Some experimental results regarding creep behavior on synthetic materials used to produce offshore morring ropes

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Abstract

With the development of oil fields in ultra deep waters, the replacement of steel ropes used to mooring floating structures by other with lesser linear weight, become a necessity. In shallow waters the drilling and production flotation units are anchored by conventional systems composed of steel chains and wire ropes in catenary geometric configurations. For deep and ultra deep waters the "taut-leg" system based on tightened synthetic ropes with lesser linear weight, was developed. Nowadays these ropes are made of polyester (PET) and they provide the necessary compliance to the taut-leg system by means of the natural mechanical properties of the fiber. Due to the appearance of other synthetic fibers in the market, which intend to improve the performance of the proper mooring system, it became necessary to analyze and verify the mechanical properties of these fibers. Research has been doing with HMPE - High Modulus Polyethylene, material with excellent mechanical behavior in tension and low density but with a inconvenient, to substitute polyester: significant creep at normal conditions of temperature. In this work, was analyzed the creep behavior for HMPE multifilament's, in low temperature. The specimens were submitted to constant load with temperature and displacement control. The obtained creep results were evaluated and compared to results obtained from multifilament specimens submitted to creep at environmental temperature.

Keywords: creep, synthetic ropes, polyethylene, low temperature.

1 Introduction

Nowadays in Brazil, the oil exploration is made each more in ultra deep waters, and, this situation had created a necessity of news mooring systems and materials for offshore platforms. As a result of these situation, the mooring conventional system (chain and steel ropes in a Catenary configuration) will be replaced by other mooring configurations with excellent flexibility and easy handling behavior like as the mooring system called "Taut-leg", where the steel ropes are replaced by synthetic ropes

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that work with elastic strains. For this new mooring design, the exposition time with low variation of amplitude solicitation, shows the creep as a possible fail mode.

The polyester [1, 2], ordinary material used, is very efficient with excellent performance in stress, creep and fatigue work conditions [3, 4], but presents yet, the following inconveniences: density bigger than water and large diameters size. Research has been doing with HMPE - High Modulus Polyethylene, material with excellent mechanical behavior in tension and low density, to substitute polyester. Moreover, it was verified that at the environmental temperature, [5, 6], HMPE show large strain even with low constant tension load intensity. Some interesting works regarding HMPE creep behavior at environment temperature was write [7, 8] in recent times. However, considering what those ropes work submerged in approximately 200 meter deep waters and the water temperature in this environment is around 4º C, studies at normal temperature conditions become inappropriate. At the present time there are not many studies that check the behavior of HMPE fibers creep (mono or multifilament yarn) in low temperature. So, the current study about creep behavior in low temperature, becomes important. In the present study we consider two kind of HMPE: Dyneema SK 75 and Dyneema SK 78, manufactured by the DSM–Holland. The obtained HMPE multifilaments creep results in low temperature were evaluated and compared to results obtained from multifilament specimens submitted to creep at environmental (20º +/- 2ºC) temperature.

2 Polyester versus HMPE creep behavior

Just to compare the mechanical creep behavior between polyester and HMPE fibers, it has been obtained the tension rupture load and the linear weight of the multifilaments and their characterization in according to "OCIMF, 2000". It has been performed long term creep of the multifilaments using dead weights tests with constant load values of 30% of the YBL (Yarn Break Load), [6]. Table 1 show the average of the mechanical characteristics – 10 tests sample for each material.

The Table 1 shows the advantages of HMPE fibers regarding, tenacity and weight when compared with polyester fibers. The questions remain the creep behavior of both fibers. Figure 1 show the dead weights creep test device used to determine the creep behavior and figures 2 to 4 shows the creep behavior of HMPE 75, 78 and polyester when submitted at 30% of YBL, in tension.

Table 1: Tension tests.

