DETERMINATION OF MAGNET REALIGNMENT PERIOD BASED ON SMOOTHING ANALYSIS *

S. C. Lee, A. H. Maeng, K. W. Seo, J. S. Bak, and I. S. Ko
Pohang Accelerator Laboratory, POSTECH, Pohang 790-784, Korea

Abstract

A deformation measurement of the PLS storage ring tunnel shows that the settlement of the tunnel floor keeps going on about 3mm (peak-to-valley) a year, and the lateral deformation is within the range of ±1mm. The tunnel settlement of 3mm results in the storage ring deformation of ±1.5mm a year in vertical direction. Results of the case studies for the estimation of relative positional errors by a smoothing analysis from 1995 to 1997 are summarized as follows: a low filter method for the smoothing analysis was successfully employed, and the storage ring magnets are placed within 2σ (±0.3mm) range from the smoothed curve. While the relative positional errors are well within the tolerance of 0.15mm, the absolute positional tolerance that is the range of maximum deviations of magnets from the ideal beam path is extended to ±3mm, which is derived from the experience of storage ring operation. Therefore, we estimate the period of magnet realignment of the PLS storage ring should be about 2 years.

1 INTRODUCTION

Since the Pohang Light Source (PLS) storage ring was aligned to the ideal beam path in 1994, the tunnel deformations have been monitored periodically. The storage ring tunnel was deformed unequally in the vertical direction about 3mm (peak to valley) a year, which resulted in the machine deformation of ±1.5mm[1]. We studied how to determine the actual beam path of the storage ring and estimate positional errors based on the beam path. Employing a smoothing analysis by a low-pass filter method, we assumed the actual beam path in the form of a smoothed curve[2][3]. Considering a few case studies on the smoothing analyses and the machine operation from 1995 to 1997, we found that the relative positional errors of 0.15mm (rms) based on the smoothed curve could be achieved regardless of the machine deformation of ±3.0mm[4]. Therefore, not only the range of maximum deviations from the ideal beam path but also the tunnel settlement is one of major factors, which effects on determining the period of PLS magnet realignments.

2 TUNNEL DEFORMATION

Measurements for the determination of tunnel deformations in lateral and vertical directions have been repeated at intervals of every six months since the first survey of the PLS control networks in the tunnel was performed in June 1993. 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) are used for the direction and distance survey, respectively. For the elevation survey N3 Level and NEDO invar staff are used. The absolute error ellipses obtained for the TNET survey are in the range of 0.2mm. This estimation is based on a GEONET which was program developed at SLAC. The accuracy of ENET survey is about 0.07mm in the 1σ value.

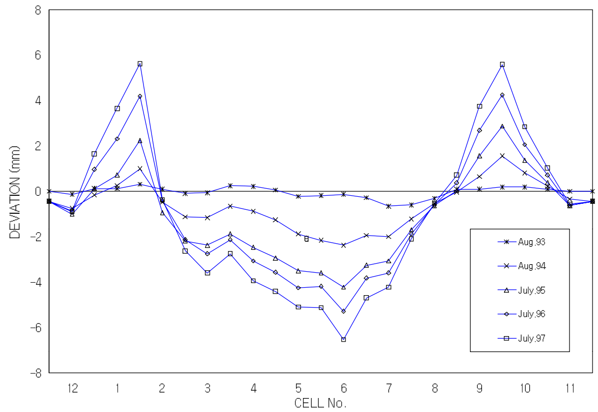

Figure1: PLS storage ring settlement surveys.

As shown in Figure 1, the comparison of each ENET survey epoch to the reference elevation which was established in June 1993, the settlement of the storage ring tunnel keeps going on unevenly about 3.0mm (peak to valley) per year. The lateral deformations, which is not mentioned in this paper, are within the range of ±1.0mm.

3 STORAGE RING DEFORMATION AND MAGNET REALIGNMENT

3.1 Storage Ring Deformation

We surveyed the storage ring two times a year and determined the change of positional errors from 1994 to 1997. The storage ring deformation, the maximum deviation of magnet positions from the ideal ones, proceeded by ±1.5mm per year, while the machine operation showed normal condition. When the storage ring installation was completed in August 1994, the magnets were aligned to the ideal beam path with the positional accuracy (rms) of 0.15mm in both transverse and vertical directions. Then it was found the storage ring had a deformation at the end of 1994. We realigned the storage ring to the ideal beam path in February 1995.

