SOME SURVEYS OF MULTIPLE TMD SYSTEMS FOR LARGE SPAN STRUCTURES

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ABSTRACT : The main objective of this research is to develop the vibration control systems for large span structures using spatially dispersed arranged TMDs. When applying this method, we should consider the arrangements and design parameters of plural TMDs by different method using the usual single TMD. In this paper, focusing on the issue of set-up of design parameters, the effects of the systems using the single TMD and two existing methods of MTMD (multiple TMD) are analytically compared. The results show that the determination of the bandwidth of MTMD is very important.

Key Words : Vibration control, TMD, Tuning ratio, Damping ratio, Multiple TMD

INTRODUCTION

TMD (tuned mass damper) is a passive vibration control device consisting of a mass, spring and damper. TMD has been mainly used for buildings excited by wind or earthquake load, and its effect has been widely proved. But recently it has been often applied for controlling the ambient vibration of large span light weight structures. For example, 29 pairs of TMD's are installed to the London Millenium Bridge [1] for avoiding excessive oscillation caused by pedestrians.

Then, we are developing the vibration control system using TMD for large span space structures, e.g. dome, stadium and etc. Generally, for large span structures, many vibration modes whose frequencies are closely spaced are excited, so we should control those plural modes. But TMD has only one natural frequency, so usually it is used for controlling one mode. Then, we proposed the vibration control system using spatially dispersed arranged TMDs (**Figure 1**). In order to apply plural TMDs, the arrangements and design parameters which differs from the case using single TMD should be considered. Regarding the set-up of design parameters of plural TMDs, two methods are already proposed. In this paper, two methods and the usual method using single TMD are analytically compared. All analyses are undertaken by using the MSC-NASRAN finite element program.

METHODS OF SET-UPS OF DESIGN PARAMETERS

For the set-ups of design parameters of plural TMDs, tunings and damping ratios, Multiple TMD

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(MTMD) systems were developed by Seto [2] and Abe [3]. Both methods consist of a number of TMDs whose natural frequencies are distributed over a certain range around the natural frequency of the main structure (**Figure 2**).

Regading the optimization of design parameters, Seto optimized by minimizing variation and value of peaks of rezonance curve. In this paper, this method is abbreviated to MTMD1. On the other hand, Abe solved optimal bandwidth of TMDs being strongly coupled with the structure in any modes (abbreviated to MTMD2). The comparison of two methods regarding set-ups of design parameters is shown in **Table 1**. It is said that there are two common properties in both methods compared to the usual single TMD:

a. Effective at the point of resonance of the main structure.

b. Robust against mis-tuning of design pamrameters.

Especially, the latter robustness could be considered to be effective for controlling many modes using spatially dispersed arranged TMDs.

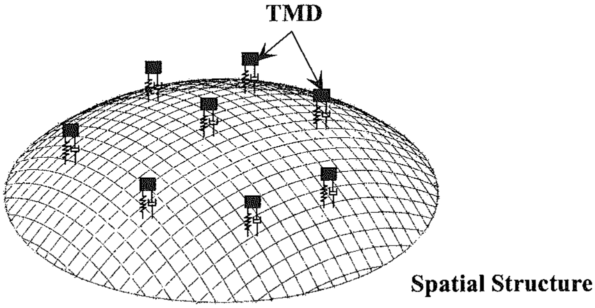


Figure 1. Concept of Spatially Dispersed Arranged TMDs

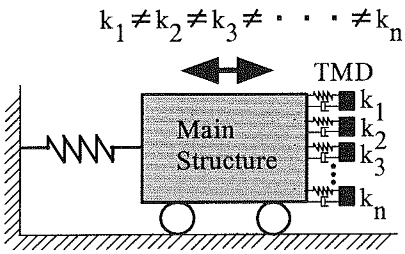


Figure 2. Concept of MTMD

Table 1. Comparison of two MTMD methods regarding set-ups of design parameters

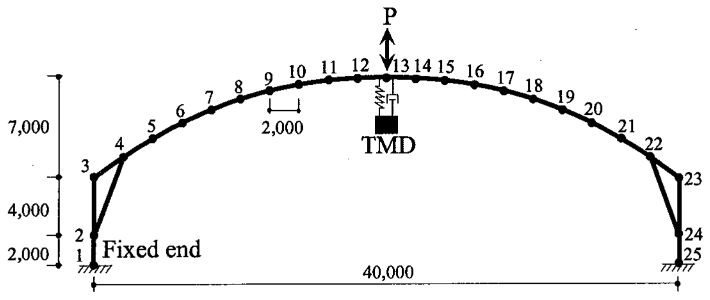
Type	Number	Mass Ratio	Tuning	Damping Ratio
MTMD1 (Seto)	N	common in all TMDs	optimize each TMD respectively	optimize each TMD respectively
MTMD2 (Abe)	N	common in all TMDs	*solve optimal bandwidth Bc *all spaces of frequencies of each TMD are equal to Bc/(N-1)	equal in all TMDs

ANALYTICAL MODEL

An arch structure which is generally applied for 30-40m span mid-scale gymnasium is selected for analytical model (**Figure 3**). The span, rise and radius of curvature of arch are 40m, 7m and 32m, respectively. The marterial is assumed to be steel. The self-weight data of arch and column are inputed by mass density of steel (7.86t/m^3).The boundary condition is given by fixed ends of colums and all members are rigidly jointed. The cross sections of arch and column are H-488 × 300 × 11 × 18 and H-800 × 300 × 14 × 18, respectively.

