DAMPING LINK FOR MAGNET GIRDER ASSEMBLY AND E-BEAM STABILITY IMPROVEMENT AT THE ESRF

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Abstract

To improve electron beam stability and x-ray beam stability, the micron-order of magnitude vibrations of the quadrupole magnets have to be attenuated. A damping system to reduce quadrupole magnet vibrations, the so-called 'damping link', has been implemented at the ESRF storage ring. The damping link is a damping device using ViscoElastic material, installed between the girder and the floor. It is used to attenuate the resonant motion of the magnet girder assembly. Vibration tests on the magnet girders in the storage ring before and after installation of damping links show very satisfactory damping performance. On-line monitoring of electron beam motion, and of quadrupole magnets vibration have been carried out simultaneously during the operation of the ESRF machine. Measurement results show clearly vibration attenuation of the quadrupole magnets, significant improvement of electron beam stability. As a consequence, x-ray beam stability is also enhanced.

1 INTRODUCTION

For 3rd generation synchrotron light sources, the electron beam stability is one of the most important requirements. Mechanical stability of the magnet-girder assemblies (MGAs) is essential for this beam stability, since the mechanical vibrations are amplified on the electron beam closed orbit more than 10 times by the quadrupole magnets [1]. Measurement results showed that the dominant frequency (7 Hz) of the electron beam motion at the ESRF was identical to the fundamental resonant frequency of the MGAs [2, 3]. This electron beam motion influences the position stability of the x-ray beam as well as the intensity stability of the x-ray beam. In order to improve electron beam and x-ray beam stability, it is necessary to attenuate the vibrations of the quadrupole magnet girder assemblies in the storage ring. Passive damping systems were appropriate for this application. Three passive damping systems have been studied at the ESRF to reduce the vibration of the MGAs: (a) damping plates, (b) tuned vibration absorbers, and (c) damping links. In all these damping designs, VEM is used to absorb the dynamic strain energy of the MGA. The damping plate consists of a sandwich structure with steel and VEM layers alternately. These devices were positioned between the base of the girder jacks and the floor. This design was first used at the APS [4]. Different damping plates have been tested at the ESRF [5]. A damping ratio larger than 10 were achieved with specifically designed 6-layers damping plates in the ESRF storage ring. However, the damping plates significantly reduced the horizontal stiffness of the MGA, it was incompatible with the long-term stability of the machine. Tuned vibration absorbers have been studied with finite element simulation, the added mass on a quadrupole would be 450 kg, which is too high for real application. Finally, the damping links were designed and implemented and were demonstrated to be most appropriate for attenuation of the resonant vibration of the MGAs.

In this paper we present the analysis, design, installation and test results of the damping links for the ESRF magnet girder assemblies.

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2 DAMPING LINK DESIGN

2.1 Analysis

Both experimental testing and finite element modelling (FEM) showed that the fundamental resonant vibration was a lateral rocking motion at about 8.7 Hz for G10 and G30, about 7 Hz for G20 [2,3]. The frequency

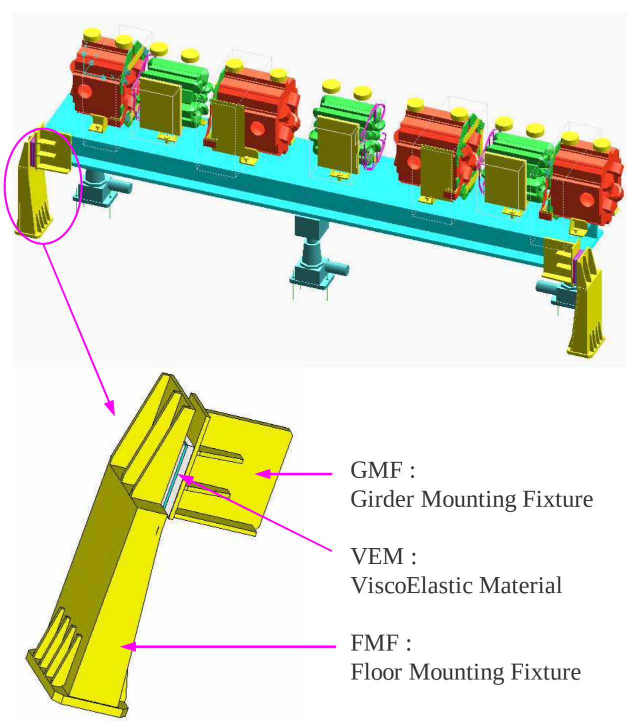

Figure 1: Damping link and installation on a G20 magnet girder assembly in the ESRF storage ring

