Experimental Study of the Feasibility and Hydrodynamic Responses of an Array of Interlinked Spars

YunHo Kim, SeokWon Hong*, SaYoung Hong* and YoungShik Kim
Korea Research Institute of Ships & Ocean Engineering
Dae-jeon, Korea

Chul Jung
CYTRONIQ
Cheon-an, Korea

An experimental study of a 2 × 2 array of interlinked spars was performed in order to identify the motion and structural responses and to determine the feasibility of this system. The motion responses of the floaters were measured with noncontact cameras, while the tension in the connectors and mooring lines was measured with single-axis load cells. Strains along the connectors were measured with Fiber Bragg Grating (FBG) sensors and electro-resistant strain gauges. The measured results were compared with the allowable stresses of ASTM-32 mild steel. The sea-keeping ability and structural reliability of this new conceptual system were evaluated.

INTRODUCTION

The need to develop renewable energy resources continues to increase because of the limited supply of fossil fuels and danger of environmental pollution. As energy resources start to be exploited and explored, many countries are finding environmentally friendly resources at offshore sites. Even though liquefied natural gas (LNG) and shale gas have emerged as next-generation energy supplies, offshore wind remains a viable alternative energy resource. European Union (EU) countries have an agreement that 20% of their total energy consumption will be supplied by offshore wind energy by 2015 (EWEA, 2012).

To exploit offshore wind, several underwater structures have been proposed such as spars, tension leg platforms (TLPs), and semi-submersibles. However, none have yet gained a dominant share of the market. There have been a number of conceptual design studies of floating wind turbine structures (e.g., Jonkman, 2010; Shin, 2010; Robertson and Jonkman, 2011; Myhr et al., 2011). Spar-based offshore wind turbines are in the industrial proof stage; in 2011, Statoil of Norway began construction of the Hywind-OC3 (2 MW) project. Numerical analysis tools, such as FAST (NREL), Texas A&M University's code, and MARINTEK's code, have been utilized to evaluate the safety and reliability of these structures.

The Korea Research Institute of Ships & Ocean Engineering (KRISO) has developed a new conceptual design for constructing offshore wind farms with submerged interlinked structures (Hong et al., 2012; Kim et al., 2014). Our previous works were concentrated on evaluating the motion characteristics of this conceptual design through a numerical approach. Boundary Element Method (BEM) was utilized to obtain hydrodynamic coefficients, while Finite Element Method (FEM) was applied to model mooring lines and the underwater connecting mechanism. These studies were used to determine the initial design of the connecting mechanism.

The present study experimentally evaluated the conceptual design from our previous works in terms of the motion and structural reliability. The static characteristics of one connector were examined first, and the surge natural frequency was obtained by subjecting the whole system to a free decay test. The dynamic characteristics of the floaters, mooring lines, and connectors were identified by using the ocean basin model test with different waves.

EXPERIMENTAL REPRESENTATION OF CONNECTOR

First, a search was conducted for a suitable experimental material to represent the previously designed connector (Kim et al., 2014). Due to budget limitations, the model could not be customized to meet the exact design specifications. Possible alternative materials were chosen: polyvinyl chloride (PVC), polyethylene (PE) hydraulic pipe, PE electronic pipe, and high-density polyethylene (HDPE). The actual numerical design for the connector was a truss-type structure, while the considered materials were all cylindrical because of the difficulty in matching the geometry. Instead, an equivalent material was found where the main properties, such as the weight, axial stiffness (EA), and bending stiffness (EI), were analogous to those of the designed model.

Figure 1 shows the experimental setup for measuring the Young's modulus of the possible materials. Two strain gauges were attached to each sample, and the measured local deflection was converted to the bending moment that was directly used to calculate the Young's modulus.

Except for PVC, the materials were too stiff or flexible, and the EA and EI values were quite far from the target values. Table 1 presents the Young's moduli of several PVC pipes and the corresponding values for their axial stiffness and bending stiffness. All values are represented at the model scale.