# Alignment Procedures of the New SUBARU Ring Magnets


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

1 )Japan Synchrotron Radiation Research Institute(JASRI). Sayo-gun, Hyogo 679-5 198, Japan
2)Himeji Institute of Technology, 2167 Shosha, Himeji, Hyogo 671 -2201 , Japan


## l . Introduction

The New SUBARU storage ring is located in the SPring-8 site. The electron is injected from the linac through the transport line called L4BT.

This ring is on the Sayo gravel bed. It consists of congromerate clay layer (Fig.1, 2)

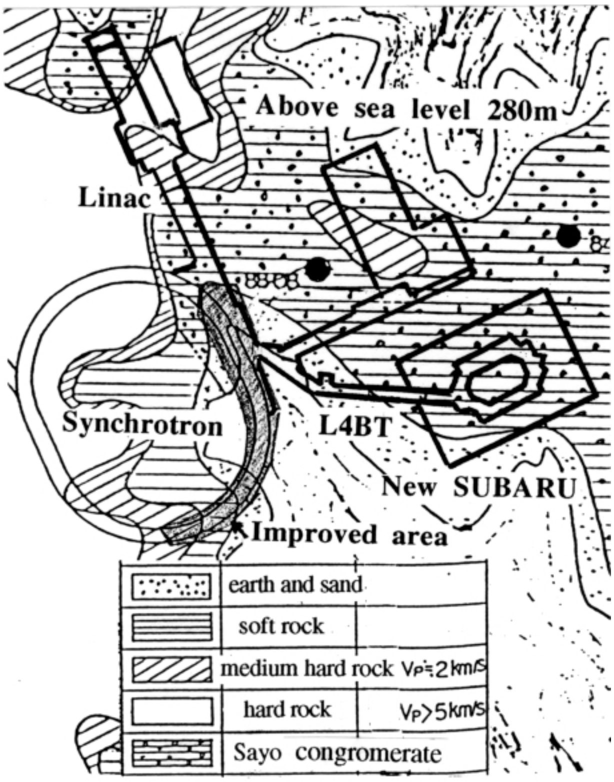
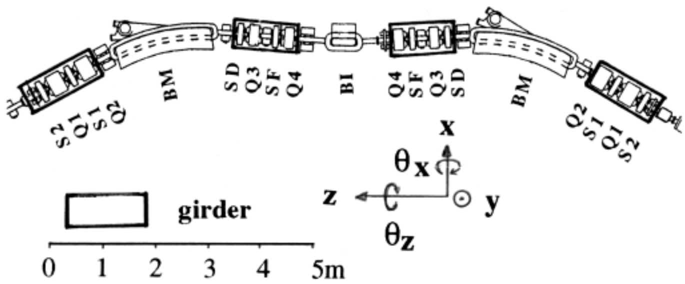



Fig.1. Surface cut along sea level 280m.

Fig.2. Photograph of Sayo congromerate. (magnified)

This ring has 6 cells with a circumference of 119m. One cell has 2 bending magnets (BM) and one invert bending magnet(BI) at the middle and multipole magnets on four girders. The length of one girder is l-2m. Two quadrupole and two sextupole magnets are mounted on a normal girder. The total number is 56 for quadrupoles and 44 for sextupoles. Coordinates are shown in Fig.3.

Adopted alignment method is divided into two stages to reduce the misalignment sensitivity, that is in a girder (tolerance 50 µm) and between girders (0.2mm). This is similar to the SPring-8 storage ring.




While the fiducial plane of SPring-8 storage ring magnets has cylyndrical hole, the one of SUBARU has tapered holes. The diameter fluctuate as for cylyndrical case, however the spherical target position has no fluctuation on the tapered hole.

## 2. Alignment Procedures

### *2. 1 Before building construction*

1) Making a few monuments for building construction.

### *2.2 Building construction*

1) During tunnel construction six holes (30cm X 30cm) were made on the tunnel wall for the line of sight. The center of the ring was punched on the stainless plate.

