PRELIMINARY FREE-VIBRATION EXPERIMENTS ON TUNED SLOSHING LIQUID DAMPERS

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INTRODUCTION

Tuned Sloshing Dampers provide an alternative system to add damping to a structure. Vibration energy is absorbed by wave action in shallow liquid filed tanks,lower amplitudes produce smooth unbroken wavefronts,higher amplitudes result in breaking waves. Tuning refers to the matching of natural wave frequency within the tank to that of the structure Typical Tuned Sloshing Damper.systems in a structure would have a working fluid mass of aproximately 1% of generalised structural mass ,this is distributed in a large number of shallow containers

This paper describes a series of experiments to compare the performance of eight different tuned sloshing dampers,subject to free vibration at a frequency of 0.7Hz. Three square damper containers with side length of 380, 450, 550 and five circular containers with a diameter of 389, 450, 500, 600, 697 were tested. Damping fluid was water, depth was varied between 10 and 50 mm.

METHODOLOGY

Evaluation of the eight dampers was conducted on a test set-up,shown in Figure 1 which provided a 60kg. platform suspended by four cantilever springs,the top of which were bolted into a rigid frame 3 meters in height. Four spherical bearings supported the test platform from the free end of the cantileaver springs,these consisted of four 20mm threaded bars 2.5 meters in length, this allowed adjustment of spring length and frequency,the length was set at 2160mm with a frequency of 0.7Hz. Initial estimates indicated most suitable sloshing dampers for 0.7Hz would use a fluid mass of 3 to 6kg, ie less than 10% of oscillating platform mass. Later testing was extended to dampers using 20kg or 33% of oscillating mass and caution should be exercised with these results. Tests were conducted by displacing the platform 125mm where it was held by an electrically controlled latch,until there was no significant disturbance of the water surface. The catch was released and the subsequent platform and damper assembly oscillations allowed to decay to zero,this was repeated for different water depths for each of the eight dampers.

The oscillating platform position was determined by eight strain gauges located at the top of diagonally oposite cantilever springs ,this provided both transverse and longitudinal position of the test platform.One accelerometer was located to provide acceleration in the longitudinal direction.A pressure transducer was tapped into the side of the damper under test,this provided an indication of wave height and duration. Velocity of the damping fluid adds a dynamic component to the resultant static pressure,making it unsuitable as an acurate measure of wave height,it does provide both wave timing and duration.

Data acqisition was made using a system consisting of signal conditioning amplifiers and a digital to analog converter board located in a 80386 IBM compatible computer, the four data channels were logged at 100Hz. All results in this paper are generated from longitudinal plate position. Later analysis will make use of acceleration and pressure data. Data processing and all calculations were completed using a spreadsheet program.

Total system energy is known at the beginning and end of each free vibration test,between these two points total energy is the sum of potential and kinetic energy,at peak displacement during each cycle velocity is zero and the total energy is potential and equal to half of the platform spring constant multiplied by displacement squared (While the platform velocity is zero by definition the fluid velocity is unknown but is assumed to be close to zero).this gave a series of points of known energy. Change in energy between these point gave rate of energy change or power this could be termed damping power,and this is a function of amplitude,excitation frequency and damping fluid depth. The test system showed a small but significant amount of coulomn damping caused by the spherical bearing friction,damping power due to this was subtracted from the above result to provide power absorbed by the damper under test, damping power was divided by mass of damping fluid to give watts per kg.these units are used in all figures in this paper .

DISCUSSION OF RESULTS

Damping power of the eight dampers tested is shown in Figure 2, this is for oscillation amplitude of 35mm and shows improved damping performance with increase in damper size, the 550mm square damper with a peak value of 0.19 W/kg provided the highest rate while the 600mm circular damper produced a peak of 0.15 W/Kg. Damping power for three of the dampers tested is shown in Figure 3 this is displayed as a surface and is a function of water depth and oscillation amplitude,Figure 3a (450mm circular) shows that optimum depth is less than 15 mm .Figure 3b (600mm Circular) shows optimum damping at a depth of 30mm ,this is most significant at lower amplitudes but also evident at higher displacements. Figure 3c (697mm Circular) shows an optimum depth of greater than 40 mm.

