Current profile extreme prediction in the South China Sea based on the EOF and ACER method, by considering current directions

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ABSTRACT

Current loads are key environment loads in the offshore engineering. In this paper, the empirical orthogonal function (EOF) and the average conditional exceedance rate (ACER) method 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. Based on the ACER prediction method, the directional extreme values of the current speed of each layer and the drag force are obtained. Finally, extreme profiles are given corresponding to different return periods.

KEY WORDS: Current profile; EOF method; ACER method; direction extremum prediction; prototype monitoring.

INTRODUCTION

Current loads are key environment loads in marine structural design and analysis. On the one hand, the current imposes significant drag forces on the underwater structures, thus affecting their strength design. On the other hand, the vortex-induced shedding process of current passing underwater flexible structures with large slenderness ratios leads to the vortex-induced vibrations (VIV) of structures such as risers and moorings and may result in fatigue damage of the underwater structure. Due to the development of offshore platforms in deepwater, the analysis of current loads has attracted great attention. Current loads work on structures in the form of profiles, while extreme values of environment factors of multi-year return periods are usually employed as criterion of load design in ocean engineering. Therefore, the prediction of current extreme profiles is the focus of studies of current loads.

As predictions of current extreme profile are issues of multivariate extreme analysis, extreme value analysis is usually applied for the current speed at each of the different layers in conventional design approaches, and the extreme envelopes of current speeds of the same return period are treated as the final design profiles. However, it is impossible for all layers to reach the extreme speed simultaneously, so the extreme profile obtained by the above method may overestimate the speeds of some depths. Meanwhile, the extreme profile envelopes may be different from actual profile patterns. Therefore, the effects of spatial correlation should be considered when calculating the extreme profiles. A possible approach is to assume that the extreme profile follows a specific spatial pattern. For example, Winterstein (2009; 2011) introduced the Turkstra model. First, extreme value analysis was performed for speed of each layer. Then, regression analysis was used to establish the relationship between the extreme current speed of a certain layer and that of other layers at the same time. This method has been applied in the calculation of the current model near Norway in the North Sea. However, the spatial correlation of current profile established by regression analysis ignores the nonlinearity of the profile model. In other words, this approach does not consider all the factors affecting the spatial correlations.

In an effort to solve this problem, Forristall (1997) achieved the dimensionality reduction of the current speed profile using the empirical orthogonal function (EOF) method and calculated the extreme design profile based on the inverse first order reliability method (IFORM) and the response function. This approach has been widely applied for deduction of extreme profiles in virtue of its undisputed theory and simple calculations. At present, the method has been recognized by Det Norske Veritas (2017) as the recommended approach for extreme profiles with a specified return period. However, it is difficult to estimate the error due to the parametric fitting for the marginal distribution and conditional distribution of parameters. Moreover, the conditional probability is difficult to carry on the fitting for cases of more than two variables. So the calculation efficiency of the approach is determined by the effect of dimensionality reduction. If the number of unknowns after dimensionality reduction is still large, the computational efficiency of this approach will degrade drastically.