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Review of Fiber Mooring Polyester Ropes for Deep Sea Floating Structures

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Abstract

Combined with the engineering practice, the advantages and disadvantages of fiber mooring polyester rope are analyzed, as well as its application in various floating structures. The properties of breaking strength, dynamic stiffness, creep and fatigue failure of fiber ropes are introduced. At the same time, the paper summarizes the preparation process of polyester cable from fiber to yarn to strand, as well as the technical points and test equipment of cable length measurement test and performance analysis test. This paper also introduces the difficulties in the research of synthetic fiber mooring rope, which provides a certain degree of reference and guidance for the future development of deep-sea mooring engineering.

Keywords

Polyester Rope; Deep Sea Mooring; Mooring Engineering; Floating Structure Mooring.

1. Introduction

The 21st century is the century of the ocean. Accelerating the exploitation and utilization of Marine resources has become the strategic orientation of the development of all countries in the world. As a country rich in coal, poor in oil and less in gas, China's dependence on foreign oil and gas is rising rapidly with the continuous and rapid growth of oil and gas consumption [1]. In order to ensure China's energy security strategy and improve its ability to guarantee oil and gas resources, China will strengthen the exploration and development of deep offshore oil and gas resources.

In order to ensure the safe exploitation of deep-sea oil and gas resources, the key is the positioning technology of floating offshore platform. At present, the positioning technology suitable for floating platform mainly adopts catenary mooring system or tight mooring system. The catenary mooring adopts steel chain or steel cable as the main system cable. With the increase of water depth, the platform needs longer anchor chains for mooring, which leads to the increase of the mooring radius and the decrease of recovery efficiency. Moreover, the increase of the dead weight of the mooring cable leads to the decrease of the effective carrying capacity of the platform [2]. Tight mooring is characterized by using synthetic fiber mooring as the main body, and has the advantages of lighter dead weight, better mooring performance and smaller mooring radius, which can effectively solve the problems existing in traditional catenary mooring [3]. At the same time, the nonlinear characteristics of synthetic fiber tether are very strong, which are completely different from steel cable or steel chain. In recent years, researches on synthetic fiber tether such as polyester, nylon and high-strength polyethylene have been favored by many scholars, hoping to apply the fiber tether to the deep-water Marine mooring engineering more safely and reliably.

Based on the deep ocean engineering application of high performance fiber polyester mooring rope, complex mechanical properties, preparation research, experimental research work related technical analysis and other aspects, to promote deep sea mooring floating structure fiber polyester rope application, high performance fiber mooring rope further research direction.

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2. Application Status of Synthetic Fiber Mooring Rope

The design, analysis, installation and operation of the mooring system of the offshore platform are extremely complex and huge key projects in the development of Marine resources in the complex and harsh deep Marine environment. Floating body, mooring cable and anchor are the three elements of mooring system, among which the mooring cable is the indispensable intermediary between the platform and anchor, and is the carrier of load. As an essential mooring tool for offshore engineering equipment such as offshore platforms, Mooring is characterized by tensile, impact, abrasion, corrosion resistance, and flexibility. It was originally made of steel cables, hemp, or cotton.With the development of Marine resources advancing to the far sea, Marine engineering equipment has higher requirements on the performance of basic materials, and mooring cables also need higher mechanical properties, corrosion resistance and lower specific gravity.

In the 1960s, some scholars proposed a taiming mooring system using synthetic fiber cable as the main system cable in order to avoid the shortcomings of low stiffness and self-weight of anchor chain and wire rope. Since put into production, including FPSO, Spar, Semi and TLP train, the floating platform of a total of more than 300 cases, from 15 m to 2600 m operation depth change, between its mooring positioning in positioning way is the most common location technology, more than 95%, taut mooring is suitable for the shallow water and deep waters, but increases with the depth of the water used, the more multi-purpose especially in deep water, taut mooring type for the most common long-term positioning technology in deep water, is the forefront of international deep-water positioning technology, is also a large deepwater and ultra deepwater mooring system is the developing trend of [3].

