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Safety Analysis of Marine Engineering Based on Joint Probability Model of Wind and Waves

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Abstract: Offshore oil reserves are abundant, most of which are concentrated on the continental shelf, with broad development prospects. Offshore oil and gas platforms used to use offshore oil are called offshore platforms. Compared with marine facilities, marine platforms have the characteristics of harsh natural environment, small space, large investment and high technical requirements. Accidents such as pressure vessel leakage, platform damage, fire and explosion on offshore platforms will cause huge property losses and casualties. The high risk of safety accidents on offshore platforms requires more perfect safety measures. The purpose of this paper is to study the marine engineering safety analysis based on the joint probability model of wind and waves. This paper proposes a safety analysis method based on a probabilistic test model to conduct quantitative safety analysis of ship technology and improve the analysis performance. The research content focuses on the following points: Firstly, the density concentration of the cylindrical foundation, the SQP optimization method and the improvement of genetic algorithm are applied to the overall size optimization design of the cylindrical foundation. Under the conditions of satisfying the strength, stiffness and stability of the foundation, the design optimization and topology optimization are generated, and the finite element method is used to carry out the local optimization design of the large-diameter cylindrical foundation power transmission system. Finally, to demonstrate the reliability of the results and the validity of the method, this paper validates the performance results using a traditional family tree and compares the entire model-based approach with traditional security methods. The method adopted in this paper can carry out a comprehensive safety analysis of complex systems, the calculation results are reliable, and the efficiency of safety analysis is improved.

1. Introduction

Offshore oil reserves have increased, with proven reserves reaching 38 billion tons. It is

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estimated that offshore oil reserves account for about one-third of the world's oil reserves. Offshore oil has great growth prospects, but the marine environment is different from land. Compared with marine equipment, the technical requirements of offshore platforms used for offshore oil exploitation are very different, mainly due to harsh natural environment, narrow platform space, high capital density, and serious leakage consequences. We must pay attention to the particularity of offshore platforms, and propose safe and intelligent management methods and procedures [1-2] .

In the research on the safety analysis based on the combined probability model of wind and waves in marine engineering , many scholars have studied it and achieved good results . The foundation failure mode of the tube foundation. And referring to the Engel assumption of the limit equilibrium method, the stress condition of the single-tube foundation when the foundation reaches the horizontal limit load is analyzed [3]. The approximate calculation method of the horizontal ultimate bearing capacity of rigid short piles in layered soil foundations proposed by Putra A can be easily used to estimate the horizontal ultimate bearing capacity of suction caisson foundations [4].

This paper mainly considers wind load, wave load and water flow load when the fan is running. The load on the wind turbine is determined by the combination of the wind turbine operating mode or other design conditions and the external wind speed. According to the load data of the 3Mw fan provided by the fan manufacturer, the load value of the bottom of the tower under the normal operating condition and the extreme working condition of the fan is determined. Select the hydrological conditions and wave load, and use the Morison formula to obtain the maximum wave force on the tube foundation as the ultimate wave load of the foundation.

2. Research on the Safety Analysis of Marine Engineering Based on the Combined Probability Model of Wind and Waves

2.1. Model-Based Security Analysis

(1) System design and security requirements analysis

The first step in the formal security analysis of the system is to clarify the physical architecture, logical architecture and functional design of the system. For the system architecture design, the system design requirements and the requirements defined in the target file, the system design scheme, the system architecture diagram, etc., should be obtained, and on the basis of in-depth analysis of the physical architecture of each level of the system, the most fine-grained acquisition of the underlying system design scheme, It helps to improve the accuracy of system safety analysis. For complex avionics systems, it can generally be accurate to the design of internal function modules.

After the system architecture design is clear, all functions related to the level of analysis should be determined, including system internal functions and interactive functions. By obtaining the necessary original materials, determine and establish the function list, including the aircraft top-level function list, the main function list of the system, the external interface function diagram, etc. After the system architecture and functions are determined, the normal model modeling of the system can be carried out [5-6] .

In addition, as the first step in the system safety assessment, the failure status should be further determined based on the determination of the function, that is, the system-level FHA report should be obtained. The report will be directly used to obtain the quantitative security requirements of the system, and then express them as system properties in the form of temporal logic, and verify whether the system meets these requirements in model checking.

(2) Modeling of the high-level model of the system

The system high-level model describes the system design and failure from a qualitative perspective, including two parts, the system nominal model and the failure expansion model.

