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Mooring Floating Offshore Oil Platforms with Polyester Cables

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A R T I C L E I N F O

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The offshore oil industry plays a crucial role in the exploration and production of energy resources, requiring cor innovation and technological advances to ensure safe and efficient operations. The mooring of floating platfor one of the critical areas in this context, directly influencing the stability and safety of structures in challenging m environments. This article sets out to explore the use of polyester ropes in mooring offshore platforms, highlig the benefits, challenges and technological advances associated with this application.

1. Introduction

The exploitation of oil fields in offshore environments involves the installation of floating platforms to extract subsea resources. The mooring of these platforms is crucial to ensure stability, safety and efficient operations, especially considering the adverse conditions of marine environments. Polyester ropes have emerged as a promising alternative for this purpose, presenting unique characteristics that make them attractive candidates for offshore mooring (Leite et al. 2010). Polyester is a synthetic fiber known for its abrasion resistance, low elongation and high chemical resistance. These properties make polyester an attractive material for marine applications, where environmental conditions can be harsh (Leite et al. 2010), (Amorim, 2010), (Araújo, 2001).

The aim of this paper is therefore to explore the use of polyester cables in mooring offshore platforms, highlighting the benefits, challenges and technological advances associated with this application. This stems from the fact that offshore structures are subjected to more aggressive loads than on land and that these exceed the magnitude of the latter, revealing a great field of development for engineering such as civil engineering, for example, motivating a greater number of engineers to specialize in this area.

To validate the feasibility and effectiveness of mooring floating offshore platforms with polyester cables, case studies and examples of practical applications were presented. These analyses include performance in extreme conditions, comparisons with traditional materials and the economic impact of adopting this technology.

Bastos et al. 2020 report that with the discovery of marine oil fields in increasingly deep waters, and more recently with the emergence of new localized reserves known as "pre-salt", the use of exploration platforms supported by rigid structures fixed to the bottom has become impractical. New solutions have been developed to enable deep-sea exploration at depths greater than 400 meters and now reaching 2000 meters, which allow for lighter and more rigid lines (Bastos et al. 2010; Medeiros 2009). Oil exploration in ultra-deep waters can be considered recent, dating back only about 20 years and is constantly evolving. The offshore structures used in oil exploration can be classified as fixed or floating, as shown in Figure 1.

The positioning of floating units during oil exploration operations is guaranteed by anchor lines, which are flexible structures generally made up of steel cables or synthetic cables (usually polyester). In floating structures, polyester cables are used according to the conventional system in Figure.

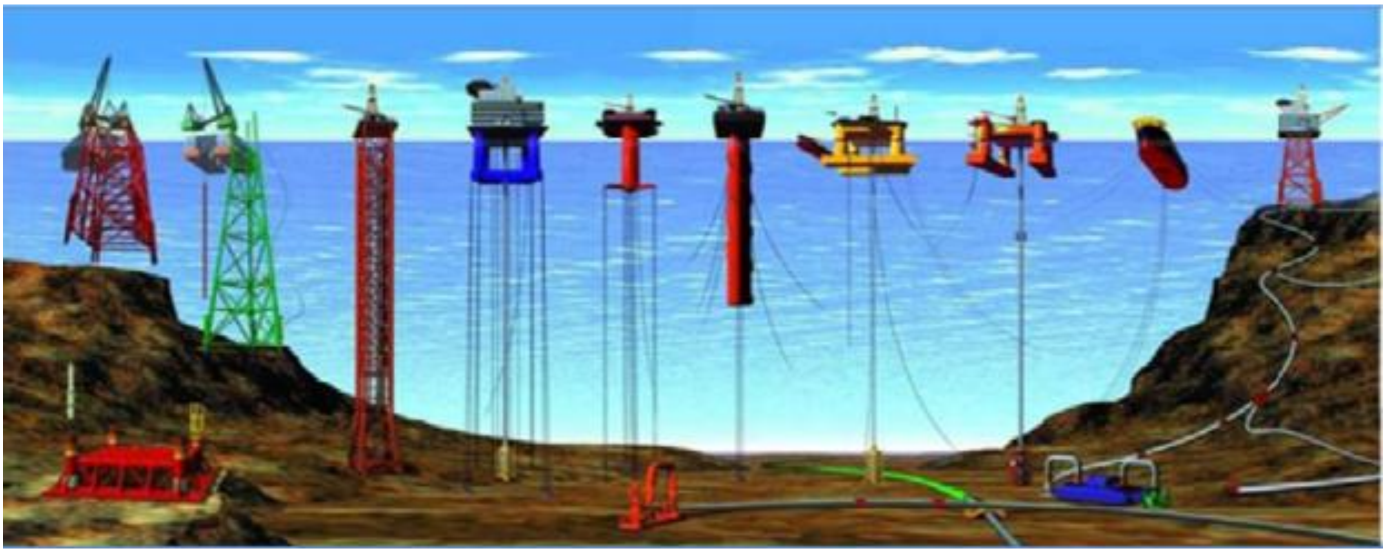

Figure 3: Overview of the main types of platforms (Medeiros, 2009)

