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Two-Layer Liquid Sloshing Produced by Horizontal Excitation

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Extended Abstract

Many studies on single-layer sloshing have been carried out due to accidents involving damage to floating roofs in oil tanks caused by long-period earthquakes and technical issues in the transport of liquids by ships [1]. Research on two-layer sloshing is currently needed to examine seismic resistance and to ensure safety in situations in which two-layer liquids are mixed, such as floating production systems that are used in offshore resource development as well as tuned liquid dampers that are used as vibration control systems for buildings [2]. To study two-layer sloshing, Veletsos and Shivakumar [3] derived a linear analytical solution and showed that the natural frequency depends on the tank width, depth of the two liquids, and density ratio. Lin et al. [4] experimentally investigated the resonant and non-resonant responses of a two-layer liquid in a tank under pitch excitation and found that when the excitation frequency is equal to the natural frequency of the free surface, resonance occurs at the free surface, whereas the wave height at the liquid-liquid interface is much smaller than that at the free surface. However, the wave height at the liquid-liquid interface may show in-phase motion that follows the motion of the free surface, although the wave height is considerably smaller than that of the free surface.

There have been few existing studies on the sloshing of bilayer liquids, and only fragmentary findings have been obtained thus far. Therefore, this study focuses on the effect of the depth ratio of the two liquids on the vibration characteristics of two-layer liquid sloshing. Horizontal excitation experiments using a two-dimensional rectangular tank are conducted, and visual observations are made. The main results show that when the depth ratio of the two liquids (=height of the upper liquid / height of the lower liquid) is small, the motions of the free surface and the liquid-liquid interface are in phase during resonance, and the wave heights of the two liquids are close. When the depth ratio of the two liquids is unity, the resonant responses of the upper and lower liquids are confirmed to be in the lower-order mode, but the wave height of the lower liquid is lower than that observed with a smaller depth ratio.

References

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