning that its drive amplifier increases pulse generation rate continuously up to 30000 pulse/sec. The minimum velocity of 1 pulse/sec is the rate at the start of motor rotation. The time-step of 30 microsec is the time interval necessary to increase the velocity from a determined value V pulse/sec to (V + 1) pulse/sec. The servo-motors reach the maximum velocity more slowly at a larger value of time-step. The time-step of 30 microsec in the table is the shortest time-step without producing any mechanical overshoots when the magnet arrays change direction at turning points during periodic movements.

3. Results

In the case of the potentiometer method, all readings were obtained by sampling the electrical resistance at a rate of 100 Hz (10 msec). Fig. 1 is a result of the measurement, where the vertical coordinate indicates resistance of the potentiometer (proportional to the phase position of magnetic arrays) and the horizontal indicates elapsed-time. The gap distance was fixed to 38.0 mm. The axis position of 800 Ohm of the potentiometer corresponds to D= 40 mm, and 5,400 Ohm to D= -40 mm. When we started the tests with the time-step of 2 microsec the overshot distance was 0.8 mm (case A), but through repetitive trials we succeeded in diminishing it to less than 0.1 mm (case B). We see that the hold time fluctuates around 1.4 sec during the periodic movement. Possibly the fluctuation is reduced by using EMA program, which is under investigation.

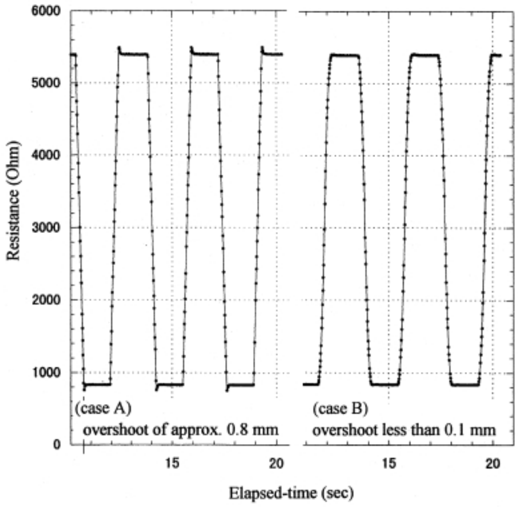

Fig. 1. Resistance variation as a function of time.

The required accuracy of sampling time less than 1% (< 0.1 msec) was also confirmed. As shown in Fig. 2, all 1300 readings occurs inside a region of time division between 0.0098 msec and 0.0102 msec, centered at 0.01 msec. So, we could confirm a good quality and a high reliability of readings at a sampling speed of 100 Hz.

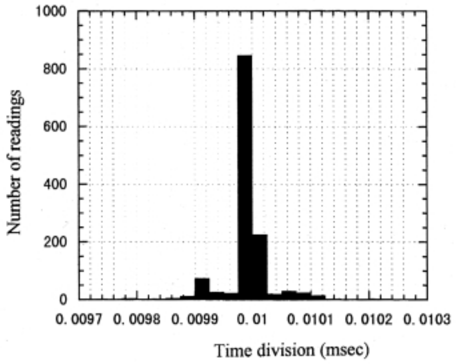

Fig. 2. Deviation of the sampling time.

Figure 3 shows a result of measurement performed by the method of rotary-encoder. The vertical coordinate indicates the phase position of magnet arrays and the horizontal indicates elapsed-time. Also here, the gap distance was fixed to 38 mm. We see that both upper-phase and lower-phase are moving from the position of 16 mm to -16 mm, indicating that the phase-shift D is varying between 32 mm and -32 mm. Again here, we can verify that the hold time fluctuates around 1.4 sec. No mechanical overshoots are observed.

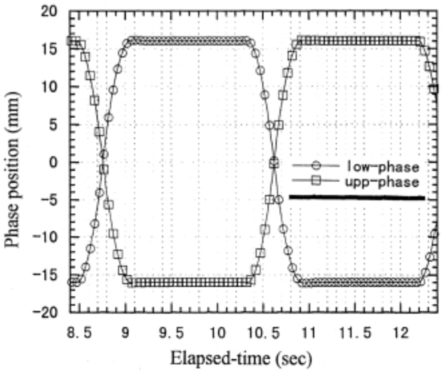

Fig. 3. Phase position as a function of time.

The results are close to the first method. This suggests that we could use the rotary-encoder method in coming experiments to measure the phase position at a sampling speed of 100 Hz.

4. Summary

As described above, we have developed two independent methods to measure dynamically the phase position of permanent magnetic arrays. We have a plan to check the reliability and degree of precision of these methods by calibrating with the existent linear scale. After that, during the coming year of 1999, we are planning to perform experiments on the following themes:

a) read the current supplied to steering magnets in reference to the measurement of phase position using the rotary-encoder method.
b) obtain a correlation between phase-shift D, current intensity for steering magnets and COD (by on-beam study).

References

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