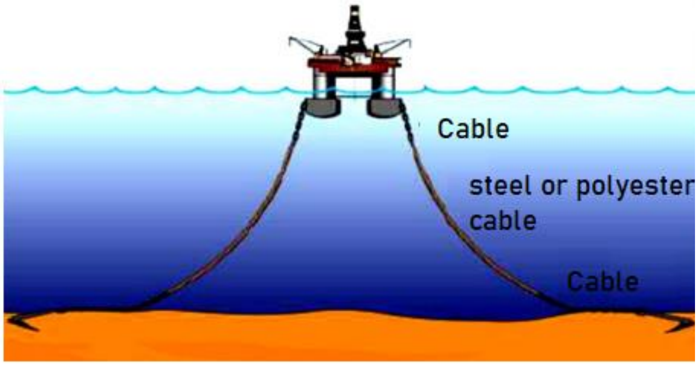

Figure 2: Conventional mooring system (Medeiros, 2009)

Both the anchoring of floating units and the transport of oil and information between the seabed and the floating unit are carried out using slender structures commonly known as lines. The set of equipment used to explore for and extract oil at sea is known as "Offshore Systems" and basically comprises five groups: the hull, the lines, the subsea equipment, the wells and the moorings (anchors and moorings).

Offshore platforms are divided into fixed and floating. Fixed platforms are installed according to their structure (geometry and weight), while floating platforms differ in the way they are moored under the hull (Araújo et al. 2001; Bastos et al. 2010; Medeiros 2009). The most commonly used fibers are sisal (more in small ships and not used for many years), polyethylene, polyamide (which has the commercial name of nylon), polyester (PET, which is widely used for anchoring platforms and is expected to have a useful life of 25 years), polypropylene, polyaramid (whose fiber has a high modulus of elasticity and has trade names such as Kevlar, twaron and technora) and HMPE (High Modulus Polyethylene, which has trade names such as dyneema and spectra) (Araújo et al. 2001; Medeiros 2009).

Driven by the need to reduce the mooring radius due to the prospect opened up by the promising results of the research work done with polyester, laboratory tests carried out by Del Vecchio (Araújo et al. 2001) in 1992 and a study carried out by the University of São Paulo in 1993, led BR to decide to use polyester ropes on its production platforms. With the results of all this research work, carried out in both laboratories and in the field, PETROBRAS began experimenting with this type of rope, installing some segments of polyester rope at the beginning of 1995 on the lines subject to the highest loads on the mooring systems of the BR-P-9 and P-22 platforms (Araújo et al. 2001).

2. Methodology

This work involves documentary research and working with reality in the field of operations. The research methodology for this work was based on books, electronic and internet documentation, magazine and newspaper articles and bibliography belonging to different companies. It was also based on seminars, lectures and training given by the author at oil companies. Technical visits were made to cable manufacturers and oil companies, as well as other related companies in Angola, Brazil and Portugal. Various works on the subject were reviewed (Van-Deste 2012; Amorim 2010; Leite et al. 2010, etc.), as well as the related bibliography and fundamental data analyzed, with clarifications on aspects that were not fully defined.

3. Results and Discussion

There are several software programmers to support the oil industry, such as ISYMOST, NOS, RIFLEX, OUTMOD/PLOUMOD and VIVANA, among others. To show the complexity of the variables that make up these programmers, five Excel spreadsheets were created, taking into account the following parameters:

a) The submerged weight of the polyester rope (and the others used in this study) is a constant and the 251 mm diameter Langhorst rope was used;
b) Two other types of rope were used for comparison purposes, chain with steel links (tethers, chain) and the Trefileurope steel drawn type;
c) The sea depth is also a constant and depends on the real case, so it is possible to insert the desired depth, it is the vertical positioning coordinate (ζ);
d) The loads have been predetermined as well as the length of the cables;
e) The main formulae are shown in Table 1.
f) With the data obtained and entered into the table, which was duly formulated, we obtained the components of the forces acting on the cables and the horizontal coordinate (ξ) of the profile developed by the cables, according to their component material. Finally;
g) We obtained the horizontal displacement of the cables as a function of the acting loads.

