PRELIMINARY DESIGN AND TEST OF DAMPING MECHANISM FOR REDUCING VIBRATION OF TPS SR VACUUM CHAMBER

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Abstract

Since flow-induced vibration of vacuum chamber effects of the stability of the electron beam storage ring in Taiwan Photon Source (TPS), a damping mechanism was designed and installed to reduce vibration. The damping mechanism is composed of a clamper of vacuum chamber, a fixed fixture on the girder and a sandwiched stainless steel support with damping materials inside. Different kinds of materials were applied in the damping mechanism for vacuum chamber. The vibration of vacuum chamber were obtained and compared. The design and vibration measurement results of damping mechanism for vacuum chamber are presented in this paper.

INTRODUCTION

Taiwan Photon Source (TPS), a third-generation accelerator, was constructed with a circumference of 518.4m with 24 girder magnet assembled (GMA). It reached its goal of 500mA in 2015. However, it was found that the vibration of vacuum chamber is major especially in the upstream of the dipole magnets. The source of vacuum chamber vibration are thought to be generated by cooling water passing through the pipe as shown in figure 1.The vibration of vacuum chamber affect the motion of electron beam due to eddy current effect [1]. In order to reduce the vibration of vacuum chamber, the damping mechanism was designed.

Figure 1: cooling pipe of vacuum chamber.

DESIGN OF DAMPING MECHANISM

Due to limited space between the touch sensor module and quadruple magnet on the girder, the damping mechanism is designed as a thin support as shown in figure 2 .The damping mechanism was composed of a clamper of vacuum chamber, a fixed fixture on the girder and a sandwiched stainless steel support with damping material inside. The clamper is designed to clamp the vacuum chamber with two M8 bolts with two sets of screws to adjust the vacuum chamber from the top surface. The fixture is fixed on the girder with two M16 bolts, and linked with the stainless steel sandwiched support with three m8 bolts. The thickness of stainless steel is 2mm. The sandwiched stainless are mounted with six M8 bolts with damping material inside. The six bolts are fastened lightly at the last step of assembling the damping mechanism in order to prevent from deforming the vacuum chamber.

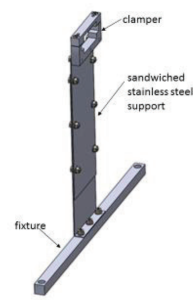

Figure 2: Design of damping mechanism for vacuum chamber.

MATERIALS IN DAMPING MECHANISM

Since it is difficult to obtain commercial passive damping material in Taiwan, only 3 types of material applied in the damping mechanism were chosen to study the performance of vibration reduction. These materials for our test are listed in Table 1 and Figure 3.

Table 1: Testing Materials

Material	Thickness (mm)	Loss factor	Storage module(Mpa)
3M ISD 112	0.127	1.0	0.22
Nitto D-300N	1.5	N/A	N/A
3M 4026	1.6	N/A	N/A

Figure 3: Different materials (from right: 3M ISD112, Nitto D-300N and 3M 4026).

3M ISD112, a kind of viscoelastic damping polymers, is used in many engineering designs to reduce vi-

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bration [2]. Another material, Nitto D-300N, composed of aluminum layer, synthetic rubber adhesive and release liner, is claimed to having high performance in damping minimization [3]. However, the damping properties of D-300N are not available from the material supplier. The other material, 3M 4026, a kind of double coated urethane foam tape for bonding various types of surfaces together, which cannot be claimed as a damping material [4]. Thus, there is no damping properties in the specification of 3M 4026 either. Being the case, the performance of these 3 materials which applied in damping mechanism are compared and discussed.

EXPERIMENTAL SETUP

In order to know if it has the same results in different vacuum chamber, we set up both tests in the R13 and R20 cell. Since the vibration of vacuum chamber we measured may alter at different time points due to the variation of the girder vibration, the girder vibration measured is set to be the denominator of the transmissibility. The transmissibility is defined as the ratio of the vibration of vacuum chamber to that of girder as in equation (1). Thus, both the vibration of vacuum chamber and girder are measured simultaneously with digital FFT analyser. The two PCB 393B31accelerometers (sensitivity: 10V/g) were mounted on the vacuum chamber and the girder respectively in the same direction as shown in figure 4. The X and Y direction are defined as the horizontal and vertical respectively. We measured 4 conditions (free, ISD112, D300N, 3M4026) in each direction to study the effectiveness of the vibration suppression. The condition named "free" means that the vibration of vacuum chamber is measured without damping mechanisms. The condition named ISD112/D300N/3M4026 means that the vibration measurement of vacuum chamber with 3M ISD112/Nitto D300N/ 3M 4026 damping mechanism are executed. The bandwidth range of vibration measurement is 0-300Hz and the 4096 points are recorded in each frame. The spectrum of vibration are linear averaged with 10 frames. The averaged vibration spectrum of each condition are obtained twice to check the consistency of the data.

