Vibration Measurement for the Girders with Multi-Stage Adjustable Dampers in TPS Storage Ring

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Theme: Precision Controls and Mechanical System

Abstract

The stability of electron beam is a major concern for the operation of the Taiwan Photon Source. To overcome mechanical vibration of the accelerator components due to ground motion, the multi-stage adjustable dampers are introduced for passive vibration damping, and presently installed between the girders and the pedestals. Through adjusting the amount of hydraulic fluid which bypasses the damping passage between two hydraulic chambers, the desired damping coefficient of the shock absorbers can be achieved. Results of vibration measurement presented in this paper show that the multi-stage adjustable dampers in conjunction with wedge locking systems under the assembly of the girders reduced the level of girder vibration.

Introduction

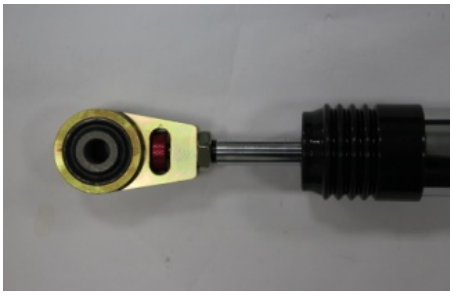
The Taiwan Photon Source (TPS) project is planning to construct a third-generation synchrotron accelerator in Taiwan. The most advanced and reliable techniques are applied to fabricate the TPS subsystems. Any instability in the machine could destroy the high performance of a low-emittance machine. The instabilities are classifiable from perturbing environments. To suppress the sources of vibration, generated from motor-vehicle traffic and utilities and from vibration along transfer routes to sensitive device, and to construct a girder insensitive to a source of vibration are two major topics concerning vibration suppression.

An innovative "extended kinematic mount" [1] design is used for the TPS girder to improve the stiffness of the kinematic mount from 3-point to 6-point support without sacrificing the flexibility of adjustment. A further increase from 24Hz to 30Hz for the first natural frequency was achieved after using locking wedges for the TPS girder prototype. The natural frequency obtained is almost twice that of a machine with a flexible adjustment mechanism. For equipment in a facility, the frequency of vibration typically locates in a range 10Hz to 100Hz. A basic requirement is that machines must be dynamically balanced. The uses of damper underneath a heavy machine and pipeline damper at the outset of a pipeline are popular mechanisms of solution. Although these effects might be effective (decrease 10 to 100 times), they are insufficient. Further suppression along transfer routes is necessary to decrease the level of vibration. Locating facility equipment as far from sensitive components as practicable is effective [2].

Previously, to effectively reduce the level of vibration resulting from the ambient excitation in TPS accelerator-engineering system, between the girders and pedestals, we install hybrid dampers combining a conventional passive oil damper with an adjustable device to obtain the effect of various damping forces [3]. Through adjusting the amount of hydraulic fluid which bypasses the damping passage between two hydraulic chambers, the desired damping coefficient of the damping absorbers can be achieved. In this paper, we introduce the locking systems in conjunction with adjustable damper under the assembly of the girders to further improve the natural frequencies of girders. It becomes effective to increase the natural frequency of a magnet-girder assembly by increasing the stiffness of the girder in TPS. With a use of a locking mechanism, it is helpful to increase the natural frequency of a girder.

Concept and operating methods of Hybrid Dampers

This damper is partitioned into three pressure chambers: the compression chamber, rebound chamber, and gas chamber. In the gas chamber, a compressible gas, such as nitrogen, is used as the springing medium; it is separated from the compression chamber by the floating piston. In both the compression and rebound chambers, a hydraulic fluid is used to convert pressure to force. This relationship allows the damping force of the adjusting member within a cylinder to be easily controlled in real time. The Components of a hybrid damper are shown in Figure 1. During the compression stroke, the hydraulic fluid in the cylindrical housing flows from the compression chamber into the rebound chamber. For the rebound stroke, the pressure definitions become the opposite and the flow reverses. These flows passing through the piston assembly are related to the pressure differences in the pressure chambers. These pressure differences drive the flow from the compression chamber to the rebound chamber and generate the damping force. At low-speed conditions, the damping force is caused by the resistance of fluid that passes through some orifices. At high-velocity conditions, the fluid pressure is high enough to deform the shim stacks and the fluid can also pass through the space between the shims and piston orifices. Since the fluid is effectively incompressible, as the piston rod enters the rebound chamber, the sum of the volumes of the fluid and the rod in the rebound and compression chambers must increase. To accommodate the increased volume, the floating piston compresses the nitrogen gas in the gas chamber to decrease the gas volume by an amount equal to the volume of the inserted rod. In reality, the pressure in the compression chamber is a function of the piston acceleration, gas-chamber pressure, and piston displacement. Additionally, the effect of the acceleration is much smaller than the pressure in the gas chamber, which effectively shows that the gas pressure is a function of the floating-piston displacement, and affects the pressure in the compression chamber.



