THE CORRELATION BETWEEN THE BEAM ORBIT STABILITY AND THE UTILITIES AT SRRC

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Abstract

The correlation among the air temperature, the water temperature and the beam position was studied at the Synchrotron Radiation Research Center (SRRC). A photon beam position monitor was set up to clarify these relations. The result data indicated that beam orbit fluctuation was strongly correlated to the temperature variation, and recent improvements on SRRC utilities increased the beam stability. Experimental results showed that the fluctuation of the vertical beam position could be controlled to be ≤±10μm in one shift operation.

1 INTODUCTION

The Taiwan Light Source (TLS) [1] at the Synchrotron Radiation Research Center (SRRC) is one of the third generation light sources which characterize with low emittance of the electron beam. In such a machine, any variation of the machine parameters might make the beam unstable. In order to keep the beam position stable, it is necessary to control the environmental conditions around the machine.

In 1997, Keller et al. [2] studied the correlation between the beam orbit stability and the utility conditions for the Advanced Light Source (ALS). At the TLS, a similar work has also been conducted. A photon beam position monitor was set up [3] for increasing the detection resolution. The correlation between the beam orbit variation and the temperature fluctuation (of the air and the cooling water) were studied.

2 UTILITY SYSTEM

2.1 Cooling Water System

The cooling water system consists of three subsystems, the cooling tower water (CTW) system, the chilled water (CHW) system, and the de-ionized water (DIW) system.

The CTW, with a capacity of 3300GPM, was used for removing the heat generated in the chiller. Four cooling towers, each with a capacity of 453 RT, were used. The CTW system temperature was controlled by an ON/OFF switch of the cooling fans. The outlet temperature was controlled to be at 29.5±1.5°C.

Three chillers, each with a capacity of 320 RT, were equipped. The CHW was divided into two major branches, one is used for the DIW system, and the other is used for the air handling units (AHU, with a capacity of 1334 GPM). The CHW outlet temperature was controlled to be at 7.6±0.2°C.

Three individual DIW loops supplied DIW to the storage ring copper system (500 GPM), the aluminum vacuum system (100 GPM) and the beam line system (100 GPM). The temperature control of the DIW was mainly achieved by regulating the flow rate of the chilled water through the heat exchanger. In this work, the authors emphasized the studies on the storage ring copper DIW system, which supplied DIW to the magnets, the power supplies, and two secondary-loop heat exchangers of the RF system. The DIW outlet temperature was controlled to be at 25.0±0.15°C.

2.2 Air Conditioning System

There were ten sub-branches of the CHW system suppling chilled water to ten AHUs, with two for the booster synchrotron, three for offices, four for the storage ring tunnel and the beam line floor, and one for the core area of the storage ring. In the core area, all the magnet power supplies, RF transmitters, vacuum controllers, and many other instruments were located.

The temperature in the storage ring tunnel was controlled by activating the dampers at the AHUs and the reheat boxes near the outlet ports in the storage ring tunnel. The temperature fluctuation in the tunnel was controlled to be at about ±0.2°C within one operation-shift (~6 hrs). However, the absolute temperature (about 25°C) could change from place to place depending on different heat sources at different locations in the tunnel.

3 RESULT AND DISCUSSION

3.1 Beam Position Measurement

A photon beam position monitor (PBPM) system was set up [3] to measure the photon beam position in vertical direction. The resolutions of the PBPM system were < 0.5 μm and <0.5 μrad in position and angle, respectively.

The time-behavior, amplitude in position and angle, and the possible source of the observed beam position variation are summarized in Table 1. The results are classified into four different time-behaviors: periodical variation, transient after injection, long term drift and sudden change of the beam position.

Table 1: Beam position fluctuations and related sources

Time Behavior	Vertical Amplitude	Possible source	Remark*
(A) Periodical			
T < 1 min.	< ±1µm	Vibration	C
T ≈ 1 min.	≤ ±1µm		C
T ≈ 5 min.	≤ ±2µm		C
T ≈ 30 min.	≈ ±5~10µm	Utility (Cooling Tower)	A
T ≈ 1~2 hr.	≈ ±5~10µm	Utility (Cooling Tower)	A
(B) Injection			
Discontinuity	≈ ±10µm	Hystersis	C
Transient after injection τ~0.5 hr, τ~2 hr.	≈ 20µm	Temperature variation (magnet, RF, power supply)	B+
(C) Long Term Drift T = 1 day	≥ 100µm/day	Tunnel temperature or outdoor temperature variation	A
(D) Sudden Change	≤ 20µm	Magnet field	C

*A – strong evidence, B – weak evidence, C – speculation.

