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Entropy Generation Minimization for the Sloshing Phenomenon in Half-Full Elliptical Storage Tanks

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Abstract

In this paper, the entropy generation in the sloshing phenomenon was obtained in elliptical storage tanks and the optimum geometry of tank was suggested. To do this, a numerical model was developed to simulate the sloshing phenomenon by using coupled Reynolds-Averaged Navier–Stokes (*RANS*) solver and the Volume-of-Fluid (VOF) method. The RANS equations were discretized and solved using the staggered grid finite difference and SMAC methods, and the available data were used for the model validation. Some parameters consisting of maximum free surface displacement (*MFSD*), maximum horizontal force exerted on the tank perimeter (*MHF*), tank perimeter (*TP*), and total entropy generation (S_{gen}) were introduced as design criteria for elliptical storage tanks. The entropy generation distribution provides designers with useful information about the causes of the energy loss. In this step, horizontal periodic sway motions as $X=a_m\sin(\omega t)$ were applied to elliptical storage tanks with different aspect ratios namely ratios of large diameter to small diameter of elliptical storage tank (*AR*). Then, the effect of a_m and ω was studied on the results. The results show that the relation between *MFSD* and *MHF* is almost linear relative to the sway motion amplitude. Moreover, the results show that an increase in the *AR* causes a decrease in the *MFSD* and *MHF*. The results, also, show that the relation between *MFSD* and *MHF* is nonlinear relative to the sway motion angular frequency. Furthermore, the results show that an increase in the *AR* causes that the relation between *MFSD* and *MHF* becomes linear relative to the sway motion angular frequency. In addition, *MFSD* and *MHF* were minimized in a sway motion with a 7 rad/sec angular frequency. Finally, the results show that the elliptical storage tank with *AR*=1.2-1.4 is the optimum section.

Keywords: Sloshing Phenomena; Elliptical Storage Tank; Entropy Generation; Sway Motion; Tank Perimeter, *MFSD*, *MHF*.

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 of 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 (Huang et al. [12] & Pirker and Aigner [13]), elliptical (Hasheminejad and Aghabeigi [14]), cylindrical (Papaspyrou et al. [15] and Shekari et al. [16]), circular conical (Gavrilyuk et al. [17]), and spherical (Yue [18] and Curadelli et al. [19]) for storage tanks to model the sloshing phenomenon. However, typical modeling