DESIGN OF AN APPARATUS TO PERFORM HYDROLYSIS TESTS IN POLYMERIC YARNS

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Summary: *Throughout the extent of its life, a mooring line used in an offshore oil platform working in deep and ultra-deepwater is subjected to the environmental conditions present at seabed. Along with low water temperature, high salinity, and acidity, the materials capacity of absorbing water plays an important role when it comes to its mechanical behavior in service conditions.*

Previous studies have shown that the longer a synthetic rope is in contact with seawater, both its force-elongation behavior and its ultimate strength are affected. The phenomenon of the materials water absorption is known as Hydrolysis, and typically this type of experiment can take several months to a few years until observable results can be noticed. One way to speed-up the hydrolysis process is to subject the samples to high temperature water, and then stipulate a correlation factor between the results of the experiment time at high temperature and the real time at low temperature. This way one can have an accurate prediction of how long it will take until a material loses a certain percentage of its ultimate strength at a low temperature water, having the samples tested on a shorter period of time at higher temperature water.

The aim of this paper is to propose the development of an apparatus specially designed to perform hydrolysis tests on synthetic fiber ropes and yarns. Variables such as water temperature, along with its composition, acidity and salinity will be monitored and controlled, so that different combinations of these factors and their influence on the mechanical behavior of those materials can be studied.

Keywords: *Synthetic mooring ropes, hydrolysis, ultra-deepwater*

1 Introduction

POLICAB Stress Analysis Laboratory is a university-company partnership created in 2001 aiming to assist the Brazilian petroleum industry - Petrobras - in the research and development of mooring systems synthetic ropes used in platforms for prospection and exploration in deep and ultra-deepwater. Recently, a new branch of studies is being explored regarding environmental effects in mooring lines, such water absorption capacity (hydrolysis) and ultraviolet (UV) aging effects, so new facilities and equipment must be developed.

In a general way, hydrolysis consists in a chemical process throughout which water reacts with the material, promoting a scission in its chemical bonds. In the specific case of polymers, the scission takes place in ester group, thus reducing molecular weight as well as the material's strength. It shall not, however, be confused with the physical process of humidity absorption, since the latter is a phenomenon that can be easily reverted by simply drying the material.

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Hydrolysis effects are somehow well documented in the literature for long known materials for rope making, such as Polyester [1, 2, 3, 4] and Aramid [2, 5], however due to industrial secrecy, sometimes it can be very difficult to find experimental data concerning hydrolysis effects in mooring ropes, specially newly developed materials. For that purpose, in order to do research in the field of water absorption in materials applied to mooring ropes, it is important the development of a specific equipment to carry out the necessary experiments.

The aim of this paper is to propose the design of an apparatus to perform hydrolysis tests in polymeric yarns used in mooring lines. Together with the apparatus itself, the experimental procedure will be presented so that it would be possible to evaluate the strength loss of a given material after its submersion in water for a determined period of time. The water temperature is a factor that plays a great influence by increasing the water absorption capacity of any material, so experiments can be performed in water at high temperatures to speed-up hydrolysis, and the apparatus must present such capability.

2 The apparatus

Due to the simplicity of the experiments, the apparatus proposed is consisted basically in a large water container inside which the samples should be placed for long periods of time, that can range from a couple of days up to years. There shall be enough room to place a reasonable number of samples and it must be equipped with an auxiliary water heating system. To prevent heat exchange with the ambient, it is required that the container is somehow isolated with a proper isolation material. The procedure of taking out the samples before performing the tension tests must happen so that it is not needed to empty the container, since there will be other samples that need to remain submerged in water for longer periods.

Based on those premises, Figure 1 shows the basic construction of the prototype, and its internal and auxiliary accessories. The outer structure is consisted in a rectangular-shaped box (a) made out of fiber glass or steel, and the internal tank (b), which will be in contact with the water, shall be made out of a corrosion-resistant material, such as stainless steel. Between the two, a layer of expanded polyurethane (c) will be placed in order to prevent heat exchange between the water and the external environment.

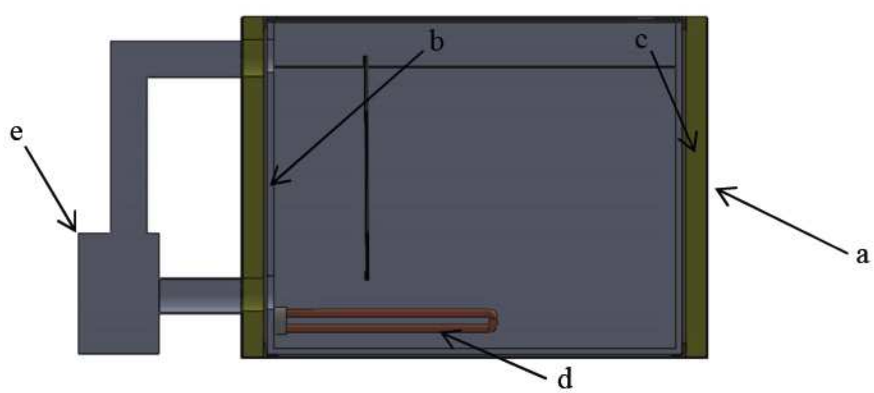

Figure 1: schematic design of the prototype.

