Making Alignment Datums for the New SUBARU Ring

Chao ZHANG[1], Sakuo MATSUI[1] and Satoshi HASHIMOTO[2]

1) Japan Synchrotron Radiation Research Institute(JASRI), Ako-gun, Hyogo 678-1201, Japan
2) Himeji Institute of Technology, 2167 Shosha, Himeji, Hyogo 671-2201, Japan

1. Introduction

The New SUBARU is a synchrotron radiation source being constructed at the SPring-8 site. Its main facility is a 1.5 GeV electron storage ring which provides light beam in the region of VUV and soft X-ray using the linac of the SPring -8 as injector. The storage ring has a circumference of about 119 m, which has two very long straight sections for a 11-m long undulator and an optical klystron, four short straight sections for a 2.3-m undulator and a super conduction wiggler, rf cavity and injection, etc.

The magnets of the storage ring are composed of 12 dipoles(BMs), 6 invert dipoles(BIs), 56 quadrupoles and 44 sextupoles, etc. The multipoles are mounted on 24 girders between the bending magnets (the BMs and the BIs). Elevation for the beam line is 1.21 m and for the fiducial points on the bendings and multipoles are 1.56 m and 1.51 m respectively. There is 50 mm height difference between magnets.

The New SUBARU is a relatively small ring compare to the super photon ring of the SPring-8. Survey & alignment is somewhat different between the two. Both length and angle measurements are executed when aligning the bending magnets for the New SUBARU ring.

2. Alignment of bending magnets

The bending magnets are chosen as the alignment datums, because they are higher in elevation and heavier and stable in position. Making alignment datums is to setup the reference points for other components of the ring. The multipoles, injection magnets, Insertion devices, etc. are aligned from these datums.

2.1 Pre-alignment of the bending magnets

A central monument is erected. This monument defines a physical center of the storage ring. Six invert dipoles and the central monument are used to form a backbone of the survey network. In pre-alignment of the invert dipoles, the mekometer ME5000(Kern) or the theodolite T3000(Wild) is set up on the central monument to measure magnet horizontal positions.

There are three fiducial points on the bending magnets. The central point of the BI and the two end points of the BM are used as the datums. Twelve BMs are pre-alignment by referring the BIs with the 3-D coordinate measurement system SMART 310.

All datum magnets of the bendings are adjusted in six dimensions except for the invert dipoles which rotation around vertical axis is adjusted at the last step of bending magnet alignment. Height and inclination of the magnets are required to be precisely adjusted even at the earlier stage of magnet alignment. Because with bad height and tilt condition the component is difficult to be moved to expected horizontal positions. On the wall of the tunnel six stages are fixed to hold the targets of Ø70 mm ball. These stages are used as the elevation references for the magnets and to be measured with the high precision level N3(Wild). Magnet tilt is measured with the 2-D inclination sensor NIVEL20 put on the magnet fiducial planes.

In the stage of pre-alignment, the BI is expected to be adjusted to ±0.3 mm with respect to designed position in horizontal plane. The BM is further ±0.2 mm displacement from the BI. In the vertical plane the reference stage on the wall is required to be set to ±0.1 mm of displacement.

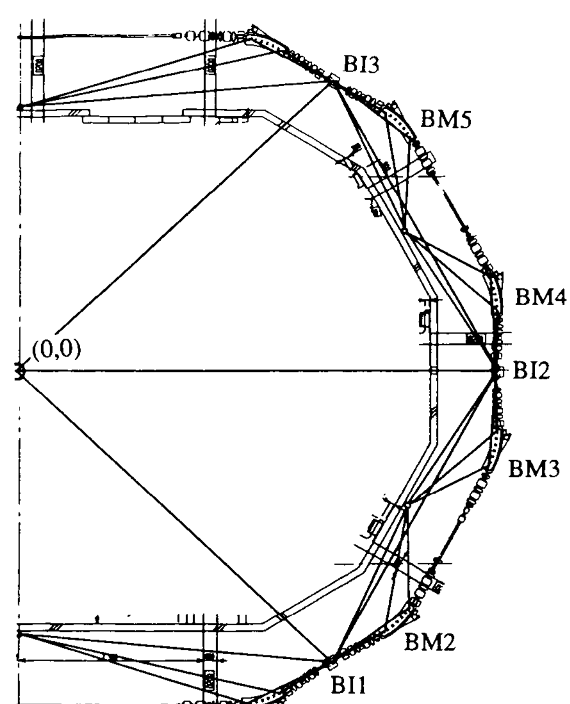

Fig.1 Layout of alignment datum survey(half ring).