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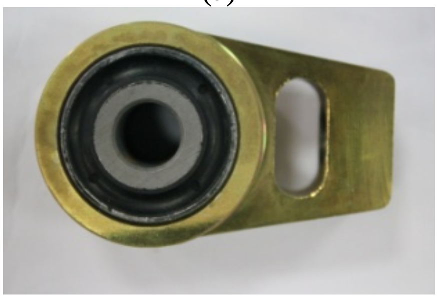

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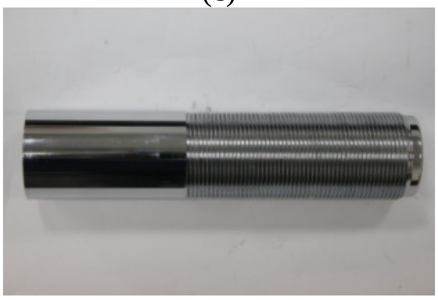

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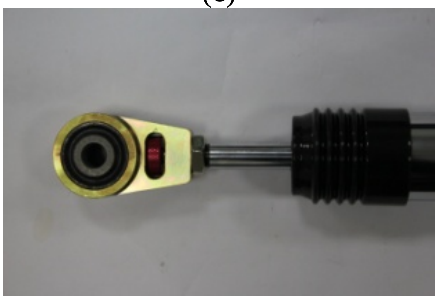

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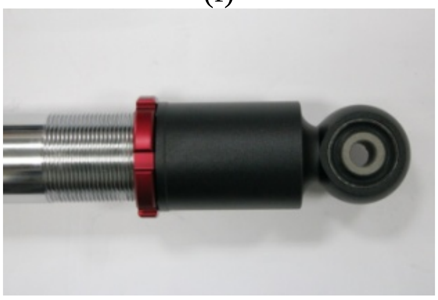

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Figure 1. Components of a hybrid damper

Impact Hammer Modal Testing

In general, experimental analysis is usually performed for verification of the results obtained from the analytical approach. Experimental analysis of structural vibration often helps us understand many vibration phenomena encountered in practice, and then we can have better design or control over the structures. One of the most important areas in experimental analysis is modal testing, which is more generally referred to as experimental modal analysis. Modal testing is usually the process of identifying the modal parameters of a structure from measured input/output data through system-identification methods.

To increase the natural frequencies and to reduce the level of girder vibration, we apply the multi-stage adjustable damping absorbers in conjunction with wedge locking systems, as shown in Figure 2, under the assembly of the girders reduced the level of girder vibration, and impact hammer modal testing can then be performed. Figure 3 shows Instrumentation setup of impact hammer modal testing for a magnet-girder system with the multi-stage adjustable dampers in conjunction with wedge locking systems. An impulse force serves as the excitation input acting on the points 1 and 6 of the girder (G1), as shown in Figure 4. The measured acceleration responses of a girder system will be obtained from accelerometers (PCB PIEZOTRONICS / Model 393B12), and the corresponding frequency response function acceleration data for each measured point are shown in Figure 5. In Figure 5, we clearly see that the locking systems in conjunction with adjustable damper under the assembly of the girders improve the natural frequencies of girders due to increasing the stiffness of the girder in TPS. Therefore, with a use of a locking mechanism, it is helpful to increase the natural frequency of a girder.

