INVESTIGATION OF ENVIRONMENTAL FACTORS AFFECTING ELECTRON BEAM ORBIT AT PLS STORAGE RING

Y. C. Kim, S. J. Kwon, S. J. Park, K. R. Kim and C. W. Chung
Pohang Accelerator Laboratory, POSTECH, Pohang, Korea, 790-784

Abstract

The investigation on the stabilization of the beam orbit in the PLS storage ring has been conducted to enhance ID beamline performances. We have carefully performed the measurement on the thermal deformation of machine components comprising magnets, girders and vacuum chambers. The measurements were especially focused on local sector #4 in PLS storage ring due to the experimental setup scale limitation at the beginning stage. Data collection was conducted during normal user service beam time to evaluate the environmental influence. As a result, the clue was found that there might be a strong correlation between the beam orbit stability and the mechanical behaviors of the magnets. It is analyzed that the ramping process caused the deformation of quadrupole magnets during user beam time and bending magnet during beam injection period in the order of a few and a few tens of micrometers respectively, resulting in beam orbit drift about one order higher in magnitude.

1 INTRODUCTION

As the number of beamline requiring the micro-spot high resolution photon beams such as U7, EPU and U10, has been increased, the stabilization of the electron beam orbit drift emerges to be essential. Hence, efforts to improve the beam stability are being conducted in various related fields such as RF, diagnostics of electronic devices, control, etc. Besides these electronics fields, it is known that the motions of mechanical components mostly due to thermal variations have a great influence on the electron beam orbit drift [1][2][3]. As an activity of those efforts, we measured mechanical movements of machine components at the storage ring cell #4 to analyze the relations between these motions and beam orbit, and further to investigate the functions of the environmental factors such as temperature changes of components themselves, cooling water and surrounding air, etc.

2 EXPERIMENT

Included in the measurements are vertical movements of a dipole magnet (BM3), ports of beam position monitors (BPMs) installed in the vacuum chamber and a quadrupole magnet (Q2D). Fig. 1 shows the sector chamber 2 of cell #4.

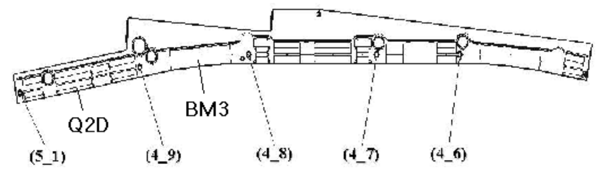

Figure 1: Location of measurement objects. Sector chamber 2 of cell no. 4 is selected for measurements.

The measuring points for BPMs and the location of magnets are also shown.

Measurements of vertical deformation of BM3 and Q2D are performed at each 3 points on the top and bottom surfaces of magnets. Digital probes (0.3 ㎛ of resolution, Solartron Metrology) and SUS rods were used as the motion measuring devices and the stands of measurement set-up, respectively.

To rule out the effects of the thermal deformation of SUS stand on the records of real motions of components, additional test measurements of carbon block were performed by use of the SUS stand for the calculation of thermal expansion coefficient of this stand. This measurement yields the SUS stand thermal expansion coefficient value of approximately 11 ㎛/m/℃ and the error bounds of approximately ±2 ㎛. The measured raw data were accordingly calibrated.

3 RESULTS AND DISCUSSION

3.1 Dipole magnet (BM3)

The vertical motion of BM3 measured for 48 hours during normal user service beam time are plotted with the BPM (4_9) measurements of the electron beam position for comparison in Fig. 2. Big excursions of approximately 1 to 2 mm in the electron beam orbit appeared from the BPM measurement at every beam injection time, and the similar phenomenon in the deformation of BM3 in vertical direction. Details of 2nd and 3rd sharp changes in Fig. 2 are shown together in Fig. 3 with enlarged time

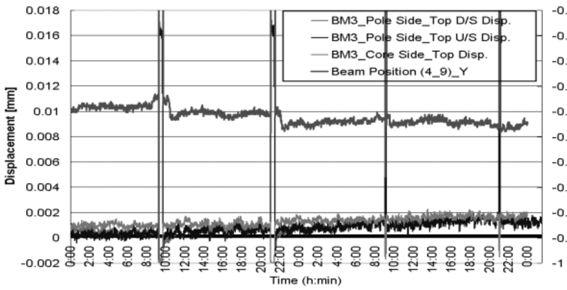

Figure 2: Deformation of BM3 in vertical direction and trace of electron beam position taken from BPM (4_9) for 2 days

