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INVESTIGATION OF REGULATION PLAN FOR THE VIBRATION UTILITY EQUIPMENT OF HEPS

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Abstract

For the third or fourth generation synchrotron light sources, the brilliance of the x-ray beam is 2 to 3 orders higher than other generations, and in the meanwhile the beam emittance is at least one order smaller. To ensure the stability of the beam, the vibration caused beam motion is usually controlled to be within 10% of the RMS beam size. Thus the smaller beam emittance is, more restrict of the regulation plan to the vibration sources should be. Inside of the light source site, one major vibration source is the utility equipment such as water pump, compressors and so on. There are two controlling approaches for the vibration amplitude of those sources, one is damping, and another way is decay. However reasonable specification is the key of the controlling method. This work will present the detailed establish process of the regulation plan for HEPS in China.

INTRODUCTION

Currently, the low emittance storage ring has considered being the future development direction of the photo sources. However, with the decreasing of the designed emittance of the ring, the problems caused by the ambient ground motion have been increasingly highlighted. Delicate research has to be done during the design stage for the inducing beam instabilities caused by those sources. HEPS has a very challenging beam stability requirements with the transverse beam emittance specification of 0.1 nm.rad and designed natural emittance of ~0.03nm.rad while the effective vertical emittance of ~5pm.rad [1-2]. To ensure the stability of the beam on the experimental station, the vibration caused beam size increment has to be controlled being smaller than 10% of the RMS beam size. Thus, according to the current designed 34pm.rad lattice, the RMS beam position and angular motion has to be smaller than 1µm & 0.2µrad, 0.3µm & 0.1µrad, transverse and longitudinal respectively. [2] Special cares are mandatory in developing site vibration specifications, stable building design concepts, and passive and active ways to minimize effects on the stability of the photon beam and critical accelerator and beamline components caused by ambient ground motion sources.

To investigate the vibration influence to the beam, one has to identify the critical vibration sources, including the Egan frequencies and the amplitudes of the vibrations. There are two controlling approaches for the vibration amplitude of those ambient ground sources, one is damping, and another way is decay. The vibration amplitude attenuate with distance as it propagates along the ground from the source to each element of the main ring with certain speed. The ambient ground motions caused by all sources transmit through the slab and girder-magnet assembling inducing orbit instability of the beam. Usually these two methods have to be combined together to realize the final specifications, and the damping level is determined, to some extent, by the decay ability of the HEPS ground. Once the critical vibration sources are identified and the decay of the vibration on HEPS ground is measured, the specification and regulation plan for the ambient ground motion of HEPS could be established.

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AMBIENT GROUND MOTION SOURCES

The ambient ground motion includes ground motion of the HEPS site and other ambient motions caused by critical vibration sources around the HEPS ring including utilities (such as pump, compressor, air conditioner et. al), machine related vibrations sources (such as pulsed booster magnet, water flow et. al) and cultural noises which has day-night cycle (such as traffic and other human activities). The former one has been introduced in another paper [3], this paper will only focus on the latter one.

2 Hz Booster

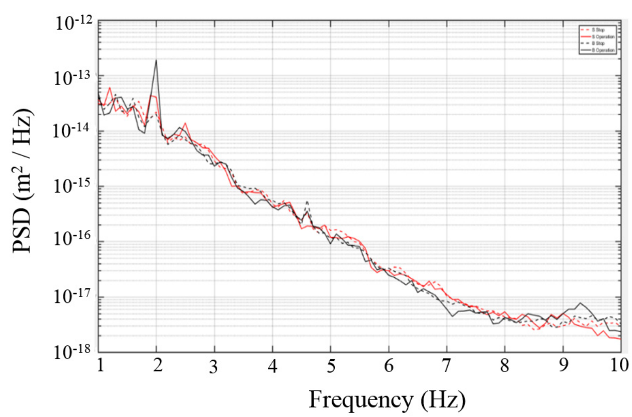

Figure 1: The black line and dash line represent PSD spectrum (in x direction) measured at booster derivation part while booster on (real line) and off operation (dash line) respectively, the red line and dash line represent PSD spectrum on main ring ground while booster on (real line) and off operation (dash line) respectively.

