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Improvement Scheme of Mooring Line in Marine Engineering Based on Quasi-statically Indeterminate Method

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Abstract: In the deep sea with complex natural environment, the dynamic effect of the mooring line, the grooving phenomenon in the bottoming area and the cyclic weakening of the soil may cause the mooring line to become slack, make the anchor body useless, and threaten the mooring system , so study the improvement scheme of mooring line is vital. The purpose of this paper is to propose a creative improvement plan for mooring lines in marine engineering based on the quasi-statically indeterminate method. Therefore, in the experiment, the basic parameters of the mooring line are set, the mathematical model is established, and the static are investigated and analyzed.

1. Introduction

The mooring line is an important part of the mooring system. If the mooring line fails, it will cause great economic losses and even endanger personal safety. As the most commonly used deep-water catenary mooring line, it will frequently contact and separate from the seabed the intersection of the bottom part [1]. Under the action of environmental loads, the touchdown point is constantly changing, and it is very easy to generate sudden stress and then fatigue damage, which not only affects the dynamic response of the entire mooring system, but also endangers the safety of the entire deep-sea platform.

The mooring positioning system has the advantages of mature equipment, simple structure, low cost of initial installation and operation and maintenance, and convenient control. In this study, Kang TW analyzed the effect of the second hydrodynamic load on the response of the mooring line and the damage-equivalent fatigue of the wave energy component under extreme sea conditions. To examine this effect, the dynamic response of the offshore wind turbine structure was evaluated by isolating each component and coupling it with the software's HydroDyn module. The study found that the effect of wave energy on mooring tension is greater in waves than in wind seas, thus producing a larger average positional change in the structure. In conclusion, the second hydrodynamic load affects the performance of the structure, which significantly affects the damage equivalent fatigue of the mooring lines [2]. The Simo M L study found that the mooring system response of a floating production unit to environmental loads is nonlinear. Even though the wave height can be assumed to be a Gaussian process in the short term, the corresponding line tension response is usually not due to the second-order slow-drifting float motion and the inherent nonlinearity of the system. Short-term extreme responses are estimated based on two different methods. In the first case, multiple probability distributions were fitted to the tension time-history peak samples and classical order statistics were applied to determine the most likely extreme wire tensions corresponding to short time periods to determine the best performing wire tensions. With the continuous improvement of offshore oil exploration into the deep sea, the catenary length and total weight of the traditional mooring system have increased sharply, which has led to a sharp increase in the difficulty of system layout, installation complexity and cost [3]. Aratani S used the quasi-static loading method in the study to study the variation of Rath fracture and bending load, which is characterized by holding a fixed time at each displacement level and applying incremental displacement. Glass fracture occurs as the bending load decreases with time, This can be explained by the occurrence of fracture over time and is viscoelastic even at room temperature. The fracture performance of alumina ceramics may be closer to that of float glass than ordinary silicon carbide. With the continuous development of offshore oil exploration into the deep sea, the catenary length and total weight of traditional mooring systems have increased sharply, which in turn leads to difficulties in system layout and installation. The complexity and cost have increased dramatically [4].It can be seen that the research on the mooring line improvement scheme is of great significance.

Based on the current research situation at home and abroad, this paper studies the mooring positioning system, the quasi-static method, and proposes an improvement plan based on the quasi-statically indeterminate method for mooring lines in marine engineering. In the experiment, the basic parameters of the mooring line are set, the mathematical model is established, and the static and dynamic characteristics of the mooring line are investigated and analyzed.

2. Research on Mooring Line Improvement Scheme in Marine Engineering Based on Quasi-Statically Indeterminate Method

2.1. Research Status

In order to improve the positioning accuracy of the traditional mooring positioning system, the traditional passive mooring system is improved. In view of the stable changing sea conditions, the mooring system has the function of realizing fixed-point positioning through the active retraction and release of the anchor chain by the windlass, and on this basis, the mooring line is uniformly stressed by the evaluation function to prevent the fracture caused by uneven force. Thereby reducing the security risks of the platform [5].