Table 1: The main formulae used in the work.

Vertical positioning coordinate (m)	Depth ζ
Vertical component of the tension force in the cable (N)	$Z = w \times s$
Horizontal component of the tension force in the cable (N)	$F = (Z^2 + X^2)^{½}$ & $X = F - w*\zeta \Rightarrow X = (Z^2 + X^2)^{½} - w*\zeta$
Tension force on the cable (N)	$F = (Z^2 + X^2)^{½}$
Horizontal positioning coordinate (m)	$\xi = (X / w) * \text{senh}^{-1} (s*w / X)$
Angle of action of tension forces (´)	$\theta = \tan^{-1} * (Z / X)$

According to the vessel and the loads acting on it, we can calculate the catenary to be produced at rest with the system remaining static, shows the final graphic (Figure 3).

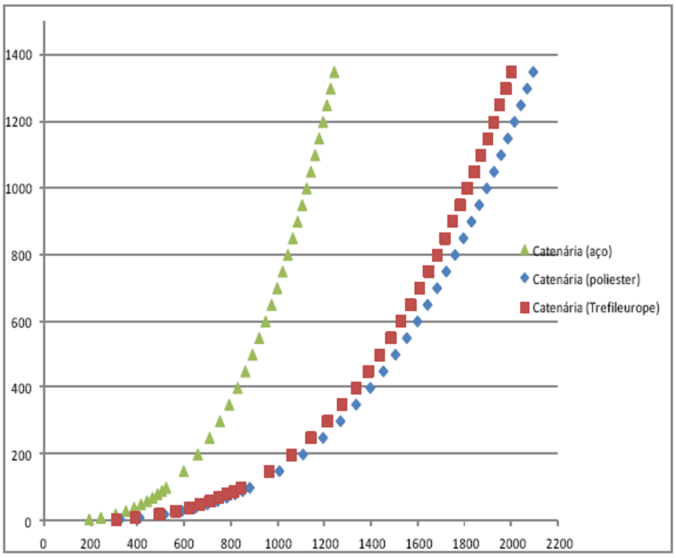

Figure 3: Catenaries developed by the different cables.

High-strength polyester yarn is based on polyethylene terephthalate (PET), a product produced on a large scale worldwide and used in everyday life, such as in the manufacture of clothes and bottles. Synthetic fibers, because of their polymer origin, show visco-elastic behavior depending on the time they are used and ambient temperatures, thus possessing both elastic and viscous behavior. The most widely used synthetic fiber for mooring ropes is polyester, which enables the production of strong, lightweight mooring ropes with a long service life at very competitive costs compared to other synthetic fibers.

3.1. Challenges and Technical Considerations

Despite the advantages, the application of polyester ropes in offshore mooring also faces specific challenges. Resistance to UV degradation, interaction with salt water and the dynamic loads imposed by waves and currents are critical aspects to consider.

There is a great deal of complexity in studying the winds and gusts that act on offshore structures. This complexity is due to the incidence of these loads, which are not directed in a single trajectory over the platform; they act at different angles. In the case of wind, a wind speed is generally applied at a certain height at different angles. The wind load has a major impact on the various elements of the platform, including the structure itself, the various pieces of equipment, the installations, etc. It should be noted that for conventional steel structures wind forces normally contribute less than 10 per cent of the total overall load, but in deeper waters, where compatible structures are found, waves contribute a much higher percentage. This is especially the case where the wind frequency is close to the platform's natural vibration frequency in order to create resonance. This article addresses strategies to mitigate these challenges, including coating techniques, advanced monitoring and maintenance practices.

4. Conclusion

With the result presented in this paper, we could be concluded that:

a) With the discovery of oil fields in ever deeper waters, it has become necessary to invest in the development of anchoring systems that enable lighter and more rigid lines;
b) The mooring of floating offshore platforms plays a crucial role in the oil industry, and the adoption of polyester ropes represents an innovative approach to meeting the challenges associated with this application;
c) This article highlights the unique properties of polyester, addresses technical challenges and presents case studies, providing a comprehensive overview of the current and future state of offshore mooring with polyester ropes;
d) The development of stiffer mooring lines has been prompted to guarantee the ride limits of floating units;
e) In this work, an attempt was made not only to analyses wire performance, but above all to comparatively check the behavior of ropes made with polyester in relation to the traditional steel model:
f) The work made it possible to give an overview of the engineering aspects of offshore platforms and to obtain data so that it was possible to observe results relating to the main characteristics of an anchor cable such as accommodation, quasi-static stiffness and dynamic stiffness, fatigue resistance, constructive efficiency and toughness.

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