World Academy of Science, Engineering and Technology
International Journal of Mechanical and Industrial Engineering
Vol:12, No:05, 2018

Nonlinear Interaction of Free Surface Sloshing of Gaussian Hump with Its Container

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Abstract : Movement of liquid with a free surface in a container is known as slosh. For instance, slosh occurs when water in a closed tank is set in motion by a free surface displacement, or when liquid natural gas in a container is vibrated by an external driving force, such as an earthquake or movement induced by transport. Slosh is also derived from resonant switching of a natural basin. During sloshing, different types of motion are produced by energy exchange between the liquid and its container. In present study, a numerical model is developed to simulate the nonlinear even harmonic oscillations of free surface sloshing of an initial disturbance to the free surface of a liquid in a closed square basin. The response of the liquid free surface is affected by amplitude and motion frequencies of its container; therefore, sloshing involves complex fluid-structure interactions. In the present study, nonlinear interaction of free surface sloshing of an initial Gaussian hump with its uneven container is predicted numerically. For this purpose, Green-Naghdi (GN) equations are applied as governing equation of fluid field to produce nonlinear second-order and higher-order wave interactions. These equations reduce the dimensions from three to two, yielding equations that can be solved efficiently. The GN approach assumes a particular flow kinematic structure in the vertical direction for shallow and deep-water problems. The fluid velocity profile is finite sum of coefficients depending on space and time multiplied by a weighting function. It should be noted that in GN theory, the flow is rotational. In this study, GN numerical simulations of initial Gaussian hump are compared with Fourier series semi-analytical solutions of the linearized shallow water equations. The comparison reveals that satisfactory agreement exists between the numerical simulation and the analytical solution of the overall free surface sloshing patterns. The resonant free surface motions driven by an initial Gaussian disturbance are obtained by Fast Fourier Transform (FFT) of the free surface elevation time history components. Numerically predicted velocity vectors and magnitude contours for the free surface patterns indicate that interaction of Gaussian hump with its container has localized effect. The result of this sloshing is applicable to the design of stable liquefied oil containers in tankers and offshore platforms.

Keywords : fluid-structure interactions, free surface sloshing, Gaussian hump, Green-Naghdi equations, numerical predictions
Conference Title : ICFMHS 2018 : International Conference on Fluid Mechanics and Hydraulic Systems
Conference Location : London, United Kingdom
Conference Dates : May 14-15, 2018