THE EFFECT OF IMPROVING THE TEMPERATURE VARIATION AT THE SRRC STORAGE RING

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Abstract

Temperature variation is a major effect to the electron beam orbit stability. A series of studies were conducted at the SRRC. A significant improvement was achieved by upgrading the injection energy from 1.3GeV to 1.5GeV. Also, the effect due to the decay of the beam current was improved by re-arranging the cooling system and by improving the control method.

1. INTRODUCTION

In 1997, Keller et al. [1] studied the correlation between the beam orbit stability and the utility conditions for the Advanced Light Source (ALS). The Synchrotron Radiation Research Center (SRRC) has also preceded a series of studies on thermal effects and improvements of the beam orbit stability [2][3]. These studies were to investigate what the thermal path was and to reduce the related effects on the beam stability. Currently, the de-ionized water systems and the air conditioning systems are two major cooling systems for the storage ring and booster at SRRC. If the water or the air temperature fluctuates, the original physical characteristics of the devices, such as girder position, vacuum chamber location, magnet field etc, might change. In result, some beam characteristics might also change significantly. This paper investigated the orbit instability problems that might be caused by temperature effect and presented a variety of control and cooling methods to reduce the temperature variation.

2. UTILITY SYSTEM

The de-ionized water systems and the air conditioning systems are two major cooling systems at SRRC. The de-ionized water systems consist of three subsystems, the copper system, the aluminum system and the beam line system. The copper DIW system supplies DIW to magnets, power supplies, RF transmitters and cavities. The aluminum and the beam line DIW systems supply DIW to vacuum chambers and to beam line devices that require water-cooling, respectively. In each DIW loop, there are two heat exchangers. By adjusting the flow of the chilled water and cooling water through the heat exchangers, the temperature variation of the DIW is control to within ±0.15°C. In the mean time, by regulating the pump frequency, the flow pressure is stabilized to within ±0.1kg/cm^2. In the aspect of air conditioning, there are ten AHUs (Air Handling Units) in charging of air cooling of the ring, two to the booster synchrotron, three for the ring labs, four for the storage ring tunnel and the beam line floor, and one for the core area. By adjusting the two-way valves and vanes, the temperature in the storage ring tunnel could be kept constant. Currently, the temperature variation in the tunnel is controlled to within ±0.2°C, with relations to the time.

3. TEMPERATURE VARIATIONS AND PROPAGATION PATHS

A series of experiments and observations have been done to trace the thermal paths of the temperature variation in details. The thermal load of the ring is exchanged by the cooling water and the air conditioning systems. The major heat load is taken away by the DIW system. The rest of the heat load diffusing to the air is taken away by air-handling units (AHU). The DIW system in the tunnel is divided into two loops, the aluminum and the copper DIW systems. The copper DIW temperature variation caused by the heat generation of magnet coils affects the magnet fields and consequently induces further beam orbit instability with the sensitivity factor of 5~50μm/°C, as shown in Fig. 1. On the other hand, the temperature variation of the returned aluminum DIW that is caused by beam decay leads to a temperature change of the vacuum chamber for about 1°C in each beam shift. The thermal load remains in the chamber could produce mechanical strain of the chamber. As a result, the chamber will extrude itself from each other, which causes an unexpected mechanical position shift for about 2~10μm in each beam shift as shown in Fig. 2. Meanwhile, if the heat load diffusing to the air in the ring is not well controlled, those non-water-cooling devices such as insertion devices, the yokes of the dipole, quadrupole and sextupole, and the girders etc., will be affected as shown in Fig. 3, 4. Some mechanical structures of the devices will be changed and lead to a magnet field variation and a beam obit shift with the sensitivity factor of 20~50μm/°C as shown in Fig. 5. From the above observations, the thermal paths and its effects on the beam obit instability were depicted in Fig. 6.