The HEPS booster will be operated on pulsed mode with repetition rate of 2Hz. As the AC dipole of the

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CSNS/RCS operating at 25Hz sinusoidal alternating current caused severe vibration [4], we decided to do some measurement of the vibration caused by the 2Hz booster magnet in SSRF tunnel. We put one detector in the tunnel of SSRF booster derivation part and another one in the main ring tunnel close by the injection part (the closest position from the booster to the ring). The vibration data are collected while the booster on and off operation respectively. Comparing the data, the vibration influence (in x direction but no such influence in vertical direction) at 2Hz is clearly observed in the booster tunnel while booster magnet is on, but no such effect is observed on the main ring ground as shown in Figure 1. We learned that the booster ground is isolated from the main ring tunnel in SSRF. The same measures might need to be taken for HEPS.

Besides the influence of 2Hz booster, we also noticed from the collecting data in the main ring tunnel that the frequencies of culture noises are mainly under 15Hz, and noises with frequencies of 30 to 100Hz are mainly induced by the operated machine as shown in Figure 2.

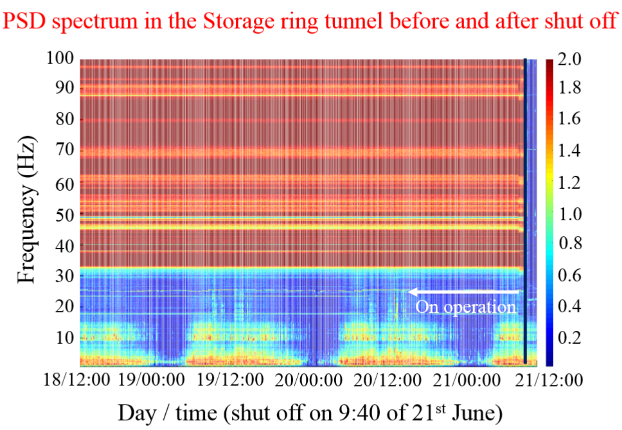

Figure 2: The comparing of vibration PSD spectrum in the SSRF main ring tunnel on & off operation.

Air Conditioner & Compressor

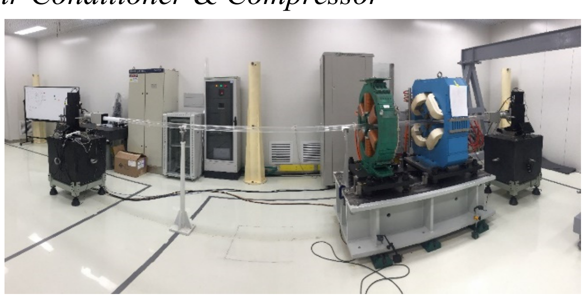

Figure 3: The constant temperature lab of IHEP.

A problem emerged during the alignment in the constant temperature lab (as shown in Figure 3) of IHEP as the alignment line was oscillating during the measurement. The vibration sources are investigated to get troubleshooting. The lab are equipped with air conditioner with variable frequencies of 50Hz / 45Hz / 42Hz /40Hz / 35Hz / 30Hz. Beside the air conditioner, there are also a water pump for the magnet cooling and a compressor providing fluorine gas pressure for the alignment and magnet field measurements. We arranged a series of measurements using seismometers on the floor of the alignment lab with one equipment operating each time.

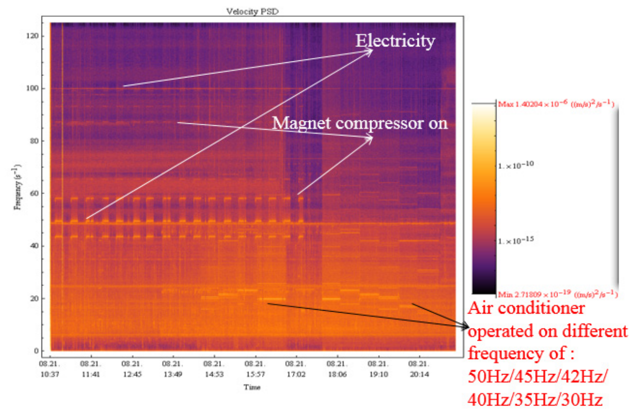

Figure 4: The vibration PSD spectrum with variable frequency air conditioner on and compressor on respectively in the constant temperature lab of IHEP.

