PRECISION SURVEYING AND SMOOTHING ANALYSIS FOR POHANG LIGHT SOURCE

K. W. SEO, A. H. MAENG, S. C. LEE, and I. S. KO
Pohang Accelerator Laboratory, Pohang 790-784, Korea

Abstract

The Pohang Light Source (PLS), a 2 GeV synchrotron radiation source, started its operation from August 1994. The magnets of the storage ring were aligned to a designed beam path with a relative positional error of 0.15mm(rms) in 1994. Since then the storage ring tunnel has moved by 1.0mm and 3.0mm per year(average) in the horizontal and the vertical directions, respectively. The deformation by the ground motion gives rise to the maximum offsets from the designed beam path. We introduce a smoothing analysis using a low-pass filter method in order to estimate the relative positional errors close to the actual beam path. Based on the measurement of the machine deformations and daily machine operational status, we come up with an idea of the allowable maximum offset of 2.0mm from the designed beam path. The relation between boundary conditions of the smoothing analysis and estimated maximum offset is also studied.

1. INTRODUCTION

Allowable tolerances of relative position errors (rms) for quadrupoles and sextupoles of the PLS storage ring are 0.15mm in both horizontal and vertical directions. To achieve this goal, we have introduced various precision surveying techniques such as a non-contact 3-dimensional surveying system with theodolites, conventional surveying techniques, and a GEONET program for data analysis and data base management. The positional errors (rms) of 0.15mm was obtained in positioning the quardrupoles and sextupoles in 1994. Since then, the floor of the storage ring tunnel has settled about 3.0mm per year unevenly around the tunnel. In order to estimate the floor settlement and offset errors of magnets in the storage ring, we have studied various smoothing schemes and developed a smoothing analysis using a low-pass filtering method. This technique was applied to the PLS storage ring magnet alignment successfully in August 1995, August 1996, and March 1997. Based on the smoothing analysis and daily machine operational status, we come up with an idea of the allowable maximum offset of 2.0mm from the designed beam path, and we suggest the 6 MHz of allowable filtered frequency.

2. STORAGE RING ALIGNMENT

The PLS storage ring has a 12-period Triple Bend Achromat (TBA) lattice. Its circumference is 280.56m. There are 36 bending magnets, 144 quadrupoles, and 48 sextupoles. The allowable positional errors (rms) for quadrupoles and sextupoles are Δx=0.15mm and Δy=0.15mm.[1] The alignment process of the storage ring consists of magnet fiducialization, vacuum chamber prealignment, girder rough-setting, magnet rough-setting, fine positioning, and smoothing analysis. A magnet fiducialization is the process of establishing machine coordinates by coordinate measuring machine (CMM) measurement. A pre-alignment of vacuum chamber is the process of establishing girder coordinates and aligning vacuum chamber to the girder within the maximum offset of 0.5mm using a non-contact 3-dimensional surveying system. A girder rough-setting is the process of bringing the vacuum chamber and girder assembly into the storage ring tunnel and setting it to the designed position on the basis of a storage ring tunnel survey network. A magnet rough-setting is the process of positioning magnets by adjusting 6 struts. Applying an intersection method using two theodolites, the magnets are aligned horizontally as accurately as possible. Magnet fine positioning processes which consist of surveying and adjustment are repeated 4-5 times until the positional errors of magnets are reduced within tolerance. Positional errors consist of positioning errors and offset errors. While the positioning errors in the horizontal positioning, which represent reading errors in the form of standard error ellipses, are calculated by GEONET program, those in the vertical positioning are derived from the statistics of elevation survey data. The offset errors, which are mainly described in this paper, indicate the magnet alignment status. This is the standard deviation of magnet offset values from the electron beam path.