Sample	HMPE SK78	HMPE SK75	POLYESTER
YBL (N)	540.70	532.25	171.10
Strain (%)	3.15	3.24	12.67
Linear weight (dtex)	1766	1760	2200
Tenacity (cN/dtex)	30.62	30.24	7.78

Figure 1: Dead weight creep test device

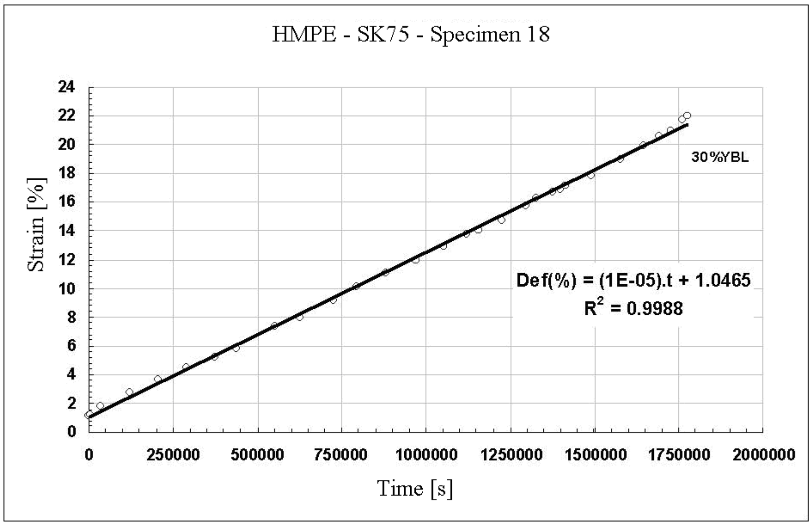

Figure 2: Creep behavior HMPE SK 75, 30%YBL.

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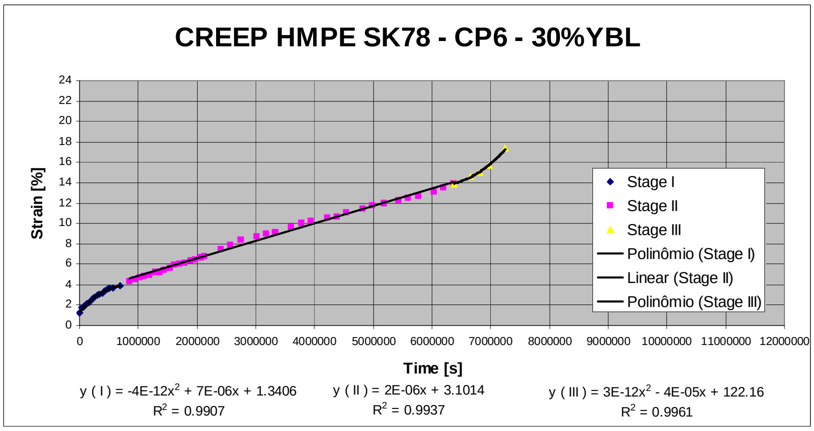

Figure 3: Creep behavior HMPE SK 78, 30%YBL.

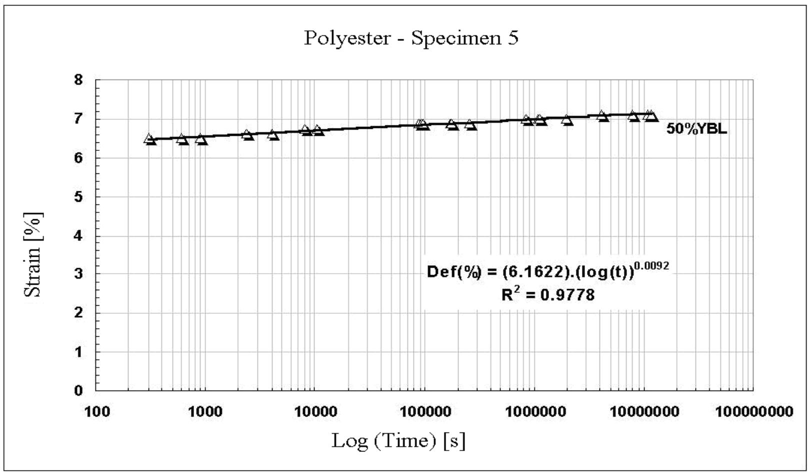

Figure 4: Creep behavior, Polyester, 30%YBL.

It is evident the good creep performance of polyester fibbers when compared with the HMPE fibbers. So, the use of HMPE was limited because the multifilaments showed high creep behavior in environment temperature.

But if we consider what the mooring rope work submerged, because the “taut-leg” anchoring configuration consist of a chain in superficial water plus synthetic rope submerged plus chain plus anchor in the bottom of the sea, maybe the behaviour will be change. The use of synthetic mooring ropes submerged in deep water at temperature near 4 °C, perhaps will be introduce new possibilities regarding the HMPE creep behavior. This fact motivate the study of HMPE creep evolution at low temperature.