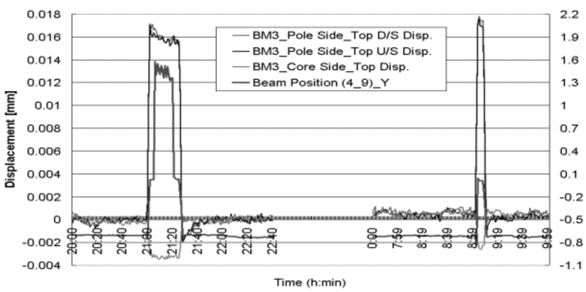

Figure 3: Details of two typical motions of BM3 and the trace of electron beam orbit at two different beam injection times

span. It can be seen from this figure that the sudden deformation of BM3 of about 17 ㎛ in vertical direction induces two types of sudden changes in the electron beam orbit. One is a big electron beam excursion of about 2,300 ㎛ in maximum with a step at about 700 ㎛, and the other is of 700 ㎛ in maximum. The difference of orbit drift by the same amount of BM3 deformation is caused by the beam injection mode that needs more investigation.

These behaviors of magnet were proved to be caused by the ramping process for electron beam fill-up. The operation of storage ring machine at the energy of 2.5 GeV in spite of kicker system fitted for lower energy of about 2 GeV is the reason of ramping process for electron beam injection. At present operation mode, electron beam injections of around every 12 hours interval is done under the lowered beam energy of 2 GeV, and the energy is ramped up to 2.5 GeV soon after the injection for normal user service beam time. To verify this BM3 motion FEM analysis were done with the input of beam energy of 2 GeV and 2.5 GeV. FEM analysis yields the value of approximately 35 ㎛, almost twice of actual measured value, as a vertical deformation of BM3 at the upper part of core side due to the difference of electromagnetic forces between the energy of 2 GeV and 2.5 GeV.

Vertical deformation of BM3 during normal user service times was found to be negligible in view of magnitude of deformations except the time of beam injections. However the vertical reading values from the BPM (4_9) located just after (downstream) the BM3 show quite a big electron beam orbit drift with the maximum value of about 50 ㎛ during the same time span between beam injections. These orbit drifts are not directly related to the movement of BM3 but to other unidentified causes.

3.2 BPM Chamber

The measured vertical motion of BPMs during 48 hours was compared with the electron beam position recorded by the same BPMs as shown in Fig. 4. From this figure it is noted that the real mechanical movements of BPMs in

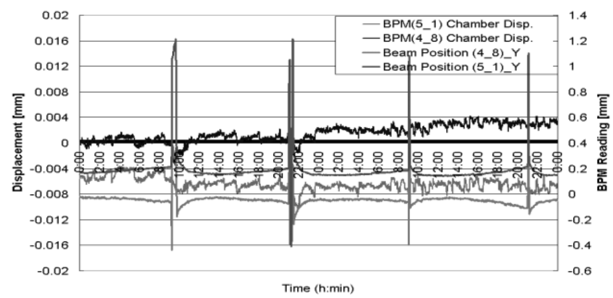

Figure 4: Vertical motion of BPM chamber and electron beam position measured by BPM (5_1) for 2 days

vertical direction are about 4 ㎛ in maximum during the whole measuring time, and the values of electron beam position vary up to about 100 to 200 ㎛ except the times of ramping process. From this fact, it is assured that the real mechanical movements of chamber at the BPMs do not contribute to the value of electron beam orbit drift recorded by the BPMs on the contrary to our suspicion.

