STUDY ON THE DETERMINATION OF REFERENCE CLOSED ORBIT OF THE STORAGE RING IN POHANG LIGHT SOURCE*

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Abstract

We have studied the methods for the determination of reference closed orbit of the storage ring in PLS using magnet misalignment data. The reference closed orbit was determined by (1) a smoothing analysis using a low-pass filter method, and (2) a MAD (methodical accelerator design) simulation using the real parameters such as magnet misalignment data. Based on the estimated reference closed orbit, the relative positional errors of the storage ring magnets were evaluated. The results of case studies on the comparison of the smoothing analysis and the MAD simulation are described in this presentation.

1. INTRODUCTION

Since the control networks in the Pohang Light Source (PLS) storage ring tunnel were established in June 1993, we have monitored the networks periodically. The PLS storage ring tunnel was deformed unequally in vertical direction about 3 mm (peak-to-peak) a year. The range of the maximum deviation of storage ring magnets was extended to ±3 mm from the ideal beam path [1]. Therefore, we have studied the methods such as smoothing analysis and MAD simulation for the determination of reference closed orbit using magnet misalignment data. The relative positional errors of magnets were estimated from the reference closed orbit. The estimated relative positional errors from 1996 to 1998 are summarized as follows: while the absolute positional tolerance, which was defined as the maximum deviation of magnets from the ideal beam path, showed ±3 mm, the magnets were placed within the relative positional tolerance of 0.15 mm (rms) [2]. As a result, we decided that the period of magnet realignment of the PLS storage ring should be about two years [3].

2. TUNNEL DEFORMATION

The first survey of the PLS control networks was done in June 1993, and tunnel deformations in lateral and vertical directions have been monitored at every six months. The control networks consist of an ENET which controls elevations and a TNET which controls horizontal locations. Conventional survey instruments such as theodolites (E2, T3000) and mekometer (ME5000) were used for the direction and distance survey, respectively. For the elevation survey, N3 Level and NEDO invar staff were used. The absolute error ellipses of TNET survey were in the range of 0.2 mm. The accuracy of ENET survey was about 0.07 mm (1σ value). This estimation was obtained by a GEONET program, which was developed at SLAC.

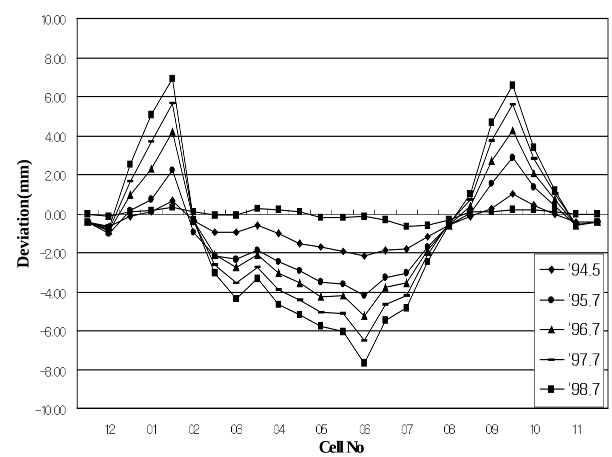

Figure 1: PLS storage ring settlement surveys.

As shown in Fig. 1, the storage ring tunnel was deformed in the vertical direction unevenly about 3.0 mm (peak to peak) per year. The lateral deformation, which is not shown in this graph, was within the range of ±1.0 mm.

3. REFERENCE CLOSED ORBIT USING A SMOOTHING ANALYSIS

The tunnel deformation, which is discussed in the above, coincided with the storage ring deformation as a whole. We needed to apply a proper method for the estimation of the relative positional errors that could eliminate systematic errors due to the tunnel deformation. Studying a few smoothing analysis methods using deformation data of the storage ring surveyed in August 1995, we chose a smoothing analysis using a low-pass filter method. The smoothing analysis is a process of

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determining the reference closed orbit of the storage ring which is close to the actual electron beam path [4].

Table 1: Results of the smoothing analysis for the PLS storage ring deformation in July 1996.

Freq. (MHz)	Relative Positional Errors (1σ;mm)		Number of Outliers		Remarks
	Lat	Ver	Lat	Ver	
0	0.456	1.087	81	113	
1	0.300	0.742	51	92	
2	0.250	0.538	40	91	
3	0.217	0.294	32	59	
4	0.171	0.199	7	21	
5	0.153	0.162	6	9	
6	**0.136**	**0.130**	**2**	**3**	***≤ 0.15mm***
7	0.130	0.127	2	2	
8	0.126	0.115	2	1	
9	0.125	0.104	2	1	
10	0.125	0.089	2	0	

The deformations of the storage ring from the ideal beam path were 0.5 mm and 1.1 mm in the lateral and vertical directions, respectively in 1996. The relative positional errors and the number of outliers decreased as the filtered frequency increased as listed in Table 1.