Table 1. Application of synthetic fiber polyester rope mooring Engineering

Time	Depth/ m	Type	Region	Material
1997	530	Semi-FPU	Camps Bay	Polyester rope
1999	1 615	MODU	Gulf of Mexico	Polyester rope
1999	1 200	FPSO	Camps Bay	Polyester rope
2000	1 360	Semi-FPU	Camps Bay	Polyester rope
2000	1 885	MODU	Gulf of Mexico	Polyester rope
2000	515	Semi-FPU	Camps Bay	Polyester rope
2001	1 400	FPSO	Angola	Polyester rope
2001	2 286	MODU	Gulf of Mexico	Polyester rope
2001	2 860	MODU	Gulf of Mexico	Polyester rope
2002	1 360	FPSO	Camps Bay	Polyester rope
2003	705	FPSO	Brazil	Polyester rope
2004	1 080	Semi-FPU	Camps Bay	Polyester rope
2004	1 160	FPSO	Camps Bay	Polyester rope
2004	1 370	Spar	Gulf of Mexico	Polyester rope
2004	800	FPSO	Camps Bay	Polyester rope
2004	1 615	Spar	Gulf of Mexico	Polyester rope
2005	1 040	FPSO	Camps Bay	Polyester rope
2006	1 240	FPSO	Camps Bay	Polyester rope
2006	2 135	MODU	Gulf of Mexico	Polyester rope
2006	915	FPSO	Gulf of Mexico	Polyester rope
2007	1 350	FPSO	Camps Bay	Polyester rope
2007	2 135	MODU	Gulf of Mexico	Polyester rope
2007	2 440	Semi-FPU	Gulf of Mexico	Polyester rope
2007	1 330	Spar	Malaysia	Polyester rope
2007	373	Semi-FPU	Camps Bay	Polyester rope
2007	1 794	Semi-FPU	Roncado	Polyester rope
2008	1 370	FPSO	Brazilian Santos	Polyester rope
2008	1 979	Semi-FPU	Gulf of Mexico	Polyester rope
2008	1 219	Spar	Gulf of Mexico	Polyester rope
2008	1 280	Spar	Gulf of Mexico	Polyester rope
2008	2 383	Spar	Gulf of Mexico	Polyester rope
2009	1 847	Semi-FPU	Gulf of Mexico	Polyester rope
2010	2 600	FPSO	Gulf of Mexico	Polyester rope
2010	2 438	Spar	Gulf of Mexico	Polyester rope
2010	2 934	Spar	Gulf of Mexico	Polyester rope
2011	400	FPSO	Norway	Polyester rope
2011	2 164	Spar	Gulf of Mexico	Polyester rope

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For a long time, the high performance synthetic fiber cable market has been monopolized by a few companies in Europe and America, and the international market is mainly occupied by Lankhorst from Portugal, Bridon from Britain and Bexco from Belgium. After years of research, although China has mastered the core technology of synthetic fiber production and formed a relatively perfect large-scale production capacity, it still does not have a competitive advantage in terms of equipment, technology, capacity, quality and cost, which is mainly manifested in the following two aspects: (1) in the polyester, polypropylene, polyamide, ultra high molecular weight polyethylene and other raw materials, process performance and its Marine microbial contamination and abrasion and other aspects of the similar products and foreign there is a large gap. (2) The manufacturing technology, production process and equipment of continuous non-joint synthetic fiber mooring rope with large diameter, super length and high strength, which is suitable for deep sea conditions, are still blank.

3. Mechanical Properties of Synthetic Fiber Mooring Ropes

3.1 Breaking Strength

The breaking strength is the most simple and efficient method to measure the mechanical properties of the fiber cable. The size of the breaking strength can be obtained through the tensile test of the cable with relative static tension. In terms of today's engineering practice, in the completion of the mooring design test analysis of ocean engineering, the cable manufacturer is required to provide the index requirements of the breaking strength of the supporting cable. At the same time, the calculation method of the breaking force of mooring cable is explained in the Marine mooring engineering specification, especially in the index description of averagebreakingstrength ABS (Average Breaking Strength) and minimumbreakingstrength MBS (Minimum Breaking Strength), in order to provide better guarantee and guidance for practical engineering.