When the magnets of the storage ring were aligned in 1994, the magnets were aligned to the designed electron beam path. Since then, we found some positional changes of the magnets and tunnel deformations. Magnet offset errors is then increased to out of tolerance which is estimated from the designed beam path. Therefore, it is necessary to study a method of estimating reasonable errors, which are called relative positional errors, based on the actual beam path, because

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the machine operation shows a normal condition in spite of magnet positional changes.[2]

3. TUNNEL DEFORMATION

The tunnel deformation is estimated by surveying the survey networks in the storage ring tunnel. The survey network of the PLS is composed of a surface net and tunnel nets. These are linked with one another that they provide the global coordinate of the PLS. The surface net consists of 10 geodetic control points around the PLS site. The tunnel net is composed of TNET and ENET. It is linked to the surface net. Control monuments of TNET are installed on the inner wall. The TNET controls the horizontal locations of the magnets. In order to control the elevation, control points of the ENET are embedded in the tunnel floor. Fig. 1 shows that the storage ring tunnel has settled unevenly about 3.0mm per year, and deformed horizontally about 1.0mm.

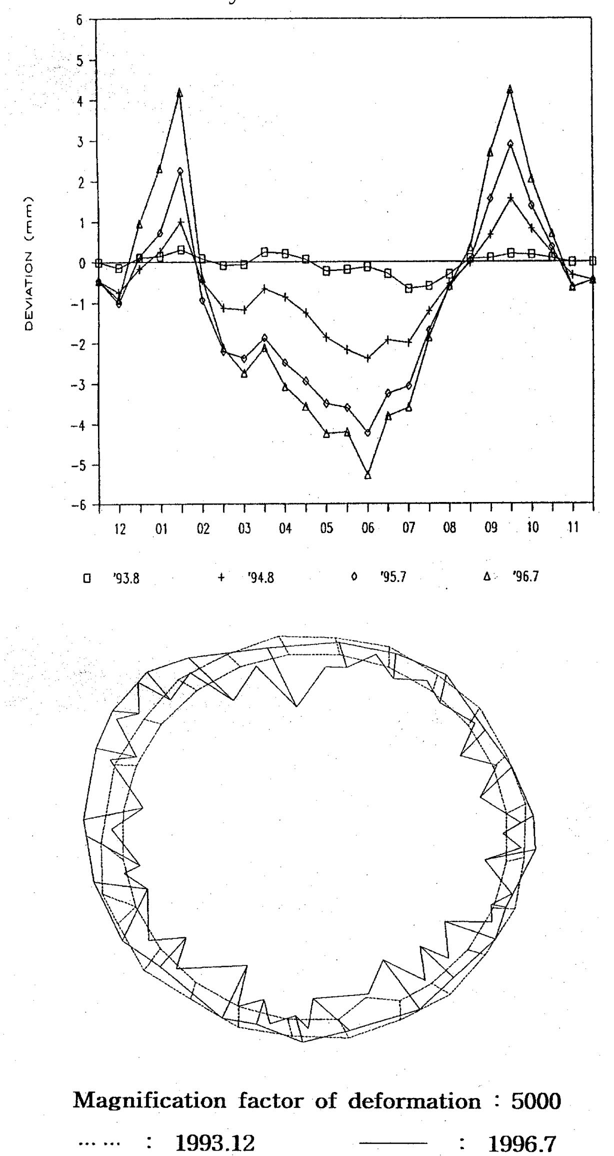


Figure 1 : Deformation of the PLS storage ring tunnel.

4. SMOOTHING ANALYSIS

A Smoothing analysis is the process of estimating a storage ring electron beam path to the actual electron beam path as closely as possible. The actual electron beam path is shown in the form of a smoothed curve by analysing the offset values of quadrupoles from the designed path. In this case, the offset errors of magnets are estimated on the basis of the smoothed curve. A smoothing analysis using a low-pass filtering method was developed and applied in August 1995. Table 1 shows that, while the offset errors on the basis of designed electron beam path are increased to out of tolerance, the errors from the smoothed curve remain within the tolerance.[3]

Table 1 : Estimation of offset errors (rms) by smoothing analysis in PLS storage ring quadrupole magnets.

