Innovative Design of a Wind Generation System for Marine Structures Model Testing

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ABSTRACT

This paper describes the development of an innovative wind generation system for physical model test of offshore floating structures (e.g. floating offshore wind turbines). A CFD modeling is also carried out to verify the wind field in the wave basin. The experimental set-up is associated with the Ocean Engineering Wave Tank of Ecole Centrale de Nantes in order to reproduce offshore winds with respect to their mean speed vertical gradient, including dynamic aspects (frequency spectrum, gusts) above directional water waves. Developed within a collaborative framework between Centre Scientifique et Technique du Bâtiment (C.S.T.B) and E.C.N, the wind generation system is based on several centrifuge fans located behind the wavemaker. Flexible air ducts are carrying the airflow to the vicinity of floating models. The experimental facilities engaged are unique in the field of academic research in France.

KEY WORDS: Wind generation; small-scale model test; swell; floating offshore wind turbine.

INTRODUCTION

Wind energy is moving offshore providing an alternative to land-based wind turbines. In deep water areas, ground-based platforms become uneconomical and floating wind turbines appear as an alternative to capture the vast offshore wind resource. However, if the hydrodynamic stability of a floating system has been demonstrated, coupled analysis of hydro-aerodynamics loading has to be taken into account to characterize the global system behavior.

Beside the Marine Renewable Energy domain, other classical fields of naval hydrodynamics are dealing with wind loads. For example, safety at sea is demanding new type of experiments involving simultaneous simulation of waves and wind. Regulations for ship intact stability and damage survivability may still be discussed and improved through combined tests. The wind effect on superstructures is also a complex phenomenon when the ship is maneuvering in confined areas (harbor, canal etc.).

These kinds of analysis require a correct wind generation in model basins. Some wave basins are installed inside the test section of a wind tunnel which allow the generation of a good airflow quality. However, this kind of equipment is expensive and wave generation is often limited to regular waves.

Usually, wind generation systems use a fixed bank of axial fans, placed in front of the model, to simulate the wind field; see Roddier et al., Rouault et al. and Nihei et al. The major drawback of this kind of set-up is the generation of a twisted flow inadequate to create a homogeneous wind.

Other studies try to generate a correct wind load instead of a correct wind field; see Bobillier et al. who developed a single variable speed controllable ducted fan mounted on the structure platform. This fan models the effects of variable wind loads on the model without the superstructure details. However, as pointed by Buchner et al., with fans on the model, it is difficult to have the correct point of application of the wind load, resulting in incorrect aerodynamic moments. Furthermore, wind is not only a load but also provides damping, which is realistically modeled with a real wind field only.

This paper describes the development of an innovative wind generation system for physical model test of offshore floating structures (e.g. floating offshore wind turbines). An innovative experimental facility is associated with the Ocean Engineering Wave Tank of Ecole Centrale de Nantes in order to reproduce offshore winds with respect to its mean speed vertical gradient, including dynamic aspects (frequency spectrum, gusts) and directional water waves. Developed within a collaborative framework between C.S.T.B and E.C.N, the wind generation system is based on several centrifuge fans located behind the wavemaker. Flexible air ducts are carrying the airflow to the vicinity of floating models. Single and multiple nozzle configurations are studied using a C.F.D code in order to cope with various experimental arrangements.

The paper also presents the wind generation set-up and qualification without swell. Results concerning the homogeneity of the velocity profile are detailed. Further improvements are on the way including the decrease of turbulence level through the use of honeycombs and porous screens and the control of the low frequency range of offshore spectra generated by the fans’ variable speed.