3.2 Dynamic Stiffness

Under the continuous action of cyclic load, the ratio of the difference between the peak value and the valley value of the tension of the synthetic fiber cable and the corresponding elongation of the cable is the dynamic stiffness. At the same time, the minimum breaking stiffness is used to conduct dimensionless treatment. The cyclic loads with different tension amplitudes and cyclic loads with different average tension are used to test the dynamic stiffness of general cables.

3.3 Creep

Due to bad working environment of mooring rope, the rope due to the effect by the fixed-length load over a long period of time, can lead to structural strength significantly decreases, and even in constant load is less than the breaking strength of the rope, the rope is still there could be creep damage, at the same time, in the application of fiber cable in deep sea mooring project will emerge many unknown problems about cable performance, therefore, the cable in the external force loading time did not reach the load before actual creep life, you should replace the cable. In order to evaluate the service life and carrying capacity of the cable and ensure the applicability of the cable in permanent mooring engineering, it is necessary to conduct directional analysis on the possible factors that can affect the creep life of the cable, which is also the reason why the synthetic fiber cable is concerned by the majority of Marine engineering researchers.

4. Study on Preparation Technology of Synthetic Fiber Mooring Polyester Cable

Synthetic fiber cable including nylon and polyester, aramid fiber, high strength polyethylene cable, such as synthetic fiber cable has a strict hierarchy in manufacturing, in terms of polyester rope which includes fiber, yarn and complex yarn, rope and the rope hierarchy, formed from thousands of root of polyester yarn, then the combined beam yarn forming complex yarn, a large number of complex yarn into rope, rope shares more into line, the arrangement of the last child rope through specific formulation of cable structure formation [5]. In practical engineering applications, for full size

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synthetic fiber mooring polyester cable bracket cable, outer protective sleeve and end eye ring. Among them, the sub-cable technology includes polyester fiber, yarn making, ply, braiding, sand belt winding; The outer protective sleeve process includes polyester fiber, yarn making, ply, coating; The end eye ring process includes a insert ring and an anti-wear coating.

