ANALYSIS OF SLOW ORBIT MOVEMENT IN PLS STORAGE RING*

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Abstract

Slow orbit movement in the horizontal and vertical planes at the Pohang Light Source (PLS) storage ring is analysed with the accumulated data of BPM and environment variables such as the ambient temperature of the storage ring tunnel, the LCW temperature, the outside weather condition, and the tunnel floor elevation. Each factor causes an orbit variation with different pattern and magnitude in the horizontal and/or vertical planes. Facts and causes of slow orbit movement are described as well as the orbit feedback in use or under preparation.

1 INTRODUCTION

The PLS lattice is a triple bend achromat with 12 superperiods and 280.56m circumference, and each superperiod has 12 quadrupole magnets. The operating beam energy is 2.5GeV and the maximum beam current is 200mA. In the usual user-service operation the beam is directly injected from the 2.5GeV electron linac twice a day, which was changed from the energy ramping from 2GeV in October 2002. For the PLS with the natural emittance of 18.9 nm-rad, assuming a 1%-betatron coupling, the orbit stability requirements in position for 0.1% photon intensity fluctuation at beam lines are 20μm for the horizontal plane and 3μm for the vertical plane.

From the operation data of two years since 2000, it was clearly seen that the magnitude of the slow orbit movement, which is below 0.1 Hz in the frequency range, is much larger than that of the fast one that is mainly due to magnet power supply ripple, and particularly the orbit movement in the vertical plane is an order of magnitude larger than the orbit stability requirement. A simultaneous change in both horizontal and vertical planes is typical in the slow orbit movement: the average change in the horizontal plane and the rms change in the vertical plane, and the slow orbit movement is correlated with the outside temperature change and dominates during the change of season like spring and fall.

There is also an orbit movement only in the vertical plane, while no movement in the horizontal plane, in case of rainfall or a localized change of the ambient temperature of the storage ring tunnel. Even though regular survey alignment is performed twice a year at the PLS, ground settling and ground diffusion result in changes of the position of each magnet during the machine operation time.

This paper describes the effects of various environmental factors on the slow orbit movement at the PLS storage ring by analysing the accumulated orbit data since 2000. Factors are investigated in detail such as outside temperature, rainfall, tunnel air temperature, LCW temperature. In particular, the issue of differential ground settlement is emphasized.

2 ENVIORNMENTAL FACTORS

The horizontal and vertical movement of the beam relative to the quadrupoles can be observed directly with the BPMs. The number of BPMs installed per superperiod (hereinafter “cell”) is 9, and totally 108 BPMs. Several BPMs show frequent problems or suspicious behaviours. Such BPMs (about 14 out of 108) are removed from the analysis.

2.1 Tunnel Air Temperature

For ambient temperature control the tunnel area is divided into six zones each of which covers two cells. The tunnel air temperature of each zone is independently controlled with a stability of ±0.1°C by a temperature-controlled circulating airflow. The temperature control system for each zone controls the average temperature of eight temperature sensors that are installed close to the quadrupole magnets. Therefore, the ambient tunnel temperature must be different from the sensor temperatures and not uniform, and a temperature gradient along the tunnel or around magnets is unavoidable because the airflow is different everywhere and even around a single dipole magnet. The ambient temperature non-uniformity depends on the airflow rate and flow mixing in the tunnel.

Figure 1 shows the sensor temperatures at cell 9, 10, and 11, and BPM readings in the vertical plane at cell 5 when the supply air temperature for cell 10 and 11 changed abruptly by about +1°C for 3 hours. At the event the tunnel air temperature at cell 10 increases by 0.42°C, a very small change in cell 9 and 11, and no change in other cells. The BPM readings started to change at the onset of change of supply air temperature, around 5:30 AM. The resultant rms change in the vertical orbit is about 20μm. However, no change is observed in the horizontal plane.

At the temperature-changing area there might be a position change of quadrupole magnet in the vertical direction rather than the horizontal direction. Each cell has two sector girders on which 12 quadrupole magnets are installed. It is difficult to estimate the accurate position change of each quad when the ambient tunnel temperature changes. The deformation of the 10-m long sector girder is so complex that each quad on the sector girder changes its position very differently.

