AN APPLICATION OF MULTI-STAGE ADJUSTABLE SHOCK ABSORBERS FOR THE GIRDERS OF STORAGE RING IN TAIWAN PHOTON SOURCE

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Abstract

Beam stability is a major concern for the operation of the Taiwan Photon Source. One of the many factors to instability of electron beam is mechanical vibration of the accelerator components. The TPS uses steel girders to support the magnets and vacuum chambers in the storage ring. Three pedestal and six mover assemblies support the girders. Multi-stage adjustable shock absorbers are designed 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 damping absorbers can be achieved. Experimental results of modal testing presented in this paper show that the multi-stage adjustable damping absorbers under the assembly of the girders reduced the level of girder vibration.

INTRODUCTION

The accelerator-engineering system of Taiwan Photon Source (TPS) is composed of numerous complicated subsystems. 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.

A girder with a large natural frequency is always sought because the noise amplitude decreases rapidly with increasing frequency. The natural frequency of mechanical structure is inversely proportional the square of mass and directly proportional to the square root of the stiffness. It becomes effective to increase the natural frequency of a magnet-girder assembly by decreasing the mass of the magnet. TPS increases the stiffness of the girder to increase the resonance frequency of the magnet-girder assembly. With a wider, shorter structure, a light frame, and a lower position of the center of mass, use of a locking mechanism, etc. are helpful to increase the natural frequency of a girder.

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].

To effectively reduce the level of vibration resulting from the ambient excitation, and to improve the performance of conventional passive oil dampers, in this paper, between the girders and pedestals, we consider to install hybrid dampers that combine conventional-passive-oil dampers with an adjustable devices to obtain the effect of various damping forces as well as reduce cost and weight. Normally, in passive dampers, the pressure difference between the compression and rebound chamber drives the flow and generates the damper force. When an additional force that can change the pressure difference is supplied, the pressure difference can be adjusted and controlled. In this study, an adjustable device is employed to supply an additional force and fitted to the floating piston in a gas chamber. The pressure in the gas chamber affects the pressure in the compression chamber and is a function of the displacement of the floating piston. In other words, the pressure difference in the damper is regulated by means of control of the displacement of the floating piston, resulting in a change in the damping level. Therefore, the level of damping is continuously variable through control of the rotation of the adjusting member within a cylinder that is fitted to a floating piston. The simple adjustable device is used only to provide a force that can restrict the movement of the floating piston; that is, the directions of movement of both the damper and floating pistons are the same.

ISBN 978-3-95450-115-1

CONCEPT AND OPERATING METHODS OF HYBRID DAMPERS

A configuration of a hybrid damper is shown in Figure 1. 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 accumulator is a pressurized volume of gas that is physically separated from the hydraulic fluid by a floating piston. The accumulator serves two purposes. The first is to provide a volume for the hydraulic fluid to occupy when the piston rod is inserted into the cylindrical housing. The second is to provide a pressure offset so that the pressure in the low-pressure side of the piston assembly does not induce cavitation in the hydraulic fluid by reducing the pressure below the vapor pressure of the hydraulic fluid.

Figure 1: A schematic configuration of the hybrid damper.

The Components of a hybrid damper are shown in Figure 2. 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, which is a function of the floating-piston displacement, affects the pressure in the compression chamber. Considering an additional force that can adjust the movement of the floating piston, the pressure in the compression chamber will be regulated. Consequently, the force that is generated by the adjusting member within a cylinder that is used to restrict the movement of the floating piston plays an important part in causing the pressure differences; hence, the damping force that is augmented by an additional force produces a pressure drop across the damper piston assembly. The augmentation will be accomplished through control of the rotation of the adjusting member within a cylinder.