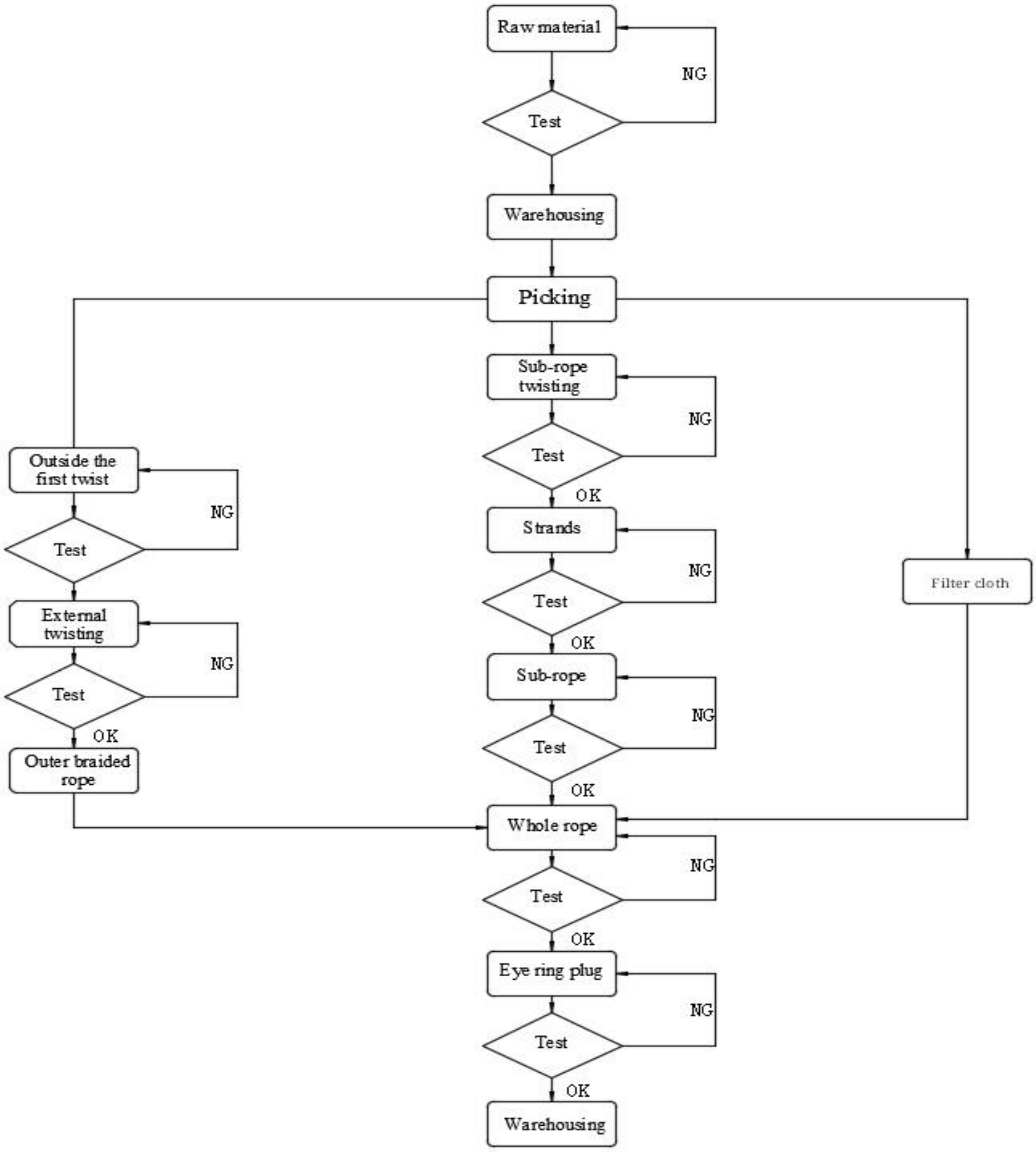

Fig. 1 Polyester cable preparation process flow chart

Yarn making process mainly studies the influence of the initial twist and the number on the strength and stretch properties of the yarn. According to the principle that the larger the twist is, the lower the strength is, the yarn should not have more twists, but it should not be treated with zero twist. The joint process mainly studies the influence of the number of strands, layers and strands on the uniformity and strength of the rope. According to the number of yarns, the design of the strands is carried out. The influence of braiding process parameters on the shape of the rope section and the length of the product without joint is studied in the core braiding process. Firstly, the number of load-bearing rope cores is determined to determine the diameter and length of single sub-rope. The cladding process mainly studies the optimization of the overall anti-wear performance of the rope by the cladding coat or the sheath. The special outer braiding technology is used to wrap all the rope cores and fix their arrangement position. The end eye ring treatment is mainly to study the end resin treatment technology of the rope to make the end eye ring of the rope more wear-resistant when it is connected

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with the metal parts to prevent the metal parts from cutting or wearing the polyester cable. Through the research of the whole polyester cable preparation technology, the polyester cable with long length, high strength to weight ratio and good fatigue resistance can be developed, so as to make the polyester cable that can meet the actual demand of the mooring of far-reaching floating structures.

The most commonly used polyester cable in Marine floating structure mooring consists of parallel and helically arranged fiber rope strands and braided fabric outer layer. The outer protective cover of the polyester cable can filter soil sand particles, and the protective cover should be tight enough to avoid light transmission [6]. The size, number and arrangement of fiber strands make polyester cables have different structure forms. Figure 2 is the polyester cable structure design schematic diagram, the outer layer is woven protective sleeve, wear-resistant, protect the force core rope; The secondary outer layer is a filter layer, which can prevent sand particles from entering the cable and causing wear.The inner layer is polyester core rope, bearing tension.