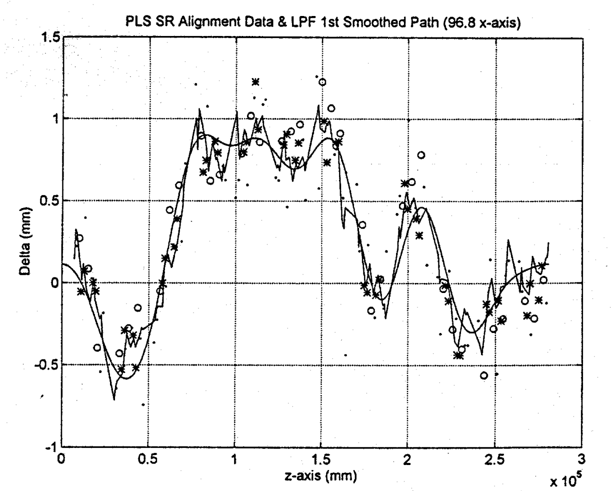
Year	Offset errors(in mm) on the basis of designed path		Offset errors(in mm) on the basis of smoothed curve	
	Δx	Δy	Δx	Δy
1994	0.139	0.075	-	-
1995	0.388	0.365	0.127	0.118
1996	0.542	1.103	0.136	0.130
1997	0.456	1.087	0.131	0.122

Applying the smoothing analysis, we investigate the relationship between allowable filtered frequency range and the offset errors of magnets. As the filtered frequencies are increased by 1 MHz step, the relative positional errors, Δx and Δy, are decreased dramatically as shown in Table 2.

Table 2 : Estimation of filtered frequencies for smoothing analysis in the PLS storage ring quadrupole magnet alignment from August 1996 to March 1997.

Freq. (MHz)	Relative positional error (rms) (unit : mm)				Remark
	1996		1997		
	Δx	Δy	Δx	Δy	
0	0.456	1.087	0.162	0.698	
1	0.300	0.742	0.144	0.427	
2	0.250	0.538	0.142	0.336	
3	0.218	0.294	0.140	0.224	
4	0.171	0.199	0.140	0.202	
5	0.153	0.162	0.131	0.166	
6	0.136	0.130	0.131	0.122	≤0.15
7	0.130	0.127	0.130	0.109	

When the filtered frequency is 6 MHz, the errors become smaller than the positional tolerance of 0.15mm (rms). In order to maintain the allowed position tolerance, we expand the boundary condition of allowable filtered frequency to 6 MHz. Previously, the filtered frequency was estimated as 3 MHz in August 1995. Fig. 2 shows a smoothed curve, which is derived from analysing the offsets of quadrupole magnets in August 1996, and magnet distributions along the curve. Also, the maximum offsets of 2.0mm from the designed electron beam path is shown in this figure.[4][5]



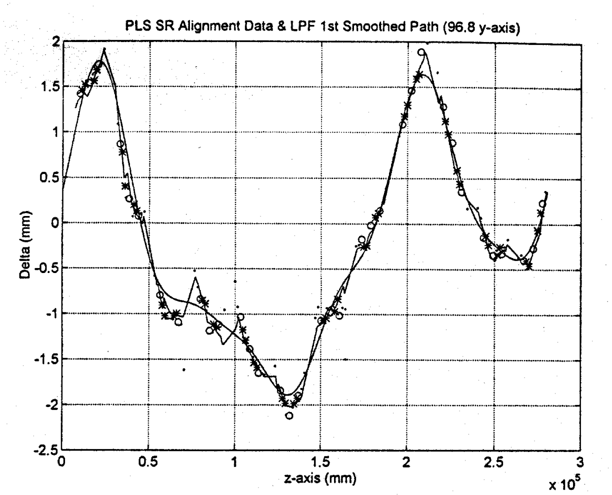


Figure 2 : Smoothed curve and magnets distribution of the PLS storage ring.

5. SUMMARY

Since the magnets of the PLS storage ring were aligned to the designed electron beam path with the positional error of 0.15mm(rms) in 1994, magnet movements due to the tunnel deformation are monitored in order to estimate when and how much the magnets of the storage ring are to be realigned. A smoothing analysis is studied and developed in order to estimate an actual electron beam path. It is shown in the form of smoothed curve, and offset errors from the estimated path. With several case studies over 1995 and 1996 period, we can understand the situation that the machine operation shows normal condition while the maximum offsets of magnet are increased as much as 2.0mm from the designed electron beam path.

REFERENCES

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[4] Annual Report, PAL, Postech, 1995.

[5] Annual Report, PAL, Postech, 1996.