COMMENTS ON RESULTS

1) Amplitudes below 15 mm were not included in this analysis. Every indication is that tuning becomes critical to damper performance at low amplitudes. Several of the large dampers showed a beating at low amplitude this is caused by the damper returning energy to the oscillating platform at low amplitudes and the significance is unclear at the high Fluid/Platform mass ratio.
2) At high amplitudes tuning requirements are less important although some improvement is evident from the results .
3) While square containers showed higher damping power this is under unidirectional oscillation,performance at other orientations has to be considered.

4) In any practical application the ratio of damping fluid mass to mass of container must be optimized. Increasing damper size shows an increase in damping power for both circular and square containers. Larger damper sizes,with associated greater fluid depth gave improved ratios for damping fluid mass to container mass,however it is not clear what the maximum size is. Results for the 697mm diameter container should be treated with some caution due to the high ratio of damping fluid mass to test platform mass ie 33% .Further work is required to interpret these results for free vibration at a high mass ratio to random forced vibration at low mass ratio.

REFERENCES

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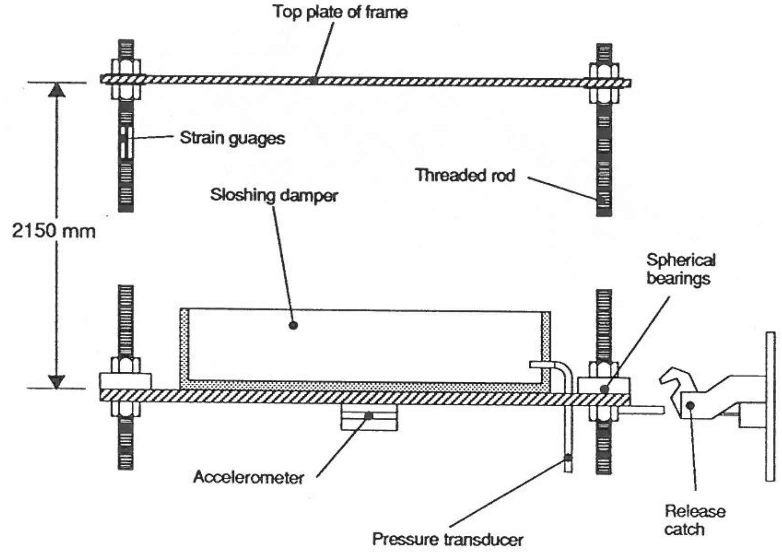


