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MEASUREMENTS OF WAVE MOTION AND WAVE-INDUCED FORCE IN TUNED LIQUID DAMPER ----AN EXPERIMENT USING SHAKING TABLE

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INTRODUCTION Tuned Liquid Damper (TLD) is a new kind of damper which relies on motion of shallow liquid in a rigid tank. A few studies have been done recently (REF.1), but adequate modelling and clear explanation of its mechanism are lacking. The experiment herein was carried out to study fundamental behaviors of shallow water wave motion and mechanism of energy dissipation in a rectangular tank under steady-state sinusoidal forced excitation, and furthermore, to search a model for this kind of damper.

EXPERIMENTAL APPARATUS As shown in Fig.1, a rectangular tank, 60 cm long, 33.5 cm wide and 40 cm high, was used in the experiment. The water depth was 3.0 cm, corresponding to a theoretical fundamental natural frequency of f_0=0.458 Hz. The tank was excited sinusoidally by a shaking table, and the displacement of shaking table, D, and water free surface height near the end-wall of the tank, H, were measured at steady state. Also, two loadcells were used to measure shear forces at the base of TLD model and of the mass M_0 equivalent to the tank, so as to obtain the net dynamical force F due to water motion only (REF.2).

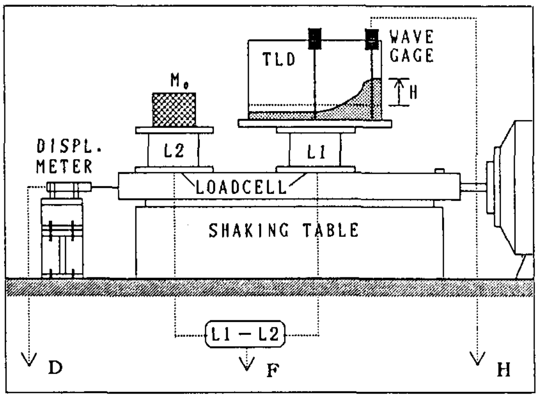
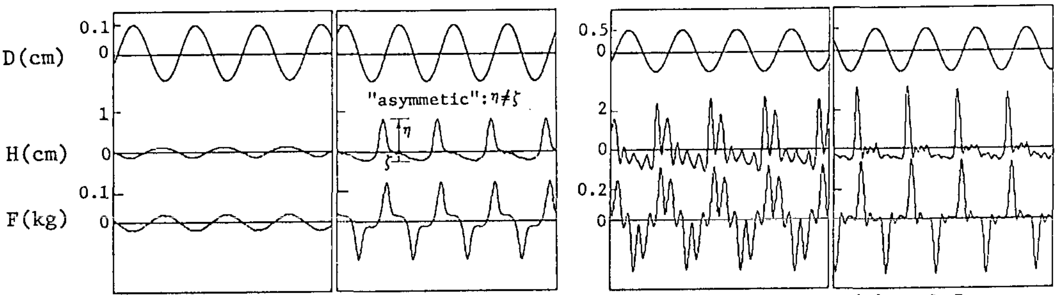


FIG.1 THE EXPERIMENTAL APPARATUS

For three amplitudes of displacement of shaking table, A=0.1 cm, 0.5cm and 2.0cm, the excitation frequency f was varied in the range of 0.9 < f/f_0 < 1.2. Sample time histories of D, H and F are shown in Fig.2.

RESULTS AND DISCUSSION The experiment results show that the wave motion is strongly nonlinear. H is nearly sinusoidal for the case shown in Fig.2(a), with f/f_0=0.90. But, as f/f_0 increases to about 1.06, the amplitude of H increases and becomes asymmetic about the still water level (Fig.2(b)). Figure 2 also shows that the base



(a) A=0.1cm f/f_0=0.90 (b) A=0.1cm f/f_0=1.06 (c) A=0.5cm f/f_0=1.06 (d) A=0.5cm f/f_0=1.14

FIG.2 TIME HISTORIES OF DISPLACEMENT OF SHAKING TABLE, D, WATER SURFACE HEIGHT NEAR THE END-WALL, H, AND BASE SHEAR FORCE, F shear F varies in similar shapes as H changes, but their phases are slightly different. Figure 3 shows that the frequency response curves of positive extrema of H, η, are not symmetric about $f/f_0=1$. The maxima of η occur around $f/f_0=1.06$, and 1.14 for cases A=0.1cm and A=0.5cm respectively, where the response curves exhibit a large "jump". This behavior is attributed to the effect of nonlinearities and can be related to "hardening spring".