At present, the engineering application of mooring positioning system in foreign countries has been relatively mature, and it is widely used in the positioning of various marine floating structures. However, there is still a certain gap between domestic research on mooring positioning and developed countries. Based on the analysis of static and dynamic characteristics, the mooring system is modeled, and its structure is optimized in a targeted manner. In view of the fact that my country is currently vigorously advocating the strategy of marine power , the research has good engineering significance [6-7].

2.2. Mooring Positioning System

It is the most commonly used passive positioning method for floating structures. Its working principle is to use the mooring line to connect the floating structure on the water surface with the anchoring foundation fixed on the seabed.To ensure that the strength design of the mooring system itself does not generate excessive mooring tension. According to the linear shape of the mooring line, it can be divided into two categories: catenary type and tension type [8-9].

The catenary mooring system is the traditional and most commonly used positioning method for floating structures. It provides restoring force for floating structures through the change of its own gravity. However, for deep water or ultra-deep water floating structures, with the increase of operating water depth, The dead weight of the traditional catenary mooring line composed of steel chains and steel cables will also increase rapidly, which makes the economic cost increase relatively too large. At the same time, its horizontal stiffness decreases, resulting in a rapid decline in the positioning ability of the floating structure and the vertical bearing capacity. Reduced, but due to the existence of the lying lot, it has a higher safety reserve performance. Tensioned mooring systems generally use synthetic fiber materials, which have the advantages of light weight and high recovery stiffness. However, the complex properties of materials and mechanics such as dynamic stiffness, creep and hysteresis of synthetic fiber materials make the failure form of tensioned mooring systems very complex [10-11].

2.3. Quasi-Static Method

The mooring damping mainly comes from the drag force caused by the relative motion of the mooring line and the fluid, the friction force of the mooring line on the seabed, and the internal damping caused by the internal deformation of the mooring line [12-13]. The quasi-static method is to give the low-frequency simple harmonic motion of the top of the mooring line, assuming that the mooring line is in a quasi-static state in a motion cycle, and use static analysis to calculate the mooring line when the mooring line is at the equilibrium position and the two maximum amplitude positions. The position of the node of the line element is used to estimate the normal motion of each element of the mooring line, and then the relevant formula is used to derive and calculate the drag force in one cycle as the dissipation energy and the equivalent linear damping coefficient. Although the static method is relatively simple to use, it has obvious shortcomings. It ignores the action of the ocean current and the elastic deformation of itself. This method is conservative. Since the dynamic response of mooring lines is a complex nonlinear problem, the research on mooring lines mostly adopts dynamic methods [14-15].

2.4. Improvement Scheme of Mooring Line in Marine Engineering Based on Quasi-Statically Indeterminate Method

Using the active mooring system, the active mooring positioning method can keep the position and heading of the ship within the allowable range by adjusting the tension of the anchor line according to the changes of the position, the heading deviation and the external environmental load, which can replace the dynamic positioning propulsion It can overcome the platform position or heading drift caused by the external load, so as to reduce the motion of the propeller [16-17]. Multi-point mooring positioning needs to reasonably distribute the force among it to resist external loads, and at the same time, it needs to meet the system safety and economic indicators on the premise of ensuring positioning accuracy. The application practice of the project shows that the uneven force is an important reason for the fracture of it. When the fracture occurs, the static restoring force of the system is redistributed in the remaining mooring lines, which leads to an increase in the tension of a certain mooring line. Until it is all broken, the system loses its positioning ability. The improved scheme is an automatic mooring positioning scheme aiming at uniform distribution of tension. The uniform distribution of anchor chain tension is achieved by reasonably determining the mooring line switching threshold method [18-19].