### *2.3 After tunnel construction*

1) Six monuments on the floor were made by the survey from the center. “Total station” (3 dimensional coordinates are measured) was used , but the accuracy was not good. The error were about 3mm.
2) The floor level around the beam line was measured. The range was within ±10mm. We defined the most high level of the floor as floor 0 level. We also marked the 1210mm beam level.
3) We attached six target stages on the wall for the alignment of BM’s and BI’s and for network survey. Target height is 1560nun.

### *2.4 Magnetic measurement of multipole ,magnets*

### *2.5 Pre-alignment*

1) According to six floor monuments, many lines and holes were made on the floor for girders set up.
2) The BI’s and BM’s were set on these points.
3) Multipole magnets were put using the fiducial hole

on the bending magnet.
4) We made a steel stage for survey instruments at the ring center. After this we joined the alignment work.
5) From this center BI's were aligned again using distance meter ME5000 (0.2mm±0.2ppm) and a theodolite T3000.
6) BM's were aligned by a laser tracker.

*2.6 Precise alignment*
1) The fiducial holes of BI and BM on the horizontal plane were surveyed by the laser tracker and the theodolite T3000, and displacements were calculated.
2) The BI's and BMs Were adjusted.
3) The cycle of 1 and 2 were repeated about two times.
4) The angle of BI were aligned by the laser tracker.
5) Levels of the multipole magnets on both end on a girder were surveyed with N3. (Fitting $\sigma$=0.01mm)
6) The multipole magnets on both ends on a girder were aligned by the laser tracker. The reference positions were on the fiducial holes on the BM and BI.
7) The multipole magnets inside the girder were aligned by laser and CCD camera system.
8) Two septum magnets were aligned by laser tracker.

*2.7 After alignment*
1) Straightness check of the magnet pole.
2) Measurement of inclination of fiducial plane.
3) Divide magnet.
4) Vacuum chamber is installed.
5) Restoration of upper-half magnet.
6) The inclination of fiducial plane were also measured.

## 3. Magnetic Measurement

The shift from ideal fiducial holes was obtained by using rotating coil. A He-Ne laser, a CCD camera embedded in a spherical target, and a Macintosh computer for processing image data were used to measure the deviation from straight line. The deviation of shift distribution were $\sigma x$=51µm, $\sigma y$=38µm for quadrupole, $\sigma x$=42µm, $\sigma y$=25µm for sextupole.

## 4. Multipoles Alignment on a girder

A magnet is fixed to a intermediate plate by 4 bolts and the plate is fixed to the girder by another 3 bolts as shown in Fig.4. Thus we can separate the adjust of height and tilt from that of horizontal shift. The fiducial plane is attached on the top of the magnet.

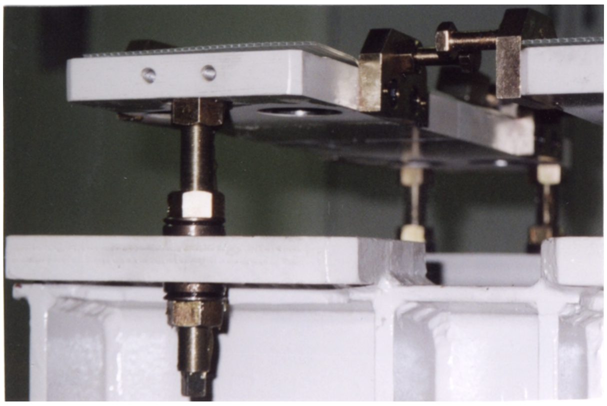


Fig.4. Girder for multipole magnets.
Alignment on a girder is being done by taking account of the shift data in magnetic measurement.

*4.1 Both end magnets*
Firstly, both the end magnets were aligned by the laser tracker. Reference points on the horizontal plane were the fiducial points on the BM and BI. The levels of these multipole magnets were already surveyed. The tilt was measured by bubble tiltmeter.