$$\text{Tramsimissibility} = \frac{\textit{the vibration of vacuum}}{\textit{the vibration of the girder}}. \qquad (1)$$

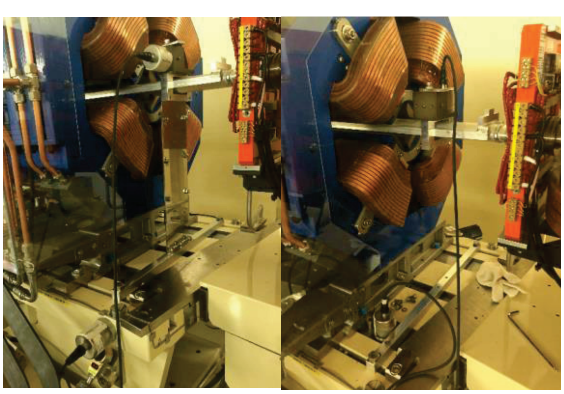

Figure 4: The experimental setup.

EXPERIMENTAL RESULTS

Since both the vibration spectrum of the vacuum chamber and girder are measured, the transmissibility spectrum of R13 and R20 vacuum chamber, supported by damping mechanism with different damping material, to the girder in X and Y direction are shown in Figure 5 to 8.

Figure 5: The transmissibility spectrum of R13 in X direction.

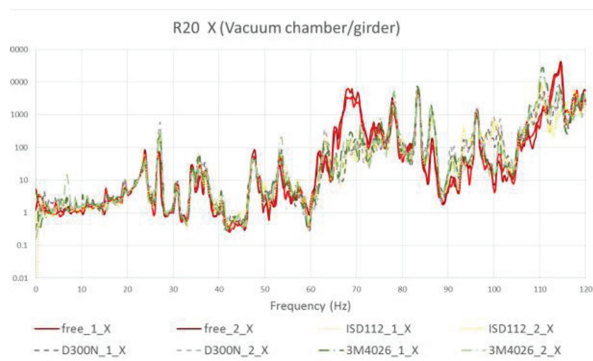

Figure 6: The transmissibility spectrum of R20 in X direction.

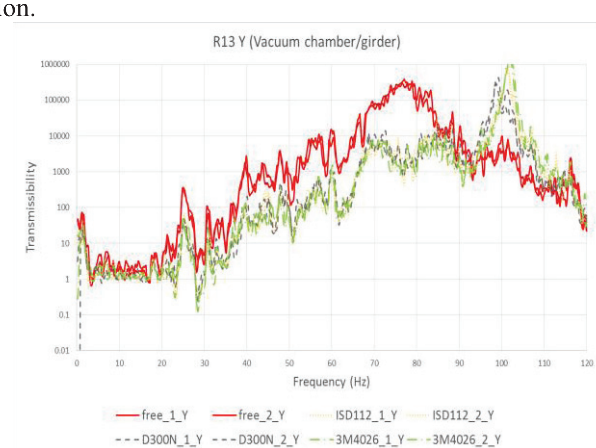

Figure 7: The transmissibility spectrum of R13 in Y direction.

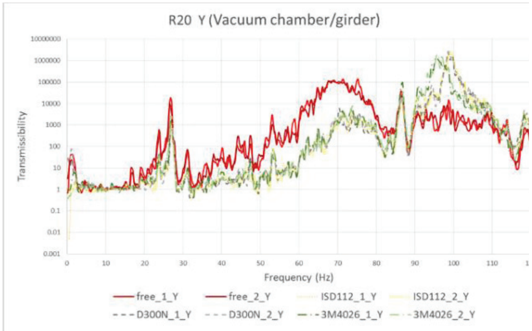

Figure 8: The transmissibility spectrum of R13 in Y direction.

From these transmissibility spectrum, it was found that the results with the same condition measured twice are similar. Nevertheless, the results in different cells (R13& R20) are different even with the same damping mechanism and material in the same direction. In X direction, the transmissibility spectrum are similar with different conditions; in Y direction the spectrum of "free" condition are significantly different from other condition from 20 to 90Hz.

For the legibility to compare with different damping material, the transmissibility of those damping material divided by that of no damping mechanism (free), is called transmissibility ratio. The transmissibility ratio spectrum of different materials are shown in figure 9 and 10. When the transmissibility ratio is smaller than 1, the damping mechanism reduces the vibration of vacuum chamber. In Y direction, the vibration of vacuum chamber with damping mechanism are reduced effectively from 40Hz to 80Hz.