3 HMPE creep behavior in low temperature

3.1 Tensile tests

The new question introduced, is how creep behaviour change, if change, when the rope work at deep water temperature near 4º C. First it is necessary verify if the static mechanical behavior, like as break load and related strain, changes in low temperature. Two samples of 10 specimens of Dyneema SK 78 each was tested in tension: one at temperature of 4º +/- 1ºC and the other at temperature of 20º +/- 2ºC, both with relative humidity control (between 50 to 55%). The specimens and the tests were made in according to ASTM [9] with specimen length of 500 +/- 1 mm and speed test of 100 mm/min. The figures 5 and 6 shows the tests performed in a tensile test machine EMIC 2000L, with calibrate load cell.

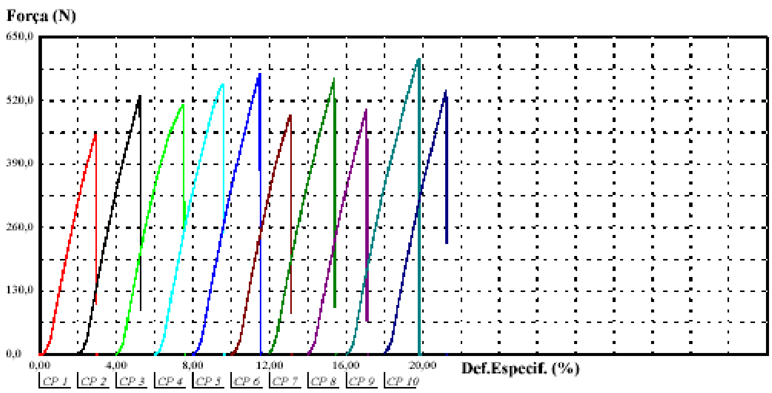

Figure 5: Dyneema SK78. Tensile multifilament break test (YBL) at 4 °C.

In the table 2 it is easy to see that no important changes happens in the averages of tensile mechanical properties data for tests at 20º +/- 2ºC and tests at 4º +/- 1ºC. So, it is possible follow to the creep tests at low temperature to verify possible mechanical behavior changes.

3.2 Creep tests device

To study the creep behavior of HMPE fibbers, was made an apparatus with appropriate devices, to simulate the real temperature at the bottom of the sea (or at more than 200 meters deep water). A cooling equipment [10], was used as volume of control to maintaining the temperature near the real

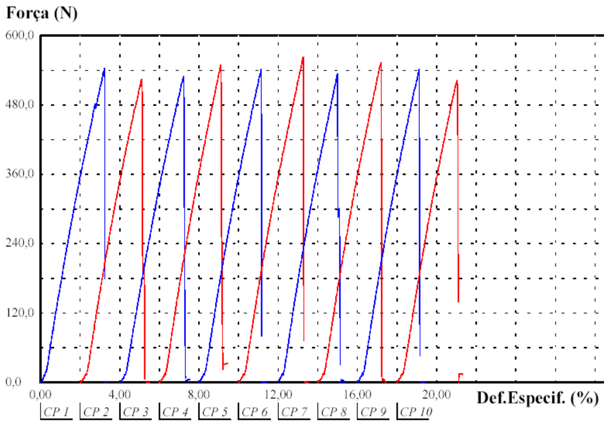

Figure 6: Dyneema SK78. Tensile multifilament break test (YBL) at 22 ºC.

Table 2: HMPE SK78 average tensile tests at 20º +/- 2ºC and 4º +/- 1ºC

Material	YBL (N)	Strain (%)	Elongation at YBL (mm)
Dyneema SK78 at 20º +/- 2ºC	540.70	3.15	15.75
Dyneema SK78 at 4º +/-1ºC	541.00	3.37	16.83

temperature in the ocean deep water. We choose a fridge and made some mechanical modifications to improve their performance, like as: was installed a double glass door to reduce heat transfer between environment.

In the structure was also placed a temperature controller (on and off in the set point), to certify that the temperature will be around 4ºC (+/- 0.5 ºC). This equipment was designed for test three specimens, at same time, loaded with died weight, corresponding the value of 30 % of the multifilament YBL. Moreover, the specimens are clamped in terminations like sandwich, developed at POLICAB, [6], whose the main characteristics are not allow the slipping of fibres.

