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Simplified Method on Obtaining Extreme Multidirectional Current Profile from a Current Database for Deep-water ROV Operation

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Ocean current should be carefully defined during analysis and design of any deep-water system. This study focuses on introducing and testing a proposed simplified method—namely, a weighted current profile (WCP)—in filtering current profiles from a large database so the response analysis of a deep-water system can be carried out more efficiently. The method is tested for the operation of a deep-water work class remotely operated vehicle (ROV), connected to the surface vessel through an umbilical line, under more than 10,000 current profiles. The study reveals that the WCP method can successfully eliminate thousands of unnecessary current profiles from a big database.

INTRODUCTION

Ocean current is one of the important aspects that is essential to consider when designing any deep-water system. Because of the scarcity of measured current speeds and directions along the water column in the past, a vertical current profile was commonly assumed to follow one of the simplified profiles that can be conservative for deep-water systems. In the last decades, several measurements have been conducted on different deep-water locations, producing different current databases that can be used to define a more precise multidirectional current profile for designing and executing a deep-water operation. However, each database usually consists of thousands of fine current profiles that are cumbersome to analyze through conventional methods because of their large computational time. Performing statistical analysis on the deep-water current database is also still prohibitive without sacrificing the coherence of current speed and direction between depths along the water column.

Different approaches have been tested to capture the vertical current profile that produces the largest structural response of a deep-water system, known as an extreme current profile, from a big current database. One of the approaches is by forming a family of extreme current profiles through conditional current analysis (Winterstein et al., 2009, 2011). The other approach is by performing the average conditional exceedance rate to define a statistical current profile with a certain return period (Liu et al., 2018). One popular method is the empirical orthogonal function (EOF), which utilizes the mode-based analysis to extract the characteristic extreme current profile from the database (Forristall and Cooper, 1997; Jeans et al., 2003, 2012; Mattioli and Pizzigalli, 2016). This method was later compared with current profile characterization (CPC) and an advanced clustering procedure called a self-organizing map (SOM) algorithm in reducing the big current database when analyzing the vortex-induced vibration of a steel catenary riser (Prevosto et al., 2012). The clustering procedure showed a great advantage compared with the other two options because it can extract the extreme current profile from a big database in a more efficient way, even when the database consists of fine current profiles. Because of the promising result shown by the clustering procedure, Jeans et al. (2015) compared different clustering algorithms in an attempt to extract a fine extreme vertical current profile from a deep-water current database in the Gulf of Mexico for riser design. However, most applications of clustering in extracting the extreme current profile still excluded the information of the current direction along the water column. Hunt et al. (2020) then tried to measure the significance of current directions during the clustering process when finding the extreme current profile for a vertically fixed flexible structure in deep water with different fine current profile databases. They showed that the inclusion of current directions on the clustering procedure may improve the resultant extreme current profile. They also tested the combination of the unsupervised clustering approach and different dimensionality reduction methods to define the current profile that produces the largest structural response during deep-water operation of a remotely operated vehicle (ROV). In this case, they tried three different dimensionality reduction methods: one is similar to the EOF procedure, whereas the other two apply the artificial neural network with different approaches.

Though clustering and dimensionality reduction can successfully extract the extreme current profile from a big database, the process can be complicated and still relatively time consuming. Therefore, a simplified method—namely, a weighted current profile (WCP)—is introduced in this paper as an alternative in extracting the extreme current profile from a big database without great loss in accuracy. The proposed method uses the basic principle of the dimensionality reduction process through a combination of simple mathematical formulations.

This study focuses on testing WCP in filtering vertical current profiles from a large database into a small set of current profiles so that the response analysis can be carried out more efficiently. In WCP, each multidirectional current profile in the database is weighted based on its current speed, direction dispersity, and relative location along the water column. The method is tested for underwater operation of a deep-water work class ROV-umbilical system under more than 10,000 current profiles taken from an hourly measurement database in the Gulf of Mexico. Static simulation of the ROV-umbilical system is carried numerically for all the current profiles in the database, and the multidirectional current profile that produces the extreme response of the system is compared with that obtained from the proposed WCP method.

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KEY WORDS: ROV, deep water, umbilical, current profile, simplified approach, response analysis.