LOW EMITTANCE ENGINEERING AND PERFORMANCE AT SSRF

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Abstract

SSRF is a 3.5GeV, 3.9nm.rad synchrotron light source presently under commissioning. The accelerator components and their spatial relations in the lattice are considered in detail to ensure successful engineering design and operation. A series of analyses and prototype tests were carried out to simulate and optimize the mechanical designs. Thousands of strong piles were set under a thick concrete slab to suppress ground vibrations. The magnets are grouped and fixed on girders. Each girder is mounted to the floor with three main supports and three secondary supports. The high precision BPMs are mechanically isolated from adjacent vacuum chambers by bellows and supported on the floor with invar cylinders. Following two-times of test installation experience, the installation of the machine was completed successfully in December, 2007. A 3.0GeV, 100mA beam was stored in the storage ring in the beginning of 2008. The detail design, construction and performance of the machine are described in this paper.

INTRODUCTION

The Shanghai Synchrotron Radiation Facility (SSRF) is a 3.5GeV, 300mA light source with emittance of 3.9nm.rad presently under commissioning. The construction of the Linac and the Booster was completed and the design parameters were achieved in July and December, 2007, respectively. Following two-times of test installation experience, the installation of the storage ring was completed successfully in December, 2007. The commissioning of the storage ring started at December 21, 2007. The first turn and multi turns of the electron beam were observed at the same day. The first storage beam was obtained in about 60hrs. A 100mA beam current was stored in the ring on January 3, 2008. Because of the limit of the RF power, the commissioning of the machine could only be performed at 3GeV energy with maximum beam current of 100mA. After 5 months of commissioning, the beam lifetime is about 15hrs and the accumulated beam dose is 140A.h. The COD is less than 50μm in horizontal and vertical direction. The beam position stability is about 2μm within 12hours with slow orbit feedback. The commissioning of the first beam line for X-ray scattering was carried out with successful results in this May. After installation of the 2 super conducting RF cavities in June, the commissioning with 3.5GeV, 200~300mA beam will start from this July.

BASIC REQUIREMENT FOR THE ENGINEERING

For a third generation light source, the beam position stability should be less than 10% of the beam size at the source point, and the beam angle stability should be less than 10% of the beam deviation at the source point. For SSRF, the beam position stability should be less than 5μm in horizontal and 1μm in vertical, respectively. Fig. 1 shows the main structure of the storage ring mechanical system and the related issues with the key components stability. In order to achieve this goal, a series of items should be taken into account in the design and construction of the building, the conventional facility and the machine itself. According to SSRF specification and condition, the main requirements for the engineering are as below.

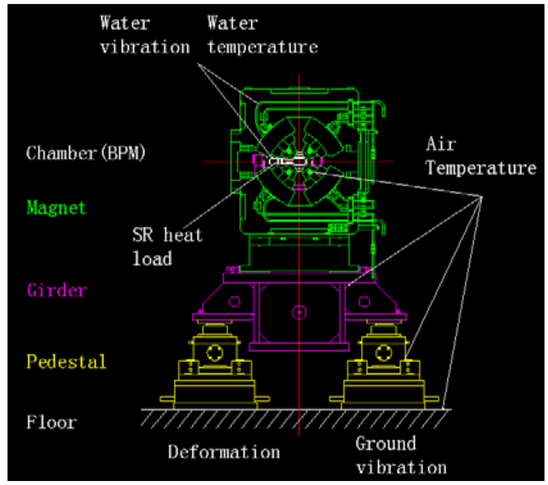

Figure 1: The main structure of the mechanical system and the related issues with stability

(1) Slab vibration amplitude: The integrated RMS value above 1Hz for the displacement should be less than 0.15μm (quiet), 0.3μm (noisy) in vertical direction, and less than 0.3μm (quiet), 0.6μm (noisy) in horizontal direction.
(2) Temperature stability: The cooling water temperature for components is 30±0.1ºC. The air temperature in tunnel is 27±0.1ºC.
(3) Girder-magnet assembly (GMA): The first eigenfrequency should be higher than 30Hz. The frequency response function value at the first eigenfrequency should be less than 10.

SITE, BULIDING AND CONVENTIONAL FACILITY

SSRF locate in Zhangjiang High-Tech Park, where is a new developing area near downtown Shanghai City. Shanghai area is an alluvium zone of the Yangzhi river.