3.3 Quadrupole Magnet (Q2D)

Vertical motion and cooling water temperature of Q2D were measured for the same days as the aforementioned measurement. In Fig. 5, the measured data are compared with the records of electron beam position from BPM (5_1) located just downstream side of Q2D. The temperature changes of the returned cooling water and Q2D are also shown in Fig. 6 to check the relation with vertical movement of the top surface of Q2D. As mentioned before, sharp spikes at the time of beam injections in the electron beam orbit are mainly caused by

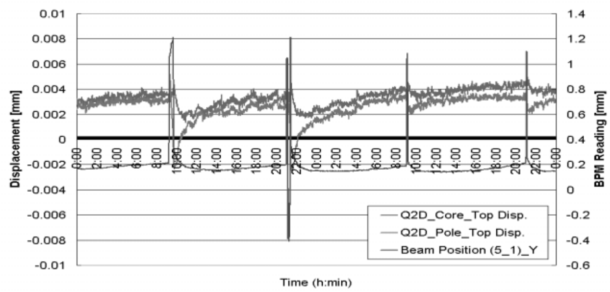

Figure 5: Deformation of Q2D and the trace of electron beam position for two days period

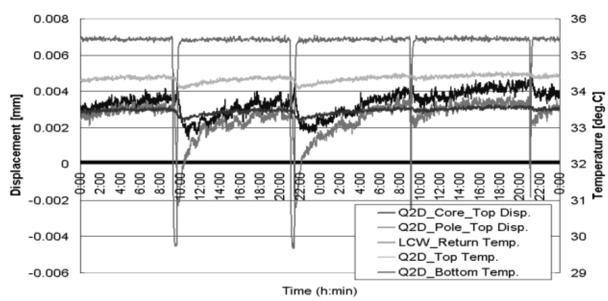

Figure 6: Graph for the deformation and temperatures of Q2D as well as the returned cooling water temperature

the deformation of BM3. From the Fig. 5, it is estimated that there are close correlation between the vertical motion of top surface of Q2D and electron beam orbit drift during the user beam time. However the correlation coefficient seems not easy to be taken from the graph in Fig. 5. It is estimated that the major vertical movement of Q2D is caused originally by the temperature drop of returned cooling water during ramping process. After ramping process the aforementioned vertical motion are recovered very slowly during the whole user service beam time in spite of quick recovery of cooling water temperature at returned side, and consequently electron beam orbit drift is induced as shown in Fig. 5.

3.4 Girder

Since all the mechanical components mentioned above are fixed on the girder with proper supports, the movement of girder especially in vertical direction is important. However, due to the limitation of numbers of measuring devices only three points, each under the pole and core side BM3 and one under Q2D, were selected for measurement.

The amplitudes of movement for 2 days were almost within the error bound of measurement. No specific relation of girder movement itself with beam orbit drift was found at this measurement.

4 SUMMARY

Vertical motions of mechanical components of storage ring cell no. 4 were measured for 2 days during user service beam time. Data for electron beam position during the above measurement period were also collected and compared with motions of components to analyze the cause and effects of beam orbit drift. Sudden large orbit drift at every beam fill-up time is found to be caused by the ramping process for 2.5 GeV operation at PLS. The vertical motion of Q2D shows close correlation with slow electron beam orbit drift during normal beam time between beam injection events. The motion of Q2D are caused originally by a large temperature drop of approximately 6 degree C due to ramping process at the returned cooling water. The mechanical movements of vacuum chamber at the locations of BPMs are very small compared to the electron beam position changes, and need not to be accounted for the analysis of electron beam orbit drift. As for the girder, vertical movements for the period were within the error bounds. And no significant effect of air temperature on the electron beam orbit was analyzed in this investigation.

Further detailed measurements are under planning and efforts to improve the identified issues such as operation mode, cooling capacities, etc. shall be implemented.

5 REFERENCES

[1] L. Solomon, D. Lynch, J. Safranek and O. Singh, "Chamber Motion Measurements at the NSLS X-ray Ring", 1999 Particle Accelerator Conference, New York

[2] J. R. Chen, Z. D. Tsai, C. K. Kuan, S. H. Chang, D. Lee, F. Y. Lin and D. J. Wang, "Utility and Mechanical Component Stability at SRRC", 1st International Workshop on Mechanical Engineering Design of Synchrotron Radiation Equipment and Instrumentation, Würenlingen/Villigen, Switzerland

[3] C. K. Kuan, D. J. Wang, K. Y. Kuo and J. R. Chen "The Mechanical Stability of the Electron Beam Position Monitor at the Taiwan Light Source", Proceedings of EPAC 2000, Vienna, Austria