Firstly, the frequency response analysis of the arch model without TMD was conducted. The excitation force is given at the central part of the arch (node13) vertically, and its amplitude is 1.0(tf). The damping ratio is set to 2.0% to each mode. The relation between the vertical displacement of node 13 and the frequency of the excitation force is shown in **Figure 4**. It is clear that the second mode is rather excited. Therefore, an object of the vibraion control with TMD is determined to be the second mode. The natural frequency of the second mode is 1.28(Hz). The shape of the second mode is shown in **Figure5**. All TMDs are mounted to node13 which is antinode of the second mode.

The total mass ratio of TMDs is set to 10.0% in every cases. The design parameters, tunings and damping ratios, are determined by using optimizing expression described in reference [2] and [3]. The number of TMDs is six which is the maximum multiple number described in reference [2]. The design parameters of each TMD are shown in **Table 2**. The tuning and damping ratio of the single TMD is determined to 0.909 and 0.185 by optimizing expression of Den Hartog.



(Numbers shown in figure are nodal numbers)

Figure 3. Analytical Model

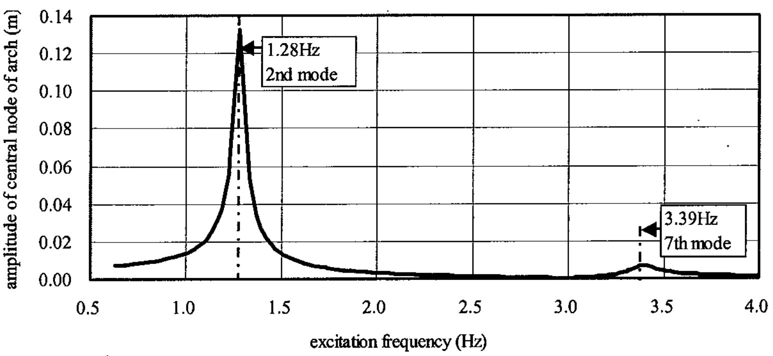


Figure 4. Frequency Response Curve without TMD

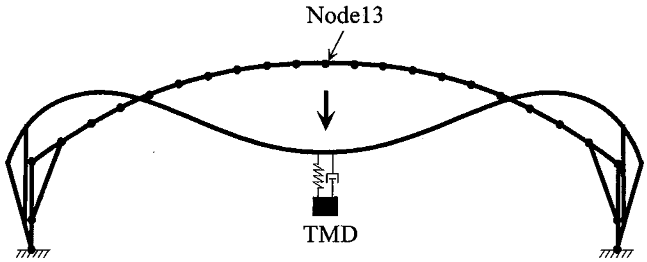


Figure 5. Shape of Second Mode

Table 2. Disign Parameters of Two MTMD Systems

	MTMD1		MTMD2	
	Tuning Ratio	Damping Ratio	Tuning Ratio	Damping Ratio
TMD1	0.775	0.0526	0.870	0.0287
TMD2	0.833	0.0567	0.922	0.0287
TMD3	0.891	0.0590	0.974	0.0287
TMD4	0.955	0.0622	1.026	0.0287
TMD5	1.034	0.0657	1.078	0.0287
TMD6	1.132	0.0634	1.130	0.0287

ANALYTICAL RESULTS

Firstly, the time history analysis applying a harmonic excitartion force with the natural frequency of the second mode,1.28 (Hz), is performed. The location, direction and amplitude are the same to the frequency response analysis of the arch without TMD. The damping ratio of the arch is assumed to be proportional damping, and the value is set to be 2.0% to 1.28(Hz). The comparison of single TMD, MTMD1 and MTMD2 with respect to the vertical displacement of node13 is shown in **Figure 6**. Both MTMD1 and MTMD2 are more efficient than single TMD. Especially, the displacements of MTMD2 are partly shorter than half of single TMD.

The relation between the vertical displacement of node13 and the natural frequency of excitation force near the natural frequency of the second mode is shown in **Figure 7**. MTMD1 and MTMD2 are more effective than single TMD from 1.0 to 1.6 (Hz), but below 1.0 and above 1.6 (Hz), the two high peaks of the response curve are yielded and MTMD are less effective. Therefore, considering the effect of MTMD, we should be careful about the restraint of the bandwidth. Comparing MTMD1 with MTMD2, MTMD1 is more robust against the excitation frequency than MTMD2.

