E-BEAM STABILITY ENHANCEMENT BY USE OF DAMPING LINKS FOR MAGNET GIRDER ASSEMBLIES AT THE ESRF

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Abstract

In order to attenuate the resonant vibrations of the magnet girder assemblies and thus improve the electron beam stability as well as the x-ray beam stability, damping links have been implemented in the ESRF storage ring. Test results show that vibrations of quadrupole magnets have been reduced by a factor of 5.8. Permanent measurements of electron beam motion, as well as quadrupole magnets and floor vibrations have been carried out simultaneously during the operation of the machine before and after the complete installation of the damping links. Results show a clear vibration attenuation of the quadrupole magnets and significant improvement of the electron beam stability. Influences of the booster and front-end shutter on the electron beam stability were also studied.

1 INTRODUCTION

The e-beam stability is one of the most important requirements for 3rd generation synchrotron light sources. The ESRF had a design target of emittance growth related to the stability of less than 10%. The efforts made in the design stage and during the construction phase resulted in an emittance growth of a few percents [1]. Since the operation of the ESRF, the horizontal emittance has been reduced from 6.2 to 4 nm.rad, the vertical emittance has been reduced from a design target value of 0.62 nm.rad to 0.03 nm.rad – a routine operation value [2]. With the reduction of the beam size, the beam stability becomes a more and more important parameter. The fundamental resonant vibration mode of the ESRF quadrupole magnet girder assemblies was a horizontal rocking motion at about 7 Hz [3,4]. This was the origin of the dominant motion of the e-beam, and of the x-ray beam instability. A damping device, the so-called ‘damping link’, has been developed to attenuate the vibrations of the magnet girder assemblies. Damping links have been completely installed in the ESRF storage ring after the 2001 March shutdown. The fundamental resonant vibrations of the magnet girder assemblies have been effectively attenuated by a factor of 5.8 [5]. This paper describes the beneficial effects resulting from the installation of the damping links: improvement of the e-beam and x-ray beam stability. Measurement results on e-beam motion will be presented and discussed. Improvement of x-ray beam stability will also be demonstrated. Influences of the operation of the booster, and actuation of the front-end (FE) shutters on the e-beam stability will also be addressed.

2 MEASUREMENTS OF BEAM MOTION

The installation of the damping links on the machine girder started during the 2000 Summer shutdown, and continued during the 2000 October and 2000-2001 Winter shutdowns, and was totally completed after the 2001 March shutdown. On-line measurements during machine operation were implemented by the end of November 2000. Half of the storage ring was equipped with the damping links at that stage. A Lennartz Seismic Recording System (LSRS) [6,7] was used. Originally, five vertical geophones associated with the LSRS were positioned on the storage ring wall. During the MDT shutdown on 28-Nov-2000, two horizontal geophones were placed on the quadrupoles : (1) QF7 on G30 in cell 16 (H-C16QF7) where damping links had already been installed, (2) QD4 on G20 in cell 08 (H-C8QD4) where damping links were subsequently installed during 2000-2001 Winter shutdown. These two geophones were connected to the LSRS, as well as a Beam Position Monitor (BPM) in cell 12 high-β section for the horizontal motion of the electron beam. Only two vertical geophones in cell 21 (V-C21W) and cell 28(V-C28W) were kept as initially. The LSRS was programmed for two types of data monitoring:

1. periodic measurements - a data acquisition over 40 seconds every hour (before the 2001 March shutdown) or half hour (after the 2001 March shutdown)
2. natural event - triggered measurements by the two geophones on the storage ring wall

The periodic measurements gave the vibration results versus time. The natural event measurements tracked events with sudden increase of the vibration level. During the first two weeks after the implementation of the on-line monitoring system, the triggering of the measurements was set by any of the five channels. In reality, the measurements were mostly triggered by the channel of the BPM. Significantly higher peaks were observed compared to periodic measurement results. These were due either to the opening/closing of the beam shutter in the front-ends or to beam injection, or earthquakes. These events induce amplitude (peak-to-peak) of up to 1 mm on e-beam motion, compared to a typical value of 38 μm. After two weeks, the triggering was set by the two geophones on the

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storage ring wall to track only the events resulting from floor excitation, such as earthquakes. The number of the triggering events was then significantly reduced.

