STUDY ON SUPPORTS SYSTEM OF BPMS FOR HEPS

Z.Z.Wang, J.He, Z.H. Wang, Y. F. Sui, H.Z.Ma, J. S. Cao,
Division for Accelerators, Institute of High Energy Physics, Beijing 100049, China

Abstract

The High Energy Photon Source (HEPS), a third generation light source with the energy of 6 GeV, is under constructed at IHEP. It has an ultralow emittance (~50pm.rad) and small beam size, thus the requirement of BPM in precision and resolution is quite high. Independent supports with high degree of mechanical and thermal stability will be employed for some special BPMs, such as the BPMs near the insert devices. The supports should have high eigen-frequencies to minimize the amplification of vibration from the ground. Vibrations information of the ground around the supports also need be estimated, with which FEA (finite element analysis) had be utilized to simulate the performance of the supports. Measurements of vibrational stability of the prototype supports have be done and compared with the simulation.

INTRODUCTION

Beam orbit stability is a key indicator of the high quality operation of modern synchrotron radiation source, which affects the accelerator performance and the quality and stability of synchronous light directly. The general requirement of beam orbit stability is 5% ~ 10% of the beam size. For HEPS, the minimum size of the bunch in the storage ring is about 0.3μm, so the resolution of the Beam Position Measurement (BPM) is required to reach 0.1μm.

BPMs are the most important components in the orbit feedback systems which are the best and last means to control the stability of beam orbit [1].

The BPMs are mechanically isolated from girder sections and insertion devices by welded stainless steel vacuum bellows and fixed to ground with its support. Thus BPMs' mechanical stability depends on the support mostly. The same consideration should be taken in the vibration around the support.

To meet the requirement of high BPM resolution, the support has a high mechanical stability. According to the difference of beam size in the horizontal and vertical direction, the either requirements of the mechanical stability are also different, the initial expected, 50nm in horizontal direction and 25 nm in vertical direction. Studying of mechanical stability of BPM, as the most important position detector in accelerator, is also helpful to predict the effect of vibration on other structures.

ANALYSIS

Analysis of Ground Vibration

The ground vibration is transmitted to the BPM via the support. The source of vibration can be divided into cultural and natural factors. Cultural factors include large-scale human activities near the storage ring, mainly due to the mechanical vibration generated by the accelerator devices. Its frequency is mainly concentrated at 4-30 Hz. The relationship between the power spectral density and the frequency of natural random vibration is generally $\propto 1/f^4$.

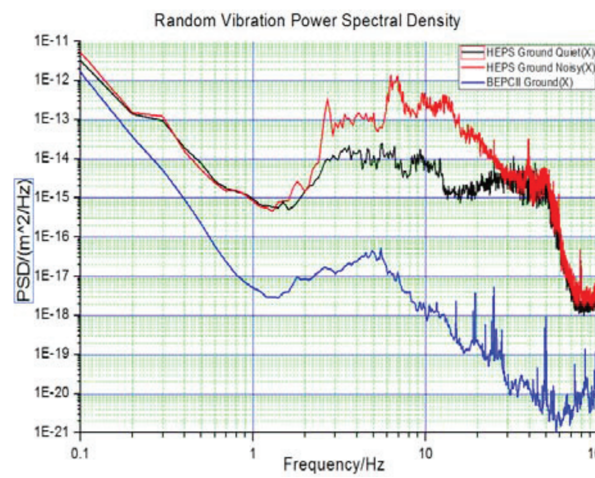

Figure 1: Displacement PSD for HEPS site and BEPCII.

The ground site for HEPS is always wilderness and far away from city noise. The BEPCII tunnel enjoys cultural noise from the city and itself. A series of measurements for ground is made in the BEPCII tunnel when accelerator is operating stably and the site for HEPS [2]. Figure 1 shows the vibration displacement in power spectral density (PSD), shown here for the horizontal direction only for example.

Comparing the PSD and RMS motion in the 4~100Hz band in the three principal directions or various period, we can know:

- the vibrations of the three principal are in the same level,
- the cultural vibration dominates in 4~30Hz band,
- cultural factors are dominant sources of vibration. Vibrations motion in the HEPS ground and BEPCII tunnel are shown in the Table 1.

Table 1: RMS Motion in HEPS and BEPCII

RMS(4~100Hz)	Noisy/nm	Quiet/nm
HEPS Ground	10	25
BEPCII tunnel	8	15

An Analysis of the Influence of Ground Vibration on Beam Oscillation

Liberal Electronics offers 10 KHz real-time BPM data measurements (FA data) in BEPCII. Figure 2 shows the FA data and the ground vibration in PSD. The comparisons are made in both two directions of beam and ground vibration. The correlation between ground vibration and beam oscillation is obvious, especially in the range of 4~60 Hz. When the peaks of vibration disappear, the peaks of the beam also weaken or disappear. An example in 16 Hz is display in the left bottom of Fig. 2.

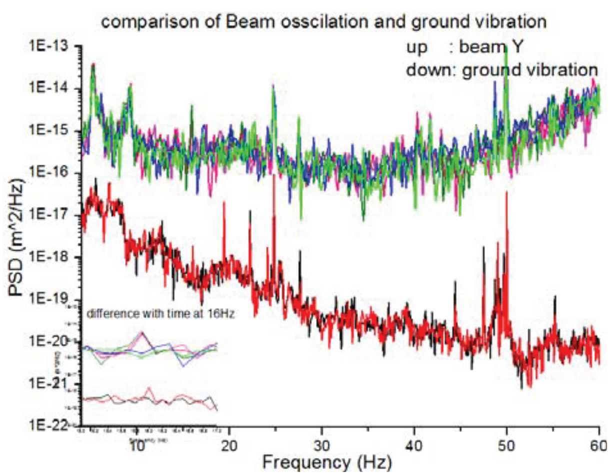

Figure 2: Comparison of ground vibration (lower) and BPM FA data (upper).

