Mechanical Stability Analysis of BPM Support at SSRF

WANG Xiao[1;1)] CAO Yun[1] CHEN Liang[2] DU Han-Wen[1] YIN Li-Xin[1]

1 (Mechanical Engineering Group of Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai 201800, China)
2 (Department of Automation, Donghua University, Shanghai 201620, China)

Abstract This paper concentrates on investigating the mechanical stability of a Beam Position Monitor (BMP) support prototype of the Shanghai Synchrotron Radiation Facility (SSRF) project. Both finite element analysis and vibration measurements have been performed. Inconsistent results between the simulations and experiments motivate us to study three connections between the support and the ground: ground bolt (used in the initial design), part grout and full grout (proposed in the later research). After changing the connection, the first eigenfrequency is increased from 20.2Hz to 50.2Hz, and the ratio of the integrated RMS displacement (4—50Hz) is decreased from 4.36 to 1.23 in the lateral direction. The mechanical stability is improved greatly.

Key words vibration measurement, Mechanical stability, finite element, eigenfrequency

1 Introduction

The electron beam stability is one of the most important requirements for the Shanghai Synchrotron Radiation Facility (SSRF) because its ground vibration is much larger than that of other light source projects[1]. Beam Position Monitor (BPM) used to monitor the beam position is a key component at the SSRF, which requires more stability than other mechanical structures[2]. Therefore, how to damp ground vibration is an important problem to the mechanical design of BPM support. This paper concentrates on investigating mechanical stability of the BMP support prototype. Both finite element (FE) analysis and vibration measurements have been performed. In the initial design, connections between the BPM support and the ground use ground bolts. Inconsistency of the simulation and experimental results motivate us to study three kinds of connections between the BPM support and the ground: ground bolt, part grout and full grout. After changing the connection, the first eigenfrequency is increased from 20.2 Hz to 50.2 Hz, and the ratio of the integrated RMS displacement (4—50Hz, according to Ref. [3]) is decreased from 4.36 to 1.23 in the lateral direction (perpendicular to the beam movement). The mechanical stability is improved greatly.

In the vibration measurements, the DH5920 data acquisition system and the 941-B seismometers with frequency range of 1–100Hz[4] are used. In the FE calculation, software ANSYS 10.0[5] is used. The signal processing fundamentals are based on Ref. [6].

2 Modal analysis of BPM support

The BPM support (shown in Fig. 1) is a sustentation system of the BPM. It consists of three parts: the adjustment system used to crutch the BPM (not shown) and adjust in different directions, the bottom plate used to connect to the ground and the support body used to sustain the BPM and provide the enough the stiffness for the whole support system.

In the FE model, there are in total 33245 nodes and 21412 elements including SOLID92, SOLID95, TARGE170 and CONTA174. In the modal measurements, connections between the BPM support and the ground initially use ground bolts. After analyzing we find that the results of measurements and FE are different, which motivate us to try another connection, the grouting technology. In the following,

Received 7 January 2008
1) E-mail: wangxiao@sinap.ac.cn

three kinds of connections are investigated.

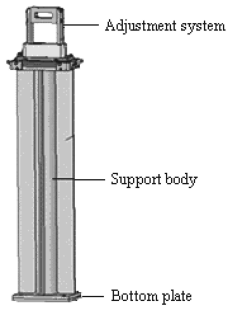

Fig. 1. Structure of BPM support.

A. Ground bolt connection

The cross section is shown in Fig. 2 (a). The installation steps are described as follows: first, to drill four holes into the ground at appropriate sites; next, to knock the ground nuts into these holes by hammer. Because their cone-shaped sections have smaller bottom and larger top (see Fig.2 (b)), the ground nuts will finally be expanded and tightened; and finally, tighten the BPM support by using ground bolts through four holes of the bottom plate and BPM support body.

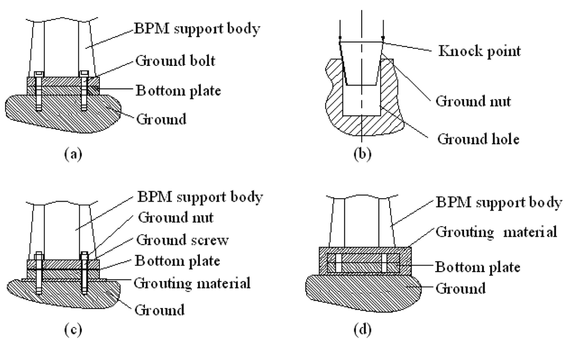

Fig. 2. Cross sections of three connections between the BPM support and the ground:(a) ground bolt connection, (b) cone-shaped ground nut, (c) part grout connection, (d) full grout connection.

B. Part grout connection

In this case, ground screws take place of the ground bolts (see Fig. 2 (c)). Installation steps are described as follows: to loosen ground nuts; lift up the BMP support about 20mm high by using other four M6 bolts(not shown in Fig.), and infuse the grouting materials diluted with water into the middle of the bottom plate and the ground. After 72-hour maintenance, the grouting materials will dry and tighten the ground nuts.

C. Full grout connection

Different from part grout connections, in this case(see Fig. 2(d)), the grouting material diluted with water is infused nearly 100mm high after the BPM support is lifted up 20mm.

Table 1 gives the modal analysis results of FE and measurements. Fig. 3 (a) and (b) show the modal shapes by measurement and FE analysis at the first eigenfrequency when the BPM support has full grout connections. Both shapes are similar with rock in the lateral direction.