3 TEST RESULTS AND ANALYSIS

From on-line monitoring measurements during the machine operation, RMS horizontal displacements have been calculated in the frequency range of 4-12Hz. Results are shown in Figure 1 for the following periods:

- from 30 November to 18 December 2000 with half storage ring equipped with damping links,
- from 23 March to 10 April 2001, after complete installation.

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, with some data close to 9 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. There were still some data close to 9 μm. These events were found to be due to the operation of the booster. Indeed, most of these peaks were observed during the weekly day of Machine Dedicated Time (MDT), when studies with the booster were frequently carried out. The other peaks of 9 μm were observed around re-injection time. Note that the ESRF booster is a 10 Hz fast cycling synchrotron. Spectral

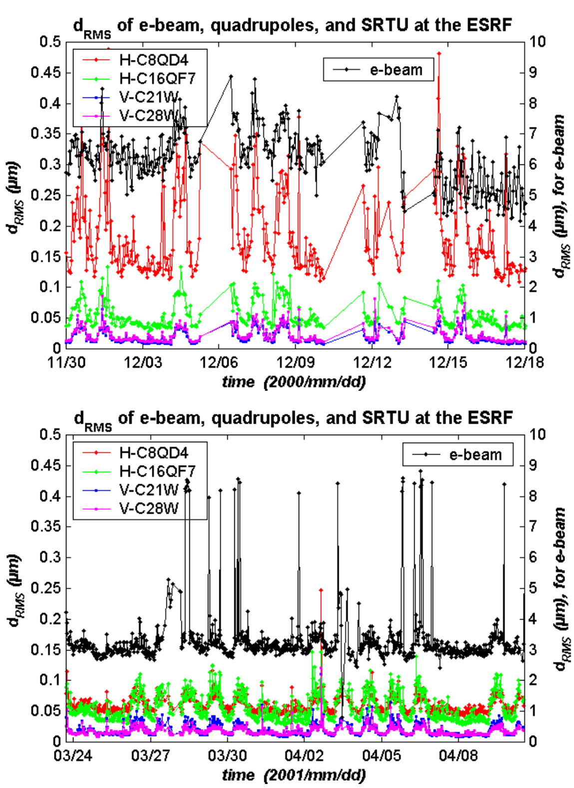

Figure 1: RMS displacement in the frequency range of 4-12 Hz of the e-beam, quadrupoles and SRTU wall versus time.

analysis (Figure 2) revealed sharp peaks at 10 and 20 Hz in the e-beam motion when the booster was in operation (ON), a smaller peak at 10 Hz when the booster was in low power mode (ECO: ECOnomic mode). This 10 and 20 Hz component was not observed in the motion of quadrupoles. Therefore, this e-beam motion results probably from magnetic perturbation induced by the operation of the booster.

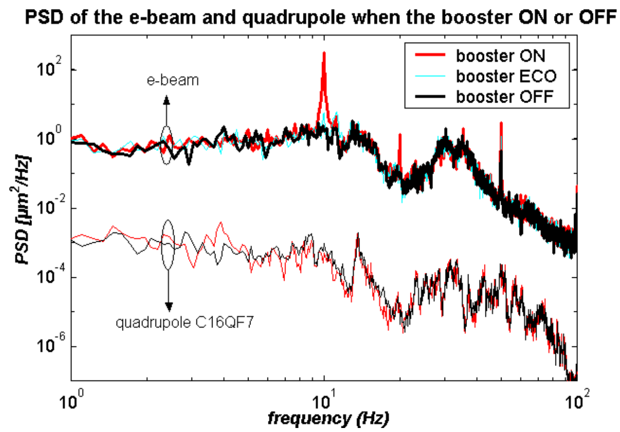

Figure 2: Displacement PSD of the e-beam and quadrupole C16QF7 when booster was ON/ECO/OFF. The three measurements were made at 17:10, 17:40, 16:40 on 29-March-2001, respectively.