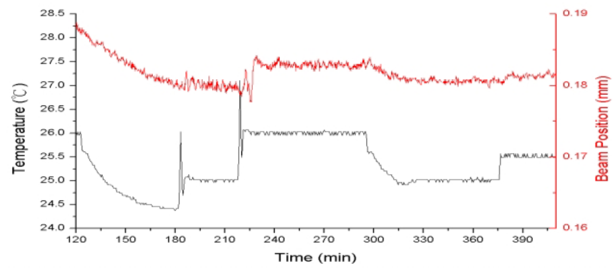

Fig. 1 Beam position vs. copper DIW temperature variations

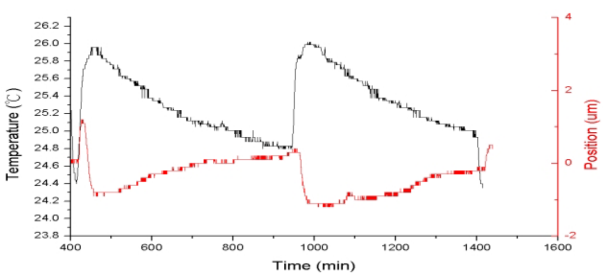

Fig. 2 Vacuum chamber position vs. aluminum DIW temperature variations

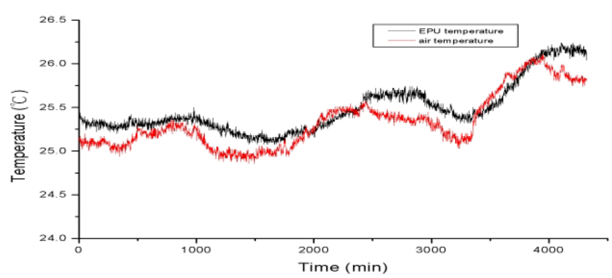

Fig. 3 Insertion device temperature vs. air temperature variations

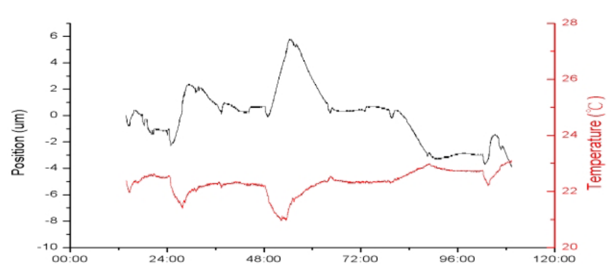

Fig. 4 Girder deformation vs. air temperature variations

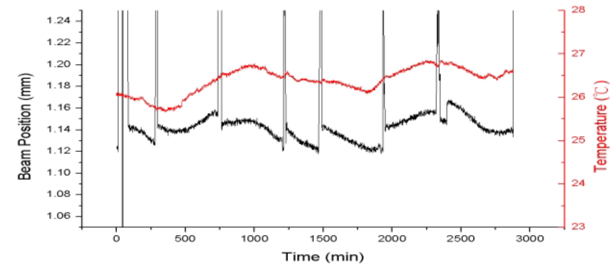

Fig. 5 Beam position vs. air temperature variations

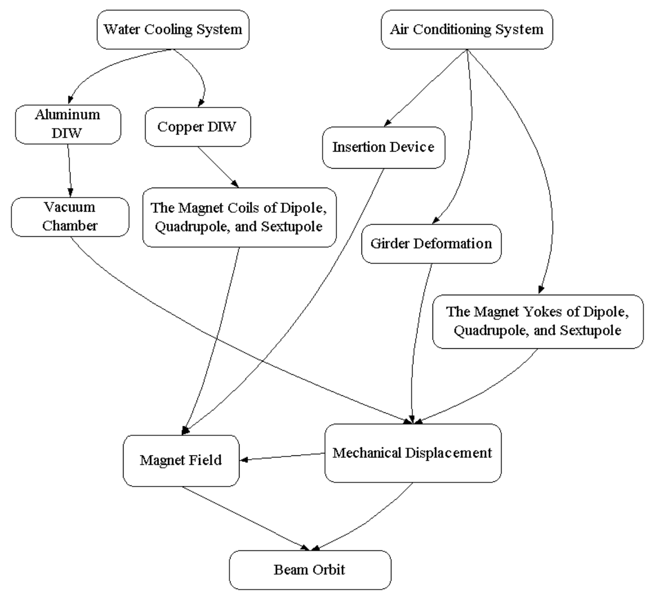

Fig. 6 Temperature variations and propagation paths

4. CONTROL OTIMIZATION AND SYSTEM UPGRADING

All devices that require cooling interact with each other and affect the beam orbit through some paths. Major studies and projects such as an upgrade of the booster energy, minimization of the transition effect, adoption of the cascade control method and re-arrangement of the cooling pipes, have been conducted to improve the cooling systems.

