4.0 CONCLUSIONS

In addition to the above discussion, based on the existing literature and authors' experience, the following general comments were made by considering the importance of mode of excitation. A partially filled tank in a ship experiences six degrees of excitation in the real marine environment. As a result, the induced sloshing oscillation and the resulting pressure on the liquid containment depends upon wave direction in which it approaches the vessel, the tank position in the vessel, wave frequency and shape of the tank (rectangular, circular or square). The liquid sloshing dynamics in a square tank subjected to excitation in yaw mode is quite important for design purpose which would be positioned in the fore and aft of the vessel. The mass of liquid movement is restricted to unidirectional while the tank is being subjected to either sway or roll excitation. Hence the sloshing pressure anticipated on the liquid containment is high. In general, the sway or surge (depends on the tank longitudinal axis with excitation direction) contributes high to their part for sloshing while comparing to the other mode of excitation. The roll or yaw excitation comes to the next. The pitching effect is important in a case that the tank longitudinal axis positioned along the vessel's length. However, the heave excitation doesn't have any influence on disturbing the free surface unless it is combined with any other mode of excitation. By keeping the above issues in mind and considering the importance of beam sea excitation, the present study explored the physics implicated with the sloshing phenomenon subjected to individual sway, heave and roll excitations. The following conclusions were drawn by solving the theoretical models.

Sway excited tank

- In general, the sloshing energy contribution by odd modes dominate even modes which means that odd modes are likely to be excited in sway excitation
- While $f_w<f_1$, the sloshing energy is observed at f_w (dominant) and f_1. As the excitation frequency (f_w) increases, energy concentrates at f_1 and diminishes at f_w. At resonance ($f_w = f_1$), a single energy peak is observed at f_1.
- At $f_w > f_1$, energy starts to concentrate on higher order sloshing frequencies

Heave excited tank

- It is learnt that the static free surface of liquid would be remain undisturbed, unless, a particular mode shape (n=1,2,3…….) is assumed as perturbation in the heave excitation. It excites the same mode and the sloshing energy is amplified at parametric resonance condition ($f_w = f_n$, n=1,2,3…….).

Roll excited tank

- The sloshing energy is observed to be concentrate on excitation frequencies (f_w) due to first mode contribution and at classical resonance ($f_w = f_1$) the amplitude of sloshing oscillation is high.

The obtained knowledge is quite supportive in analyzing the sloshing dynamics (identification of resonance and harmonics) of combined degree of excitation of sway, heave and roll (authors' experimental work) along with inherent characteristics of a nonlinear system. The existence of harmonics and mode shape was further confirmed with phase portrait and surface profile measured by resistance type probes, respectively. Faltinsen (2000) modal theory has been exploited to obtain the nonlinear amplitude-frequency response curves for the aspect ratio (h_s/l) 0.163, 0.325, 0.488 and 0.585

considered in the experimental work. A qualitative comparison shows that the sloshing responses follow the trends of theoretical work and exhibit nonlinear characteristics.