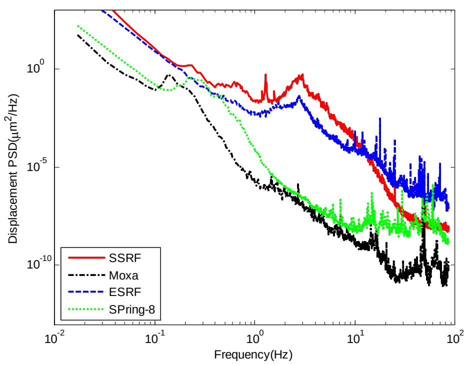

Figure 2: A typical sector in SSRF storage ring

The rock bed is about 300m underground. The soil is soft and the ground wave velocity is about 110m/s. The ground vibration in this area is much higher because of the culture noise. The ground vibration in the SSRF site was measured for several times. The displacement PSD is shown in fig. 2 together with the curves in several other sites [1]. The PSD data below 10Hz is much higher compared with the one in other sites. When the frequency is higher than 10Hz, the displacement decrease fast, and reach a low level after 30Hz. The integrated RMS displacement is about 0.3μm in quiet time and ＞0.5μm in noisy time.

In order to decrease the vibration amplitude and the deformation of the floor for storage ring and experimental hall, a large whole concrete slab with thickness of 1.05m (tunnel) and 1.35m (hall) was designed. About 2100 bored piles with diameter of 0.6m and base grouting are set under the slab to support the structure. The piles extend 48m downward to the silty sand layer. The large slab is separated with the building base structure to avoid the influence of the building movement. The schematic cross section of the slab and the building is shown in fig. 3. After construction, the vibration on the floor of the tunnel was tested and the results show that the slab and the piles system can damp the ground vibration to about 50% in vertical direction. The maximum sedimentation of the slab is about 2.3mm and the relative deformation is less than 0.15mm/10m in the first year after construction.

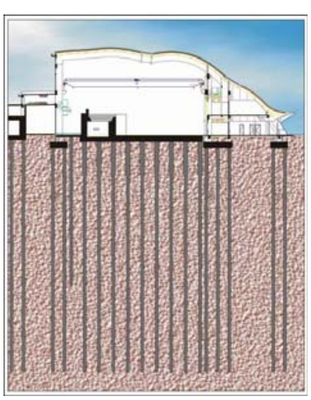

Figure 3: Schematic cross section of the SSRF building

The main vibration source machine in the conventional facility, including the cooling water pumps, the instrument air compressors, etc. are set in a dedicated utility hall, which is located about 50m away to the main building. There are two underground tunnels connecting the two buildings for piping and cable. There are 12 air condition stations, 4 for the storage tunnel and 8 for experimental hall. The stations are arranged inside of the main building. The motors and the fans are set on damping structure to avoid its influence to ground. Soft pipes are adopted to connect the components to the main cooling pipes. The cooling water flow rate in the pipes of the main loop and in the components are limited to less than 2m/s to avoid generating any vibration. The temperature stability of ±0.1ºC for the cooling water and for the air are obtained in the commissioning period.

MECHANICAL STRUCTURES FOR THE STORAGE RING

The physical study in the storage ring led to an optical design composed of 4 super-periods, each divided into five sectors. Each sector contains 10 quadrupoles, 7 sextupoles, 4 static correctors and 3 dynamic correctors distributed on three girders, as well as 2 dipoles isolated from the girders by its own supports. The structure of a typical sector in the storage ring is shown in figure 4.

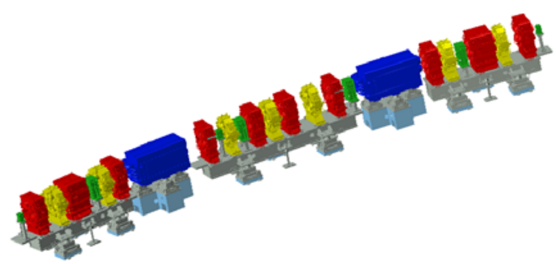

Figure 4: A typical sector in SSRF storage ring

The support system for quadrupoles and sextupoles is composed of three parts, the girder, the adjuster unit and the concrete pedestal. Each girder is supported by three adjuster units on the pedestals. Three assistant supports are also designed to fix the girder to floor directly if necessary. The girder is a box-structure welded from Q235A steel plates. The adjuster unit contains a spherical bearing mounted on a wedge block adjuster. The bearing with flange is fixed to the leg of the girder. The flange can rotate 7 degrees in any direction. The range of adjustment for the wedge block is ±7mm. There are two base plates under the wedge block to adjust the position in horizontal plane by blots. Self-lubricating plate is used between friction couples to reduce the force needed in alignment. A concrete pedestal with damping effect is set between the adjuster unit and the floor. The pedestal can be set at the same height by adjusting the space to floor. It is fixed on the floor tightly by using the anchor bolts and filling the space with non-shrinking concrete. For the dipole, the steel girder is eliminated and the magnet is supported on a higher concrete pedestal by the same adjuster unit.