The vibration PSD spectrum of these equipment are shown in Figure 4 illustrating the Egan frequency of each vibration source. The vibration frequency of the compressor and air conditioner operating on 35Hz / 40Hz might coincided with the Egan frequency of the alignment line leading to the resonant oscillation. The real culprit is still under investigation.

Water Pump

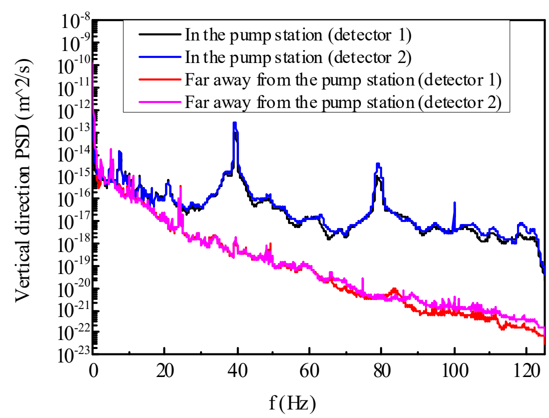

Figure 5: The comparing of vibration PSD spectrum measured in the pump station and far away from the pump station (to approximate the pump off situation).

A steam heat exchange station is planning to be built in HEPS site. The vibration influence was measured in an existing station to determine the necessary distance between the station in plan to the main ring or the at least damping level of the vibration equipment. As shown in Figure 5, the black and blue lines represent the PSD spectrum measured in the pump station by two seismometers simultaneously. The pink and orange lines represent the PSD spectrum 100 meters away from the pump station to approximate the pump off case as they are operated 24 hours a day. From the figure, we can see that the resonant frequency of around ~40Hz and ~80Hz are clearly observed and the RMS displacement is around 300nm vertically integration over frequency of 1-100Hz. According to the beam dynamics results, the allowed equipment vibration influence in the

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main ring tunnel is 1nm, the damping level of the vibration pump could be determined according to the location of the station and the decay of the vibration on the HEPS ground. Besides, it is also necessary to avoid frequency overlap between machine related mechanical designs with the pump.

WAVE VELOCITY AND DECAY FACTOR

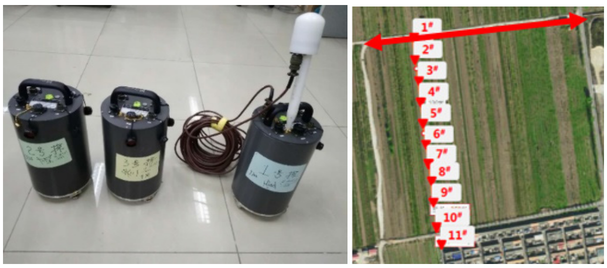

Figure 6: The seismometers used for the ground motion measurement of HEPS (left) and the measurement position on HEPS site (right).

The beam orbit vibration is closely related to the wave velocity of the vibration. And the wave velocity is different for different geology conditions. We use three CMG seismometers (as shown in Figure 6: left) equipped with GPS for the wave velocity measurement and five monitors for the decay factor measurement. The time accuracy of the seismometer with GPS is 10^{-9} s. The sampling rate could be 1000Hz, corresponding to 1000 collecting points within one second. Cooperating with CEEDI institute, we dug eleven holes to accommodate the monitors as shown in Figure 6 (right figure) and cover with plate on the top to avoid impacting of wind. The distance between the holes is 30 m. The five seismometers equipped with GPS are placed in the 2#, 3#, 4#, 6#, 8# pits. A truck loaded with ~30t construction waste were arranged to go through in the vertical direction of the measurement line. When the truck going through, the vibration caused by the truck at 1# position decay along the measurement line because of long distance.