3.2 Water Temperature Variation

The original designed specification of DIW temperature variation was ±1°C. However, it was noticed that soon after the beginning of the operation, this criterion was not enough for stable beam. Recently, the DIW temperature at TLS has been improved from ±1°C to ≈±0.2°C (peak to peak). No significant correlation between the DIW temperature variation and the beam orbit fluctuation was observed. However, as listed in Table 1, beam position variation of as high as 5~10µm with periods of 30 minutes or 1~2 hours was observed. The time structure of this kind of beam orbit variation was found strongly correlated to the time structure of the CTW temperature variation.

The fans of the cooling towers were set to operate in an ON/OFF mode by the temperature-limit-settings. So that a high and unsmooth CTW temperature variation (±1.5°C) was induced. In the near future, the variable frequency controllers are to be adopted to decrease the CTW outlet temperature fluctuation.

3.3 Air Temperature Variation

Similar to the specification of the water system, the original specification of the air temperature variation (±1°C) in the storage ring tunnel could not meet the requirement for a stable beam. Recently, several temperature sensors have been installed in the tunnel. After the preliminary study and the followed improvement, the air temperature variation was controlled to be at ≤±0.1°C (peak to peak) in one operation-shift. Figure 1 shows typical curves of the tunnel temperature and the vertical beam position in one single operation-shift. The beam position variation could be kept at ≤±10µm.

In addition to the small temperature variation within a smooth operation-shift, three kinds of air temperature variations were existed. All these three variations strongly impacted the beam orbit.

The first variation was the daily variation of the air temperature in the tunnel. Although the daily variation was small (Δt≈0.4°C peak to peak), a significant beam orbit fluctuation (≥100µm) was induced as listed in Table 1. Because the daily air temperature variation in the tunnel was not so large, the beam orbit variation might be induced through other routes.

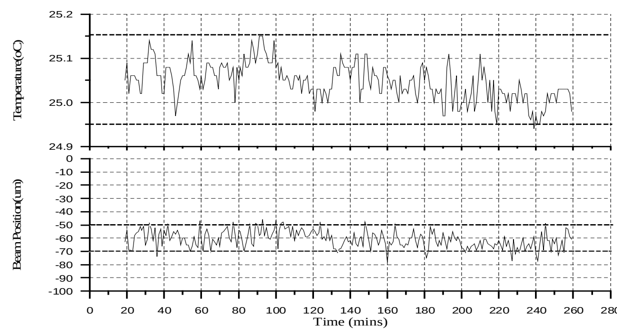

Figure 1: The status of the temperature in the tunnel and the beam position during one operation-shift period.

The second variation was the temperature variation at each injection. At the TLS, the electron beam energy was 1.5GeV during the normal operation. However, due to the energy limitation of the booster, it is necessary to ramp down the electron beam energy to 1.3GeV for injection, and then ramp up to 1.5GeV again for user shift. This procedure caused a large variation of the magnet coil temperature and thus a large air temperature variation (~0.5°C) in the tunnel with a transient time constant of ~0.5 hr. The corresponding beam orbit variation was about 20µm. Some other devices, such as the septum and kickers also contributed to the temperature variations during the injection period. To minimize the variation caused by the injection, a plan of upgrading the injection energy to 1.5GeV is underway.

A special case existed at the first injection in a week. In such case, the air temperature in the tunnel was heated up for about 4°C with a transient for several hours.

The third variation, with a temperature variation of ≤±0.2°C in the tunnel and different timing structures (could be either random or periodical), introduced a beam position variation of ≤±5µm. The effort to resolve the correlation between this kind of temperature variation and the beam orbit variation is mentioned in the next section.