The ME5000 is controlled with the program PROMEKO which can extend measurement range below 20 m. The ME5000 is compared to the SMART 310 beforehand and is confirmed to has an accuracy about 0.2 mm for BI's survey. In actual pre-alignment the BIs are set within ±0.3 mm and the BMs are almost in the range of ±0.5 mm horizontally, but have an average displacement of about 0.3 mm. Elevation of the bendings are aligned within 0.26 mm. Elevation tolerance is critical for the multipoles. To ensure the tolerance a separate set of elevation survey is made which emphasizes the relative smooth between adjacent multipoles. The tilt adjustment of bending magnet is achieved of 0.03 mrad of r.m.s. and the maximum error is 0.09 mrad, for a particular BI's three fiducial planes are not well machined.

Horizontal positions of the bending magnets are finally adjusted by the network survey.

2.2 Precise alignment of bending magnets

To final adjust the bending magnets, magnet positions are measured with a survey network. The network is designed to avoid to interfere with the insertion devices and both length and angle measurements are executed to reduce measurement error. It is composed of 90 length measurements and 30 angle measurements. Figure 1 shows its configuration for the half ring. Survey elements of lengths are collected with the SMART 310, and angles

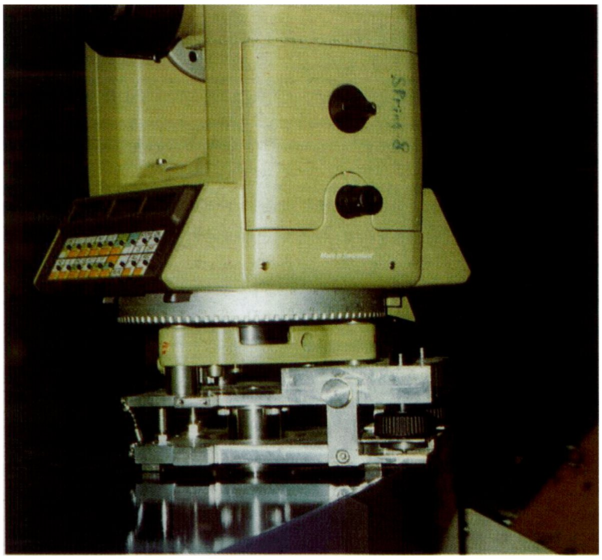

Fig.2 Force-centred stage for setting the theodolite.

are measured with the theodolite T3000 from each bending magnet to neighboured BIs or the points on the wall.

Because survey accuracy is largely depend on angle measurement, a force-centred adjustable stage for the theodolite is made(Fig.2). The theodolite stage let the vertical rotating axis of the theodolite coincides with the center of magnet fiducial point. Because angle measurement error is proportional to the offset of theodolite axis as described as:

$$\Delta a = k_1 \frac{e}{d_1} + k_2 \frac{e}{d_2}$$

where, e is offset of theodolite from the fiducial point. d_1, d_2 are distances from theodolite to targets, the shorter the distances the larger an angular measurement error will be for the same amount of offset. Therefore the theodolite axis must be calibrated to the fiducial point as precisely as possible. In calibration of the stage, the angle for a certain point is measured four times with the stage changing directions separated by 90 degree each time. Difference of the four angles is kept within 1 arc second, corresponding to about 10 μm offset error.

3. Result of bending magnet alignment

Simulation shows that with survey element errors of 50 μm in length measurement and 1.5 arc second in angle measurement, the bending magnets will be positioned within 0.06 mm for absolute displacement and 0.04 mm for relative displacement. Therefore, to what extent we adjust the magnet will correspond to the survey accuracy. Several cycles of survey and adjustment are executed. At the first round of survey the BIs are found to be systematically displaced toward outside of the ring for about 0.3 mm. It is caused by errors of the ME5000 and its reflector. Consequently the BMs are also displaced outside. After the first round adjustment the bending magnets have about 0.1 mm of residual. This is still large comparing to the survey accuracy. The problem is considered causing by magnet adjustment method. For the dial gauge used in the adjustment is not on the same elevation as the fiducial plane, there is about 0.7 m difference between the two. Movement amount is not the same as required amount because the tilt of magnets are changed simultaneously from 0.02 to 0.2 mrad. The SMART 310 replaces dial gauge to monitor the adjustment afterwards.

