

# THE PAST, THE PRESENT AND THE FUTURE OF POLICAB: THE CHALLENGE OF SYNTHETIC MOORING ROPES ANCHORAGES AT PRE-SALT PETROLEUM BASIN, IN BRAZIL

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## 1. Introduction

The technology of platform anchorage systems has been developing quickly nowadays. Due to the oil extraction in deep waters, the traditional mooring types, such as anchor cable/wire rope/anchor cable in catenary shape, were replaced by a “Taut-Leg” geometry. This type, characterized by an anchor cable/synthetic cable/anchor cable, operates in a straight mode, reducing weight and modifying the mooring operation. Therefore, the synthetic ropes for offshore platform anchorage are long and robust, with large number of sub-ropes arranged in parallel mode in order to increase mechanical strength. Petrobras has used this new form of technology with polyester cables since the beginning of the last decade; despite this fact, there is a lack of knowledge of the behavior related to structural integrity (residual life).

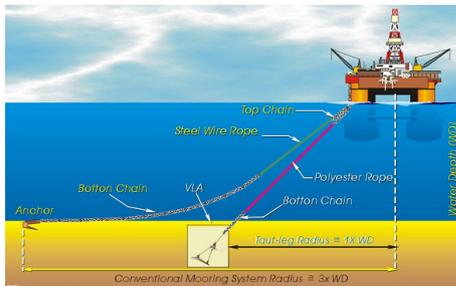


Fig. 1: Offshore anchorage: catenary x taut-leg.

In 2001, with the support of PETROBRAS, the laboratory was created and started studying and researching about synthetic ropes for offshore mooring application. Our study started with yarns (polyester multifilaments) and now we begin to learn about ropes architecture as well as rope and sub rope tests.

POLICAB is a laboratory focused on the study of stress, strain and strength regarding synthetic ropes. POLICAB is part of the Engineering School at Federal University of Rio Grande.

## 2. The structure of POLICAB

- Research room with computational facilities (internet, library and individual student desks) for mechanical engineering undergraduate students.
- Photomechanical lab with Banch and reflection polariscopes, kits of tools, devices and facilities.
- Tests and Assembly Saloon. Reaction structure for cable and rope strenght tests.
- Climatized room for mechanical tests with:
  - Servo-hydraulic machine (Instron), 100kN (push, pull and fatigue);
  - Electro-mechanic test machine, 20kN (traction, compression and creep);
  - Facilities and accessories for handling and testing synthetic ropes: hydraulic and pneumatic Clamps, special clamps for ropes and cables.
- Meeting and educational (teaching) room, with projection facilities (data show, computer) and specific library.
- Computational room for researchers, graduated and undergraduate students, where they develop researches related to the laboratory.

## 3. The Research at POLICAB

**Materials Research:** Development of new products and their mechanical behaviors. HMPE (High Modulus Polyethylene); Polyester; Other synthetic materials (polyblend, polysteel, ...).

**Rope Architecture:** We intend to know the behavior of devices and some working situations:

- Rope terminals
- Fatigue (scale ropes)
- Creep
- Rope storage
- Wearing (COATS)

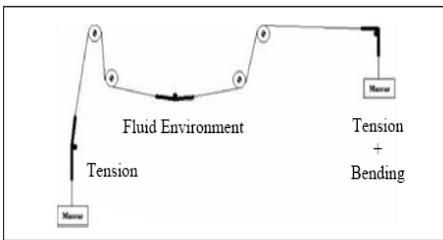
**Mechanical Modelling:**

- Theoretical:
  - Damage and structural integrity
  - Creep
  - Tenacity

- Experimental:
  - Strength: Scale factors
  - Creep
  - Residual life
  - Yarn on yarn abrasion.

**3.1 Rope jackets abrasion.**

The endurance of the rope jacket of a mooring rope is very significant to verify the real life of the rope. If the jacket were broken or discontinued by wearing, we consider the rope collapsed. Figure 2 shows a sketch of the wearing and abrasion device.

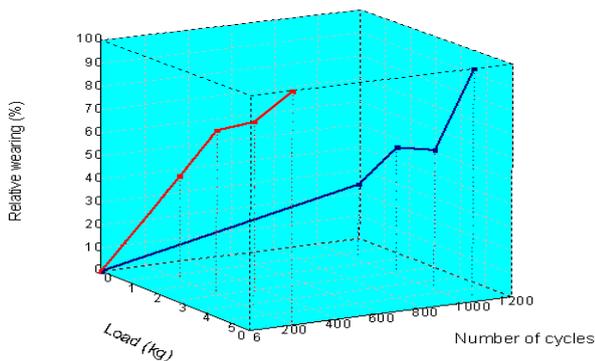


**Fig. 2:** Abrasion under different kinds of tension situations



**Fig. 3:** Abrasion test machine

The graphic 1 shows the behavior of a synthetic rope jacket (HMPE) when submitted for two kinds of test: tension plus bending and tension in tap water.



