Dynamic Test of SSRF Storage Ring Girder-Magnet Assembly

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Abstract

Storage ring magnets support stability is essential to beam stability. In SSRF, a high stiff girder and unique ball-bearing plus wedge block adjuster were designed. A girder-magnet assembly prototype was assembled, and extensive tests were carried out on the girder-magnet assembly. The results show that its lowest eigenfrequency is 19.5Hz under three points support and 23.5Hz under four points support. And the amplification in lateral is much higher than vertical. Anti-vibration concrete was used in dipole support and girder pedestal. It is tested to be useful in attenuating the amplification. Damping structures were designed for the assembly and tests are in progress.

1. INTRODUCTION

The 3.5GeV Shanghai Synchrotron Radiation Facility (SSRF) under construction is a third generation synchrotron radiation facility. It is a user oriented facility, which is designed to produce high brightness and high flux X-ray in the photon energy region of 0.1~40 KeV. As a third generation synchrotron radiation sources, SSRF has tight requirement for electron beam orbit stability. The electron beam orbit stability with 10% or better of the photon beam size at radiation source points is desired for the SSRF storage ring[1].

The orbit stability is influenced by motions of storage ring elements, such as magnet, vacuum chamber and diagnostic devices, which are supported on a mechanical system. We call it as girder. So the girder should have high static and dynamic stability to ensure the orbit stability. The specification of SSRF storage ring girder is:

The typical frequency is higher then 20Hz with maximum vertical amplification factor smaller then 10, and maximum horizontal amplification factor smaller then 30, and no amplification in low frequency range (e.g. <4Hz)[2].

2. GIRDER DESIGN[3]

The factors which should be considered in girder design are: girder body strength and stiffness, adjusting range and accuracy, alignment and survey, maintain and re-adjust convenience.

The storage ring of SSRF is consisted of 20 standard cells. Each cell includes three separated girders and two concrete tables for two dipole magnets (Figure 1).

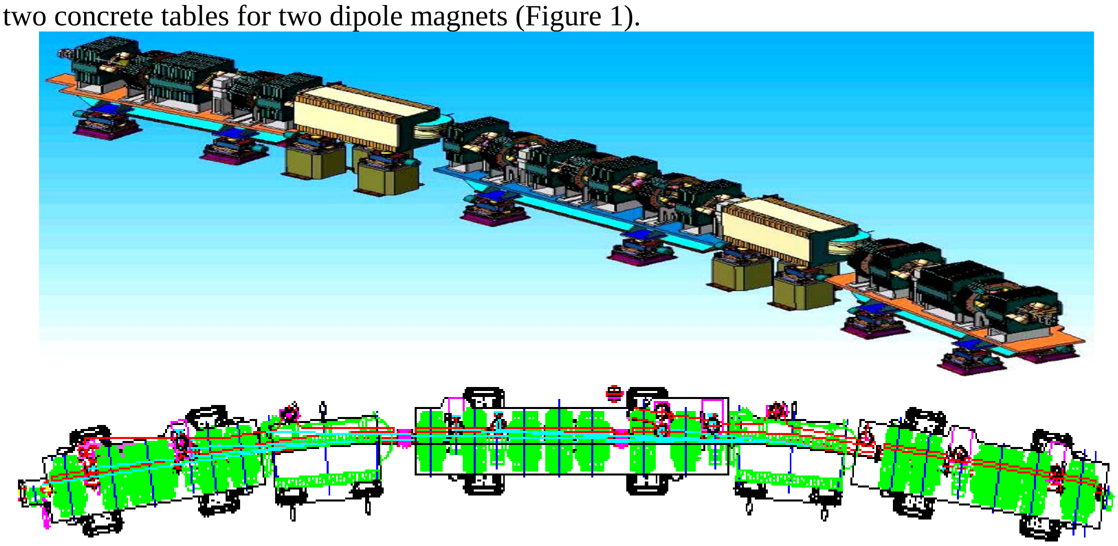

Figure 1: 3D view and layout of one cell

In order to test the dynamics of girder, the middle long girder was manufactured and assembled in January 2006. Four quadrupoles, three sextupoles and three corrector magnets, ion pumps and vacuum chamber are installed on the girder (Figure 2). Since the magnets are still in producing, iron blocks with the same size and mass were used instead. In order to test different support plans as three points, four points and five points' supports, five support points were assembled with it. In order to test the effect of anti-vibration concrete, two identical dipole magnet supports and girder pedestals using normal concrete and anti-vibration concrete respectively were made.

For adjusting, an unique adjusting unit was designed. It includes a flexible ball bearing for support and wedge for height adjustment (Figure 3). At top of the unit, a ball bearing with flange connects the girder body leg. With the flexibility of the ball bearing, the flange can rotate for seven degrees in any direction. The bearing is combined with a wedge block unit. The unit is composed of two plates. The lower one is connected with a nut, it can be removed when rotate the screw rod. When rotating the screw rod, the upper plate is driven to move just in vertical direction, with the range of ±7mm and 0.01mm/10° precision. The horizontal position can be adjusted after removing two base plates, with the range of ±10mm. For future upgrading, a flange is design for motor connection at the end of screw rod.