As pointed out, one important feature is that the equipment must have the capability of working with hot water, so a heating system shall be provided. For that purpose, two independent systems will be installed: the first one (System 1, Fig. 1[d]) must be responsible for heating the water from its room temperature (which could range from $5\,^{\circ}\mathrm{C}$ in the winter up to $25\,^{\circ}\mathrm{C}$ in the summer) up to the temperature set for the experiment (from $40\,^{\circ}\mathrm{C}$ to $90\,^{\circ}\mathrm{C}$), and the second (System 2, Fig. 1[e]) will be responsible for maintaining the water in this latter condition. Both will consist in simple electric systems based on electrical resistors, and as soon as the water is leveled up to the desired temperature, System 1 will shut down and System 2 starts to operate.

3 Experimental design

The main goal of this experiment is to establish the relationship between time submerged of a determined yarn (and consequently a mooring rope) and its strength loss due to the process of hydrolysis during this time. However, this is a process known to be of a very long-term, so it is virtually impossible to perform an experiment in real-time. Thus, high temperature water is used in order to speed-up the hydrolysis process, and a mathematical correlation is applied to predict the real necessary time for the yarn to lose some determined percentage of its strength when submerged at waters at $4\,^{\circ}\mathrm{C}$ (water temperature at seabed).

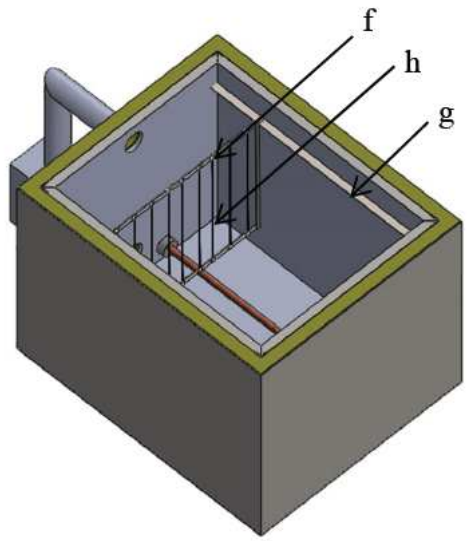

Figure 2: internal view of the apparatus.

The procedure to be followed in order to assess the loss of strength in yarns due to the process of hydrolysis must be as follows:

1. Fill the tank with water at room temperature and turn on System 1 until the water reaches the designed temperature;
2. Turn off System1 and place the set of samples (Fig.2 - [f]) on the guide structure (g). Each set consists in 10 yarn samples (h);
3. Turn on System 2;
4. After the period of time set according to the purpose of the experiment, take one set of samples out of the tank and wash them with distilled water;
5. With the samples still wet, pre-load them with a $1\,\mathrm{N}$ weight and apply to the untwisted yarn a total of 60 torsions per meter around its main axis;
6. Perform tension test in each sample of the set (still wet) and, after the 10 tests are over, compute the mean yarn break load (YBL);
7. Repeat steps 4, 5 and 6 until a minimum of experimental data is reached and plot the YBL x Time graph. In this case, time refers to the total amount of time the set of samples remained submerged in water.

With these results in hand, and knowing a priori the YBL of the virgin, not submerged yarn, it is possible to plot the graph of the Residual Tension Strength versus Time Submerged at Test Temperature for the tested yarns, which is expected to look like a downward sloping straight line. Then, (1) might be applied to predict the total amount of time that a mooring line needs to be submerged at waters at seabed temperature ($4\,^{\circ}\mathrm{C}$) until it loses a certain percentage of its break load.

$$\ln(t_1) - \ln(t_2) = \frac{E_A \left(\dfrac{1}{T_1} - \dfrac{1}{T_2} \right)}{R} \tag{1}$$

where t_1 represents the time observed in the experiment until the material reaches a determined strength loss, t_2 is the real time after which one wants to compute the strength loss, T_1 is the temperature at which the material was tested, T_2 is the operating temperature of the mooring line (usually $4\,^{\circ}\mathrm{C}$), E_A is the activation energy of the system, and is the ideal gas constant and equal to $8.31\ \mathrm{J/Kmol}$.

Solving (1) for t_2, it is possible to have an accurate prediction of the necessary time until a mooring line in service reaches a determined percentage (typically 80%) of its original strength.

4 Conclusion

This project will allow Policab to increase its capacity of performing different experiments applied to mooring lines and synthetic materials, not only helping the national petroleum industry but also the academy, since it will be the first equipment devoted to the study of hydrolysis effects in synthetic mooring lines in Brazil.

5 Acknowledgment

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