International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 26, No. 2, June 2016, pp. 100–108; http://dx.doi.org/10.17736/ijope.2016.mkr05

http://www.isope.org/publications/publications.htm

Methods for Analysing Wave Slamming Loads on Truss Structures Used in Offshore Wind Applications Based on Experimental Data

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Offshore wind turbines installed in shallow water regions are subjected to highly varying hydrodynamic loads and plunging breaking waves. Many investigations have been made regarding the wave slamming forces acting on both vertical and inclined piles on flat and sloping bottoms. However, very few studies have been carried out to analyse the slamming forces on truss structures. In this paper, the wave slamming loads on a truss structure are analysed on the basis of the experimental studies carried out on a 1:8 truss model. The total force and the forces on local members are registered during the experiment. The total and local forces on the structure are analysed through the use of two different methods. The total slamming loads on the truss structure are analysed through the use of the Empirical Mode Decomposition (EMD) method, and the local forces on the truss structure are analysed through the use of the Frequency Response Function (FRF) method. The EMD method is based on a time series decomposition of the measured force, and the FRF method is based on the hammer tests performed on the local force members during the experiments. The relative strengths and weaknesses of both methods are discussed, and conclusions are drawn regarding the optimum analysis method for those data sets. In addition, the slamming forces calculated from the measurements are compared with the values obtained through the use of the existing force models.

INTRODUCTION

Due to the depletion of conventional energy sources and growing energy demands, wind energy is becoming more popular. Offshore-based wind turbines have started to become popular because of the specific nature of the wind field over maritime areas. Wind turbines can be placed in shallow water regions, where they are subjected to highly varying hydrodynamic loads and plunging breaking waves (Chella et al., 2012; Navaratnam et al., 2013; Arntsen and Gudmestad, 2014). The total forces acting on such structures can be divided into the quasi-static force (Morison force) and the slamming force due to breaking waves. The wave slamming forces are very large forces acting for a short period of time. Many investigations have been made regarding the wave slamming forces acting on both vertical and inclined piles on flat and sloping bottoms (Goda et al., 1966; Sawaragi and Nochino, 1984; Wienke and Oumeraci, 2005). Monopile and tripod structures have also been taken into consideration (Goda, 1973; Hanssen and Tørum, 1999; Ros, 2011; Watanabe and Horikawa, 1974). There are, however, a limited number of experimental studies of slamming loads on truss structures.

The wave slamming force F_S caused by the breaking wave can be treated as an addition to the drag F_D and inertia F_M forces (Morison force). The total loading force F_T can be written as:

$$F_T = F_D + F_M + F_S \tag{1}$$

where the slamming force is given by Goda et al. (1966) as:

$$F_S = \frac{1}{2}\rho_w C_s D C_b^2 \lambda \eta_b \tag{2}$$

where C_s is the slamming coefficient, C_b is the breaking wave celerity, and λ is the curling factor. According to Goda et al. (1966), the slamming coefficient C_s is π and the curling factor λ is 0.4. Wienke and Oumeraci (2005) calculated higher slamming forces than those predicted by Goda et al. (1966) with a slamming coefficient C_s of 2π and a curling factor λ of 0.46.

The WaveSlam project (Arntsen and Gudmestad, 2014; Arntsen et al., 2013) was carried out in 2013 with the aim of investigating the wave slamming forces from plunging breaking waves on a truss structure in shallow water. The large-scale truss model was tested for plunging breaking waves. During the experiment,

Received October 28, 2015; revised manuscript received by the editors January 26, 2016. The original version was submitted directly to the Journal.

KEY WORDS: Jacket, truss structures, wave slamming load, breaking wave load, empirical mode decomposition, frequency response function, hammer test.