I-314 STUDY OF SIZE AND SHAPE EFFECTS ON TUNED LIQUID DAMPER

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INTRODUCTION : Damper using liquid motion as an energy dissipator has recently been proved to be very effective and attractive by some researchers. The authors have investigated the Tuned Liquid Damper (TLD) using circular cylindrical containers as discussed in [1] and the effects of container size were briefly studied. Fujii et.al. [2] reported a successful application of circular shape TLD to suppress the vibration of Yokohama Marine Tower.

TLD USING VARIOUS TYPES OF CONTAINER : The effects of size and shape of the container on the performance of TLD was experimentally investigated. The types of container used are shown in Fig.1. The half length a (or radius for circular container) is considered as the size parameter. Free vibration test was performed using structural frequency of 0.5 Hz, as in [1].

The experimental results at tuned condition (i.e. natural frequency of water ω_w/frequency of structure $\omega_s \approx 1.0$), where high additional damping was observed, are plotted similarly with those in [1] but now using the nondimensionalized parameters $\frac{\Delta E}{E_n\,\mu}$ and α instead. $\frac{\Delta E}{E_n\,\mu}$ is the percentage of kinetic energy loss per cycle of structural vibration per mass ratio μ (μ = water mass m_w/structural mass m_s). The mass ratio actaually used in the experiments ranged from 0.4% to 2.7%. ΔE is defined as $(E_n - E_{n+1})$. The nondimensionalized vibrational amplitude is $\alpha = \frac{A}{a}$, where A is the amplitude of vibration. (Due to the experimental set-up, the vibrational amplitude data were collected within the range of 0.2 cm - 9.0 cm.) Kinetic energy can be expressed as $E = \frac{1}{2}m_s(\omega_s A)^2$. System logarithmic decrement δ can be determined in terms of ΔE as $\delta = \frac{1}{2}\ln(\frac{1}{1 - \Delta E/E_n})$. It can be seen from Fig.2 that $\frac{\Delta E}{E_n\,\mu}$ curve obtained from Φ30 cm circular TLD is almost coincide with those of Φ40 cm and Φ60 cm TLD for the shown range of α.

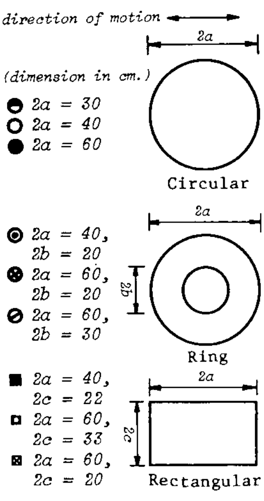

Fig.1 Types of container

Fig.3 shows results of study of shape effect. It is found that the trends of $\frac{\Delta E}{E_n\,\mu}$ of TLD with different shapes, or with the same shape but different sizes, lie in a narrow band with regards to α. This coincidence of $\frac{\Delta E}{E_n\,\mu}$ -vs.- α curves, as approximated by the equation in Fig.2, may be useful in designing TLD, e.g. selecting the size, to achieve a required additional damping at a certain amplitude of vibration.

Considering the energy dissipation / cycle /water mass $\frac{\Delta E}{m_w}$, it can be seen from Fig.4 that the value of $\frac{\Delta E}{m_w}$ varies almost linearly with $\alpha^{1.3}$ for all of the investigated containers. However, it can be observed that for any shape of the container, the

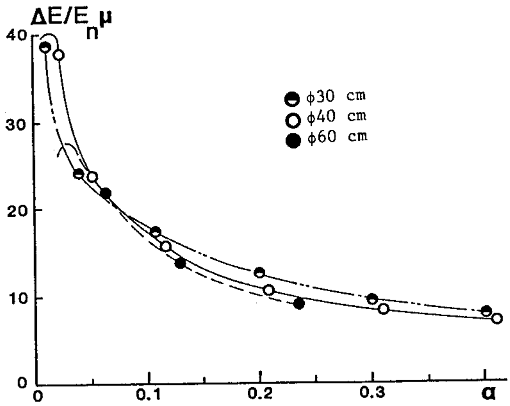

Fig.2 Experimental results of circular TLD

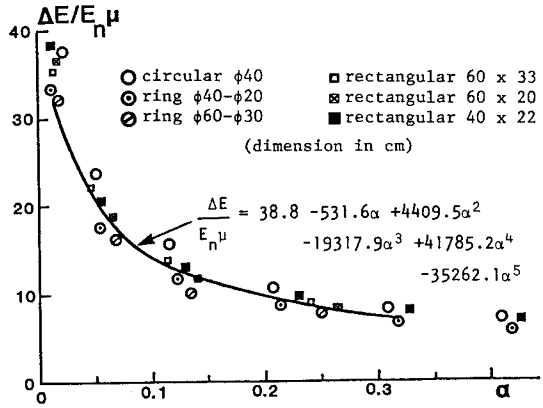

Fig.3 Experimental results of various TLD

curves can be grouped according to the container half length a.

Assuming the mechanism of TLD is to absorb the energy from the vibrating structure and then dissipate it through the process of wave breaking, the energy loss in TLD per half cycle of vibration may be expressed by $\Delta E/2 = \frac{1}{2} m_w (\frac{2a}{T})^2 \Phi$, where Φ accounts for the percentage of travelling water mass of $\frac{2a}{T}$ velocity and the capability to dissipate that energy by the mechanism of wave breaking. T is the vibrational period. After obtaining graphically the respective slope of the curves in Fig.4, the value of Φ was

$$\Phi_{(20)} = \frac{T^2}{4a^2} (0.62\times10^4 \alpha^{1.3}) \quad \text{and} \quad \Phi_{(30)} = \frac{T^2}{4a^2} (1.44\times10^4 \alpha^{1.3}) \quad \ldots(1)$$

for a = 20 cm and a = 30 cm respectively in the range of $0.01<\alpha<0.4$. It can be seen that Φ is a function of a, T, and α. Analyzing Fig.4 further, Φ within the range of $20<a<30$ cm can be expressed as

$$\Phi = 3.5 \frac{A^{1.3} T^2}{a^{1.2}} \quad \ldots\ldots\ldots\ldots(2)$$

CONCLUDING REMARKS : The TLD shape was experimentally found to have almost no effect when the parameters $\frac{\Delta E}{E_n \mu}$ and α were introduced. The $\frac{\Delta E}{E_n \mu}$ -vs.- α curves lie in a narrow band whose average has an equation as shown in Fig.2. However, the energy loss per cycle ΔE has strong relation with the half length a. A parameter $\Phi(a,T,A)$ may effectively account for the percentage of moving water mass and the ability to dissipate the energy.

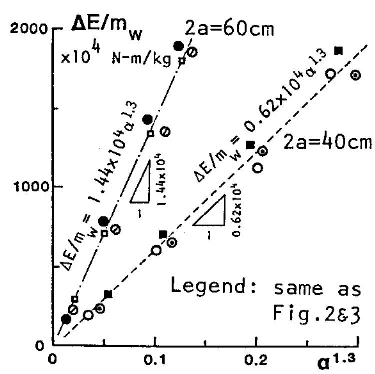

Fig.4 Energy dissipation/water mass

REFERENCES

[1] Fujino, Y. et al.,"An Experimental Study on Tuned Liquid Damper Using Circular Containers", J. of Struct. Engg., Vol.34A, pp603-616, Mar.1988 (In Japanese).

[2] Fujii, K. et al.,"Damper Using Liquid Sloshing Motion -Tuned Sloshing Damper-", Proc. of the Conf. of the Jpn. Soc. of Arch. Engg.,pp1483-1484,Oct.1987 (In Japanese).