Conference Paper

Evaluation of TLCD Damping Factor from FRF Measurement Due to Variation of The Fluid Viscosity

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Abstract

Tuned Liquid Column Damper (TLCD) has become an alternative solution for reducing low frequency vibration response of machines and structures. This is not surprisingly that the damper has simply structure and low maintenance cost. The main disadvantage of using TLCD is the complexity in controlling TLCD damping factor experimentally. Theoretically, damping factor can be controlled by adjusting the orifice dimension. However, this method is time consuming and not appropriate conducted in the real application. A more simply method for adjusting TLCD damping factor is by varying the fluid viscosity. This research is aimed to evaluate the effect of fluid viscosity to the damper performance. Two DOF shear structure with TLCD is used as the experimental model. Several TLCD fluids with different viscosity are evaluated. Evaluation of TLCD damping factor due to variation of the fluid viscosity is conducted by comparing the Frequency Response Function (FRF) obtained from the experimental data.

Keywords: TLCD, vibration, structure, damper, viscosity

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1. Introduction

Nowadays, several methods have been developped to reduce vibration response of mechanical and structural system in accordance with either serviceability or safety criteria. For a large structure such as building and bridge, strengthening the structural system or installing of the base-isolation could be very costly or too difficult to perform. For this case, incorporating a passive damper into the structure is relatively less expensive and much simpler to be realized. Therefore, many research works on the passive damper such as Dynamic Vibration Absorber(DVA) have been conducted in recent years[1,2,3]. Among passive DVA, Tuned Liquid Column Damper(TLCD) is of great interest for some of its characteristics such as easy implementation, low cost of construction and maintenance and no need to add mass to the structure if the liquid is used as water supply[4]. The passive DVA performance is greatly depend on the selection of the damper natural frequency and damping factor. In TLCD, the natural frequency can be varied by adjusting the column dimensions or the liquid level inside the damper[5]. Meanwhile, TLCD damping is affected by the degree of turbulence flow of the fluid due to TLCD column junction and the built in orifice. However, variation of TLCD damping by modifying of the orifice hole is difficult to be conducted experimentally[6].

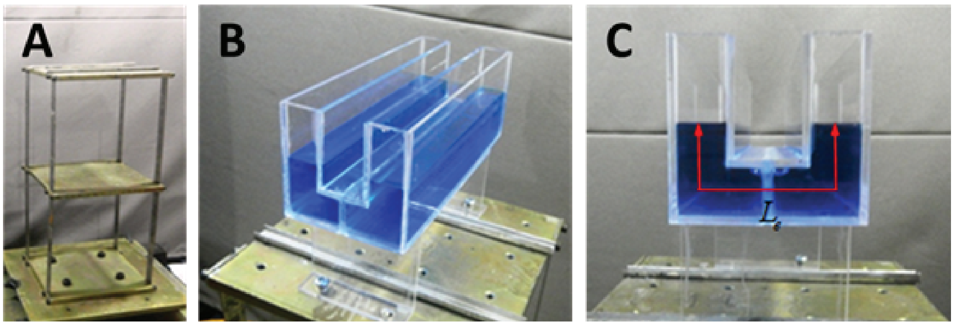

Figure 1: Structural testing model and TLCD.

Components		Value
Beam	Dimension	210 mm × 20 mm × 1 mm
	Material	Stainless Steel: E = 190 GPa, ρ = 7700 kg/m^3, ν = 0.26
Rectangular block	Dimension	200 mm × 200 mm × 10 mm
	Material	AISI 1020: E = 200 GPa, ρ = 7900 kg/m^3, ν = 0.29
TLCD	Dimension	Height = 73 mm, Width = 79 mm, Column width = 20 mm
	Material	Acrylic

Table 1: Specifications of structural testing model and TLCD

A simply method for adjusting the fluid damping inside TLCD is by varying the fluid viscosity. In this research, three TLCD fluids with different viscosity are evaluated experimentaly. The TLCD performance is analysed by comparing the measured FRF response of the structure with TLCD.

2. Experimental Setup

Two-DOF shear structure as shown in Fig. 1 is used as the testing model. The structure model consists of two rectangular blocks made of the steel plate that connected using four steel beams. The base of structure is fixed to the ground that made of a rectangular steel plate. The ground has two pairs of slider bearing at its bottom. Therefore, it can move freely in the horizontal direction. The TLCD damper is positioned at the top of the second floor of the structure. The damper housing is made of the acrylic plate as shown in Fig. 1. The column cross-section of TLCD damper is the uniform rectangular shape.

The structural testing model and TLCD spesification are shown in Table 1. The experimental model consist of three components i.e Steel beam, Rectangular block and TLCD as shown in Table 1. It should be noted that the TLCD dimensions are selected so that the natural frequency of the fluid inside TLCD column match with the first natural frequency of the structure. To increase the fluid damping, an orifice plate is positioned in the midle of horisontal column. The plate has 115 holes and each holes diameter are 3 mm. The experimental setup is shown in Fig. 2.

Figure 2: Experimental setup.

As shown in Fig. 2, the ground of the structure is excited horizontally by a vibration exciter. The excitation signal from the exciter is a random signal with frequency range from 0 until 10 Hz. Two accelerometers located at the ground and the second floor of the structure are used to measure the acceleration data. These data are acquired by B&K Pulse Digital Signal Analyser(DSA).