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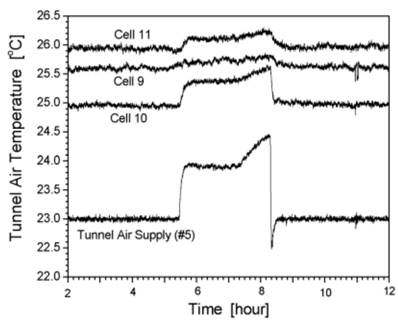
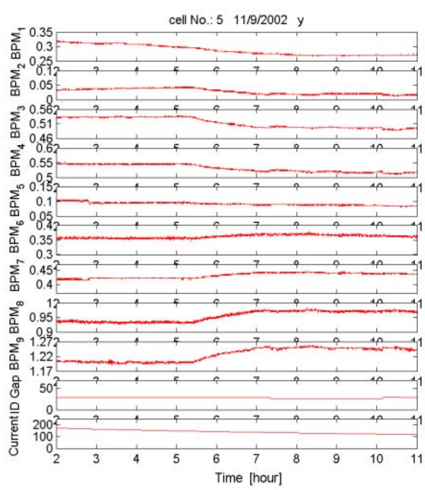
2.2 LCW Temperature

The LCW control system supplies the cooling water with a stability of ±0.1°C to all magnets, vacuum chambers, and photon stops. The closed orbit looks likes to be affected by magnet temperature change that is directly related to the LCW temperature. The structural change of magnet poles, especially, of quadrupole magnet contributes to orbit movement.

It is observed that the horizontal orbit is much more dependent on the LCW temperature than the vertical orbit. However, in the BPM reading there is also a contribution from the vacuum chamber movement due to the temperature change of the vacuum chambers, especially the photon stops where most of photon power is absorbed.



(a)



(b)

Figure 1: The tunnel air temperature at cell 9, 10, 11 (a) and BPMs in the vertical plane at cell 5 (b) when the supply air temperature for those cells increases rapidly about 1°C for 3 hours. The unit of BPMs in (b) is mm.

2.3 Weather Effect

1) Outside Temperature Change

The differential ground movement is closely related to the temperature variation of the surface ground. A substantial change of outside temperature can cause a temperature variation of the surface ground, which results in a differential ground movement. “Substantial change of outside temperature” means a continuous change for at least a few days, which can induce a ground movement, while a diurnal big change for only one day cannot do.

Even though the tunnel air temperature is well controlled by a forced airflow system, which is normally a sort of cooling system with a limited flow capacity, the outside temperature may affect the tunnel air temperature by the increase of heat transfer to the building wall. A diurnal change of the outside temperature can affect in this case.

Figure 2 shows the average and rms of the orbit in the horizontal and vertical planes without the RF frequency feedback. Without the RF frequency feedback the average in the horizontal plane changes as much as 100μm and the rms in the vertical orbit changes about 40μm, which exactly follow the change of daily average temperature in local area, about 9°C for five days as shown in Fig. 3.

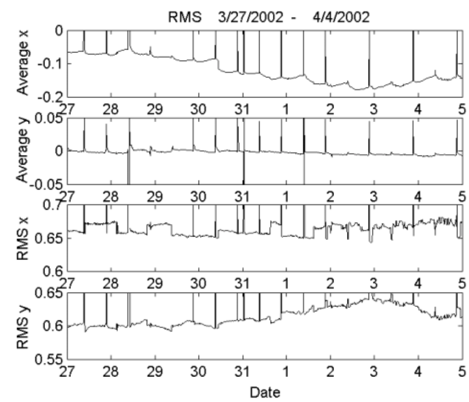


Figure 2: The average and rms of the orbit without the RF frequency feedback. X and y represent the beam position in the horizontal and vertical plane, respectively. The ordinates are in mm.

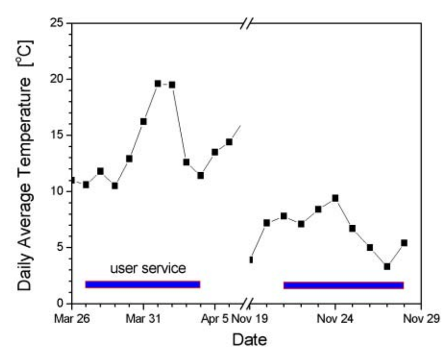


Figure 3: The daily average of outside temperature from March 26 - April 6, and November 19-28, 2002.

The rms in the vertical plane changes slowly about 40μm with the same time-correlation as the average in the horizontal plane as shown in Fig. 2. The time-correlation between the horizontal orbit drift and the COD in the vertical plane implies that both are caused by the same source. The COD in the vertical plane is mainly affected by two factors: one is the quadrupole magnet alignment errors which vary as the ground movement and the tunnel air temperature, and the other is sqew quadrupole field.

