Current Profile Extreme Prediction in the South China Sea Based on the EOF-ACER Method, by Considering Current Directions

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Current loads are key environmental loads in offshore engineering. In this paper, the empirical orthogonal function (EOF) and the average conditional exceedance rate (ACER) methods are used to develop the extreme prediction of current speed profile with different current directions. The modes in each directional profile are calculated by EOF decomposition, and a simplified model of current profile in each direction is established. Finally, directional extreme profiles are obtained, and the influence of parameter selection during calculation is also discussed.

INTRODUCTION

Current loads are the key environmental loads in the design and analysis of underwater structures in marine engineering. At present, with the continuous development of deepwater offshore platforms, the analysis of the current loads has attracted widespread attention. Current loads work on the structure in the form of profiles, so the prediction of current extreme profile is the focus of current research. In the conventional design method, the envelope of extreme speed of each layer is taken as the design current model, which has been found to overestimate speed at certain depths and cannot reflect the actual spatial characteristics of current.

To solve the above problem, Forristall and Cooper (1997) achieved the dimensionality reduction of the current data using the empirical orthogonal function (EOF) method and obtained the design profile based on the inverse first-order reliability method (IFORM) and response functions. This approach has been recognized by DNV GL (2017) as the recommended approach for extreme profile prediction. However, because the parameter fitting is adopted during the marginal distribution and conditional distribution, it is difficult to estimate the fitting error. Moreover, for the case of more than two variables, there are challenges to fit the conditional probability among the variables. In fact, the calculation efficiency and difficulty of the approach is determined by the effect of dimensionality reduction.

At present, the influence of directional characteristics on the current model is usually ignored in underwater structural engineering. However, there are significant differences in current profiles in different directions, resulting in significant directionality of current loads, which may have a certain impact on structural design. For underwater structures such as mooring, this means that the mooring tension has obvious directional characteristics, and the mooring design can be optimized based on the directionality. Therefore, it is of great significance to predict the extreme current profiles considering current directions.

Some scholars have introduced directionality into the joint method of EOF and IFORM using the complex EOF (CEOF) decomposition or decomposing speed into orthogonal components (Lima et al., 2009; Agarwal et al., 2013). However, hypotheses were introduced to avoid the inverse reliability problem of multiple variables, which will introduce uncertainty in calculation. Liu (2018) used CEOF decomposition to the measured data in the South China Sea and constructed multivariate correlation through vine copula. However, this method does not avoid the problem that the fitting error cannot be estimated during the parametric fit. Another method named the conditional extremes model, proposed by Heffernan and Tawn (2004), was utilized by Bore et al. (2018) to construct the correlation between current speed components. Because this method is based on the asymptotic theory, the problem of parametric distribution fitting is still unavoidable.

In recent years, Naess et al. (2007) proposed the average conditional exceedance rate (ACER) method. This method is a non-parametric extreme value analysis method and can give the confidence interval of the prediction result. Numerical analysis in dynamic systems verified the applicability and reliability of ACER for extreme responses predictions, and the method is improved for the case of nonstationary time series (Naess and Gaidai, 2008, 2009; Naess et al., 2010). Recently, the ACER method has been gradually developed and applied to the extreme value predictions of other marine environment variables (Karpa and Naess, 2013; Chai et al., 2017, 2018; Liu et al., 2018; Naess and Karpa, 2015) and response variables of marine structures (Gaidai et al., 2016, 2018).

In this paper, the EOF and ACER methods are applied to carry out an extreme profile prediction with special consideration of current directions. First, the measured current profile data set is classified according to the current direction within each layer. Then, the correlation analysis of the current profile is carried out. The modes in each directional profile are calculated by EOF decomposition, and a simplified model of the current profile in each direction is established. Finally, based on the divided directional