3. Experimental Results

To analyse the liquid viscosity effect, three lubricants PERTAMINA SAE 10, SAE 40 and SAE 20W-50 are utilized as the TLCD fluid. Because of the TLCD performance also

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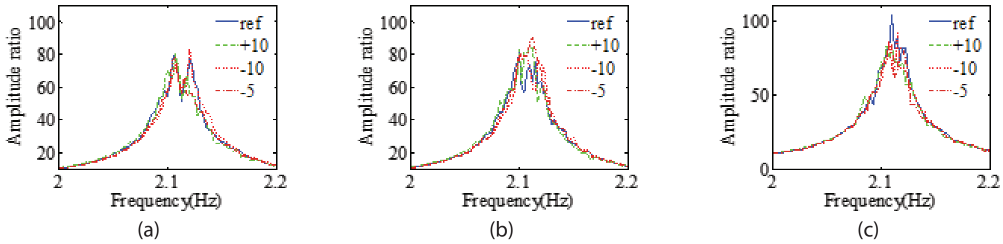

Figure 3: Frequency response of structure with TLCD, (a) using SAE 10 oil (b) using SAE 40 oil (c) using SAE 20W-50 oil.

depends on the fluid natural frequency, the experiments are conducted for several fluid levels. According to theoretical analysis[5], the fluid level is one of the dynamic parameters which affects the TLCD natural frequency. The reference level is denoted as the optimum fluid level which theoretically calculated [7]. This reference level is related to the fluid length L_e = 100 mm as shown in Fig. 1. Another level +10,-10 and -5 are obtained by added or reduced the fluid volume by 10 ml or 5 ml, respectively. The amplitude ratio which describes the Frequency Response Function (FRF) of the structure is calculated by dividing the frequency response of the 2^{nd} floor with the frequency response of the excitation signal. Figure 3 shows the amplitude ratio of the structure with TLCD. Because of the TLCD damper is designed according to the 1^{st} natural frequency of the structure then the enlargement of frequency response is focused to the area located near to this frequency zone.

The TLCD liquids are varied from SAE 10, SAE 40 and SAE 20W-50, respectively. It should be note that the viscosity of SAE 20W-50 is larger than that of SAE 40 in the room temperature. Figure 3 shows that for low viscosity liquid, the dynamic vibration absorber phenomenon can be simply detected. The absorber effect is seen clearly from the separation of two peak frequencies close to 2.1 Hz as shown in Fig. 3(a) for SAE 10 fluid. This results indicate that the optimum TLCD damping factor can be obtained when using low viscosity of TLCD liquids. The dynamic absorber effect reduces when the fluid viscosity is large as shown in Fig. 3(c) for SAE 20W-50 fluid. In this condition, the separation of two peak frequeny cannot be seen clearly.

Comparison of the maximum amplitudo ratio of the structure is shown in Fig. 4. Here, the maximum amplitude ratio is calculated as the mean of maximum peaks of the frequency response curve in Fig. 3. The x- axis of bar chart in Fig.4 is arranged from the low viscosity to the high viscosity fluid. The y-axis in Fig.4 describes the percentage of maximum amplitude in comparison to the case without TLCD. As shown in Fig. 4, the maximum amplitude ratio increases when the fluid viscosity increase. The reason for this condition is the fluid motion become small so that the dynamic absorber effect decreases when the fluid viscosity is large. In this condition, two frequency peaks which detected in the case of low viscosity condition becomes a single peak which indicates the system change to a one degree of freedom(1 DOF) system.

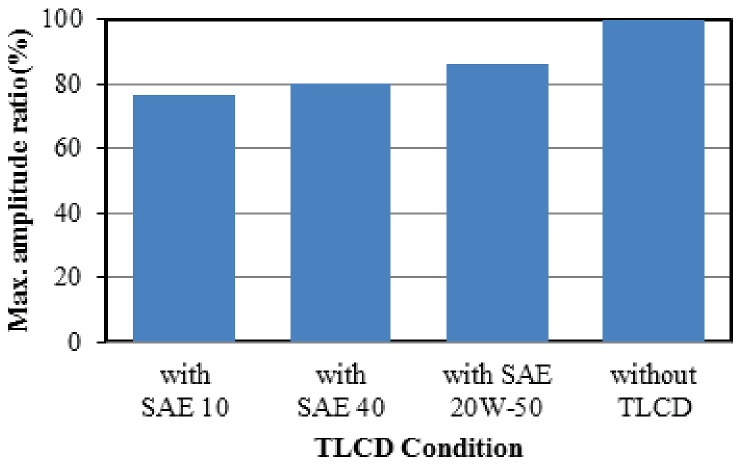

Figure 4: Comparison of maximum amplitude ratio.

4. Summary

Experimental evaluation of TLCD performance due to variation of TLCD liquid viscosity has been conducted. The experimental results show that the frequency response of the structure reduces by adding the TLCD to the structure. However, the optimum condition for TLCD damper largely depends on the damping value of the fluid system inside the TLCD column. The experimental results show that increasing the TLCD liquid viscosity will reduce the absorber performance. This condition is due to the optimum condition of TLCD damping factor closes to the case with low viscosity fluid (SAE 10). For larger viscosity fluids, the fluid motion is small and the DVA effect reduces.

5. Acknowledgment

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