The nominal model of the system refers to the use of formal language or architecture description language to describe the logic and physical architecture of the normal behavior of the system. When establishing the normal model of the system, the complexity of the system should be analyzed, the level and abstraction of the system model should be determined, and the formal language should be used to complete the modeling of the normal model of the system [7-8] .

After completing the high-level modeling of the system, analyze the failure state of the system, study the typical failure modes of each component, failure propagation paths, failure probability, failure effects, etc., which can be obtained through FMEA. Then the failure information is injected into the normal model of the system, and a failure expansion model is established to facilitate safety analysis.

(3) Research on conversion rules

Since the high-level model of the system is used to represent the system architecture, failure information, etc., it cannot be automatically and completely quantitatively analyzed. Therefore, it is necessary to fully grasp the syntax, semantics and modeling specifications of the probability model, and study the conversion rules from the failure expansion model to the quantitative model. The extended model is transformed into a quantitative validation model to complete quantitative analysis [9-10] .

(4) Modeling and analysis of the underlying model

The underlying model usually converts the system design model into a security analysis model by means of symbolic languages. The underlying formal model is divided into two parts, including modeling and model checking. After the modeling is completed, by converting the quantitative safety requirements obtained in the FHA into a sequential logic expression, the model checking adopts the traversal method to check each state of the system, and calculates the probability of the failure state based on the mathematical operation logic, and finally obtains the required Quantitative indicators of safety at all levels are used to draw conclusions on system safety analysis [11-12] .

2.2. Modeling Specification of Probability Test Model

The probabilistic test model completes the modeling of the system in a structured high-level language. The structured language consists of the most basic modules and variables. When modeling, it is necessary to establish a series of parallel modules of each component in the system, and at the same time define the failure mode and the corresponding probability of occurrence of each module by defining variables, and express the relationship between the variables in the module, the relationship between the module and the module through logical equations. Interrelationships between modules. The failover behavior of a module is represented by a series of transfer commands, for CTMC, the commands are expressed in the following syntax:

[action](guard) -> (rate):(update);

Among them, the command starts with [], and the function is the syntax symbol of the command; (guard) represents a single variable. In the process of safety analysis and modeling of civil aviation systems, the failure mode is often used as a variable? -> Represents a transition state whose transition state is (defense) true; (update) represents the changed state; (rate) represents the probability of a change [13-14] .

2.3. Joint Probability Distribution of Extreme Wind and Waves

The multivariate multivariate analysis method was used to analyze the likelihood of the one-year average value of the modern wind and wave observation data of the offshore platform. The wave height is the actual wave height. Perform unnormalized Frechet wind transformation, sample size xji (x1i represents wind speed sample size, x2i represents wave height valid sample points) to standard Frechet wind and sampled wave zji, and then convert to standard Frechet. zji takes the random variable in the pseudo-polar coordinate system as an example, and calculates the parameter φ of the multivariate correlation coefficient according to the pseudo-polar coordinate system. Finally, formulas (1) and (2) are used instead of statistics to obtain the joint probability distribution of the measured values of wind speed and wave height [15-16] .

$$F(x_1, x_2) = \exp\left\{-\left[Z_1(x_1)^{-\phi} + Z_2(x_2)^{-\phi}\right]^{1_{\phi}}\right. \tag{1}$$

$$Z_j\left(x_j\right) = -\ln 1 - p_j \left\{1 - k_j\left(x_j - u_j\right) / \sigma_j \right\}_j^{1_k} \tag{2}$$

3. Research Design Experiment Based on the Safety Analysis of Wind and Wave Joint Probability Model in Marine Engineering

3.1. Probabilistic Model Test

In order to verify whether the behavior of the system meets the security requirements, the behavior of the system must be properly described, that is, the normative description of the characteristic system. CTMC quantitative feature verification, based on the quantitative feature requirement document, uses the CSL language to formulate the system feature specification. There are two types of logic based on CSL language, sequential logic and steady-state logic. Typically, steady-state logic is used to control the probability of states occurring under long-term system conditions. However, since stationary mode maneuverability is limited to stationary mode, characteristics to be examined in a flight system safety assessment should be described, such as the average probability of a particular failure mode per hour of flight in a logical order. For example, the probability of a system showing failure mode A within two hours can be expressed as [17-18]:

P=? [true U<=2(system_FC_A)]

After completing the attribute description, the probabilistic model will automatically expand the attribute test and draw a conclusion. The process is shown in Figure 1.