Figure 1. 60kg Test platform

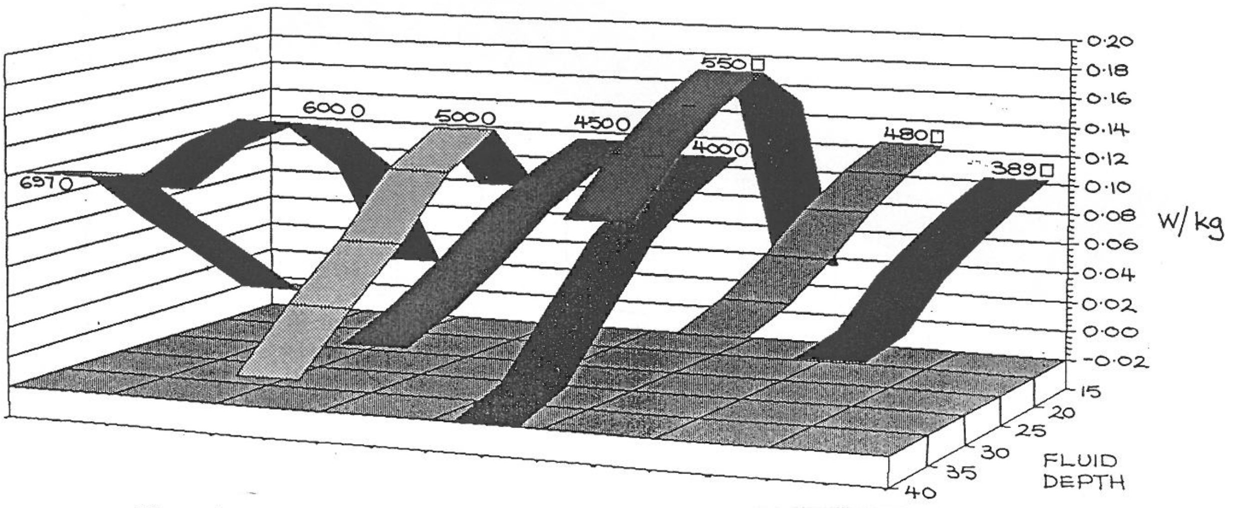
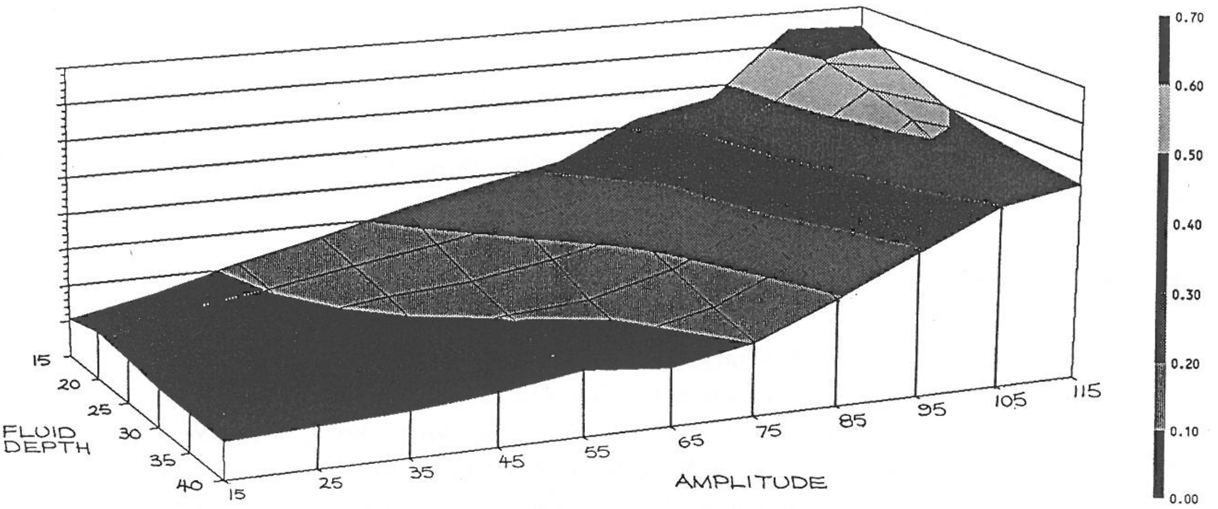
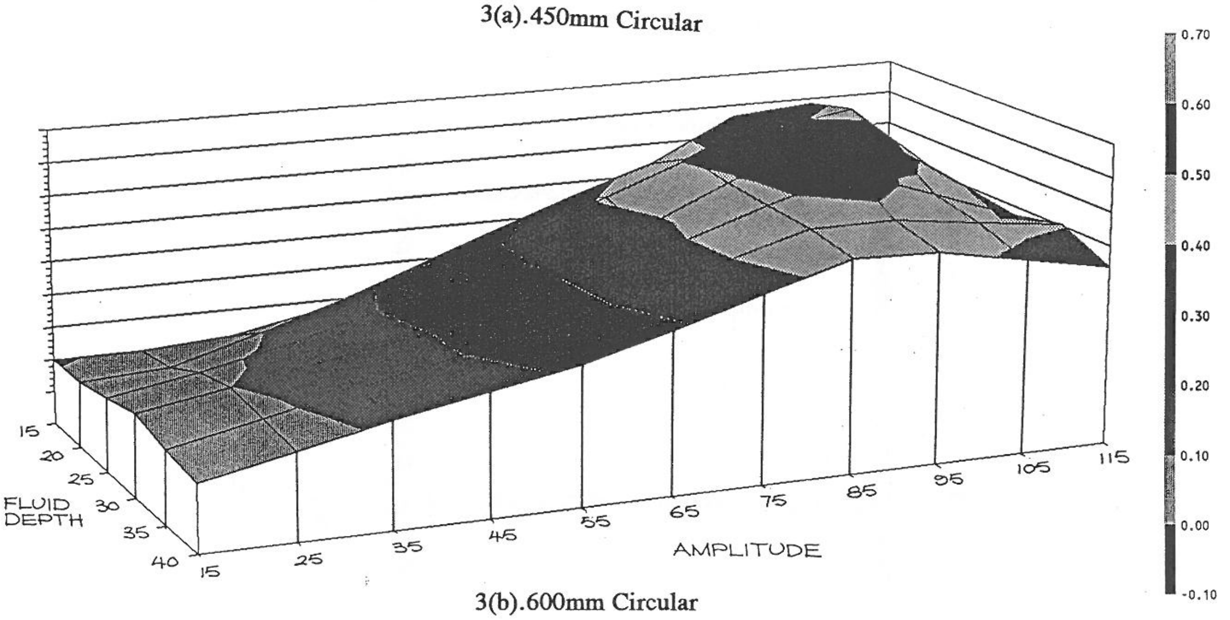