Shifting the vibration data measured by the second detector to derive the best overlap between the first detector and the second one. The best overlap gives the smallest ratio. Take out the ratio valleys as shown in Figure 7 (above) caused by the periodically emergent vibrations because of the intrinsic resonant frequencies for truck crossing, the wave velocity could be deduced accordingly. Figure 7 (below) shows the vibration PSD spectrum of truck crossing. There is a one-to-one correspondence between the labeled resonant peaks to the valley ratios as shown in the above figure. After analyzation, the wave velocity on HEPS site is deduced to be 268m/s for the vibration vertically. The velocity is close to the shear wave velocity (193m/s) measured for HEPS ground by the initial survey group [5].

Shifting the data taken by 5 seismometers according to the wave velocity deduced above. Taking RMS displacement integration of the vibration data (when truck crossing) within 1 second over frequency of 1Hz up to 100Hz. Plot the RMS displacement detected in 5 different positions as shown in Figure 8 (the black points), the decay factor (68.6) is obtained by the fitting curve of five data points.

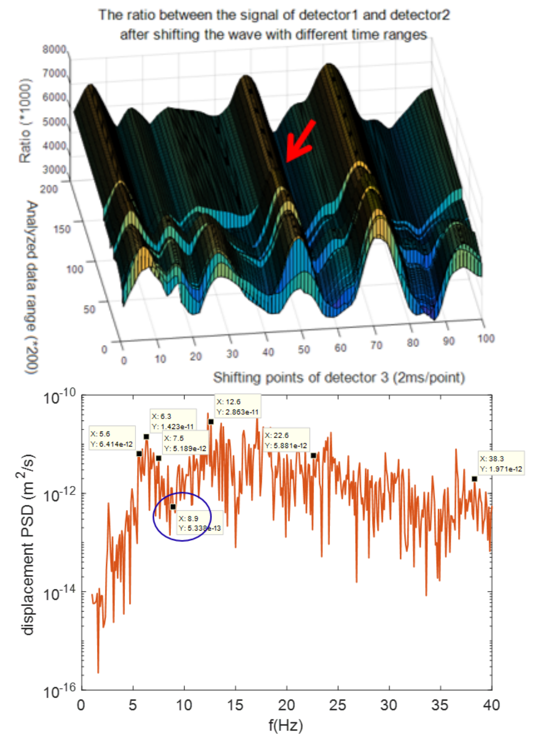

Figure 7: Vertical PSD spectrum of ground motion measured by five seismometers placed in 2#, 3#, 4#, 6#, 8# holes.

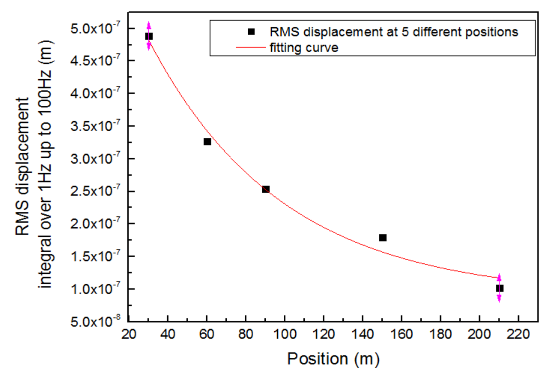

Figure 8: RMS displacement vertically at 5 measurements positions on HEPS ground when truck crossing 1# position.

CONCLUSION

To control the vibration influence of the ambient ground motion, there are two approaches. One is damping, another one is decay. Usually a practical way is combining these two measures to meet the specifications of one particular project. In this paper, the critical ambient motion measurement results have been introduced. The Egan frequencies and the amplitude of each vibration source have been obtained. The wave velocity and the decay of the vibration on the HEPS ground have been measured and analyzed. According to the beam dynamics results, the allowed equipment vibration influence in the main ring tunnel is 1nm, the damping specification of the vibration sources could be set according to the distance and the decay of the vibration on the HEPS ground.

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