Figure 2: the girder-magnet assembly prototype with damping links assembled to the two ends

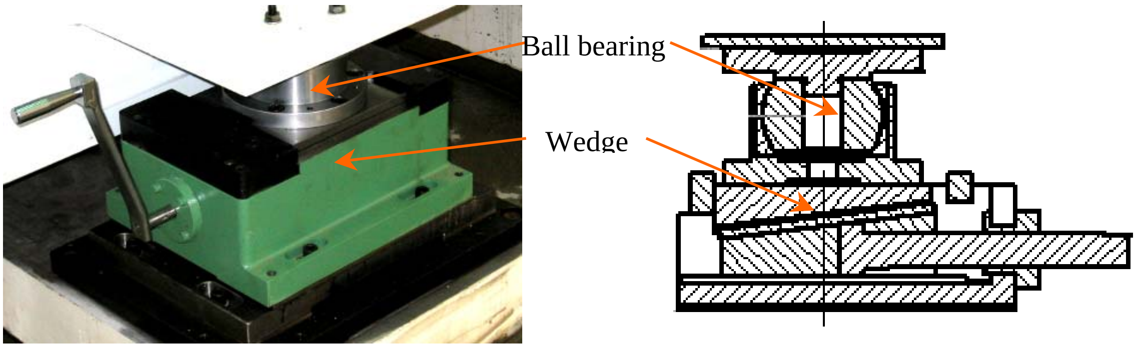

Figure 3: picture and drawing of an alignment unit

3. TEST TECHNIQUES

There are different test methods in modal test and response test. A multi-point input (excitation by hammer) and single-point output (response measured by 941B seismometers) method was used in modal tests. And totally ten excitation points were arranged on the girder surface. In girder body modal test, ten spring supporters were used to support it.

We chose ambient vibration excitation when test the magnet response. With 64 seconds FFT window length (16384 points, no overlap) and 256Hz sampling rate, about three hours data would be collected and processed.

A 16-bit 16-channel Donghua 5920 dynamic signal analyzer (Produced by Donghua Test Technology Co., Ltd., Jiangsu, China) and 941B seismometers (Sensitivity: 23V/m/s, Resolution: 4×10e-8m/s, produced by Institute of Engineering Mechanics, China Earthquake Administration) were used for these tests (Figure 4).

Figure 4: data acquisition hardware

4. TEST RESULTS

We managed to do lots of tests including: modal test and frequency response test on the girder magnet assembly, modal test of girder body, comparison test of normal and anti-vibration concrete, etc. From these tests, we can draw the following results:

1. The girder body has the lowest natural frequency of 72Hz with the shape of bending. The girder-magnet assembly has the lowest frequency around 23Hz on four points support (Figure 5) and about 20Hz on three points support. First eigenfrequencies of bad four points support (the station when one support point is free.) and five points support are 13.5Hz and 23.5Hz respectively. Comparing these, we can find out that the weak point should be the adjuster.
2. With normal concrete support, in lateral direction, the dipole magnet amplification is 36.6. With anti-vibration concrete, the amplification is 19.6. The anti-vibration concrete table for dipole magnet has about 50% decrease in amplititude. In vertical direction, because of the small amplification, the reduction is not remarkable. (Figure 7) And also, in modal test on different concrete pedestals, the anti-vibration concrete can improve the modal damping ratio.
3. In lateral direction, the PSD curves of the quadrupole and floor are almost consistent in low frequency range. The RMS curves show the same result. The first natural frequency peak is around 20Hz. In vertical direction, the amplification is little in 0-100Hz.(Figure 6, 8)

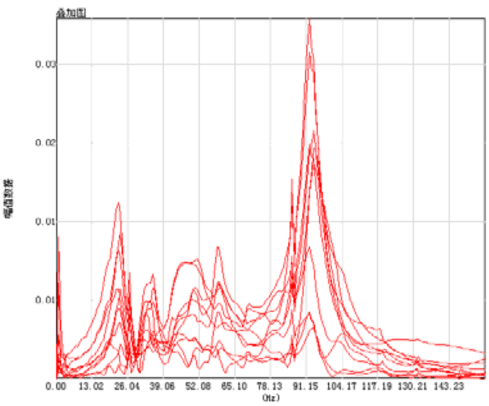

Figure 5: Four points support modal test frequency response lines, the first frequency is 23Hz and the software calculated modal damping ratio is 10.13%.

