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Experimental and Numerical Studies on Behavior of Rotating Drill Pipe Model in Uniform Flow

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In this study, the underwater behavior of a drill pipe model rotating in uniform flow was investigated through experimental and numerical analyses. The hydrodynamic force acting on the rotating equipment of the drill pipe model was measured, and its coefficient was derived. The displacement of the drill pipe model was also observed and measured. The numerical estimation of the model's displacement was implemented by applying computational fluid dynamics and absolute nodal coordinate formulation.

INTRODUCTION

In recent years, offshore drilling has become increasingly important for the exploration of new resources (e.g., seafloor minerals and methane hydrate) and scientific research, such as the elucidation of the mechanism of earthquake occurrence. There are two types of offshore drilling: riser drilling (in which riser pipes are connected to the seafloor and hull of the vessel, and drill pipes pass through the riser pipes) and riser-less drilling (in which drill pipes are lowered directly into the sea). Riser-less drilling is used for large-depth and shallow-depth drilling to overcome the operating depth limit of the riser, whereas riser-less drilling is used for riser drilling until a blowout preventer and riser pipe are installed. For riser drilling, there has been extensive research carried out. For example, studies of hydrodynamic forces acting on long pipes (circular cylinder) were conducted by Chung and Felippa (1981) and Chung and Whitney (1993). In the former paper, the behavior of an underwater deep-sea mining system (riser assembly) under environmental conditions such as current velocity, viscosity, and density, which vary with depth, was computed at the Reynolds number of the actual system (approximately 2.0×10^5). In the latter paper, several methods for suppression of vortex-induced vibration (VIV) of deep-sea mining systems (riser assembly) were examined, and the size of the models used in this paper were the same as actual. In addition, detailed measurements have been conducted and reported for the 2,000 m length of actual riser assembly in terms of riser pipe vibration caused by drilling (Blevins et al., 2017). On the other hand, the primary interest of experiments and numerical simulation for riser-less drilling is the drill pipe failure and fatigue failure of the drill pipe due to impact forces and cyclic loading acting on the drill pipe (for example, Zhao et al., 2018).

In riser-less drilling, the drill pipe is directly exposed to the external environment, and the drill pipe behavior becomes more complex. In deep drilling, the drill pipe behavior becomes more complicated as the drill pipe becomes longer, and the natural period of the drill pipe approaches the predominant period of the ship motion. The drill pipe dynamics are closely related to the drilling operation from the viewpoint of operation efficiency and safety. For example, the fluctuating axial stress in the drill pipe caused by ship motion may be up to 10 times greater than that in rigid body hypothesis due to the influence of drill pipe dynam-

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