The ground vibration in horizontal direction can couple to the BPM measure date in vertical direction, which can be explained from the measure principle of BPM. So suppressing horizontal vibrations of BPM is of equivalent importance.

Support Design and Simulation

The main considerations of the support design [3] are:

- contour size: the vertical size of the support is 1250mm, including a three-dimensional adjustment; the longitudinal length is 120 mm; only the length of the horizontal can be optimized.
- As horizontal vibration is more important, second order of the eigen-frequency (f_{2x}) of support should be improved.
- The firm method of support fixing to ground contributes to enhancing eigen-frequency [5].
- Material selection: In order to achieve the thermal stability in the vertical direction, support column is invar alloy.

With FEA, static, modal and random vibration are used to analyse the design. The three-dimensional vibration PSD of the ground for HEPS in the noisy period is used as the excitation for the input of the random vibration to simulate the design [5].

The simulation goal is to enhance the eigen-frequency and reduce the vibration. The final design is shown in Fig. 3, in which the rods' diameter is 35 mm. The results reveal:

f_{1z}= 46 Hz and f_{2x}= 68 Hz

in the eigen- frequency, and

ΔD_y = 5nm and ΔD_x = 28nm

in random vibration relative to ground.

It should be also known from simulation that hollow rods will work as well as the solid rods in the support, while the former has advantage in less supplies.

Figure 3: The design of the support

Vibration Measurement and Support Analysis

The support is fixed to the BEPCII tunnel of the BEPCII with four ground bolts. The vibration of the ground and the top of the support are measured simultaneously when the BEPCII is operating. In the vertical or Y direction, the both vibrations are in the same level and the RMS motion in 4~100 Hz band is about 15nm and meets the requirements. In the horizontal or X direction, the PSD plot in Fig. 4 in which the peak at 39 Hz means the second eigen-frequency (f_{2x}).

While the result with hammer method is 42 Hz, because in PSD method the mass of seismometer adhered to the support reduces the eigen-frequency.

However, in both methods, the eigen-frequency f_{2x} is far less than the modal analysis value. Miserably, the RMS motion in 4~100 band in X is about 200 nm.

The difference results from the non-compactness of elements of the support and the instability of the fixation between support and ground.

ISBN 978-3-95450-182-3

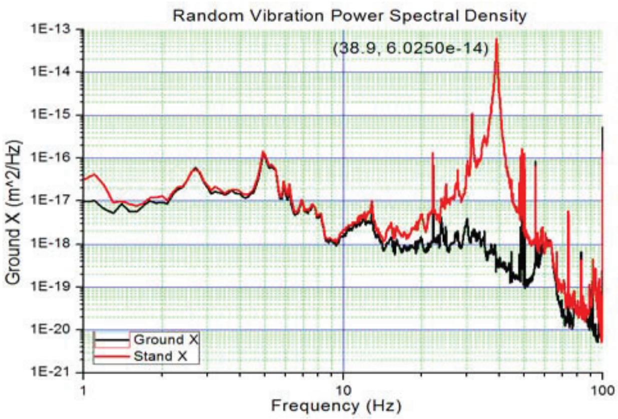

Figure 4: PSD of horizontal vibration.

CONCLUSION

Ground vibration of the HEPS and BEPCII is mainly concentrated in the 4-30Hz which come from cultural noise. So the first eigen-frequency of the support should be higher than 30Hz. Most consideration is taken in the horizontal(X) and vertical(Y) directions due to the work principle of BPM. Both in simulation and measurement, the amplification of the vibration in Y performances very well, evenly close to 1. In X, when the corresponding eigen-frequency raises up to 60 Hz, the amplification ratio is 2 in simulation. But in the experimental measurement it is about 10. Although requirements of the beam in Y is higher than in the X of about 10, the vibration of X will affect the measurement in Y.

In view of the huge difference between the experiment and simulation, some improvements will be done with the support in future, such as the support's various parts connecting with the welding and the fixing to ground with full grouting.

REFERENCES

[1] Y. Renier, D. Schulte, R. Tomas *et al.*, "Detection of ground motion effects on the beam trajectory at ATF2", in *Proc. IPAC'12*, New Orleans, LA, USA, May 2012, paper TUPPR060.

[2] Güralp Systems Ltd, `http://www.guralp.net/`

[3] B. Kosciuk, R. Alforque, B. Bacha *et al.*, "Development of high stability supports for NSLS-II RF BPMs", in *Proc. PAC'09*, Vancouver, BC, Canada, May 2009, paper TH5RFP012.

[4] X. Wang, Y. Cao, H. Du *et al.,* "Dynamic performance of the beam position monitor support at the SSRF", *Journal of Synchrotron Radiation*, vol. 16, no. 1, pp. 1-7, 2009.

[5] K. Bertsche, J.W. Amann, T.W. Markiewicz *et al.*, "Vibration model validation for linear collider setector platforms, in *Proc. IPAC'12*, New Orleans, LA, USA, May 2012, paper TUPPR047.