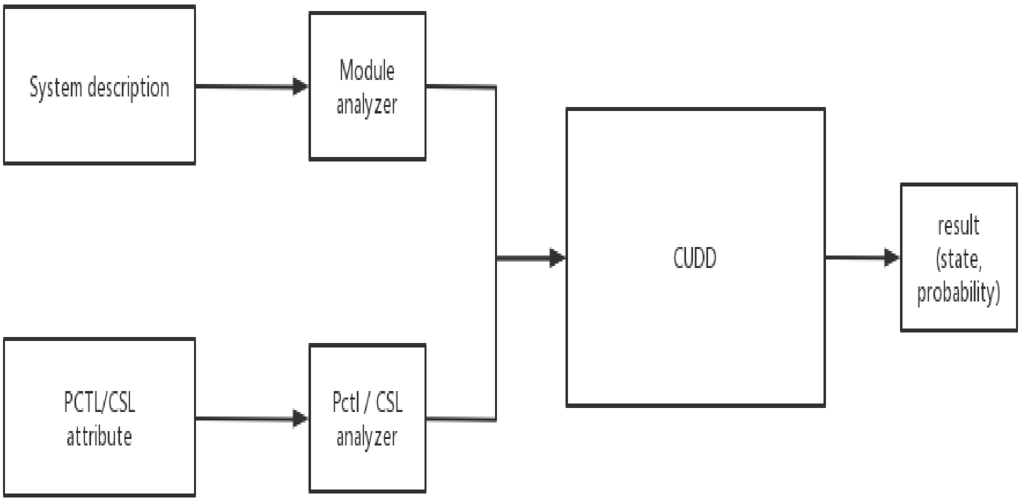

Figure 1. Working structure of the probabilistic model tester

3.2. Experimental Design

In this paper, the characteristics of various load types are analyzed, and edge integration is performed for various joint probabilities. Secondly, a reasonable analysis of the fatigue bearing capacity of two different m values in marine engineering is carried out.

4. Experimental Analysis of Safety Analysis Based on Wind and Wave Joint Probability Model in Marine Engineering

4.1. Load Characteristics

In this paper, the marginal distribution function can be obtained from the marginal classification of joint probability, and its functional form is also very complex. The load distribution characteristics of wind, wave and current are shown in Table 1.

Table 1. Environmental load probability distribution and its parameters under independent wind and wave operating conditions

	parameter A	parameter B
Flow load	17.460	1.57
Wind load	0.459	26.55
Wave load	2.090	6.09

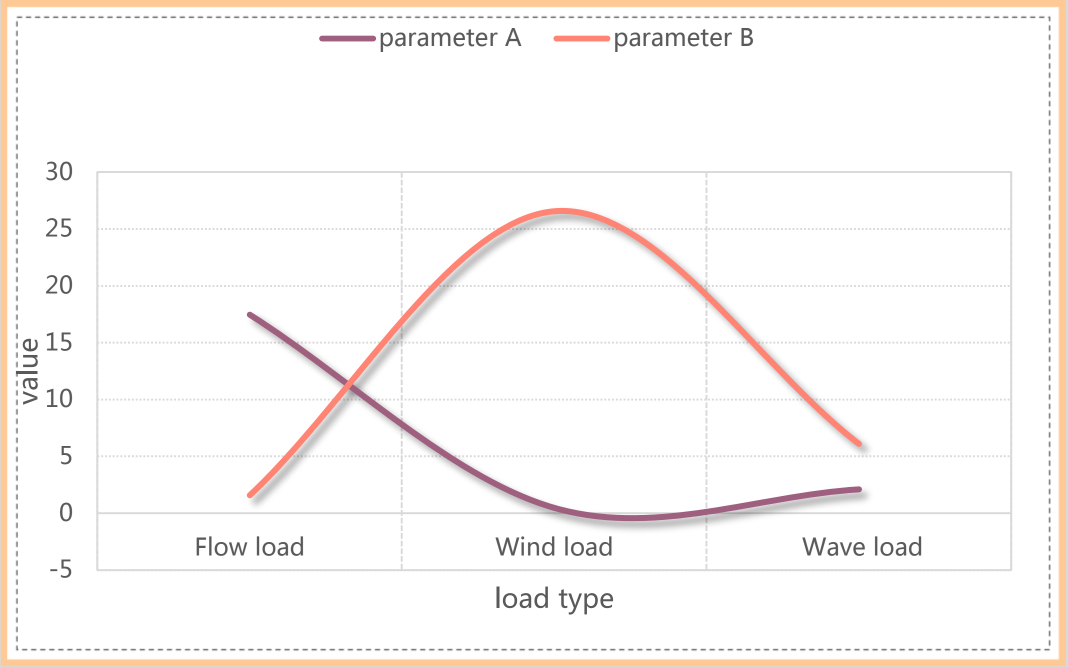

Figure 2. Load distribution characteristics of wind, wave and flow column

It can be seen from Figure 2 that the distributions of the two parameters of the three loads are quite different. The flow load has a higher parameter A and a lower parameter B, and the wind load has a lower parameter A and a higher parameter B, in contrast, the wave load has both lower parameters. Therefore, effective analysis should be carried out according to the characteristics of different loads.