**Graphic 1:** HMPE: tension + bend and tension submerged in tap water

**3.2 Mechanism of yarn-on-yarn abrasion**

POLICAB tests the abrasion behavior of the multi-filaments, according to the Cordage Institute

and ASTM rules. In figure 4 we show a sketch and in figure 5 we can see the prototype.

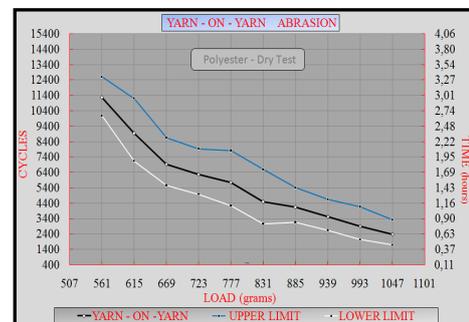


**Fig. 4:** Yarn-on-yarn device.



**Fig. 5:** Yarn-on-yarn prototype.

The graphic 2 shows us the behavior of polyester multifilament when submitted to the upper abrasion test.



**Graphic 2:** Abrasion test result

**3.3 Creep Research – HMPE.**

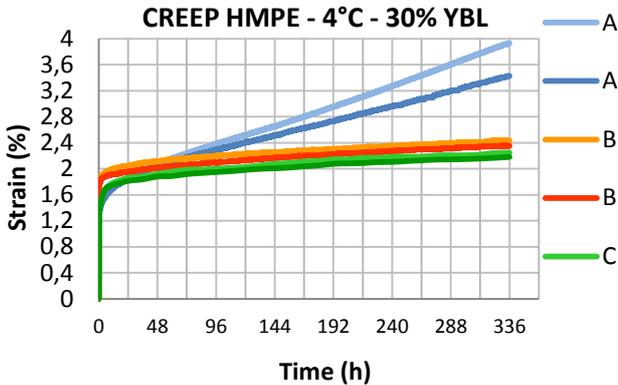
The focus of the research: anchoring the offshore structures in ultra high deep waters. The production of know-how regarding the mechanical behavior – creep – for synthetic materials, as Polyester and HMPE (High Modulus PolyEthylene). This permits the use of those materials for the production of synthetic mooring ropes. Today, we develop theoretical and experimental studies regarding creep.

**Theoretical Research:** Modeling the structural integrity for materials with visco-elastic behavior, using CDM (Continuous Mechanic Damage) with the LMTA – Laboratório de Mecânica Teórica e Aplicada, UFF – Universidade Federal Fluminense, Rio de Janeiro – Brazil.

**Experimental Research:** Mechanical behavior characterization of the yarns (stress, strain, tenacity and linear weight); Dead weight test system to determine yarn creep curves. Low tension tests, between 15% and 30% of YBL (Yarn Break Load) to determine creep curves; High level tension (or short time) creep tests, using a mechanical test machine. High tensions between 50% and 90% of YBL. Creep comparative behavior of HMPE multifilament's when submitted to changing conditions of temperature and load. Low temperature research.

- Adapted refrigerator - In this equipment the specimens can be suspended and tensioned by applying a load on the bottom causing a creep.

The tests were performed at low and ambient temperatures: 4°C, 20°C. Graph 3 shows the behavior of different kinds of HMPE at low temperature (4°C) and 30% of Yarn Break Load.



**Graphic 3:** Creep behavior, Low temperature

**4. What do we start to do?**

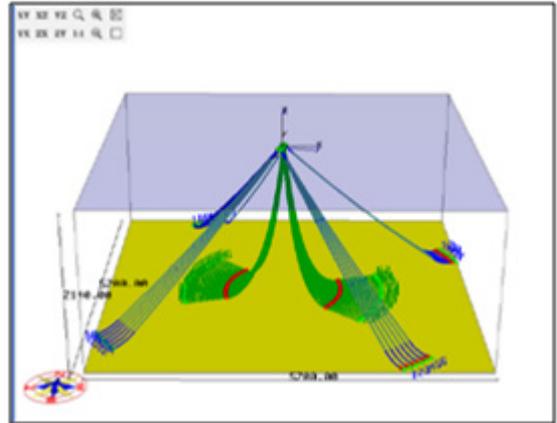
New possibilities and new horizons were opened through the pre-salt basin discovered in ultra deep water at the Santos basin in Brazil.

The location of the pre-salt Santos basin in ultra deep water we can see in figure 5.



