Pressure Distribution and Vortex Shedding Around a Cylinder due to a Steep Wave at the Onset of Breaking from Physical and Numerical Modeling

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ABSTRACT

In this paper, the experimental results based on focused wave interactions with a cylinder are reported. The focused waves are generated based on the second order wavemaker theory. The pressure time history measured at various locations on the cylinder in the experiments are compared with the numerical model based on weakly coupling of FNPT and commercial NS solver. After validating the numerical model, the pressure characteristics and the vortex shedding around the cylinder due to the steep wave interactions are discussed and reported.

KEY WORDS: Cylinder, Steep wave, Pressure distribution; Vortex shedding; FNPT-FEM, VOF

INTRODUCTION

Any structure that deployed in ocean should be studied extensively as the cost involved in construction and deploying in ocean are huge. In order to study the structure influence, the wave characteristics and its effect on the structure must be analyzed. A great amount of work has been studied and well written about the wave characteristics. Various linear and non-linear theories are developed and currently various wave models are created for determining the wave characteristics and its interactions. These theories and models holds good for non-breaking cases. But in offshore environment steep waves or breaking waves over the structure plays a major role in creating a very high impact pressure. The kinematics of the steep/breaking waves is not well understood like the linear waves, since, at the onset of breaking point, the air-entrainment may also play a major role. As the kinematics are not fully understood, the wave loads due to the breaking waves are still a topic of intense research. The general perspective for the estimations of the wave forces from the non-breaking waves obtained from the experiment produce acceptable results using the Morison equation together with the stream function or higher order theory. However for breaking and post-breaking waves the linear assumptions underestimate the hydrodynamic forces. Applying linear wave theory, the measured wave forces can be four times higher than predicted by the model. Due to this, the testing of the wave-structure interactions for extreme cases requires the experimental investigations.

The extreme waves are basically the nonlinear waves generated due to wave-wave interactions, breaking waves, freak waves and so on. A recent work by Liu and Pinho (2004) reported that the occurrence of freak waves is actually more frequent than rare. Furthermore, nonlinear wave-wave interaction has been addressed to associate with freak wave formation (Mori and Yasuda, 2002; Janssen, 2003). Two important reviews of freak waves (Kharif and Pelinovsky, 2003; Dysthe et al., 2008) reported that there is no unique definition of freak waves, but it is generally agreed that they belong to the extreme tail of the probability distribution. The most common definition is that a wave is said to be freak waves when the wave height exceeds a threshold related to the significant wave height. Thus, in the design of the marine structure the extreme wave events that are violent at the specific locations should be considered. Because of the strong nonlinearity involved, sometimes solutions based on linear or other simplified theories may be insufficient and so fully nonlinear theory is necessary.

Two types of fully nonlinear models, i.e. NS model (governed by the Navier-Stokes and the continuity equations together with proper boundary conditions) and FNPT models (fully nonlinear potential model), may be used. The latter are much easier and needs less computational resource than the former with satisfactory accuracy if waves are not breaking and/or structures involved are large, whereas, one need to use the NS model for modeling violent waves and its interaction with structures (where boundary layer is important). The problems formulated by FNPT model are usually solved by a time marching procedure. In this procedure, the key task is to solve the boundary value problem by using a numerical method, such as the boundary element or desingularized boundary integral methods (both are shortened as BEM) and the finite element method (FEM). The BEM has been attempted by many researchers, complete review can be found in Kim et al. (1999). The FEM has been developed by Wu and Eatock Taylor (1994) for 2D cases and by Ma et al. (2001) for 3D case, and it is further extended to handle complex objects and floating bodies simulation by using QALE-FEM (Quasi-Arbitrary Lagrangian and Eulerian) and SALE-FEM (Semi-Arbitrary Lagrangian and Eulerian) by Yan (2006) and Sirram (2008), respectively. In order to reduce the computational time in 3D modeling, Hildebrandt et al. (2013) used a weekly coupling algorithm for wave impact with tripod structure using FNPT-ANSYS CFX. In this paper, this methodology will be used.