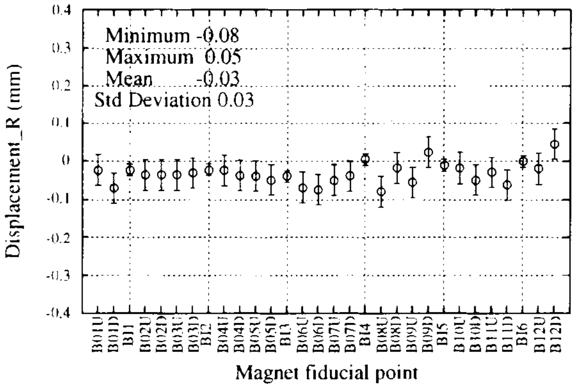

Fig.3 Displacements of bending magnets in horizontal transverse.

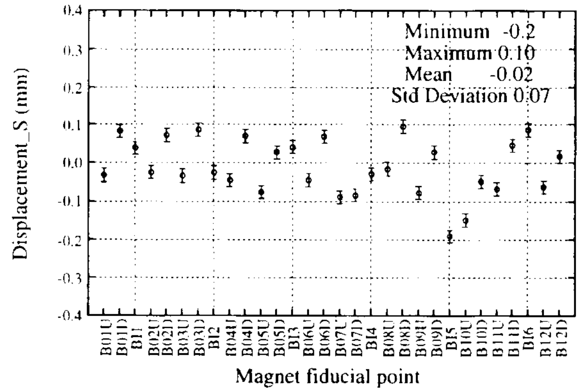

Fig.4 Displacements of bending magnets in beam direction.

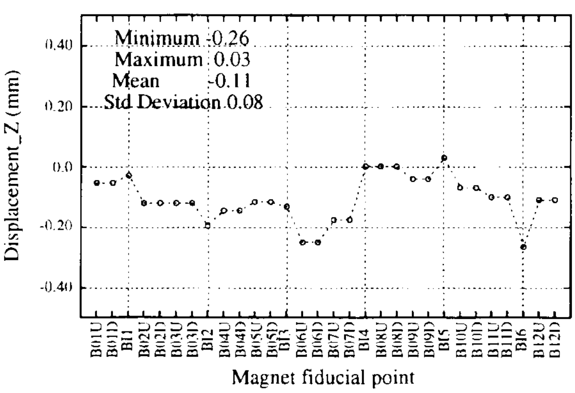

Fig.5 Displacements of bending magnets in vertical.

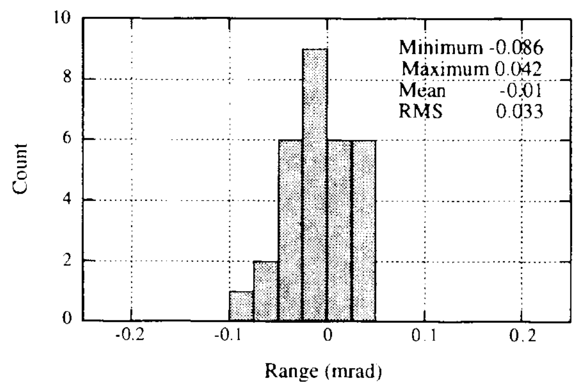

Fig.6 Error of tilt of bending magnet around beam direction.

Figure 3 is the bending magnet displacement in horizontal transverse after alignment. Average displacement is 0.03 mm towards the inner ring. Standard deviation is 0.03 mm with respected to the mean orbit. The BIs are more precisely aligned then the BMs because their positions in radial are directed measured from the central monument.

In beam direction the displacement of the magnet fiducial points is 0.07 mm r.m.s.(Fig.4). One can notice that the two fiducial points of upstream and downstream are in opposite directions, because the distance of two fiducial points is little longer than designed one. The center of the BM is more precisely aligned to expected position then the fiducial points.

In elevation, peak to peak deviation of the bending magnet is about 0.3 mm (Fig.5). Elevation of bending magnet is not used as the datums for the multipole alignment. Therefore the deviation residuals are kept as they were.

Figure 6 shows that inclination of magnets around beam direction is 0.03 mrad. The magnets are adjusted by averaging the tilt of the two end fiducial planes to eliminate manufacture error.

4. Conclusion

The bending magnets of the New SUBARU, as the datums for the other components, are aligned as precisely as we expected. The survey methods have some advanteges because of the considerations of avoiding interfering with the insertion devices, and having no need of much precise distance measurement. Attention should be paid to eliminate offset error when measuring angle of short sides.