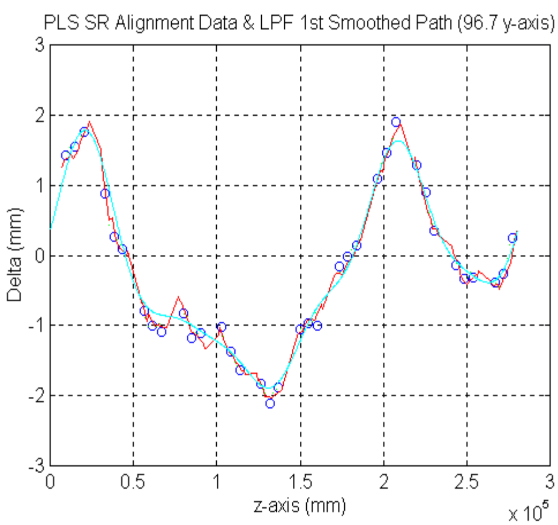

Figure 2: Vertical displacements of all storage ring magnets in 1996 (by smoothing analysis).

When the filtered frequency was 6 MHz, the errors became smaller than the positional tolerance of 0.15 mm and there were only a few outliers. Considering these results, we estimated that the relative positional errors of magnets were 0.14 mm (rms) in the transverse direction and 0.13 mm (rms) in the vertical direction. The result of smoothing analysis is shown in the Fig. 2 for the vertical direction. The estimated reference closed orbit deviates from the ideal position by ±2 mm. However, we could have left the storage ring without the adjustment of magnets by considering the following facts. First, the storage ring was in normal operation, second, the relative positional errors were within the tolerance of 0.15 mm, and third, the deviations from the reference closed orbit were within 2 σ range (±0.3 mm) except for 2 or 3 magnets. The issue of the magnet adjustment was discussed with beam physicists. The maximum deviation from the ideal closed orbit was required to be kept within ±3 mm range. Based on this requirement, we estimated the positional errors of storage ring magnets in July 1997 by the smoothing analysis. The relative positional errors of magnets were 0.13 mm (rms) and 0.10 mm (rms) in transverse and vertical direction, respectively.

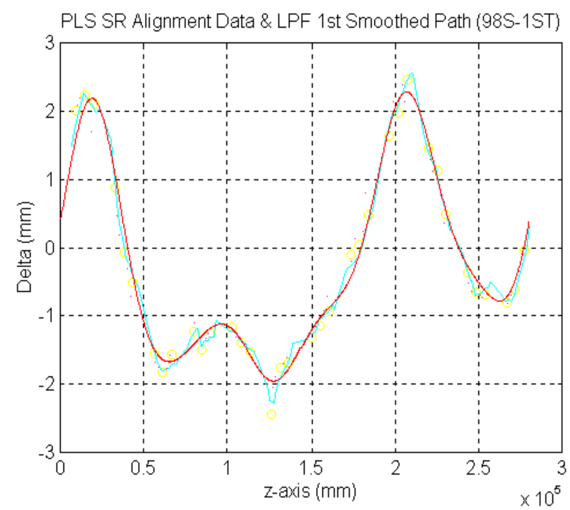

Figure 3: Vertical displacements of all storage ring magnets in 1998 (by smoothing analysis).

The results of the storage ring deformation and the reference closed orbit by the smoothing analysis in July 1998 are shown in Fig. 3. At the 6 MHz of filtered frequency, the relative positional errors of magnets were 0.12 mm (rms) transversely and 0.13 mm (rms) vertically and there was no outlier. It is shown that all magnets were placed within the expected maximum deviation range of ±2.5 mm from the ideal beam path, and the quadrupole magnets were placed within 2 σ range (±0.3 mm).