of 7 Hz was the dominant frequency of the electron beam motion that should be attenuated by use of damping links. The damping link design consists of adding a viscoelastic link between the girder and the floor. It consists of three parts (Figure 1): (1) a sandwich structure with Aluminium plates and VEM (Al + VEM + Al), (2) a girder mounting fixture (GMF) links the sandwich structure to the girder, (3) a floor mounting fixture (FMF) links the sandwich structure to the floor. The motivation was to use the sandwich structure with VEM to absorb the dynamic strain energy of the MGA related to the rocking motion. The damping links were installed on the two extremities of the girder and floor (as shown in Figure 1) in parallel to the existing jacks. Therefore the required lateral stiffness was maintained. This installation allowed attenuation of both lateral rocking motion (1^{st} mode) and horizontal rotation around the vertical axis at the centre of the girder at about 13.6 Hz (3^{rd} mode) [2, 3]. The mounting fixtures (GMF, FMF) should both accommodate the environment in the tunnel and be stiff enough to transmit maximal dynamic strain energy of the MGA to the VEM layer which then dissipates this energy. The VEM sandwich was optimised to attenuate the 1^{st} resonant vibration with an operation condition tolerating up to 2 mm shear displacement in the vertical direction. This 2mm displacement corresponds to the maximum possible accumulated stroke required by alignment for two years. Test results show that the MGA with the damping links could be adjusted 2mm in vertical and lateral directions, and that the damping performance is not degraded by this amount of adjustment. The damping links are fully compatible with the alignment operation [6].

Installation required enormous efforts since the available space for the installation was very limited. Cooling pipes and some cable trays were moved. The installation procedures ensured that no stress was applied on the VEM structure [5]. The installation of damping links in the ESRF storage ring was started during the 2000 summer shutdown and totally completed after the 2001 March shutdown.

3 TEST RESULTS AND DISCUSSION

Vibration tests have been performed on quadrupoles before and after the installation of the damping links. Lateral frequency response functions of the quadrupole QD4 on the G20 MGA in cell 23 are shown in Figure 2 for the frequency range of 0-20Hz. Results were compared for the cases without cooling water flow in the magnets and without damping links (nf-nd), with damping links (wd) and with (wf) or without (nf) water flow. Results show excellent damping performance associated with the damping links. The two resonant peaks in the lateral frequency response function of the QD4 quadrupoles at 7.16 Hz for the lateral rocking

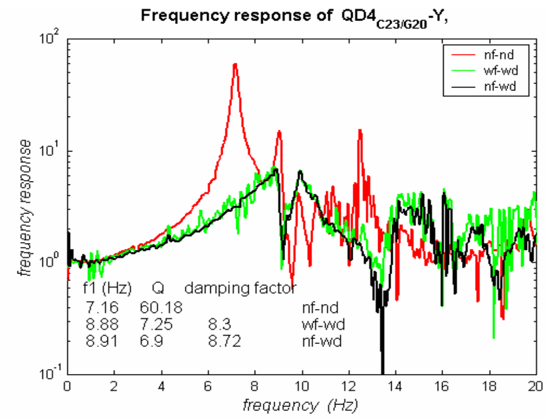

Figure 2: Lateral frequency response functions of quadrupole QD4 in cell 23,with (wd) and without (nd) damping links in the cases of cooling water flow on (wf) and off (nf).

motion and around 12.4 Hz for the horizontal rotation are significantly attenuated. A damping factor of larger than 8 was achieved. Water flow does not induce significant vibrations in the frequency range of 0-20 Hz, therefore it does not affect the performance of the damping links. This latter is effective, in some cases, to attenuate the quadrupole vibrations induced by cooling water flow which are mainly in the frequency range of 25-90 Hz.

The peak value in the frequency response function at the fundamental resonant frequency is the ‘so-called’ Q-value. The average Q-value of all the quadrupoles in the storage ring was, respectively, 43.4 and 7.6 before and after the installation of the damping links. The reduction factor is 5.8.