4.2. Fatigue Analysis

this paper , according to a specific wind field and a specific type of fan, the fan manufacturer provides the upper fan load, and takes the equivalent constant amplitude fatigue load when m = 3 and 5, as shown in Table 2 . At the same time, the fatigue analysis of the structure is carried out considering the effect of the wave load simulated above.

Table 2. Fatigue load

	Mx	My	Mz	fx	Fy	Fz
3	4550	10219	2521	224	62	50
5	9882	13756	2870	239	127	68

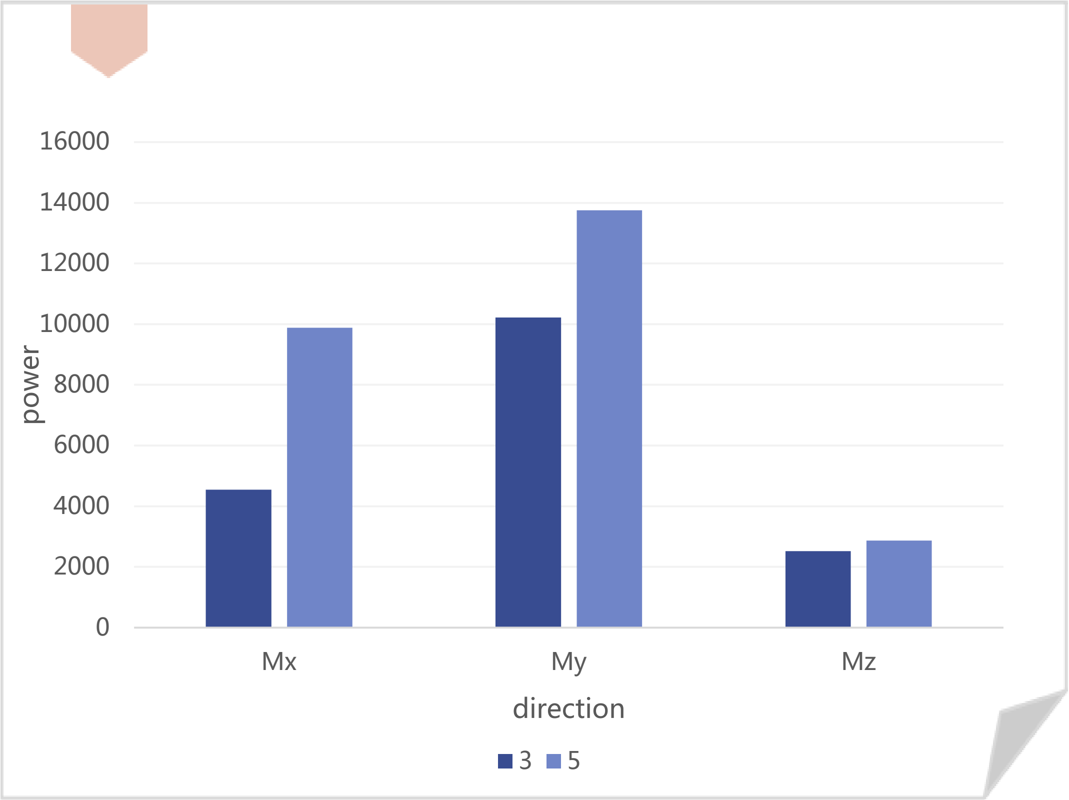

Figure 3. Force of M at two m values

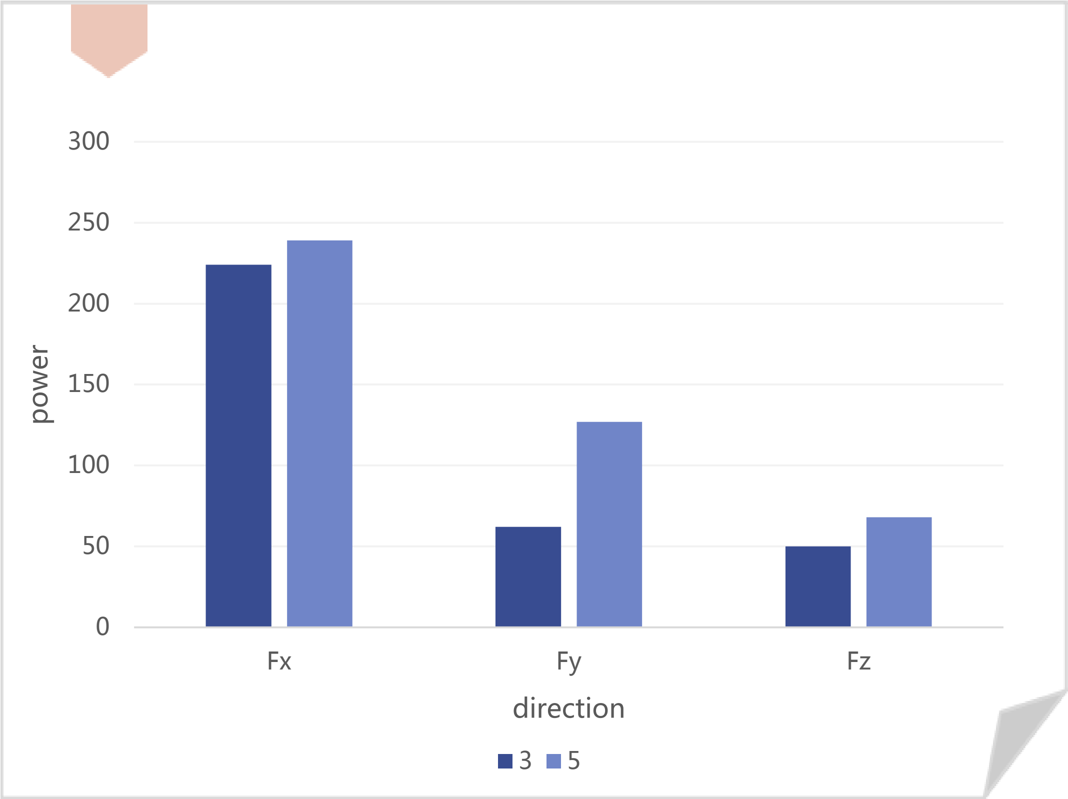

Figure 4. Force of F at two m values

It can be seen from Figures 3 and 4 that

(1) When m=3, fatigue analysis

The maximum value of the first principal stress of the steel appears at the bottom of the inner cylinder, which is 7.36Mpa. According to the formula, the corresponding number of rupture cycles is 2.29×108 times, which is more than twice the allowable cycle times of 1×107 times. According to the steel structure design specification, the welding type steel parameters C=1.47×1012, //=3, and the number of stress cycles is 2.29×108, the allowable stress amplitude of constant amplitude fatigue is 18.59Mpa, and the fatigue stress range meets the requirements .

(2) When m=5, fatigue analysis

Similarly, the maximum value of the first principal stress appears at the bottom of the inner cylinder, which is 8.10Mpa. According to the formula, the corresponding fracture cycle times are calculated to be 1.20×109 times, which is more than twice the allowable cycle times of 1×107 times. According to the steel structure design specification, the welding type steel parameters C=1.47×1012, //=3, and the number of stress cycles is 1.20×109, the allowable stress amplitude of constant amplitude fatigue is 10.70Mpa, and the fatigue stress range meets the requirements

5. Conclusion

In the design of the simple foundation structure and the theoretical calculation of the bearing capacity, only the overall stability of the structure is checked, and the local safety of the structure cannot be determined. Through the finite element analysis software abaqus, the large diameter, width and shallowness optimized according to the conditions of the Longyuan wind field are analyzed. The steel-concrete composite structural tubular foundation is analyzed for structural strength, stiffness and stability under two design conditions. The results show that the foundation displacement and deformation control and the maximum stress of each part of the foundation can meet the requirements, the structure design is reasonable, and the cylindrical foundation structure is safe under the ultimate static load. This paper proposes a large-diameter shallow pipe foundation system for offshore rheumatic wetlands, studies the mechanical mechanics of the large-diameter shallow pipe foundation system for dyed mud foundations, and systematically demonstrates the secondary bearing capacity calculation and structural design conditions of the tubular foundation. Wall bearing type and ceiling bearing type are simpler according to the actual application of the project, easy to popularize and materials. This paper compares the influence of wind and wave adjustment on the reliability of the platform's foundation system, and the results show that the system reliability under the wind and wave correlation estimation is higher than the system reliability without the wind and wave correlation estimation.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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