Paper ID: MOPAB275

STUDY ON SUPPORTS OF BPM DISPLACEMENT MEASUREMENT SYSTEM FOR HLS II *

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Abstract

HLS II is the second-generation light source with energy of 800 MeV and emittance of less than 40 $nm \cdot rad$. In order to improve the beam orbit stability and correct the errors introduced in the orbit feedback system due to the movement of the vacuum chamber and BPM, a system for measuring BPM displacement will be built. It requires high degree of mechanical and thermal stability for its supports. The support should have a higher eigen-frequency to minimize the amplification of ground vibration. In this paper, a series of simulation, measurement and analysis have been done upon the support to make sure it can meet the requirements of the stability of BPM displacement measurement system.

INTRODUCTION

The beam orbit stability is an important indicator to measure the stability of the synchrotron radiation source. The general requirement of the beam orbit stability is less than 10% of the beam size and near the insert device, it requires less than 5%. The vertical beam size is 210μm and the horizontal beam size is 379μm at HLS II B8, so the vibration of the beam orbit needs to be less than 10μm. For the stability of the BPM displacement measurement system, the vibration of the BPM displacement measurement probe is required to be far less than 21μm in vertical and 38um in horizontal. In order to meet the high stability of the BPM displacement measurement probe, the probe needs a support with high mechanical stability. Considering the difference in beam size between vertical and horizontal directions, the vertical and horizontal stability of the support are expected to be less than 210nm and 380nm.

ANALYSIS OF VIBRATION MODEL

The support system can be simplified to the model in Fig. 1, where y represents the harmonic displacement of the support point and x represents the displacement of the mass m. Considering the stiffness k and damping coefficient c, the equation of motion becomes

$$mx'' + c(x' - y') + k(x - y) = 0$$

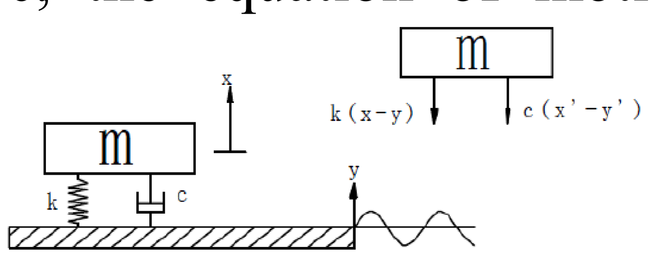

Figure 1: Vibration Model

The steady-state amplitude from this equation is

$$\frac{X}{Y} = \sqrt{\frac{1 + \left(2\varsigma\frac{\omega}{\omega_n}\right)^2}{[1 - \left(\frac{\omega}{\omega_n}\right)^2]^2 + [2\varsigma\frac{\omega}{\omega_n}]^2}}$$

where damping ratio $\varsigma = c/2\sqrt{km}$ and eigen-frequency $\omega_n = \sqrt{k/m}$. In order to minimize the displacement of m, the eigen-frequency of the support needs to be increased as much as possible.

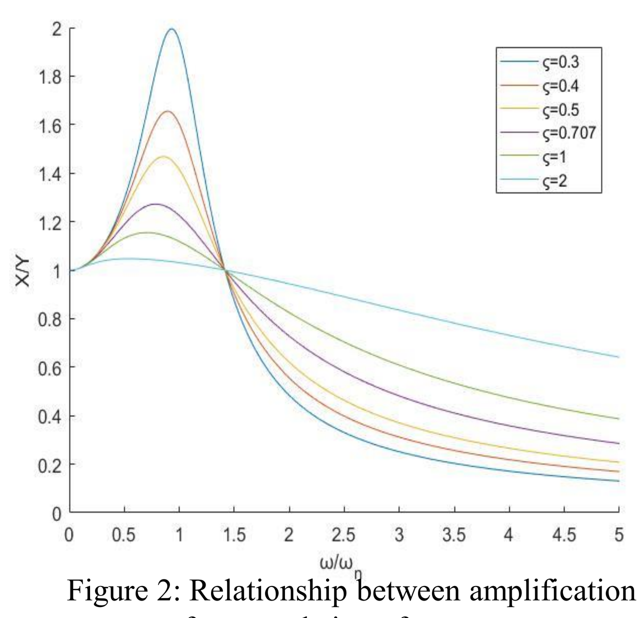

Figure 2: Relationship between amplification factor and eigen-frequency

SUPPORT DESIGN AND SIMULATION

The main design requirements of the support are:

- The support of the BPM displacement measurement probe needs to be 400mm in height and the longitudinal length is no more than 100mm.
- The support is fixed on the platform with four screws, which will reduce the eigen-frequency of the support to a certain extent.
- Considering the thermal expansion effect, INVAR36 alloy is selected as the material of the probe support.