Some remarks could be withdrwan from the results shown in figure 1 :

- The RMS displacements on the storage ring wall (V-C21W, V-C28W) were mainly in the range of 0.01-0.04 μm.
- Vibration of the quadrupole with damping links (H-C16QF7) was significantly lower than one of the quadrupole without damping links (H-C8QD4) before the end of year 2000. The RMS displacements on the quadrupoles with damping links were mainly in the range of 0.03-0.11 μm, compared to 0.12-0.4 μm without damping links.
- The variation of vibration level on the storage ring wall showed a regular pattern: higher level during weekdays (0.04 μm), and lower level during night and week-end (0.01 μm). This pseudo periodicity was also observed on the quadrupoles. Spectral analysis showed that the pseudo periodical variation is essentially in the frequency range of 1-10Hz. This effect was less remarkable on the e-beam motion. Indeed, the transfer function of the lattice showed that the e-beam is sensitive to the vibration of the quadrupoles only above 5 Hz [8].

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

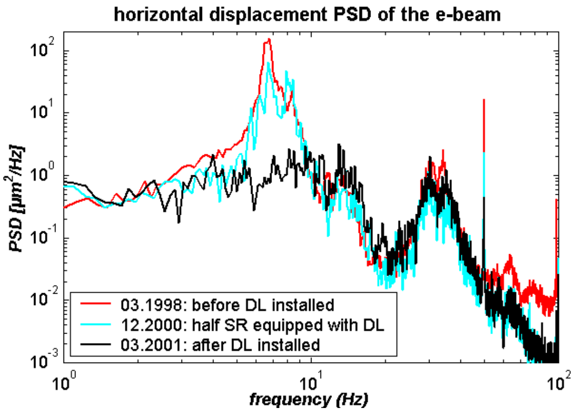

Figure 3: Horizontal displacement PSD of the electron beam before, during and after the installation of the damping links in the storage ring.

the electron beam could be observed. 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.

An ESRF front-end module 1 is attached to some magnet girders (insertion device FE for G20 girder, bending magnet FE for G30). The closing/opening action of FE shutters in the module 1 excites significantly the girder with the FE attached. The resulting excitation on the quadrupoles is local and lasts a few seconds. Corresponding e-beam motion has been observed. As the closing/opening action of FE shutters occurs essentially just before/after beam re-injection, their influences on the e-beam stability have therefore a limited impact.

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. 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. Note that a local

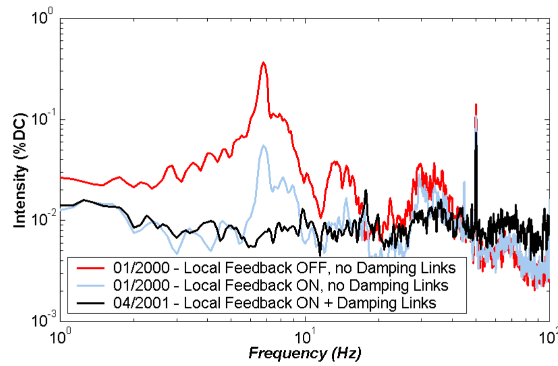

Figure 4: spectra of the x-ray beam intensity variation measured with the ID14-EH1 beamline at the ESRF

feedback on the electron beam was able to significantly reduce the intensity variation around the peak frequency 6.8 Hz, but the peak was still visible.

4 CONCLUSION

The damping links have been successfully developed and implemented in the ESRF storage ring. Horizontal vibrations of the magnet girder assemblies have been effectively attenuated. Electron beam and x-ray beam stability has improved significantly.

5 ACKNOWLEDGEMENTS

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