A measurement of the rms of vertical orbit and the average of horizontal orbit as a function of RF frequency shows that when the horizontal orbit moves about 100μm by changing the RF frequency, simulating the same change of Fig. 2, the rms in the vertical plane changes only 4μm, very small compared to 40μm of Fig. 2.

The changes of the rms in the vertical plane as shown in Fig. 2 result mainly from the change of quadrupole magnet positions which seem to be affected by the outside temperature change. However, it is difficult to estimate the differential ground movement with respect to the outside temperature because geological problem is complex and too many variables are unknown.

2) Rainfall

When it rains, some movement of orbit in the vertical plane is frequently observed at the PLS. Some of the ground movements are clearly correlated to fluctuations in the underground water table height. However, the average of horizontal and vertical orbit, and the rms of horizontal orbit almost unchanged. The changes of rms in the vertical plane seem to be due to differential ground settlement of the ring tunnel caused by rainfall.

3 DIFFERENTIAL GROUND SETTLEMENT

The changes of vertical offset between the beam position and the centre of quadrupole magnet mainly come from differential ground settlement. Ground motion is classified as wave dominated, ATL dominated and systematic motion dominated [1]. The sources of the slow ground motion are atmospheric activity, change of underground water, ocean tide, temperature variation of the surface ground and so on [2].

The very slow ground motion observed in the PLS appears to be systematic in time. The tunnel elevation of the PLS storage ring has changed continuously. It is seen that the peak-to-peak of elevation deviation has increased since June 1993, which reached the accumulated value of about 22mm as of July 2002. The tunnel floor elevation changes in average by about 1.2mm per year. The ground settlement is relatively worse at cell 1, cell 6 and cell 9. The rate of this ground motion has decreased over time, but preserving the direction of motion.

From the survey data of almost ten years it is known that the ground settlement occurs dominantly between July and February of the next year, which implies the most change is activated during the period of cold winter months. It seems reasonable to think that the differential ground settlement is mostly activated by the soil shrinkage during the cold winter months after heavy rainfall during the rainy months of July to September.

The vertical positions of quadrupole magnets change in a systematic way by the differential ground settlement. Figure 4 shows the vertical position changes of quadrupole magnets and the tunnel floor elevation between February and July 2002, which are the differences of the survey data in February and July. The positions of quadrupole magnets change smoothly in-group and step changes between groups are clearly seen because magnets are installed on the sector girders. The magnet-to-magnet alignment on each girder stays relatively constant over time, but the girders move independently with respect to each other.

The slow orbit movement in the vertical plane in the PLS storage ring is mainly due to the differential ground settlement.

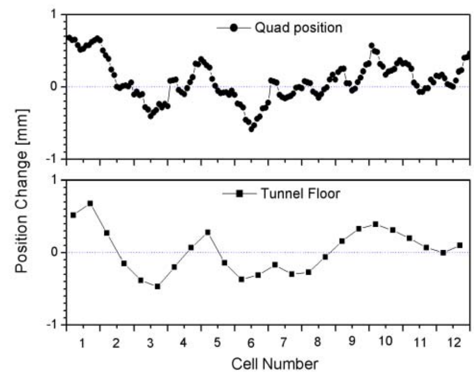


Figure 4: The vertical position change from February to July 2002; upper figure: quadrupole magnets, lower figure: SR tunnel floor elevation.

4 FEEDDBACK SYSTEM

In order to achieve the orbit stability of a few μm, a global orbit feedback system is absolutely necessary. A slow global orbit feedback system using a SVD algorithm is being prepared. The RF frequency feedback has been in operation since November 2002 to compensate the circumference change. With the RF frequency feedback the average in the horizontal orbit is bounded within ±2μm.

As for the implementation of global orbit feedback system, the reference orbit for the feedback is very important and should be re-established at a proper time; the analysis of the tunnel ground movement data helps to decide when the reference orbit should be re-established. And it is important to know the correlation between environment factors and those effects on orbit. A better understanding of slow orbit movement, sources and temporal behaviours, is essential for the orbit feedback.

REFERENCES

[1] Andrei Seryi et al., Proc. of the 20th Linac Conference, Monterey, USA, 2000, p. 68.

[2] Shigeru Takeda et al., Proc. of the 2000 EPAC, Viena, Austria, 2000, p. 2394.