High Performance of the Sloshing Characteristics in Horizontal Elliptical Tanks with Baffles by Using SBFEM

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ABSTRACT
The scaled boundary finite element method (SBFEM) is a novel semi-analytical technique, combining the advantages of the finite element and the boundary element methods with unique properties of its own. Assuming ideal and irrotational flow and small-amplitude free-surface elevation, this paper aims at developing the proposed method combining a modal approach for the sloshing problems in horizontal elliptical tanks with baffles under horizontal excitations. Firstly, based on Laplace equation and SBFEM coordination systems, the derivations for the eigenvalue problem by using the scaled boundary finite element method under zero external excitation and solutions of SBFEM equations are expressed in details, then the natural mode shapes of sloshing and their corresponding frequencies can be obtained. The SBFEM needs discretize only the water surface and walls with curved surface finite-elements and keeps the radial differential equation solved completely analytically. Subsequently, based on an appropriate decomposition, an efficient methodology is proposed for externally-induced sloshing through the calculation of the corresponding sloshing (or convective) masses. In comparison with analytic solution method and other numerical methods, numerical results show that the proposed method can produce more accurate solution than the conventional numerical methods with far less number of degrees of freedom. Meanwhile, the effects of the vertical baffles on the hydrodynamic pressure mode shapes, sloshing flows and sloshing masses are examined in details.

KEY WORDS: Scaled boundary finite element method, sloshing characteristics, Elliptical tanks, Baffles, Eigenvalue, Modal analysis.

INTRODUCTION
Sloshing is a fascinating physical phenomenon of immense practical importance that can occur in moving vehicles with contained liquid masses such as liquid bulk cargo carriers, ships, rockets, aircrafts, and spacecrafts, as well as in seismically excited storage tanks, dams, reactors and nuclear vessels (Ibrahim, 2005). The dynamic behavior of these systems, which are seriously affected by the dynamics of the free liquid surface, is of great interest with regard to safety and environment. Budiansky (1960) was the first to estimate sloshing frequencies, mode shapes, and hydrodynamic forces in a two-dimensional circular vessel under transverse excitation for arbitrary depth of liquid. At the same time, One of the most-heard references in the sloshing is NASA report presented by Abramson and Silverman (1966), which addressed the sloshing problems encountered in aerospace vehicles. Many of the valuable studies have been published in the field of liquid sloshing since 1966. Ibrahim (2005) prepared valuable references (over 2600 instances) which represent a large deal of past researches on the sloshing phenomenon modeling, evaluation of the natural frequencies and corresponding mode shapes of liquid vibrations in a tank, and the optimization and control of sloshing characteristics, etc. Baffles are generally installed in liquid storage containers, which could reduce the liquid sloshing amplitude and the hydrodynamic load, and the baffles also could improve the stiffness of the containers. A few recent studies (Evans and McIver, 1987; Gedikli and ErguVen, 1999; Biswal et al., 2003; Cho et al., 2005; Gavrilyuk et al., 2006; Firouz-Abadi et al., 2009; Wang et al., 2010; Askari et al., 2011; Hasheminejad and Aghabeigi, 2012; Ebrahimian et al., 2013; Kolaei et al., 2015) have reported the effects of baffles on natural frequencies, modes of liquid and the resonance characteristics of the sloshing by using difference methods. Meanwhile, horizontal cylindrical tanks with elliptical cross sections are a common problem in the road transportation industry that has been extensively studied for many years (Xu, 2005). However, to the authors’ knowledge, there is little study on the rigorous theoretical or numerical solutions for elliptical cross sections with baffles. Only Seyyed M., et al (2012) have used the successive conformal transformation technique (analytical solution) to solve the problem. However, the studies have only focused on analyzing the natural frequencies and corresponding mode shapes of elliptical tank with surface-piercing or bottom-mounted vertical baffles, and the analysis in time domain is not involved.

In this paper, a new semi-analytical method called scaled boundary finite element method (SBFEM) has been extended to solve the sloshing problem of elliptical tank with surface-piercing or bottom-