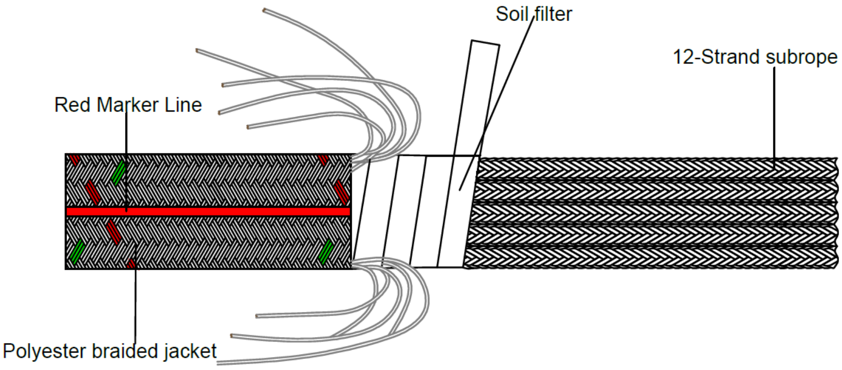

Fig. 2 Schematic diagram of polyester cable structure design

5. Technical Analysis of Polyester Fiber Cable Test

5.1 Measurement Test of Polyester Cable Length

Polyester cable belongs to nonlinear elongation. The material nonlinearity of polyester cable determines that the axial stiffness of polyester cable is nonlinear in practical engineering applications. The overall length of the mooring system should be controlled to meet the requirements of the length of the mooring system. The overall length of the mooring system should be controlled to meet the requirements of the length of the mooring system. On the one hand, pretension is the most sensitive mooring parameter, so it is necessary to study the relationship between pretension and the length of polyester cable; on the other hand, the stiffness of polyester cable varies with the size of loading force, duration, number of cycles and many other factors, so it is necessary to study the length variation of the cable under different stress conditions. Fig. 3 is the test diagram of elongation (stiffness) of polyester cable.

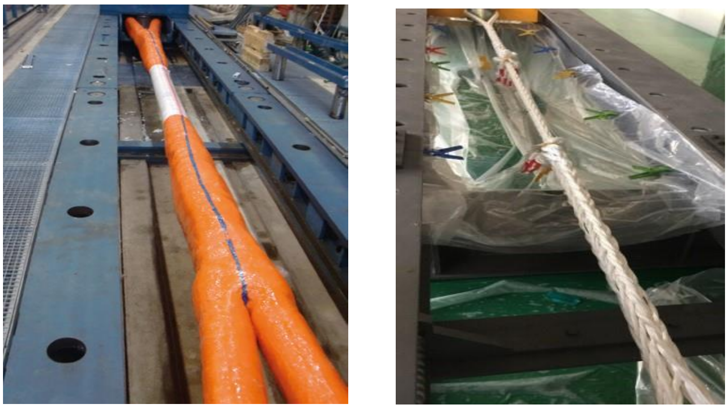

Fig. 3 Schematic diagram of polyester cable elongation (stiffness) test

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In the process of polyester cable production, the pretension is designed according to a certain strength ratio, and the design scheme of the length is marked under the pretension condition. The pretension is carried out by means of the tension device of the knitting machine at equal distance, and a comparison is made for each pretension. The elongation change (stiffness change) of polyester cable under different stress conditions for a long time was studied, such as the elongation change of 10%, 20%, 30%, 40%, 50%MBL, etc., so as to better grasp the elongation characteristics of polyester cable suitable for the development of deep sea conditions.

5.2 Performance analysis test of polyester cable

The main purpose of the performance analysis of polyester cable is to test the properties of polyester cable and evaluate its indexes objectively through the advanced testing technology. Therefore, based on the test results, the influence of various parameters in the preparation process of polyester cable on the performance of polyester cable was systematically analyzed, so as to provide guidance for improving the performance of polyester cable. The research on performance analysis of polyester cables includes two categories: cable strength test and friction test [7].