Figure 3 also shows that for the case A=0.5cm, η has a local peak at $f/f_0=1.06$, which is lower than $f/f_0=1.14$ where η jumps. The time histories of H for the cases mentioned above are shown in Fig.2(c) and 2(d). H has two large peaks in Fig.2(c). The higher modes of wave motion are excited, which is one of the nonlinear properties of wave motion (REF.3). Same phenomena can be observed also for the other cases with different A.

Figures 4 and 5 show the relationship between D and F in one cycle. The areas of the loops represent the energy input from shaking table to the TLD system per cycle, which, at steady state, equals the dissipated energy by TLD. For given $f/f_0=1.06$ the loops of the cases A=0.1cm, 0.5cm and 2.0cm are shown in Fig.4. It can be seen that even for same f/f_0, the shapes of loops are changed, depending on A. In Fig.5, the loops of the case A=0.5cm are shown for $f/f_0=1.06$, 1.14 and 1.18. The areas of the loops for $f/f_0=1.06$ and $f/f_0=1.14$ are almost the same. But the energy dissipation is nearly zero for the case $f/f_0=1.18$, which is after η jumps down (Fig.3).

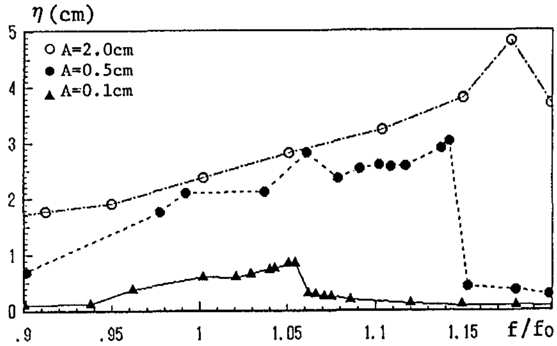


FIG.3 FREQUENCY RESPONSES OF η

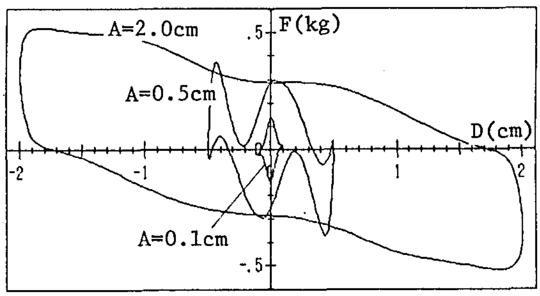


FIG.4 THE RELATIONSHIPS BETWEEN D AND F IN ONE CYCLE FOR THE CASES OF f/f =1.06

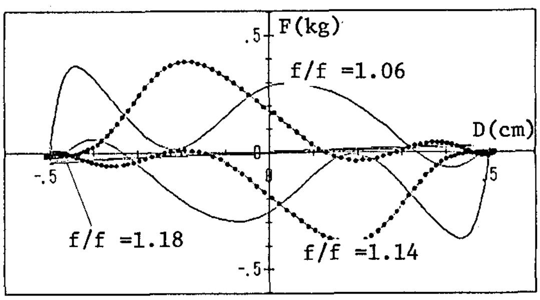


FIG.5 THE RELATIONSHIPS BETWEEN D AND F IN ONE CYCLE FOR THE CASES OF A=0.5cm

REMARKS In the investigated range, even for small amplitude of excitation displacement, wave motion was complicated and behaved strongly nonlinear. The energy dissipation is not very sensitive to frequency ratio f/f_0, for $f/f_0 \doteq 1$ or slightly higher, but before η jumps down (Fig.3). Numerical simulation is in progress.

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