3.4 System Modeling

A. Mathematical Simulation

In order to correlate the perturbations, some statistics were calculated. The equation [4]

$$r = \frac{C_{beam/air}}{\sigma_{beam}\sigma_{air}} \quad (1)$$

was applied to determine the correlation coefficient (r), where σ_{beam} and σ_{air} are the standard deviations of the vertical beam position and the tunnel temperature, respectively, and $C_{beam/air}$ is the corvariance of these two variables. Figure 2 shows the results of the daily records from Nov.1997 to Apr.1998. In this figure, it shows that a clear correlation existed as the air temperature variation was ≥0.3°C. However, the correlation was hard to be observed when the temperature variation was ≤0.2°C.

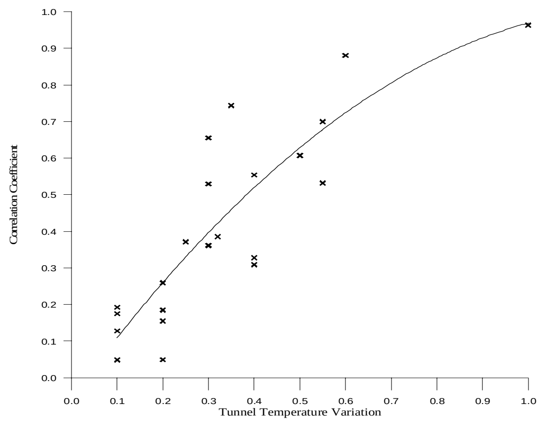

Figure 2: The relationship between the correlation coefficient and the air temperature variation in the tunnel.

B. Variation Propagation

Some of the variation sources and the propagation routes are clear, especially in the case when the beam orbit variation is >20μm, as discussed in the previous sections. The source and the propagation route are not clear, however, in the case when the beam orbit variation is <5μm.

Based on the water system and the AHU system of the TLS, figure 3 models the possible sources and the propagation routes that resulted in the temperature variation and the beam orbit variation. This flow chart provides a guideline for further studies and improvements on the variations. Further modifications of this chart might also be necessary accordingly.

4 CONCLUSION

The correlation between the beam orbit stability and the utilities at TLS was studied. A photon BPM system, with a resolution <0.5μm, was setup. The temperature variations of the DIW and the air system were improved from ≥±1°C to ≤±0.2°C.

Three major correlations were resolved between the air/water temperature and beam orbit variation. The daily temperature variation could result in a beam orbit variation as high as ≥100μm. The temperature variation at injection period could result in a beam orbit variation of ~20μm. The fluctuation of CTW temperature (±1.5°C) could result in a beam orbit variation of 5~10μm.

The sources and the propagation routes are not clear for the beam orbit variation of ≤5μm. A statistics calculation indicated that the correlation was not evident between the air temperature fluctuation and beam orbit variation as the air temperature fluctuation was ≤0.2°C. In order to understand the correlation for the cases of beam orbit variation <5μm, a perturbation propagation chart was proposed.

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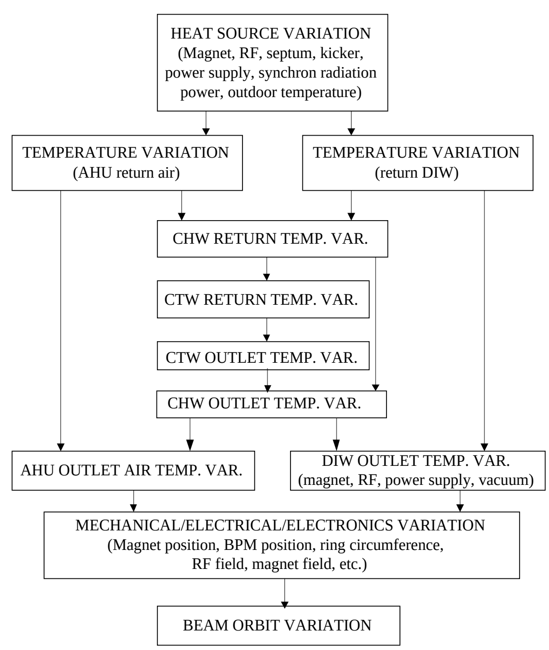

Figure 3: Flow chart of the propagation of temperature variations to the beam orbit variation.