3. Investigation and Research on Mooring Line Improvement Scheme in Marine Engineering Based on Quasi-Statically Indeterminate Method

3.1. Basic Parameters of Mooring Line

The basic parameters of the mooring line are shown in Table 1:

Table 1. Misoring line parameters

Material	ORQ-Studink
Diameter (mm)	110
Length (m)	800
Number of units	60
Unit length (m)	20
Wet weight (Kn / m)	2014.365
Crippling load (Kn)	8543.1
Pretension (Kn)	1205
Tangential additional mass coefficient	0.014
Normal direction of the additional mass coefficient	0.8
Tangential drag force coefficient	0.009
Normal drag force coefficient	2.4

3.2. Establish a Mathematical Model

If $T_h / \omega = a$, where the vertical distance of the cable segment is recorded as z, the horizontal distance is recorded as x, and the length of the cable segment is recorded as s. The basic form of the catenary equation can be expressed as:

$$s = a \times sh\frac{x}{a} \tag{1}$$

$$z = a \times \left(ch\frac{x}{a} - 1 \right) \tag{2}$$

4. Analysis and Research of Mooring Line Improvement Scheme in Marine Engineering Based on Quasi-Statically Indeterminate Method

4.1. Analysis of Static Characteristics of Mooring Line

The above-mentioned catenary theory is used to formulate a static calculation program of the anchor chain line to calculate the axial tension at a given node of a single anchor chain line of a deep-sea working platform, and to give the spatial configuration. The specific technical parameters of the anchor chain line as the Table 2 and Figure 1:

Table 2. Parameters table of a single anchor chain line of a floating platform in a sea area

Sectional situation	The first one	The second one	The third one
Unit mass in the air (Newton / m)	3421	584	3547
Wet weight per unit (Newton m)	2012.66	425.45	2102.84
Fracture load (cattle)	8421	7541	8587

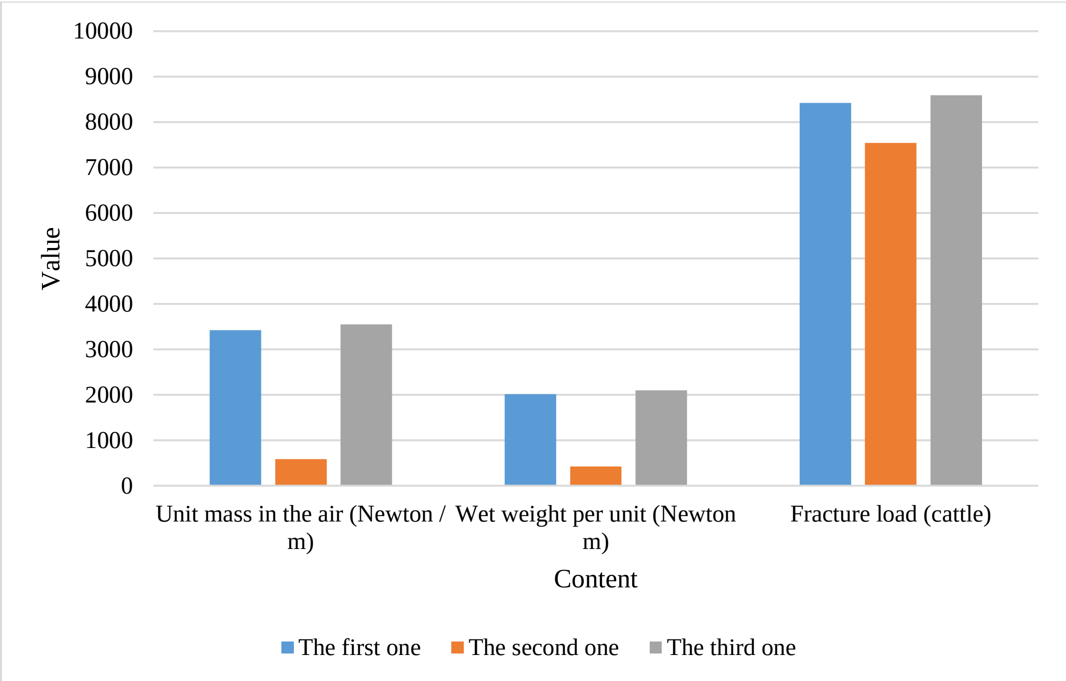

Figure 1. Chain line parameter data diagram

4.2. Analysis of Dynamic Characteristics of Mooring Line

Numerical example to verify the correctness of the nonlinear motion control equations solved by the finite difference method, a certain sea area with a working water depth of meters is used as a simulated working area, and the motion of the upper body given a certain external excitation is now calculated. The parameters of the anchor chain as the Table 3 and Figure 2:

Table 3. Anchor chain parameters

	The first paragraph	The second segment	The third segment
Chain length (m)	130	140	150
Anchor chain diameter (m)	0.8	0.8	0.8
Wet weight (N/m)	1854.31	458.6	1969.14
Crippling load (kn)	8547	7051	8945

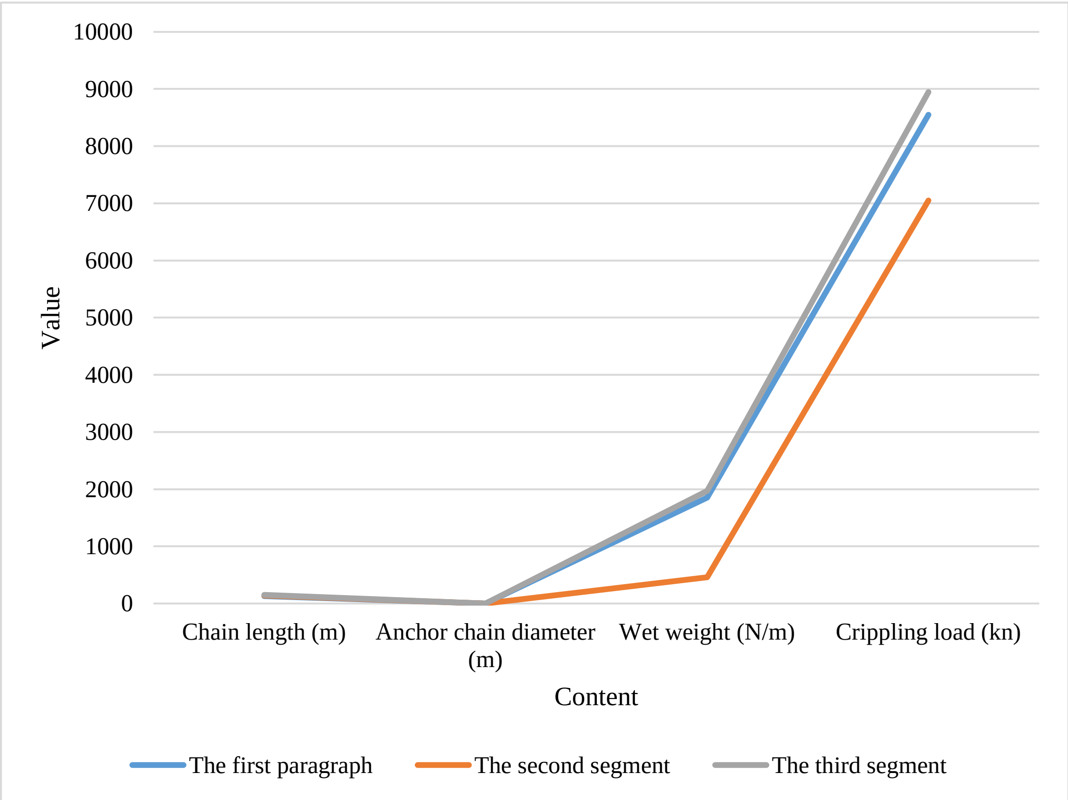

Figure 2. Datagram of anchor chain

5. Conclusion

As the total amount of shallow sea and land oil and gas resources decreases, the pace of exploitation of the earth's deep sea oil and natural gas resources begins to accelerate. There are few studies on the quasi-statically indeterminate method in my country, so the design and construction level of the platform is low, and the logistical support for marine engineering is insufficient. Therefore, the research on the mooring line based on the quasi-statically indeterminate method should be promoted, so as to improve the construction of marine engineering and improve the marine engineering. to advance, thus promoting the improvement of my country's marine engineering.

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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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