**Fig. 6:** The pre-salt Santos basin location.

A typical array of offshore system in ultra deep water we can see in figure 6.



**Fig. 7:** The array of offshore system in ultra deep water.

**4.1 New scenario and new challenges**

According Rossi et alii [1] this is a new scenario at pre-salt petroleum basin in Brazil:

- Spread moored FPSO – WD 2000 to 2500m
- Small allowable offset and footprint radius
- Medium to harsh environment (Santos Basin)
- Need to avoid higher pretension level
- Simplify logistics whenever possible.

**4.2 Offshore systems anchorage alternatives**

Del Vecchio [2] shows the future possibilities regarding new materials and others synthetic ropes architectures:

**All polyester ropes:** for this alternative, Petrobras has many data obtained during the last 10 years (tenacity, MBL, creep and fatigue), but more is necessary to do regarding the durability (we don't know so much about the effect of time and other natural effects and environment);

**Stiffer fibers ropes:** considering the great deep water we need to control and to reduce the rope strain and the spread of the platform.

**We need to know the performance of those new fibers (HMPE, Kevlar, PEN, aramida...).**

**4.3 A new research project was started at POLICAB.**

**TECHNOLOGY DEVELOPMENT TO VALUATE THE SYNTHETIC MOORING ROPES, STRUCTURAL INTEGRITY, TO BE USED INTO AN OFFSHORE ANCHORAGE.**

Through this project we intend to develop a theoretical and experimental methodology to guarantee the structural integrity of synthetic mooring ropes which are used in Stationary Production Units. The goal will be to obtain graphics and curves to evaluate the residual life and take decisions regarding ropes in work.

Beside the redundant system (the rope was made with parallel sub-ropes), the rope is a fragile

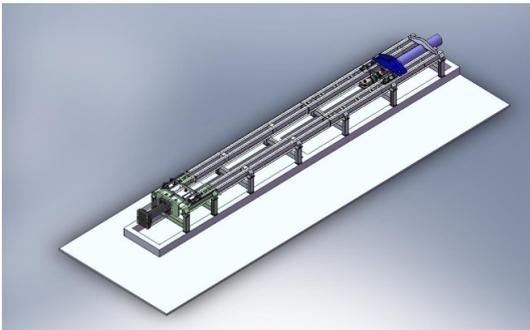
link in the structural integrity chain due its great responsibility to avoid global accidents.

The stress-life relation in usual work conditions is even unknown. This worry joined with the necessity to know better the behavior of those ropes along the work time.

Facing the new research possibilities we made a saloon with a tension and fatigue machine for synthetic mooring ropes, with hydraulic actuators MTS ( 150 tons in tension low cycle fatigue and 1,000 mm piston displacement) and HUNGER (300 tons in tension and 2,500 mm piston displacement). Machine operator and pressure generator system rooms (*SilentFlo* – MTS, works at 440 V, 3 pumps , 3,000 psi).

This gave us the possibility for new tests in real scale: rupture of synthetic mooring ropes and sub ropes, even 300 tons; Fatigue tests in tension to obtain curves of life for anchorage ropes with precise tension and displacement control; Stiffness after strain; Quasi-static stiffness; Dynamic stiffness; ISO 18692 [3] and Petrobras.

Figure 7 shows the final sketch of the machine: the 20 meters steel structure and the two actuators mounted.



**Fig. 8:** The test machine design.

In figures 8 and 9 we show the new test machine working: 85 tons polyester sub rope, 12 strands in tension fatigue test.



**Fig. 9:** Test machine.



**Fig. 10:** The test machine with polyester specimen in fatigue test.

## 5. Conclusion

With this University - Petrobras joint project a research sector was created with large possibilities of development. POLICAB started as a research project and grow up naturally as a research and projects development laboratory, generating and transferring technology for the industries and, the most important, generating knowhow for our students. Today a significant number of students obtain scientific and technological knowledge related to ropes, anchorages, synthetic fibers and experimental analysis. The technological production, create and add knowledge. I believe: this is the most important GOAL at POLICAB!

**Acknowledgements:** POLICAB and related projects are supported by PETROBRAS.

## References

- [1] Ronaldo R. Rossi et Alii, Challenges and Alternatives for Ultra Deepwater Moorings in Santos Basin, 8th International Rope Technology Workshop, MTS – Marine Technology Society, Houston, 2010.
- [2] Cesar Del Vecchio, Station Keeping in Deep Water – A Perspective from Petrobras` Activities, 8th International Rope Technology Workshop, MTS – Marine Technology Society, Houston, 2010.
- [3] ISO/18692 - Fibre ropes for offshore station keeping – Polyester, 2007