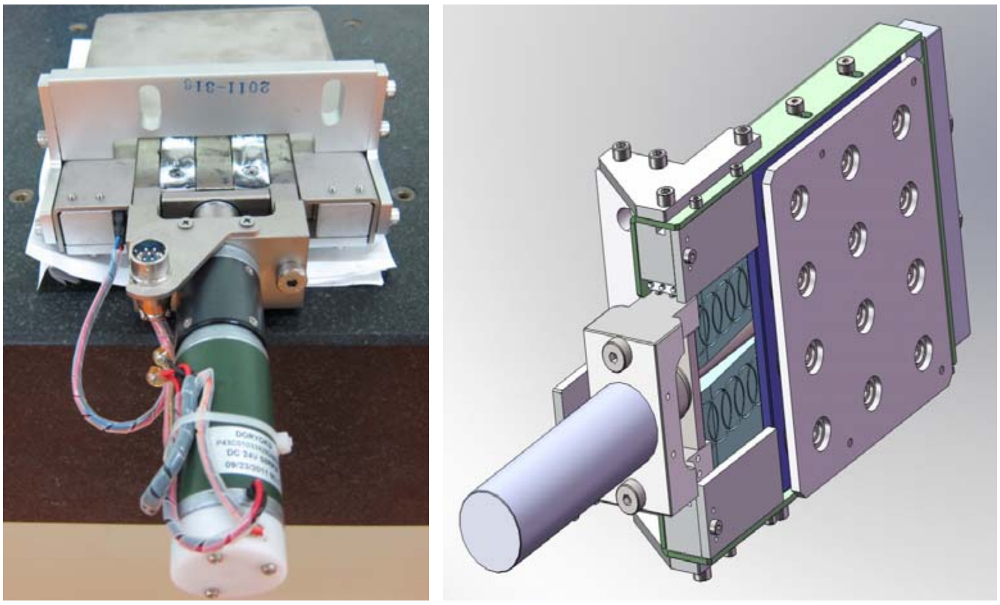


Figure 2. Wedge locking system

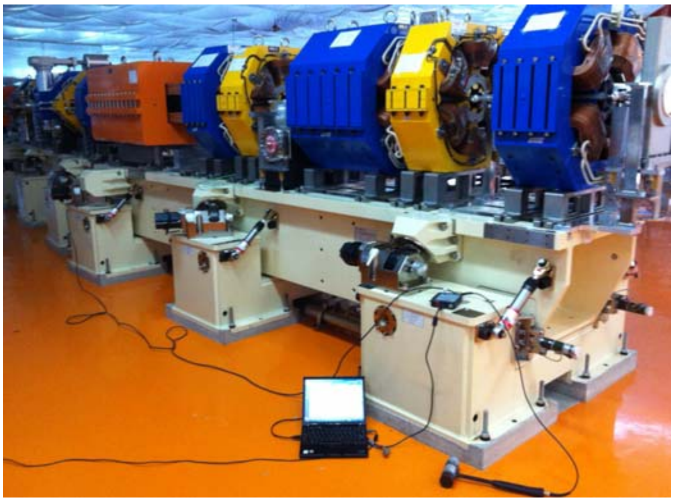


Figure 3. Instrumentation setup of impact hammer modal testing for a magnet-girder system with the multi-stage adjustable dampers in conjunction with locking system

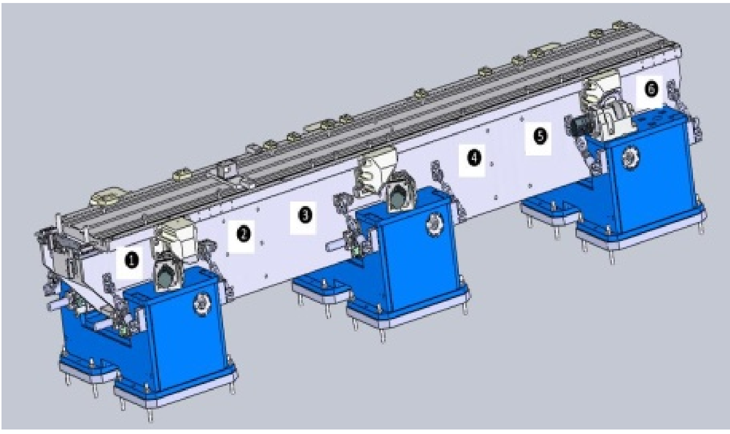
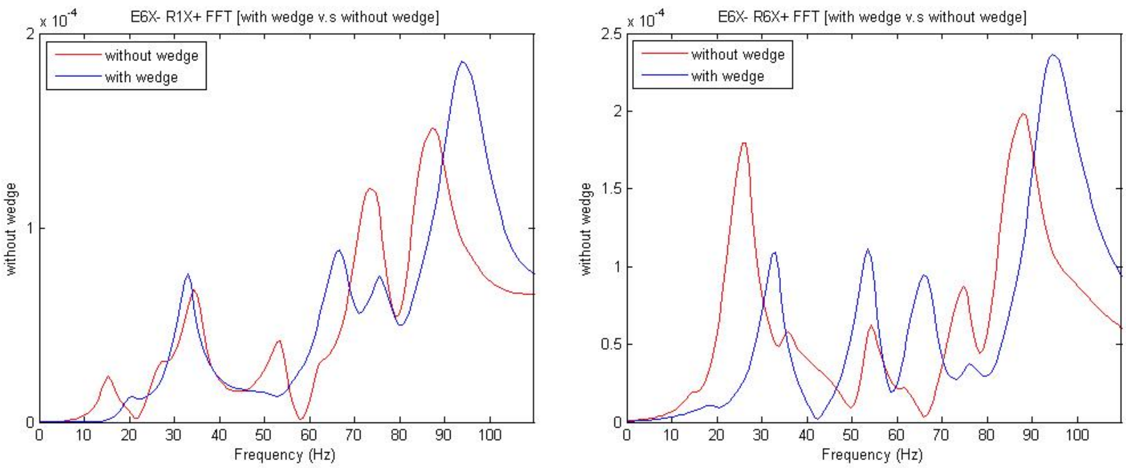