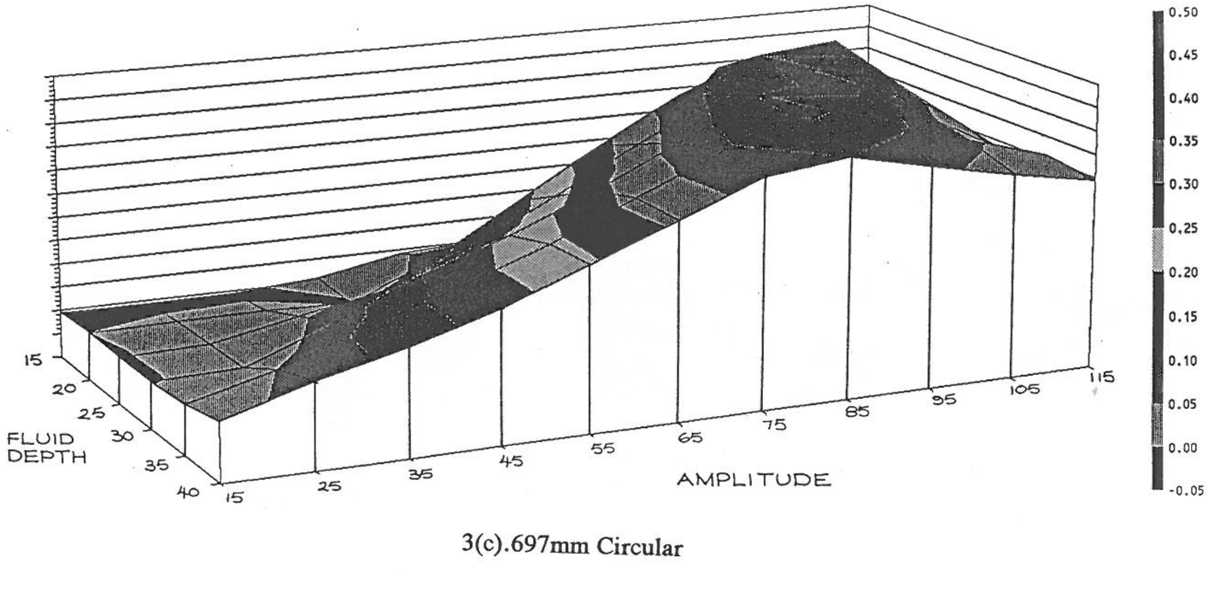
Figure 2. Comparison of damping power for the eight dampers tested at amplitude of 35mm.



3(a).450mm Circular



3(b).600mm Circular



3(c).697mm Circular

Figure 3. Damping power as a function of fluid depth and oscillation amplitude