4. REFERENCE CLOSED ORBIT USING A MAD SIMULATION

The reference closed orbit can be determined by a MAD (methodical accelerator design) simulation using real parameters. The most significant parameter that has an effect on the determination of closed orbit is as follows: quadrupole misalignment ($\Delta x, \Delta y$), bending magnet field error ($\Delta B/B$), and bending magnet rotation error with respect to the beam axis ($\Delta\phi$) [5]. We simulated the reference closed orbit using quadrupole misalignment data, bending magnet rotation error. The analytical formulas for reference closed orbit are given by:

$$x_{rms} = \frac{\sqrt{\beta_x}}{2\sqrt{2}\sin \pi \nu_x}[\theta_B^2(\frac{\Delta B}{B})^2 \sum_i \beta_{xi} + (\Delta x)^2 \sum_i (kl)_i^2 \beta xi]^{1/2}$$

$$y_{rms} = \frac{\sqrt{\beta_y}}{2\sqrt{2}\sin \pi \nu_y}[\theta_B^2(\Delta\phi)^2 \sum_i \beta_{yi} + (\Delta y)^2 \sum_i (kl)_i^2 \beta yi]^{1/2}$$

The result obtained by MAD simulation is shown in Fig. 4. The figure shows the displacements of all magnets from the ideal beam path and the estimated reference closed orbit in July 1996. The relative positional errors of magnets were 0.13 mm (rms) and 0.10 mm (rms) in transverse and vertical direction, respectively.

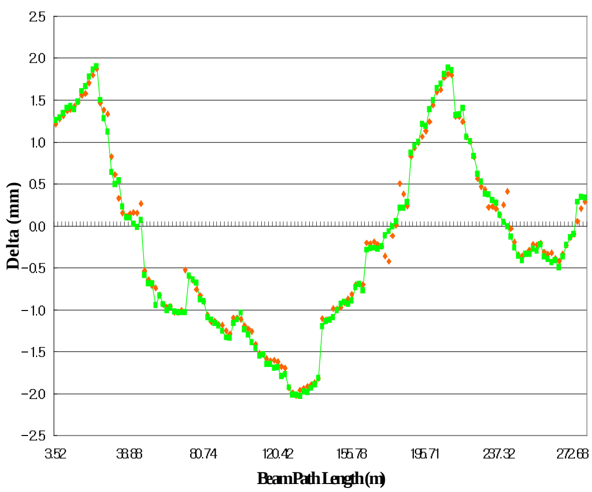

Figure 4: Magnets vertical displacements and closed orbit in 1996 (by MAD simulation).

Fig. 5 shows the displacements of the magnets measured in 1998 and the deviations of magnets from the estimated reference closed orbit in the vertical direction. The relative positional errors of magnets were 0.11 mm (rms) transversely and 0.12 mm (rms) vertically. All magnets were placed within the allowable positional tolerance of 0.15 mm (rms).

As a result, the relative positional errors estimated from the two different reference closed orbits, one was determined from the smoothing analysis and the other was from the MAD simulation, coincided with each other within the range of tolerance.

5. CONCLUSION

Settlement of the PLS storage ring tunnel results in the machine deformation of 3 mm (peak to peak) a year in vertical direction. By employing the smoothing analysis by the low-pass filter method, we could get the reference closed orbit in the form of a smoothed curve. And we determined the reference closed orbit by the MAD simulation using the real parameters such as magnet misalignment data. The estimation of the relative positional errors based on the reference closed orbits was carried out.

The results of closed orbit studied using deformation data of the storage ring from 1996 to 1998 showed that the relative positional errors estimated from the two different reference closed orbits coincided with each other within the range of tolerance. The absolute positional tolerance of magnets could be extended to ±3 mm and the deviation of magnets from the reference closed orbit extended to 2 σ range (±0.3 mm), because the storage ring operated normally and the relative positional error of magnets was within 0.15 mm (rms).

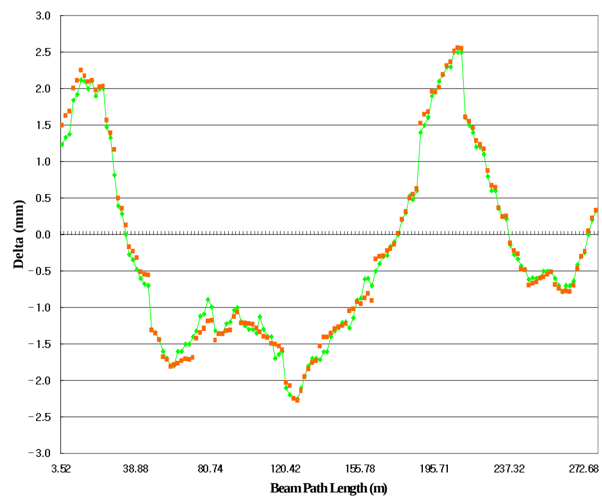

Figure 5: Magnets vertical displacements and closed orbit in 1998 (by MAD simulation).

6. REFERENCES

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