*4.2 Inner magnets*
The laser and CCD system as well as the magnetic measurement was used. The straightness of this system was estimated to be within 10 µm with 4m-long stage.
Reference points were the upper-stream fiducial holes on both end magnets on the girder. A two dimensional tiltmeter (Leica Nivel20) was used during alignment and in final step Taylor Hobson Talyvel 4 was used. The base of Talyvel 4 was made as same as the one in magnetic measurement.

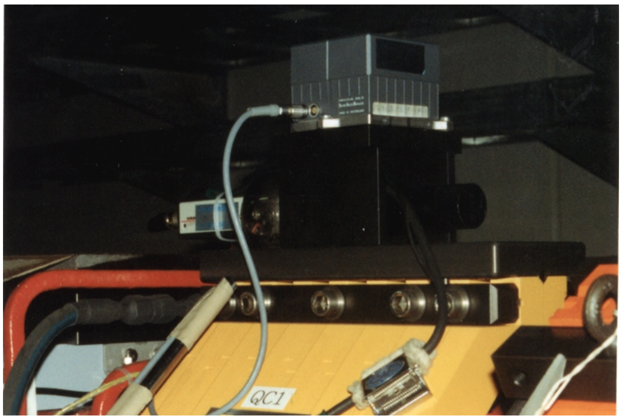



Fig.5. Tiltmeter and CCD camera during alignment.

Fig.6. Photograph of precise alignment in a girder.

## 5. Alignment Check

The fiducial points and reference line for the alignment are on a height of O.3m from the median plane of the magnet pole. Thus in order to check the alignment the symmetrical center of several magnetic poles were measured.
The radius of the aparatus is the same as bore one (35mm). Thick glass plate on which the parallel lines are coated is inserted and adjusted so that the pattern

center coincides with that of the outer circle.

The two curved surfaces touches the pole faces. Spring plungers press the other pole faces for support. By rotating it Measurements are repeated and averaged value is obtained. The apparatus positions were at both ends of quadrupole and at middle of sextupole.

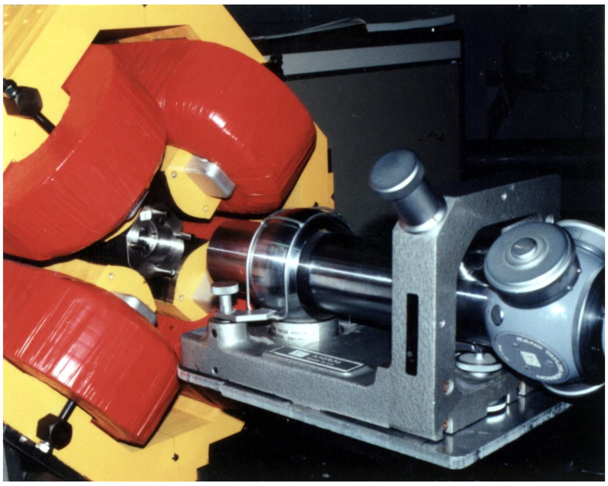


Fig.7. Setup for the straightness measurement.

## 6. Results

*6.1 Both end magnet on a girder*

The reference points deviation on the BM and BI is shown as ax=30 μm by Chao ZHANG in this report. Figure 8 shows the deviations histogram of both end magnets from these reference line in the x direction.

*6.2 Inner magnets on a girder*

The residual values after adjust were σx=15μm, σy=12μm, σ(θz)=25μrad. and σ(θx)=37μrad.

*6.3 Straightness Check In a Girder*

The deviations of pole center from the straight line are shown in Fig.9. This straight line connects the pole centers on both sides of one girder. The magnetic

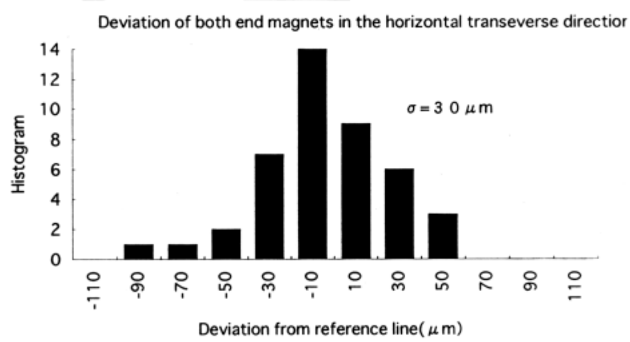



Fig.8. Both end magnets deviation in the x direction.

center shifts from the mechanical pole center maximum 0.2mm as long as the previous magnetic measurements are correct. This seems difficult to understand.