In the strength test, it is necessary to study and test the breaking strength of dry and wet rope and analyze the stress-strain curve of polyester cable in the test process. A complete strength test system usually includes the static/dynamic loading unit, the cable measuring system, the control system and the equipment base, etc. [8]. It should be noted that the polyester cable should be fully soaked before the wet test, so as to simulate the most real situation and make the test data more reliable.

Besides the strength test, the friction test between the design rope and the metal parts is another important part of the performance research of polyester cable. Fig. 4 is the site drawing of the mechanical performance test, and Fig. 5 is the design drawing of the wear-resistant performance test equipment, including the static loading unit, polyester cable specimen, friction metal parts, and the base of the test device.Friction tests between dry and wet ropes and different metal parts can be carried out to systematically analyze the wear-resisting properties of polyester cables and different interfaces. The conclusions based on the above two tests under different control variables can provide an important reference for the process optimization and performance optimization of polyester cable.

Fig. 4 Field diagram of mechanical property test

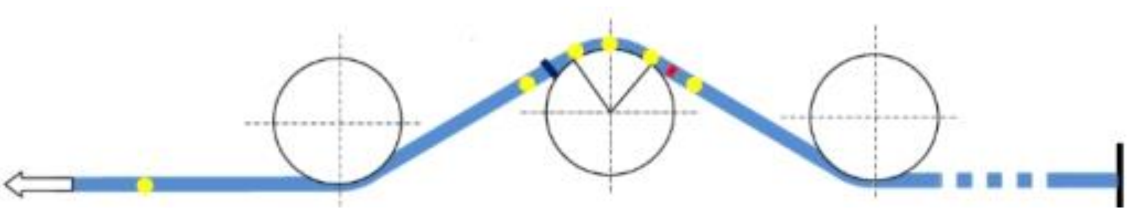

Fig. 5 Design of rope wear resistance test equipment

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6. Conclusion

In this paper, through researching the advantages and disadvantages of deep sea mooring polyester rope engineering applicability, clear that polyester rope has been widely applied to the deep sea mooring project, simply summarized the polyester rope complex mechanical properties, the polyester rope by fiber were reviewed to complex yarn to rope eventually into rope preparation technology, and in the process of rope cable length measurement experiment and performance analysis of the key points of technology and test equipment. It is conducive to comprehensively improving the design, analysis, safety and stability capabilities of deep-sea mooring engineering, further promoting the independent research and development capabilities of China's Marine engineering equipment, and realizing the strategic deployment of a maritime power.

References

[1] Y.Chi, X.L.Meng, F.H.Wang, The situation of deep-sea oil and gas exploration and development in southeast Asia and the prospect of foreign cooperation, 2008(11):50-56. (In Chinese)

[2] Y.P.Pan, A preliminary study on dynamic response of mooring cables for very large floating structures on the sea, 2004.

[3] Y.S.Lian, Complex mechanical properties of synthetic fiber mooring and its effect on dynamic response of taut mooring system. Tianjin university, 2016.

[4] Y.S.Lian, H.X.Liu, The review of synthetic fiber mooring in Marine mooring engineering, The Ocean Engineering, 2019, 37(01):145-157.

[5] L.M.Feng, Application of polyester cable in deep water mooring system, Ocean Engineering Equipment and Technology, 2016(5).

[6] B.Tong, Study on Mooring System Type and Dynamic Characteristics of Semi-submersible Platform. Shanghai Jiao Tong University, 2009.

[7] X.X.Zhang, X.T.Guo, L.Zhang, Influence of non-linear elastic cable on mooring system performance. Applied Science and Technology, 2014(01):84-88.

[8] M.Z.Lei, Experimental study on static characteristics and water damping characteristics of deep sea mooring. Tianjin university, 2009.