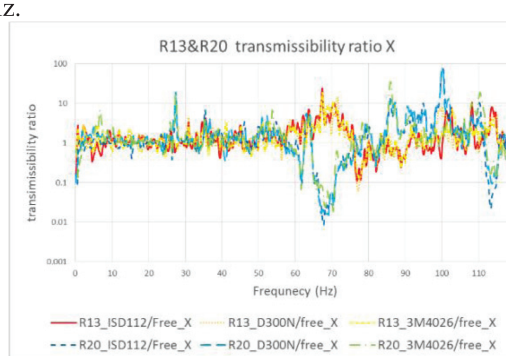

Figure 9: The transmissibility ratio spectrum in X direction.

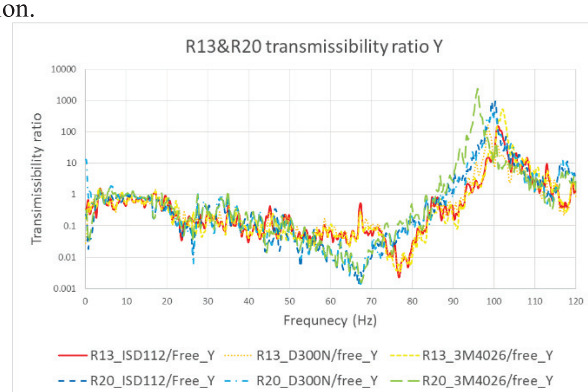

Figure 10: The transmissibility ratio spectrum in Y direction.

The transmissibility of averaged integrated displacement RMS with different materials from 4Hz to 100Hz in R13 and R20 are shown in Figure 11 and 12. As shown in the result, we can find that the vibration of vacuum chamber reduce more in the vertical direction. 3M4026 reduce vibration more effectively than other material in R13 (21%), but it has the opposite results in R20 (55%). On the contrary, it is meaningless to reduce the vibration in horizontal direction.

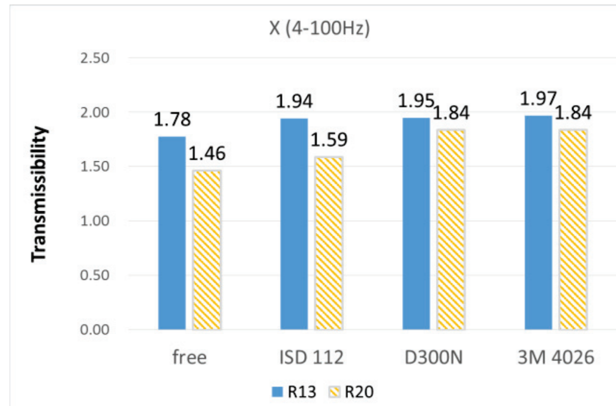

Figure 11: Comparison of the transmissibility of different materials in damping mechanism for vacuum chamber in X direction in R13 and R20.

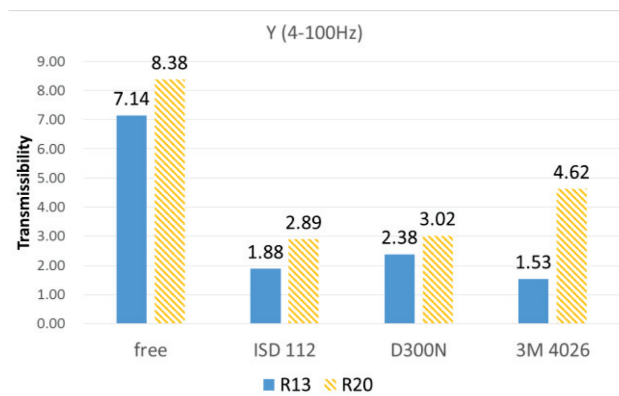

Figure 12: Comparison of the transmissibility of different materials in damping mechanism for vacuum chamber in Y direction in R13 and R20.

SUMMARY

In this paper, the damping mechanism for TPS SR vacuum chamber was designed and installed in the entire TPS storage ring. As the test results, this damping mechanism reduce the vibration of vacuum chamber in vertical direction from 20% to 55% especially from 40Hz to 80Hz. Nevertheless, the vibration of vacuum chamber in horizontal direction is not been suppressed effectively. Different materials applied in damping mechanism reduce the vibration similarly.

REFERENCES

[1] *Observation of Beam Orbit Fluctuation with Forced-Vibrating Magnets and Vacuum Chambers,* MEDSI, Illinois U.S.A 2002 pp.147-155.

[2] 3M website. http://goo.gl/yp54iZ.

[3] Nitto website. http://goo.gl/LGgHMt.

[4] 3M website. http://goo.gl/A3vXZ.