4.1 Upgrading The Booster Energy

The booster's ramping (up and down) during each injection affects the copper DIW temperature stability for about 1°C. The effect will affect other devices that require the copper DIW cooling. A significant improvement has been underway since the autumn of 1999 by upgrading the booster energy from 1.3GeV to 1.5GeV. This upgrade has reduced the surge phenomenon ever since as shown in Fig. 7. The beam orbit has also been relatively stabilized.

4.2 Minimizing The Transition Effect

The water temperature always varies when a beam loss, a shut down or a beam current decay occurs. The transition effect affects the warm-up time of machine and consequently induces further beam orbit instability. Therefore, the heating and precise control of the DIW is very important. In each DIW system, there are two heat exchangers to control the temperature. One is used to adjust the two-way valve to regulate the water flow from the CTW and to diffuse the thermal load to the water. The other exchanger is used to tune the three-way valve to regulate the water flow from CHW and to get rid of the thermal load. To balance the thermal load of the water system by heating could reduce frequent valve changes and avoid a nonlinear control problem. This helps the control precision of the DIW water temperature from ±0.5 ℃ to ±0.1℃ and reduces the transition effect efficiently.

4.3 Adopting The Cascade Control Method

There is a significant correlation between the returned aluminum DIW and the beam current. Therefore, the cascade control is adopted in the aluminum DIW system [4]. The beam current decays as the thermal load capacity changes. It could serve as a feedback sensor to change the set point of the supply water temperature and keep returned water temperature constant to within ±0.05°C or better. The method is meant to predict the thermal behavior of the ring to determine the cooling capacity, which could suppress the temperature variation of the vacuum chamber efficiently.

4.4 Re-arranging Cooling Pipe

Another method is to re-arrange the cooling pipes. The aluminum DIW system was previously divided into 6 loops. Each loop had 2 sub-loops for the cooling of the vacuum chamber. The upstream loop went through the straight and the bending vacuum chamber in series. The downstream loop also went through 2 bending chambers in series. The outlet water constantly affected the inlet water temperature of the next loop in this way of piping. Currently, the in-parallel way of piping could be adopted. Each water loop flows to a single device and the water flow could be doubled or more. The more the water flow is, the less the fluctuation of the water temperature is. The temperature difference of the vacuum chamber is also significantly reduced to ±0.3°C.

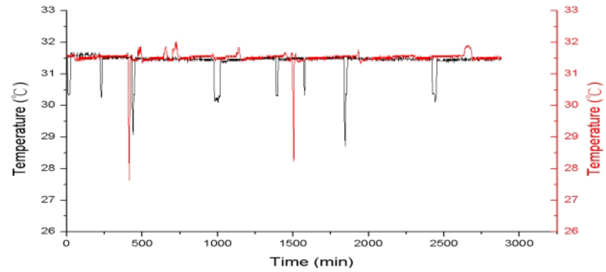

Fig. 7 The comparison of the copper DIW temperature stability between 1.3Gev and 1.5Gev

5. CONCLUSION

1. The paper coordinated thermal effects and temperature propagation paths.
2. The surge phenomenon is improved significantly by upgrading the booster energy.
3. Different control methods and re-arrangement of the pipes have been adopted to keep inlet and outlet water temperature constant.
4. Although the above-mentioned could be used to reduce the temperature variations, the overall device variations caused by the thermal effect is still observed existed. Further studies are needed, non-uniform air temperature with relations to the space especially.

6. ACKNOWLEDGEMENT

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