Table 1. The first lateral eigenfrequency (Hz).

connection	ground bolt	part grout	full grout
measurement	20.2	39.4	50.2
FE		56.7	

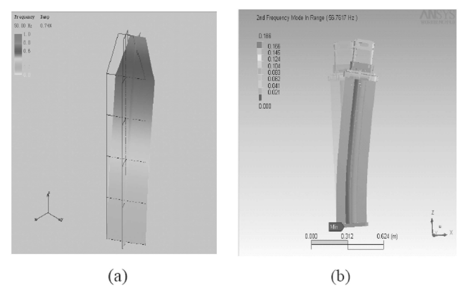

Fig. 3. Modal shape with full grout connections: (a) measurement, (b) FE analysis.

From all these results, we can conclude that in the case of ground bolt, the maximum relative error between measurement value and FE analysis arrives at 181%. Such huge difference can only be explained by the different boundary conditions between the actual structure and the FE model. Stiffness of ground bolt connection designed initially is much weaker than ideally fixed restriction. Compared with the ground bolt connection, part grout and full grout connections greatly improve the first eigenfrequencies, and decline the relative errors. Therefore, connections are changed into full grout in the last design.

3 Response analysis of BPM support

Response measurements have been performed on the BPM support and ground simultaneously to understand their vibration-transmissibility effect in detail. During the measurement, one seismometer is put on the top of the support, another is put on the nearby ground. After signal processing, the spectra of displacement power spectrum density (PSD) are got when the support has ground bolt (A1), part grout (A2) and full grout (A3) connections (see Fig. 4). Values of RMS and their ratio (4—50Hz) between the top of the BPM support and the ground are shown in Table 2.

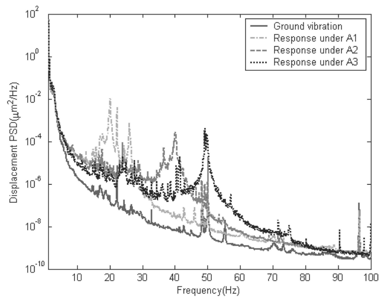

Fig. 4. The lateral displacement PSD.

Table 2. Integrated RMS lateral displacement (nm).

connection	ground	top of BPM support	ratio(4—50Hz)
ground bolt	22.3	97.2	4.36
part bolt	20.8	27.5	1.32
full bolt	22.1	27.2	1.23

Based on the results noted above, we can conclude that:

A. Curves of the displacement PSD show the peak values corresponding to the three connections are 20.2Hz, 39.4Hz and 50.2Hz, respectively, which are the same as those shown in Table 1.

B. The grout connections decrease the ratio of the RMS lateral displacement from 4.36 to 1.32 and 1.23, respectively. It means that the stability of the BPM support is improved greatly by grout connections. Such effects are produced by the fact that the displacement PSD of the ground decreases 4 times vs. frequency[7]. The higher the first eigenfrequency is, the less influence of the peak value has at this frequency.

4 Conclusion

Three connections including the ground bolt, part grout and full grout have been investigated. By changing the ground bolt in the initial design with full grout, the first eigenfrequency has increased from 20.2Hz to 50.2Hz, and the ratio of integrated RMS displacement (4—50Hz) has decreased from 4.36 to 1.23 in the lateral direction. The mechanical stability is improved greatly.

The author would like to thank the ME group of Shanghai Institute of Applied Physics, CAS, for their assistance throughout the measurements.

References

1 ZHAO Zhen-Tang. SSRF Beam Stability Challenge and Comprehensive Measures, Eastern Forum of Science and Technology, DEC. 7. 2006. Shanghai
2 DAI Z M, LIU G M. Study of Orbit Stability in the SSRF Storage Ring, Proceedings of APAC'01, 2001. 293—295
3 Doose C, Sharma S. Investigation of Passive Vibration Damping Methods for the Advanced Photon Source Storage Ring Girders, MEDSI2002, APS, Chicago 2002. 133—139
4 YANG Xue-Shan. Measurement Instrument and Thechique in Engineer Vibration, China Measurement Publications, 2001. 196—200
5 WANG Feng. The Latest Tutorial of Classic ANSYS and Workbench, Electronics Industry Publications, 2004(1): 328—338
6 LI De-Bao. Analysis of Experimens in Engineering Vibration, Tsinghua University Publications, 2004. 291—295
7 Sharma S. Design of Accelerator Girder System for Vibration Suppression, Workshop on Ambient Ground Motion and Civil Engineering for Low Emittance Electron Storage Ring, Hsinchu, China, 2005

SSRF 中 BPM 支撑的机械稳定性分析

王晓[1;1)] 曹云[1] 陈亮[2] 杜涵文[1] 殷立新[1]

1 (中国科学院上海应用物理研究所 上海 201800)
2 (东华大学信息科学与技术学院自动化系 上海 201620)

摘要 主要对上海光源 (SSRF) 束流位置监视器 (BPM) 支撑的机械稳定性进行了研究. 受有限元计算与初始设计方案的振动测试结果不一致的启发, 对 BPM 支撑与地面的连接考虑了三种方案: 膨胀螺母、半灌浆与全灌浆连接. 通过采用改进的全灌浆连接来代替初始设计的膨胀螺母连接, BPM 支撑的横向最低共振频率由 20.2Hz 增加到 50.2Hz, 支撑顶部与地面的横向均方根位移(4—50Hz) 之比由 4.36 降低到 1.32, 机械稳定性能得到大大的提高.

关键词 振动测试 机械稳定性 有限元 特征频率

2008 – 01 – 07 收稿
1) E-mail: wangxiao@sinap.ac.cn