Through finite element analysis (FEA), the eigen-frequency of the eigen-frequency of the support is simulated and optimized. By

SUPPORT DESIGN AND SIMULATION

increasing the eigen-frequency, the vibration amplitude at the top of the support is reduced. The final design is shown in Fig. 3. The FEA results are:

$$f_{1z} = 183Hz, f_{2x} = 196Hz.$$

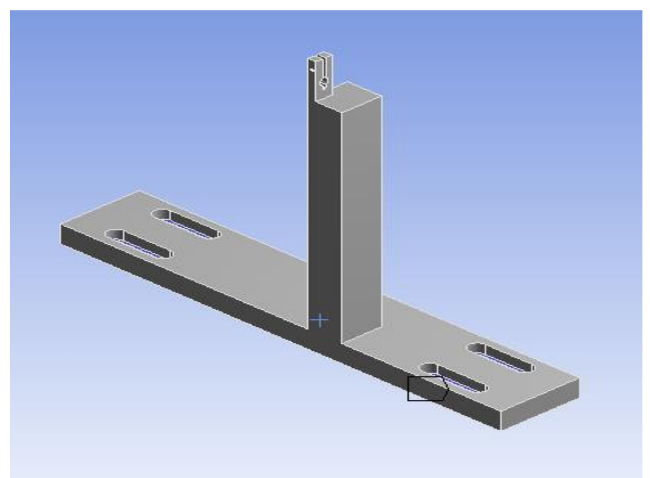
Figure 3: The final design

MEASUREMENT

Platform Vibration

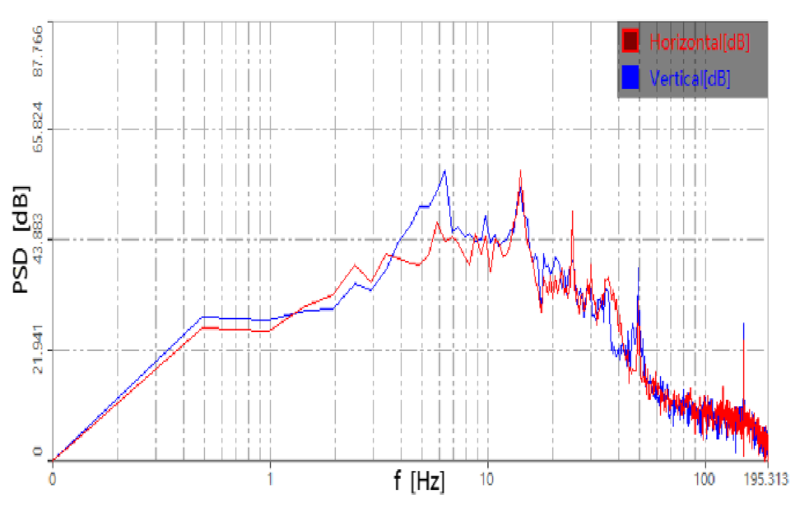

Figure 4: The vertical and horizontal PSD of the platform

Figure 4 shows the vertical and horizontal PSD of the platform vibration, the vibration of the platform is mainly concentrated in 0-50Hz. The red line indicates the horizontal direction and the blue line indicates the vertical direction.

Eigen-frequency

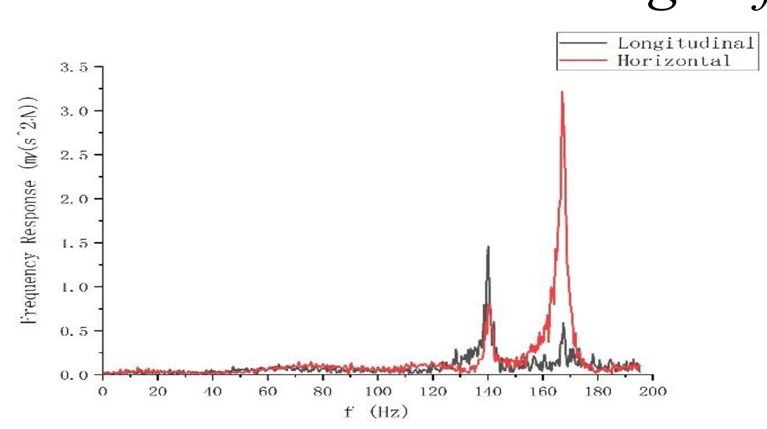

Figure 5: The horizontal and longitudinal frequency response

Figure 5 are the frequency response curves of force and acceleration in horizontal and longitudinal direction. The measurement results are:

$$f_{1z} = 140.6Hz, f_{2x} = 167.0Hz.$$

The difference between the measured results and FEA results is likely due to the difference between the fixed boundary condition in reality and in FEA.

Top Vibration

Voltage displacement sensors are used to measure the vibration on the top of the support and the platform at the same time. The RMS vibrations on the top of the support and the platform are listed in Table 1.

Table 1: RMS Vibration on the top and the platform

RMS Vibration	Horizontal	Vertical
Top	65.5nm	98.2nm
Platform	54.5nm	101.4nm
Target	380nm	210nm
Amplification Factor	1.20	0.96

The horizontal and vertical RMS vibrations on the top of the support were measured at 65.5nm and 98.2nm resulting in the amplification factors are 1.20 and 0.96.

CONCLUSION

The first and the second eigen-frequency of the support are 140.6Hz and 167.0Hz, which are much higher than the platform vibration at HLS II. The horizontal and vertical RMS vibrations at the top of the support are 65.5nm and 98.2nm, which are much smaller than the target. The stability of BPM displacement measurement system is well guaranteed.

• Work supported by National Natural Science Foundation of China under Grant No. 12005223 and the Fundamental Research Funds for the Central Universities under Grant WK2310000080
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