VIBRATION DAMPING SYSTEMS FOR MAGNET GIRDER ASSEMBLY AT THE ESRF

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Abstract

A damping system to reduce storage ring quadrupole magnet vibrations, so-called 'damping link', has been implemented at the ESRF. The damping link is a damping device using ViscoElastic Material (VEM), installed between the girder and the floor. It was used to attenuate the resonant motion of the magnet girder assembly and to improve the electron beam stability and the x-ray beam stability. Vibration tests and finite element analysis were intensively used to identify the resonant motion of the magnet girder assembly, to optimise the design and to check the performance of the damping links. Efforts have been made in the installation of the latter in order to accommodate the environment in the storage ring tunnel. Vibration tests on the magnet girders before and after installation of damping links showed very satisfactory damping performance. Vibrations of the magnet girder assemblies have been effectively attenuated by a factor of about 5.8.

1 INTRODUCTION

Mechanical stability of the magnet-girder assemblies (MGAs) in a storage ring is essential for the electron beam stability and performance, 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 after a monochromator, especially for a horizontally diffracting monochromator. Intensity variation of the x-ray beam with a peak frequency around 7 Hz has been observed in some beamlines at the ESRF, for instance, ID14, ID24, ID26.

The ESRF storage ring magnets are arranged in 32 similar cells, each including five different MGAs. Of these, three involve quadrupole magnets: G10, G20 and G30. The G10 and G30 MGAs contain five magnets. The G20 MGA is longer and consists of seven magnets [4, 5]. 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 preferred for this application, since they are known to be extremely effective for control of resonance response of structures [6, 7], and are in general cheaper and simpler to implement than active damping systems. 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 [8]. Different damping plates have been tested at the ESRF [9]. Initially girder jacks were bolted on the floor. When damping plates were installed between the base of the girder jacks and the floor, the bolts were removed in order to avoid "shunting" damping plates and to maximise damping performance. However, the damping plates without bolts significantly reduced the horizontal stiffness of the MGA. Under the actions of electrical cables, cooling pipes and thermal deformation of vacuum vessels, an equivalent of 0.6 mm of lateral displacement was observed on these magnets during machine restarting. This incompatibility with the long-term stability of the machine led us to abandon the damping plate approach despite its damping performance. 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

In the development of damping systems for the ESRF MGAs, finite element analysis and dynamic tests have been used in parallel [3, 9]. These two complementary methods can be both used to characterise the dynamic behaviour of the structure with or without damping systems. Some test results can be used to simplify and validate the finite element model. This model can then be used to simulate and optimise various damping countermeasures before manufacturing any hardware. In general, a validated finite element model can provide detailed results more conveniently than via experimental tests. Both methods are useful to assess the effectiveness of damping systems. The first resonant frequencies and mode shapes of the MGA were clearly identified by both methods in excellent agreement. The fundamental resonant vibration was a lateral rocking motion at about 8.7 Hz for G10 and G30, about 7 Hz for G20 [3, 9]. The frequency of 7 Hz was the dominant frequency of the electron beam motion that should be attenuated by use of damping links.

2.2 Damping link design and installation

The damping link design consists of adding a viscoelastic link between the girder and the floor. It consists of three parts (Figure 1):

- a sandwich structure with Aluminium plates and VEM (Al + VEM + Al)
- a girder mounting fixture (GMF) links the sandwich structure to the girder
- 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 (1st mode) and horizontal rotation around the vertical axis at the centre of the girder at about 13.6 Hz (3rd mode) [2, 3]. The mounting fixtures (GMF, FMF)

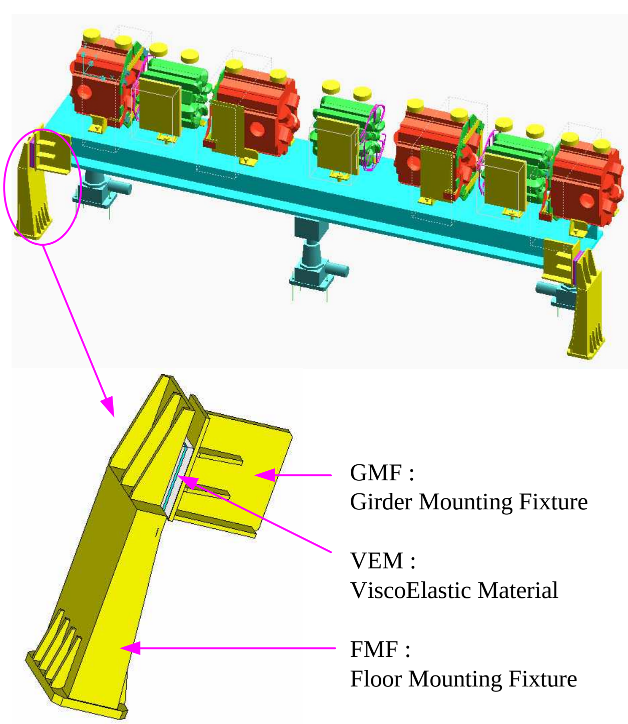

Figure 1: Damping link and installation on a G20 magnet girder assembly in the ESRF storage ring

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 1st 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 [10].