Then, in order to lower two peaks outside of the bandwidth of MTMD and obtain nearly constant responses over wide-band input, bandwidths of MTMD2 are variated into double and triple. The analytical results are shown in **Figure 8**. The all spaces of frequencies of each TMDs are also set to be equal. By spreading the bandwidth of MTMD, the effect near 1.28 (Hz) is down. But almost constant responses over wide-band input could be obtained.

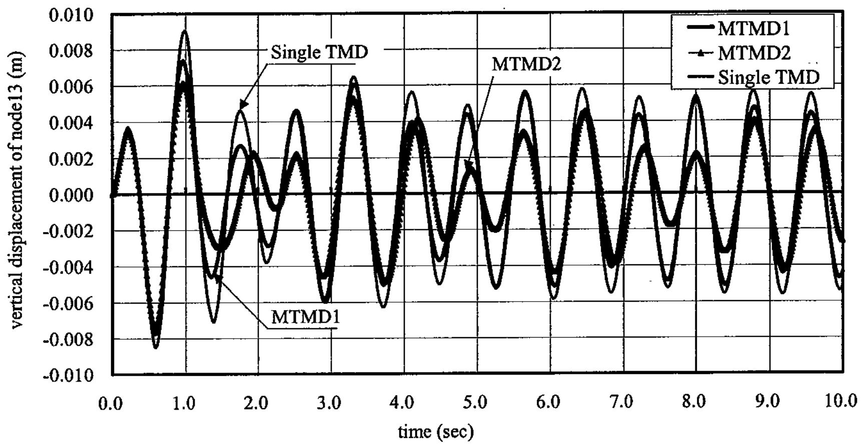


Figure 6. Comparison of Time History Response

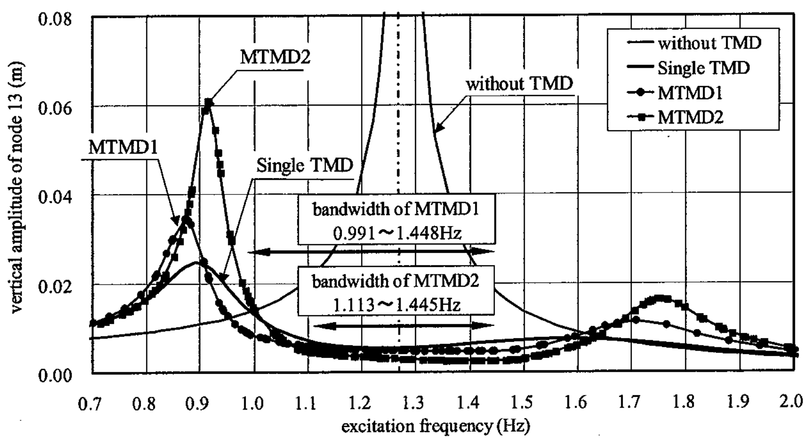


Figure 7. Comparison of Frequency Response Curve

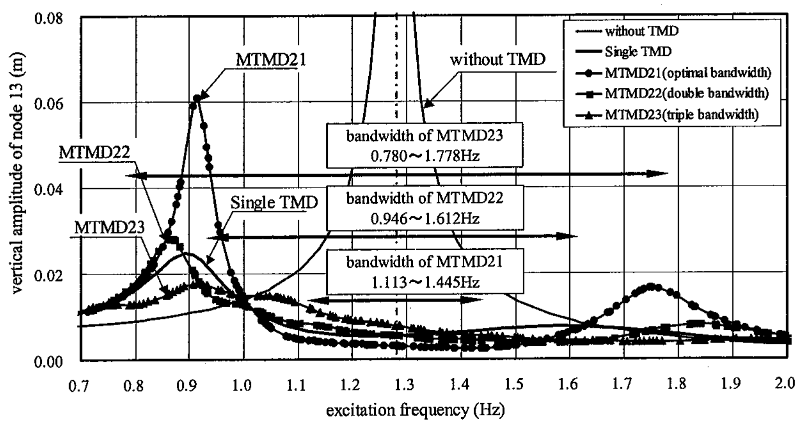


Figure 8. Comparison of Frequency Response Curve by Variation of Bandwidth

CONCLUSIONS

By using the 2-dimension arch as one example of spatial structures, the effects of vibration reduction using the usual single TMD and MTMD are analytically compared. From the results of frequency response analyses, we could confirm three properties described below:

a. MTMD can be more effective than single TMD in the tuned bandwidth.

b. Two peaks of MTMD outside of the bandwidth tend to be higher than those of single TMD.

c. By spreading the bandwidth, almost constant response over wide-band input could be obtained.

Therefore, the bandwidth of MTMD should be carefully determined for properties of vibration sources.

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