Response Regimes and Vibration Mitigation in Equivalent Mechanical Model of Strongly Nonlinear Liquid Sloshing

Maor Farid[1], Oleg Gendelman[2]

[1] *Faculty of Mechanical Engineering, Technion I.I.T, maorfarid@gmail.com*

[2] *Faculty of Mechanical Engineering, Technion I.I.T, ovgend@tx.technion.ac.il*

Abstract

Equivalent mechanical model of liquid sloshing in partially-filled cylindrical vessel is treated in the cases of free oscillations and of horizontal base excitation. The model is designed to cover both the regimes of linear and essentially nonlinear sloshing. The latter regime involves hydraulic impacts applied to the walls of the vessel. These hydraulic impacts are commonly simulated with the help of high-power potential and dissipation functions. For analytical treatment, we substitute this traditional approach by consideration of the impacts with velocity-dependent restitution coefficient. The resulting model is similar to recently explored vibro-impact nonlinear energy sink (VI NES) attached to externally forced linear oscillator. This similarity allowed exploration of possible response regimes. Steady-state and chaotic strongly modulated responses are encountered. Besides, we simulated the responses to horizontal excitation with addition of Gaussian white noise, and related them to reduced dynamics of the system on a slow invariant manifold (SIM). All analytical predictions are in good agreement with direct numerical simulations of the initial reduced-order model. Subsequently, Finite-Element (FE) method is used to determine and verify the model parameters and to identify dominant dynamical regimes, natural modes and frequencies. The tank failure modes are identified and critical locations are identified. Mathematical relation is found between degrees-of-freedom (DOFs) motion and the mechanical stress applied in the tank critical section. This is the prior attempt to take under consideration large-amplitude nonlinear sloshing and tank structure elasticity effects for design, regulation definition and resistance analysis purposes. Both linear (tuned mass damper, TMD) and nonlinear (nonlinear energy sink, NES) passive energy absorbers contribution to the overall system mitigation is firstly examined, in terms of both stress reduction and time for vibration decay.