Figure 4. A schematic plot of position numbers of acting on the girder (G1)



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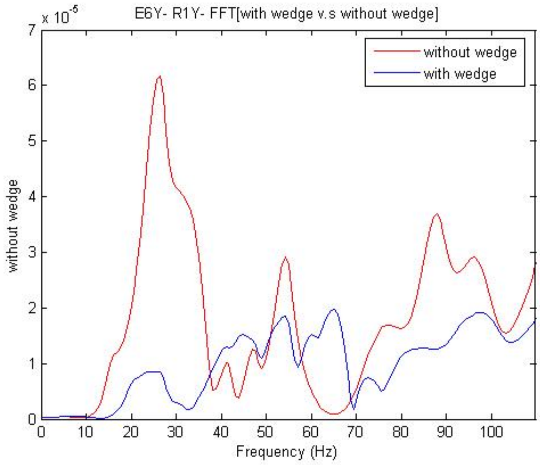

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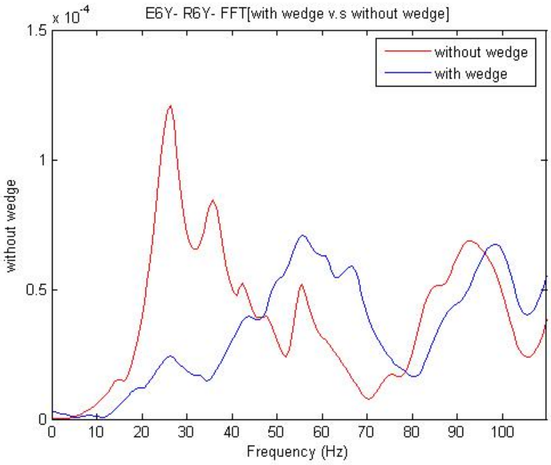

(d)

Figure 5. Typical frequency response function of a girder (G1) with/without a locking system subjected to impulse excitation

Conclusions

To improve the natural frequencies of magnet-girder system, in this paper, we introduce the locking systems in conjunction with adjustable damper under the assembly of the girders. It becomes effective to increase the natural frequency of a magnet-girder assembly by increasing the stiffness of the girder in TPS through installing wedge locking systems. Through the comparison of frequency response function of a girder (G1) between with and without locking systems subjected to impulse excitation, the results of impact hammer modal testing show that the multi-stage adjustable dampers in conjunction with wedge locking systems under the assembly of the girders, in general, not only improve the natural frequencies of magnet-girder system, but also reduce the level of girder vibration.

References

[1] Tseng, T.-C., Wang, D.-J., Wang, H.-S., Perng, S.-Y., Lin, C.-J., Ho, H.-C., and Chen, J.-R., "A Precise 6-axis Girder System with Can Mover Mechanism," MEDSI, 2006

[2] Chen, J.-R., "TPS Engineering for Low-emittance and High Stability," NSRRC Activity Report, 2011.

[3] Lin, C. -S., Hsu, K.-H., Tseng, T.-C., Lai, W.-Y., Wu, M.-H., Sung, P.-L., Perng, S.-Y., Chen, M. -L., Tsai, Y.-L., Wang, H.-S., Kuan, C.-K., Ho, H.-C., Huang, D.-G., Lin, C.-J., Luo, H.-M., Chen, J.-R., and Chiang, D.-Y., "An Application of Multi-Stage Adjustable Shock Absorbers for the Girders of Storage Ring in Taiwan Photon Source," IPAC 2012.

[4] Hsu, K.-H., Perng, S.-Y., Tseng, T.-C., Chen, H.-H., Wang, H.-S., Lin, C.-J., Ho, H.-C., Wang, D.-J., and Chen, J.-R., "The Vibration test and

Improvement of the TPS Prototype Girder” MEDSI, 2008.