The magnets are fixed on the girder by bolts. The precise position of the magnets on the girder is aligned by shimming in vertical direction and by bolt screw in horizontal direction.

There are three pieces of stainless steel vacuum chambers connected by two RF shielded bellows in each sector. The 6m long bending chamber is supported on the first and the second girders, and the 5m bending chamber is on the second and the third girders. Only the 3m straight chamber is supported on the middle girder itself. Each chamber is fixed on the girder through a stiff support attaching the downstream BPM block. Other parts are supported by spring plates. It can let the chamber expansion and constriction easily along the longitudinal direction to the fixed point. Care should be taken during the girder re-alignment after the chamber is installed in order to avoid any damage to the chamber. The high precision BPM in each end of the straight sector is isolated from adjacent vacuum chambers by bellows and supported on the floor with invar cylinders to decrease thermal and mechanical influence to it. Fig. 5 shows the structure of the BPM support.

Figure 5: BPM support

INSTALLATION

In order to check the overall design and confirm the installation procedure, a test installation for one arc sector using the first group components arrived was performed in SINAP site and in SSRF site in 2006, respectively. Some modifications for the design had been made after the test. Based on the experience, the storage ring installation work started from June, 2007. The pre-alignment of the GMA and the pre-processing of the vacuum system were carried out in the experimental hall. Then the assemblies were sent to ring tunnel using crane for alignment. The installation of the storage ring was completed successfully in December, 2007. Figure 6 shows the machine in tunnel.

Figure 6: The sector machine in the tunnel

DYNAMIC PERFORMANCE

One of the efforts in the design of the support system is to decrease the vibration amplification from floor to magnets through structure optimization. The first eigenfrequency for the GMA is about 30Hz after optimized in ANSYS. In order to compare and confirm the dynamic performance, a GMA model was fabricated and a series of measurements were carried out on it during the design period. The final design of the system was decided according to the results.

After the machine installation in tunnel, the dynamic performances are measured for the GMA and the key components. The ambient excitation method is adopted in the test. Four sets of sensors (941B seismometers) are used for the test. One set is arranged on the floor while the others are located on the girder surface, the vacuum chamber and the top of a quadrupole, respectively. The test results are shown as figure 7 and figure 8. From figure 7 we can see that the first eigenfrequency in lateral direction is 21.9Hz. The frequency response function value is around 35 for quadrupole in the first eigenfrequency. There is no amplification in the low frequency range (less than 6Hz). There is no much response for quadrupole in vertical direction, but a high amplification around 30Hz for vacuum chamber. The three assistant supports for the GMA are fixed for test. It can increase the first eigenfrequency to 27.7Hz in lateral direction. Extensive testing for the structure and its influence to the beam stability will be done along with the commissioning of the storage ring and the beam lines.

CONCLUSION

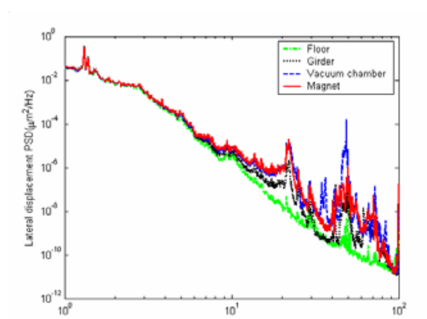

Figure 7: PSD curve of magnet and floor (Lateral direction)

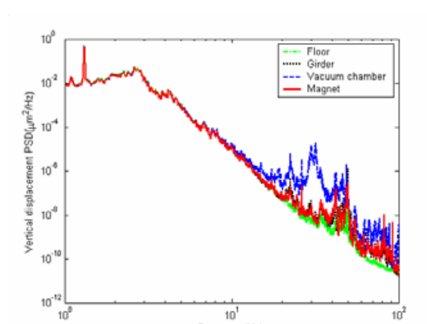

Figure 8: PSD curve of magnet and floor (Vertical direction)

The mechanical vibration of the storage ring components is one of the critical issues to influence the beam orbit stability. Some strategies are adopted in the design of the slab and the building to suppress the higher vibration of the site. Conventional facility is located outside of the main building to isolate the vibration generated by mechanism. A series of simulation and test were performed for the GMA to optimize the mechanical structure and decrease the vibration of the key components. First stage commissioning of the storage ring shows that the engineering design and construction is reliable for the light source. Detail investigation and optimization for the mechanical engineering are doing along with the commissioning of the accelerator and the beam lines to realize the beam stability goal for SSRF.

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