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Experimental Investigation of Wave Interaction with a Thin Floating Sheet

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ABSTRACT

Flexible floating structures received increasing attention in recent years as support structures for floating offshore solar installations and other forms of oceans space utilization. An early example for such structures was the Mega-Float structure proposed as floating airport runway for Tokyo Bay. More recent examples can be found in the large inland floating solar parks where interconnected pontoons form a flexible floating structure. The common denominator of these structures is their small height compared to their length and width resulting in low bending stiffness in the vertical direction. Structural length being much longer than the wavelength and low bending stiffness result in large vertical deflections of the floating structures and strong hydroelastic interaction with the waves. Similar behavior can be observed for sloshing mitigation measures with flexible membranes. In this study, we investigated the wave structure interaction of a floating flexible sheet with a length to height ratio of 1000 in regular long-crested head waves in the small towing tank of Delft University of Technology. Wavelength was varied between 1/20 and 1/5 of structure length with wave steepness in the range of 0.02 to 0.05. Digital Image Correlation (DIC) was used to measure the surface elevation of the entire structure and wave elevation was measured in three different locations to provide reference data. The results show that the floating sheet mainly followed the local wave elevation and a reduction of motion amplitude was observed over the length of the structure. Further, the results reveal 3D effects of different elevation amplitude across the width of the sheet, which suggests strong interaction with the waves.

KEY WORDS: Floating elastic sheet, Fluid Structure Interaction, Digital Image Correlation, Hydroelasticity, Wave scattering.

INTRODUCTION

Over the past decennia, investigation of hydroelastic response of floating structures was mainly motivated by research on sea ice and Very Large Floating Structures (VLFS), see the reviews of Karmakar et al. (Karmakar, Bhattacharjee, & Sahoo, 2011) as well as Squire (Squire, 2007; Squire, 2011), Chen et al. (Chen, Wu, Cui, & Jensen, 2006), and Lamas-Pardo et al. (Lamas-Pardo, Iglesias, & Carral, 2015). As Squire (Squire, 2008) points out there are modelling parallels between VLFS and sea ice investigations. On the other hand, Lamas-Pardo et al. (Lamas-Pardo et al., 2015) observe that none of the designed VLFS have ever been built, with the sole exception of the Mega-Float floating runway (Suzuki, 2005). However, these projects did spark the scientific interest and progress in the field of hydroelasticity.

More recently, hydroelasticity receives renewed attention with the rise of (offshore) floating photovoltaics (FPV). Large modular floating structures for rigid PV panels are envisaged in various projects as summarized by Trapani et al. (Trapani & Redón Santafé, 2015). Flexible structures for FPV based on thin-film PV modules are demonstrated to have technical and economic potential (Trapani & Millar, 2014; Trapani, Millar, & Smith, 2013). Jamalludin et al. conclude “that floating solar could be one of the most important ocean structures in the future” (Jamalludin et al., 2019).

From the aforementioned reviews, it becomes apparent that there is an abundance of theoretical studies on hydroelasticity. However, experimental investigations and data are much less reported. Şendil and Graf studied flexible floating sheets as breakwaters using 4.8 mm plywood with length between 0.6 and 1.2 m (Şendil & Graf, 1974). Several experiments related to the Mega-Float project are reported in the late 1990s. Yago and Endo investigated a 9.75 m long, 1.95 m wide model with a draft of 16.6 mm (Yago & Endo, 1996). Yago et al. conducted 2D experiments with a 50 m long, 5 m wide model with a draft of 10 mm (Yago, Ohmatsu, & Endo, 1997). In both studies, Yago et al. used models made of composite material to tune the model stiffness to match the scaled-down bending stiffness of the full-scale structure, which had horizontal dimensions of 300 m x 60 m and 5000 m x 1000 m, respectively. They measured the structure elevation along the centerline of the model with a string-and-pulley system attached to potentiometers at intervals of 0.4 m. Kagemoto et al. employed optical tracking of 4 LEDs along the centerline of their model with length of 2 m and width of 0.5 m (Kagemoto, Fujino, & Murai, 1998). Their model consisted of segmented floating blocks that were attached to a flexible upper deck of 5 mm acrylic glass. Ohta et al. reported on a model test with a 15 m long model related to a full-scale structure of 1200 m in length (Ohta,