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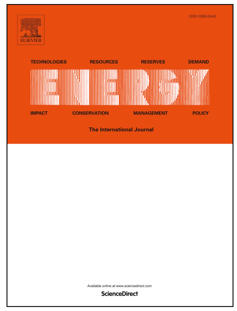

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Optimization of the Rectangular Storage Tanks for the Sloshing Phenomena Based on the Entropy Generation Minimization

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Abstract

The maneuver-induced liquid cargo motion in the partly-filled tanks called, sloshing poses a serious threat to the stability and controllability of this phenomenon. The entropy generation in the sloshing phenomenon is obtained for the first time in the rectangular storage tank. In this paper, a numerical model is developed to simulate the sloshing phenomenon by using coupled *RANS* solver and *VOF* method. The *RANS* equations are discretized and solved using the staggered grid finite difference and *SMAC* methods. The entropy generation distribution provides designers with useful information about the causes of the energy losses. As an objective, the total entropy generation is introduced as a design criterion parameter for rectangular storage tanks and is compared with the tank perimeter (*TP*) criterion. In order to do this, the horizontal periodic sway motions with different amplitudes, angular frequencies, and aspect ratios (*AR*) are applied to the rectangular storage tanks. The results show that the optimal *AR* is about 2.9 for TP criterion and is about 3.2 for the entropy generation criterion.

Keywords: Entropy Generation; Sloshing Phenomena; Tank Perimeter; Aspect Ratio; *RANS*; *VOF*.

1. Introduction

Liquid sloshing in a moving tank is an important part in a number of dynamical systems such as seagoing vessels, road tankers, liquefied natural gas carriers, aerospace vehicles, elevated water towers, and petroleum cylindrical tanks. Fluid sloshing is defined as a free surface movement of the contained fluid due to impulsive loads. This phenomenon is the result of the acceleration-deceleration induced forces of the container and it can be observed in partly-filled tanks. It still needs considerable understanding in its behavior and is a composition of highly nonlinear waves that may lead to structural damage. For numerical modeling of this phenomenon, different governing equations were applied. Some researchers such as Abramson [1], Frandsen [2], Ketabdari & Saghi [3-6], Ketabdari et al. [7], Saghi & Ketabdari [8], and Saghi [9] considered the fluid to be inviscid and, therefore, Laplace equation was used as governing equation. Some other researchers such as Chen & Nokes [10], and Wu & Chen [11] considered it as viscous and, therefore, *RANS* equations were used as governing equations. Researchers proposed different geometric shapes such as rectangular [12-13], elliptical [14], cylindrical [15-16], circular conical [17], and spherical [18-19] for the storage tanks to model the sloshing phenomenon. However, typical modeling methodologies of this phenomenon have been used to simulate the fluid flow parameters such as velocity, pressure gradient and free surface displacement. For example, Eswaran et al. [20] investigated the unsteady free-surface velocities during the surge motion of a liquid tank through experimental investigation. Papaspyrou et al. [21] developed a mathematical model for calculating liquid sloshing effects such as hydrodynamic pressures and forces in half-full spherical containers under arbitrary external excitation. Sarreshtehdari et al. [22] studied free surface sloshing of liquid in a rectangular tank induced by lateral excitation both numerically and experimentally. Mirzabozorg et al. [23] investigated the effect of free surface sloshing on dynamic response of rectangular storage tanks. Rajagounder et al. [24] studied the behavior of the free