## 7. Concluding Remark

If the accuracy of magnet pre-alignment is ±0.5mm, the one of monument must be less than ±0.5mm.

The reference level of BM and BI is 50mm higher than that of multipole magnets. If laser and CCD camera system is used, it is difficult to change the laser height, however, the laser tracker has no problem.

During the alignment it is important to read the position and two directional tilts at the same time.

Since it is difficult to make the flat fiducial plane, the tiltmeter has to have three points base, and the tiltmeter position during alignment must be same as that of magnetic measurement.

Though the alignment displacements in a girder on the reference line are so small (σx,y=10~20μm), but the straightness of the pole centers are not so good (σx,y=30~40μm). It is necessary to consider the relation between the mechanical pole center and the magnetic measuremenr data. We can align the magnets by using the mechanical centers if the magnetic synunetry is good.

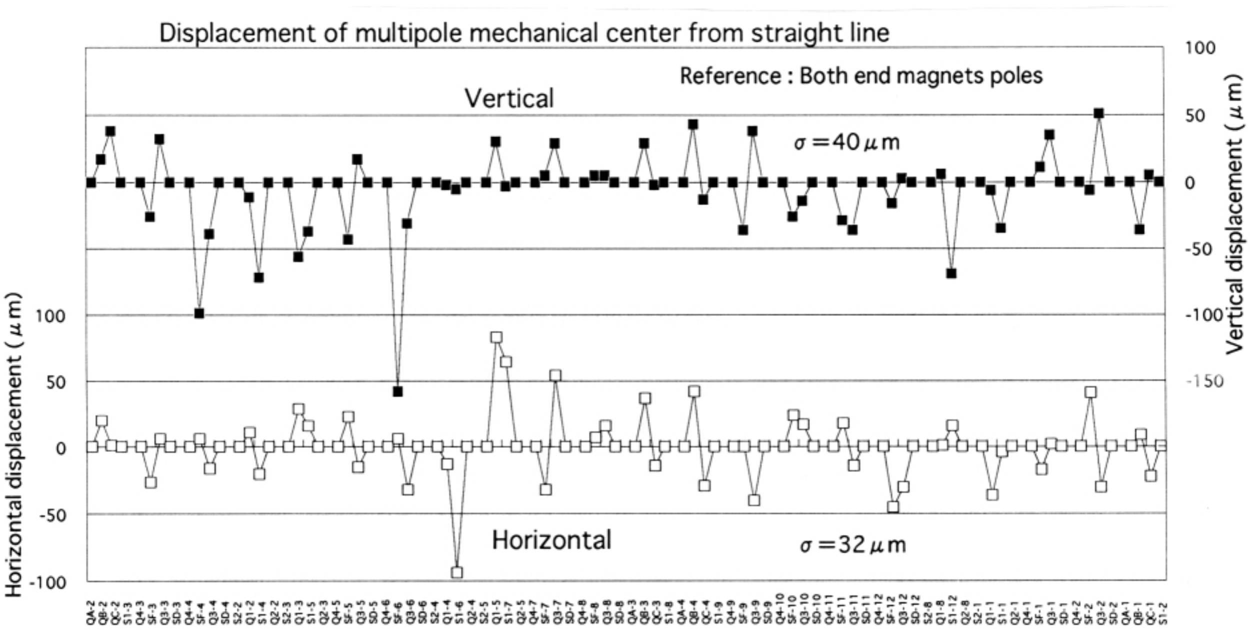



Fig.9. Deviation of magnetic pole centers from straight line a girder.