To investigate the effects of the damping links on the e-beam stability, on-line measurements during machine operation were implemented when half of the storage ring was equipped with the damping links. Vibration of quadrupoles and e-beam motion has been simultaneously measured once every hour since then. For the e-beam motion in the horizontal direction, the RMS displacement in the frequency range of 4-12 Hz in the case of half storage ring equipped with damping links was mainly in the range of 6-7 μm. A damping factor of about $\sqrt{2}$ was observed on the e-beam motion when half storage ring was equipped with damping links. The RMS displacement before the installation of damping links was about 10 μm. After the complete installation of damping links, the RMS displacement of the e-beam motion was mainly in the range of 2.5-3.5 μm. The horizontal e-beam motion in the frequency range of 4-12 Hz was reduced by a factor of 3.

Power Spectral Density (PSD) of the horizontal displacement of the electron beam is shown in Figure 3 for three cases. Before the installation of the damping links, there was a huge peak at 6.8 Hz in the horizontal displacement PSD. When half of the storage ring was equipped with damping links, limited damping effects on the electron beam could be observed, the peak at 6.8 Hz

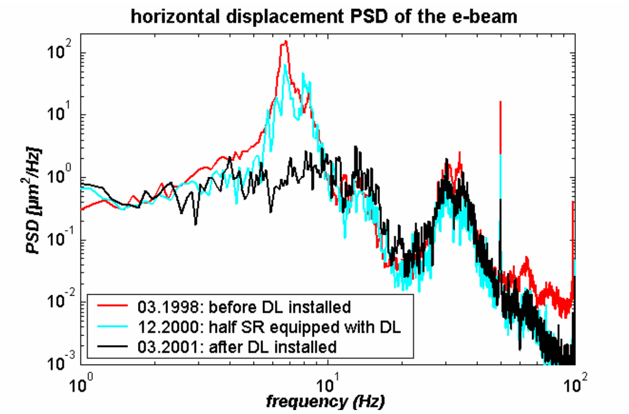

Figure 3: Horizontal displacement PSD of the electron beam before, during and after the installation of the damping links in

in the PSD was attenuated by a factor of about 2. When the storage ring was totally equipped with damping links, the peak at 6.8 Hz in the PSD was dramatically attenuated by a factor of 49. A wide peak around 30 Hz was also observed on the PSD. The damping links have no effect on that peak. This is because the wide peak around 30 Hz in the PSD of the electron beam motion is due to the lateral rocking motion of the quadrupole QF2 (or QF7) relative to the girder. The resonant motion of the quadrupoles QF2 and QF7 at 30 Hz are excited by the water flow in the cooling circuits. As the girder does not move for this vibration mode, the damping links are therefore not effective for the vibration of the quadrupoles, as well as for the motion of the electron beam around 30 Hz. Some countermeasures to reduce the vibrations of quadrupoles QF2 and QF7 have been studied by finite element simulation, and could be very effective.

The significant enhancement of the electron beam stability was also observed on the x-ray beam. As an example, Figure 4 shows the spectra of the x-ray beam intensity variation measured with ID14-EH1 beamline in January 2000 and in April 2001. Damping links for the machine girders were installed between these two dates.

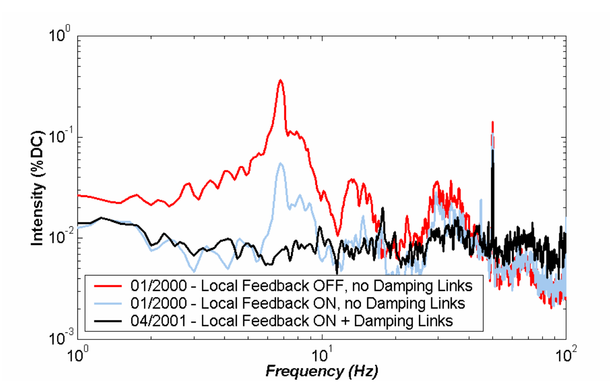

Figure 4: spectra of the x-ray beam intensity variation measured with the ID14-EH1 beamline at the ESRF

The spectra are expressed in percentage of the DC value. The fluctuation of intensity should be as small as possible, therefore the spectral value should be significantly smaller than 1. The peak at 6.8 Hz in the x-ray bean intensity spectra was totally removed after the installation of the damping links in the storage ring. The improvement of the e-beam stability is obvious.

4 CONCLUSION

The damping links have been successfully developed and implemented in the ESRF storage ring. Vibrations of the magnet girder assemblies in the lateral direction have been effectively attenuated by a factor of about 5.8 for the Q-value. The peak PSD of the horizontal displacement of the electron beam is reduced by a factor of 49. Electron beam and x-ray beam stability has significantly improved.

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