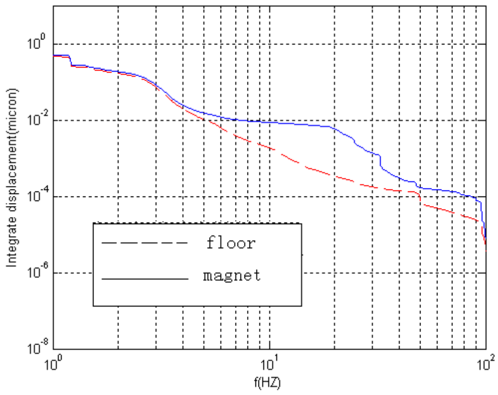

Figure 6: lateral RMS of quadrupole and floor

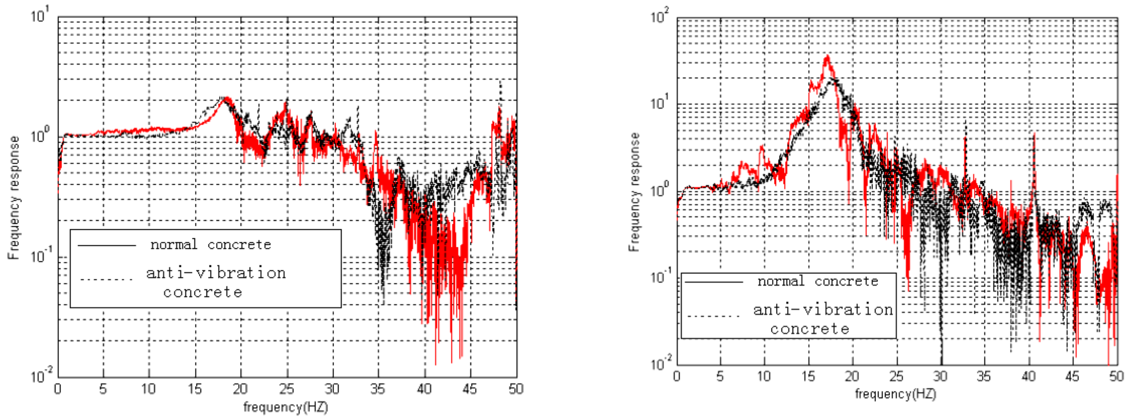

Figure 7: Vertical (L) and lateral (R) frequency response of dipole magnet to ground under different concrete support

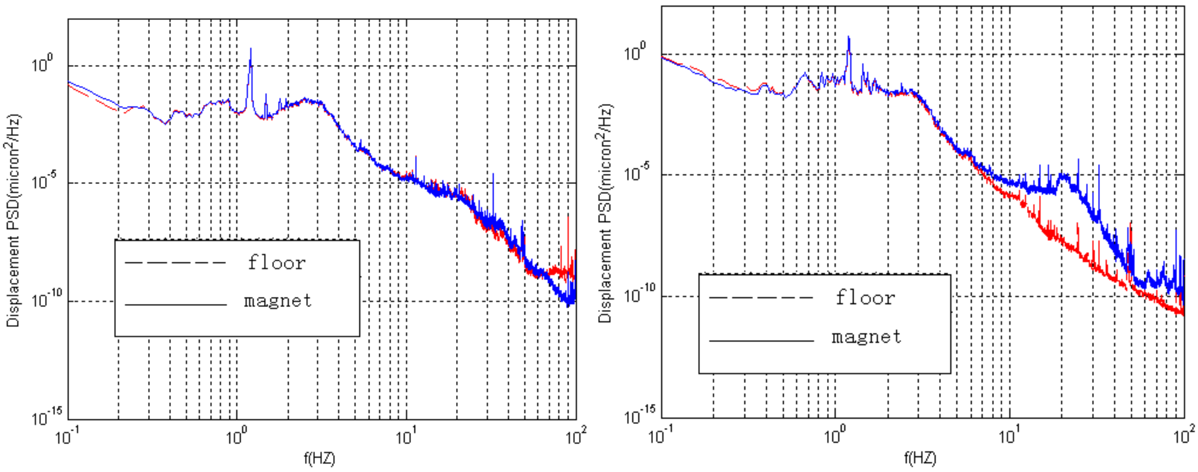

Figure 8: PSD lines of one quadrupoles and floor with four points support in vertical (L) and lateral (R) direction

5. PASSIVE DAMPING STRUCTURES

Passive damping structures are found to be useful in other synchrotron radiation facilities. It is a kind of sandwich-like structure, which consists of metal sheet and viscoelastic material (VEM) layer alternately. Its principle is to use VEM to absorb the dynamic strain energy of the magnet girder assembly, then attenuate the amplitude. In APS and Australian Light Source, a structure serial to the girder named damping pads is used.[4][5] In ESRF, a parallel structure named damping link is used.[6] We designed both these structures using stainless steel and viscoelastic material 3M468MP. The prototypes were made and assembled.(Figure 1, 9)

Till the time of writing, the test of damping link and damping pads are still in progress.

Figure 9: damping structures prototypes: damping link(L) and damping pad(R)

6. CONCLUSION

With a flexible adjuster, the SSRF girder magnet assembly still reach high natural frequency as 20Hz. In vertical direction, it is stiff enough and the amplification is low. In low frequency range, there is no amplification. The lateral amplification is higher than the requirement. Damping structures are used to decrease it.

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