3.2 Smoothing Analysis and Magnet Realignment

The tunnel deformation which are discussed in the above coincided with the storage ring deformation as a whole. Therefore, we felt we needed to develop a method for the determination of the relative positional errors which could eliminate systematic errors due to the tunnel deformation. Considering a few schemes of smoothing analyses using the first data set of the storage ring deformation survey in August 1995, we decided to employ a smoothing analysis by a low-pass filter method. The smoothing method by the low-pass filter is believed to have a convenience in selecting parameters to explain the relation between the storage ring operation status and positional errors due to the deformation.

The storage ring was deformed from the ideal beam path as much as 1.0mm and 0.8mm in the lateral and vertical directions, respectively, in 1995. In applying the smoothing method, we selected the filtered frequencies of 3 MHz and the outlier criteria of 2 σ range (±0.3mm). The relative positional errors (rms) were 0.13mm in the transverse and 0.12mm in the vertical direction, and the maximum deviations from the smoothed curve were -0.27mm transversely and 0.22mm vertically. These data were well within the criteria. So, there was no major adjustment of the storage ring magnets in 1995.

Table 1: Results of the smoothing analysis for the PLS storage ring deformation in August 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 resurvey of the storage ring was performed in July 1996. The maximum deviation of quadrupole magnets from the ideal position was 2.2mm in the vertical direction, while the operating status of the storage ring showed normal. The smoothing method was applied for the determination of the relation between the operation status and positional errors. As the filtered frequency was increased by 1 MHz interval, the relative positional errors and the number of outliers decreased as listed in Table 1. When the filtered frequency was 6MHz, the errors became smaller than the positional tolerance of 0.15mm and there was only a few outliers. Considering these results, we estimated that the relative positional errors (rms) were 0.14mm transversely and 0.13mm vertically.

The result of smoothing analysis is shown in the Figure 2 for the vertical direction. The smoothed curve deviates from the ideal position by ±2mm. As shown in the Figures 3 for the histogram of the deviations, three quadrupole magnets have been displaced out of 2 σ range (±0.3mm) in the vertical direction.

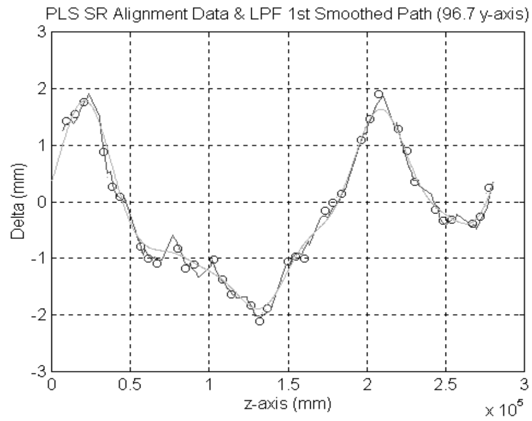

Figure: 2 Vertical displacements of all storage ring magnets in 1996.

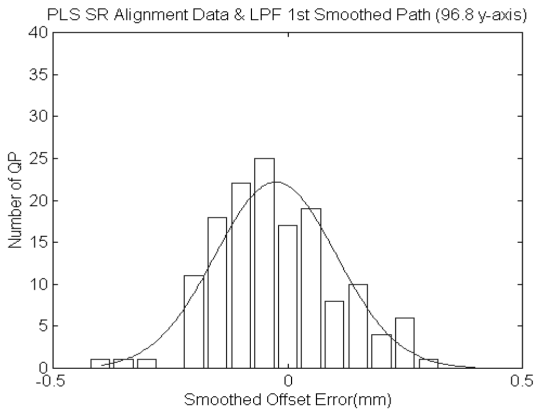

Figure 3: Histogram of the vertical displacements of quadrupole magnets in 1996.