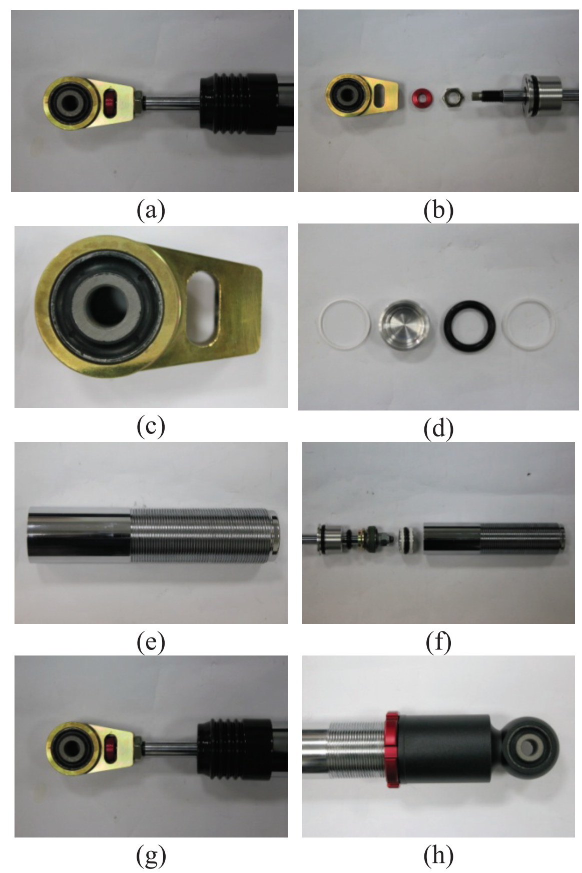


Figure 2: Components of a hybrid damper.

MODEL TESTING

In general, finite element analysis is developed and used for modelling the dynamics of large and complex structures. However, finite element modelling cannot approximate the real world situation well enough, due to the use of a limited number of elements or unrealistic boundary conditions between elements. The above mentioned disadvantage of finite element analysis points to a need for experimental analysis, which 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 under the assembly of the girders reduced the level of girder vibration, and modal testing can then be performed. In addition, to simulate the weight (around 10 ton) of magnets practically acting on a girder in TPS storage ring, we stack 10 pedestals on the girder (G1) by operating two gantry cranes, as shown in Figure 3. An impulse force serves as the excitation input acting on the point 6 of the girder (G1), as shown in Figure 4. The measured acceleration responses of a girder system will be obtained from accelerometers, as shown in Figure 5, and the corresponding frequency response function acceleration data for each measured point are shown in Figure 6. In Figure 6, we clearly see that the level of girder vibration is somewhat reduced and most peaks of modes of the girder (G1) moved right when installed the multi-stage adjustable damping absorbers, especially for the lower modes, such as 1st, 2nd, and 3rd modes, due to that their contribution to the system response is somewhat more than that of the higher modes of a system.

(a)

(b)

Figure 3: Photographs of the modal testing of a girder.

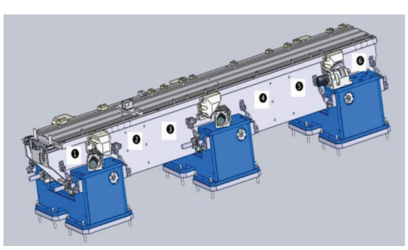
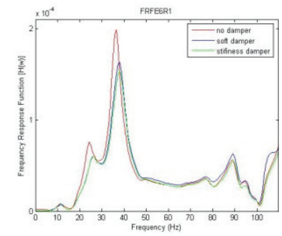


Figure 4: A schematic plot of position numbers of acting on the girder (G1).

Figure 5: A typical plot of the accelerometer (PCB PIEZOTRONICS / Model 393B12) .



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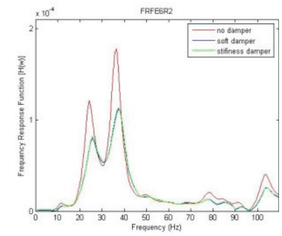

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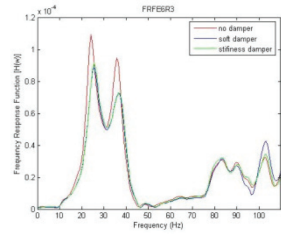

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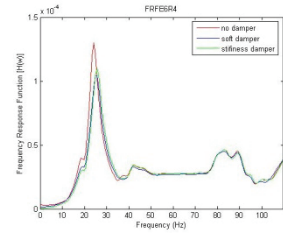

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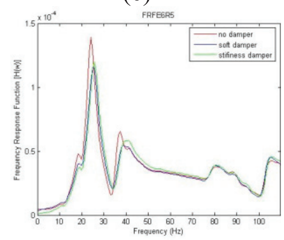

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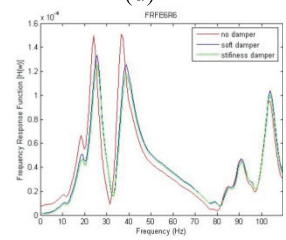

(f)

Figure 6: Typical frequency response function of acceleration data of a girder (G1) subjected to impulse excitation.

CONCLUSION

In this paper, to effectively reduce the level of vibration resulting from the ambient excitation in TPS accelerator-engineering system, between the girders and pedestals, we consider to install hybrid dampers that combine a conventional passive oil damper with an adjustable device to obtain the effect of various damping forces. 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. Modal-testing results presented in this paper show that the multi-stage adjustable damping absorbers under the assembly of the girders reduced the level of girder vibration.

ACKNOWLEDGMENT

The author would like to thank every member in the Mechanical Positioning Group, NSRRC, for their kind assistance and friendship.

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