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 [9]. The installation of damping links in the ESRF storage ring was 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

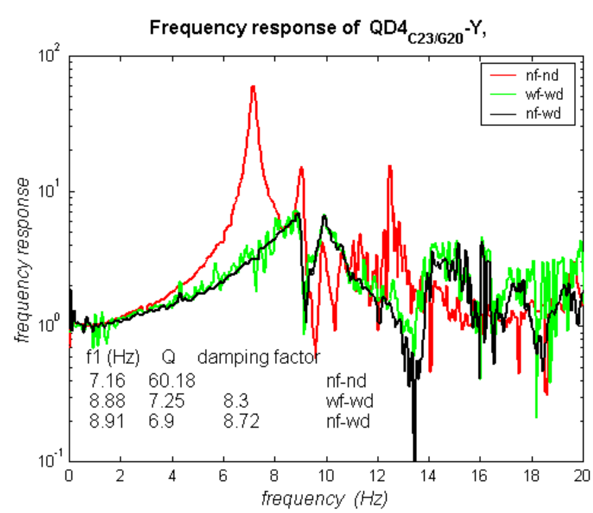

Figure 2: Lateral frequency response functions of the quadrupole QD4 in cell 23 for the frequency range of 0-20Hz,with (wd) and without (nd) damping links in the cases of cooling water flow on (wf) and off (nf).

quadrupoles at 7.16 Hz for the lateral rocking motion and around 12.4 Hz for the horizontal rotation are significantly attenuated. 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 results in terms of Q-value of quadrupoles on all the MGAs in the storage ring are shown in Figure 3 before and after the installation of the damping links. The average Q-value of all the quadrupoles was, respectively, 43.4 and 7.6 before and after the installation of the damping links. The reduction factor is 5.8. In cell 26, damping plates were installed between jacks and floor in 1997. Jacks were bolted to the floor. Damping plates were partially shunted, but some damping effects remain. This explains the lower Q-values before installation of the damping links in cell 26 than in other cells.

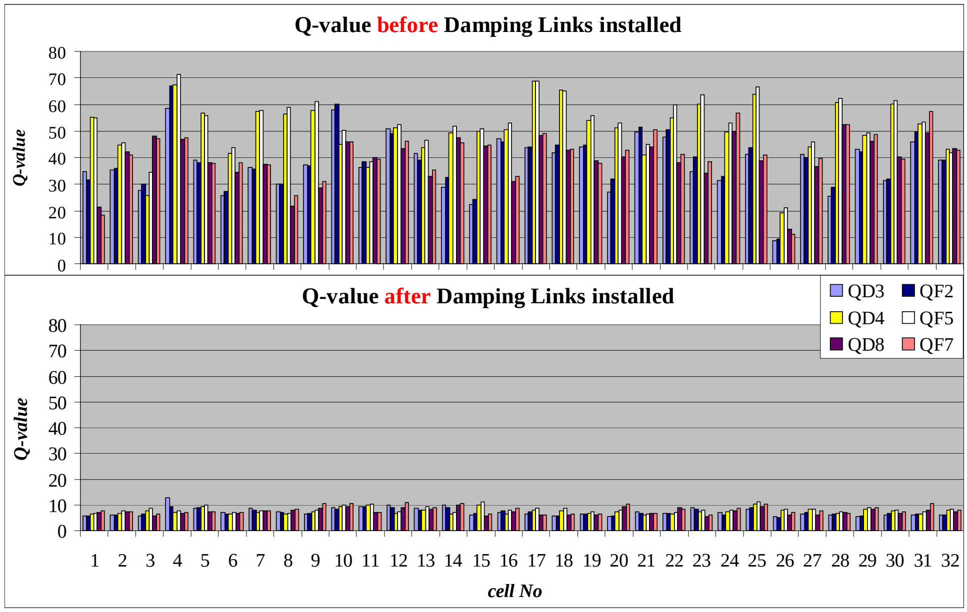

Figure 2: Q-value of quadrupoles before and after the installation of the damping links in the storage ring.

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. Electron beam and x-ray beam stability is expected to be significantly improved [11].

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