As discussed in the above, we could have left the storage ring as it was without magnets adjustment by considering the facts that 1) the storage ring was being operated normally, 2) the relative positional errors were within the tolerance of 0.15mm, and 3) the deviations from the smoothed curve were within 2 σ range

(±0.3mm) except for 2 or 3 magnets. The issue of the magnet adjustment was discussed with beam physicists. The maximum deviation from the ideal beam path was required being maintained within ±3mm range. As long as it was expected that the continuous settlement of the tunnel floor by 3mm (peak to valley) per year would result in the vertical deformation of ±1.5mm in the machine, the maximum deviation might become about ±3.5mm in 1997 and the relative positional errors be deteriorated. Based on this estimation, the storage ring was realigned to the ideal beam path in August 1996.

Table 2: Results of the smoothing analysis for the PLS storage ring deformation in August 1997.

Freq. MHz	Relative Positional Errors (1σ;mm)		Number of Outliers		Re-marks
	Lat	Ver	Lat	Ver	
0	-	-	-	-	
1	0.337	0.570	56	85	
2	0.207	0.456	24	86	
3	0.147	0.238	6	31	
4	0.131	0.166	4	9	
5	0.126	0.132	1	5	
6	**0.126**	**0.102**	**0**	**0**	

The results of the storage ring deformation measurements and smoothing analyses in July 1997 are shown in Table 2, and in Figures 4 and 5. As shown in Table 2, at the 6 MHz of filtered frequency the relative positional errors were 0.13mm (transverse) and 0.10mm (vertical) and there was no outlier. Figures 4 and 5 show the displacements of all magnets in the vertical direction from the ideal position and the histogram of the deviations of the quadrupole magnets from the smoothed curve, respectively. One can see all magnets have been placed within the expected maximum deviation range of ±1.5mm from the ideal beam path, and the quadrupole magnets are placed within 2 σ range (±0.3mm).

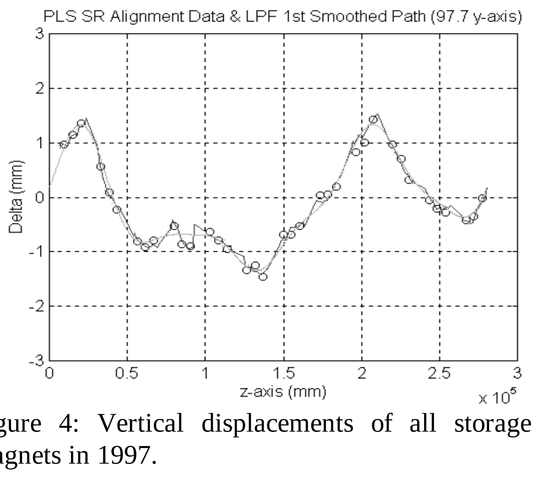

Figure 4: Vertical displacements of all storage ring magnets in 1997.

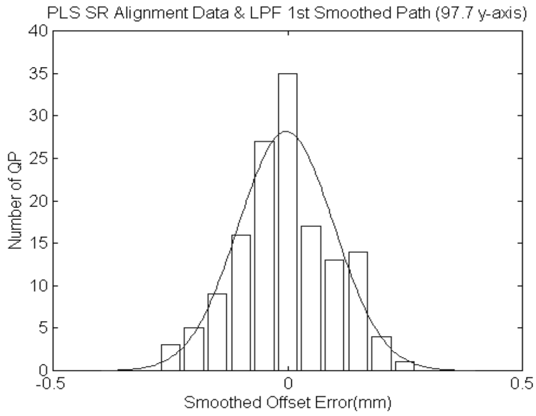

Figure 5. Histogram of the vertical displacements of quadrupole magnets in 1997.

4 CONCLUSION

The settlement of the PLS storage ring tunnel floor results in the machine deformation of ±1.5mm vertically a year. By employing the smoothing analysis by the low-pass filter method, we could assume the actual beam path in the form of a smoothed curve.

The results of a few case studies for the smoothing analyses from 1995 to 1997 show that the absolute positional tolerance that is the range of maximum deviations from the ideal beam path could be extended to ±3mm, if the 2σ(±0.3mm) of deviation criteria from the smoothed curve is achieved. Therefore, it is expected that the PLS storage ring is to be realigned in every two years.

5 REFERENCES

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