To determine the creep behavior, was used Linear Transducer (pneumatic cylinder of position). The measurement is without contact, and the transducer was protected by a body of aluminium. This transducer has a resolution of 0.01 mm and the measurement range of 250mm. Afterward, to evaluate the measurement, was fixed in the bottom of specimens, a magnet, showing each position and the related displacement of the specimens. This magnet, as we can see in Fig.7, doesn't enter in contact with the whole body transducer and thus not affecting the measurements.

The kit finally, was placed into the cold equipment on a fix support into the device like is shown in Fig.7. Figure 8 show the complete cold equipment.

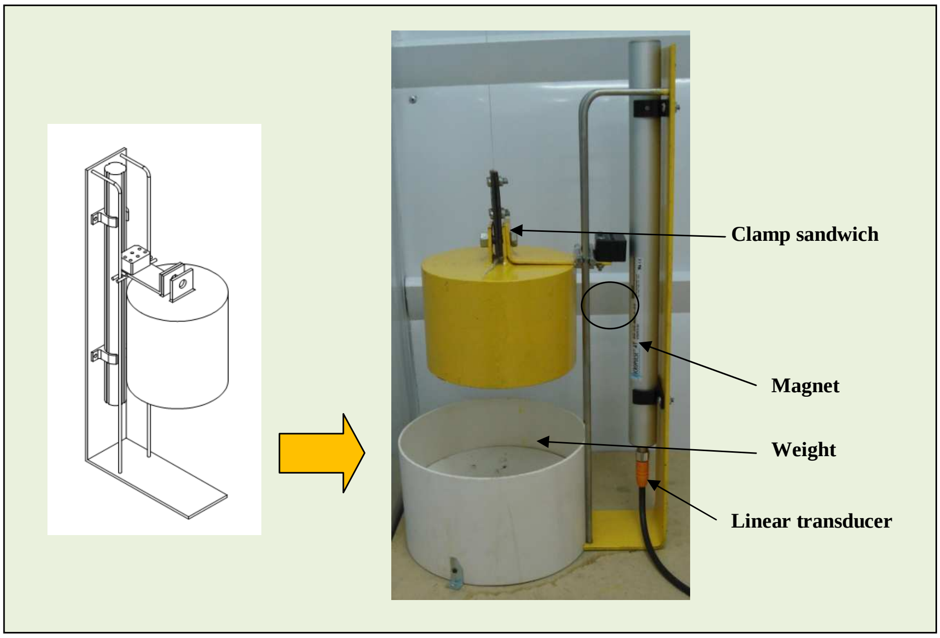

Figure 7: Creep device developed in the POLICAB.

3.3 Creep tests procedures

It is usual in mooring rope design consider the maximum tensile load applied in a rope equal to 30% of the break load in extreme work conditions. The extreme work conditions consider a storm condition. So, in this work was considered the extreme work conditions applied to the multifilament, to determine the creep load, like as 30% of YBL. Considering both HMPE SK75 and SK78 with approximately same YBL = 540.70, like is show in table 2, the weight of 30% of YBL = 162.21 N was considered for the following creep tests.

The initial procedure to assemble the specimens into the equipment considers the environmental temperature of 22 °C. The room of the laboratory was maintained at approximately 20° +/-2 °C and 55 +/- 2 % of relative humidity.

The choice of the length of the specimens was restricted to the inside height of the cold equipment in agreement with the ASTM length procedures [9]. The 890 +/- 1 mm length for each specimen was fixed on the structure.

After this, the load was slowly applied and turned on the cooling equipment to control the test temperature. Then the controller and measurement device were turned on too. The time counter started and the test go on. The dislocation of the magnet related to the initial length of the specimen provide the percentile elongation (displacement in percentile).

Figure 8: Creep cold equipment.

4 Results

The following figures and graphics show the tests made in low and environmental temperature regarding both materials Dyneema SK75 and SK78.

The figure 9 show and evaluate the creep behavior for the HMPE SK75 submitted at the same creep load (30% YBL) but in different temperature conditions. When the two creep graphs are compared, in the creep test at 22°C the material fail in 506 hours with 21.85% of strain and the creep test at 4°C not fail at the same time and show 2.86% of strain.

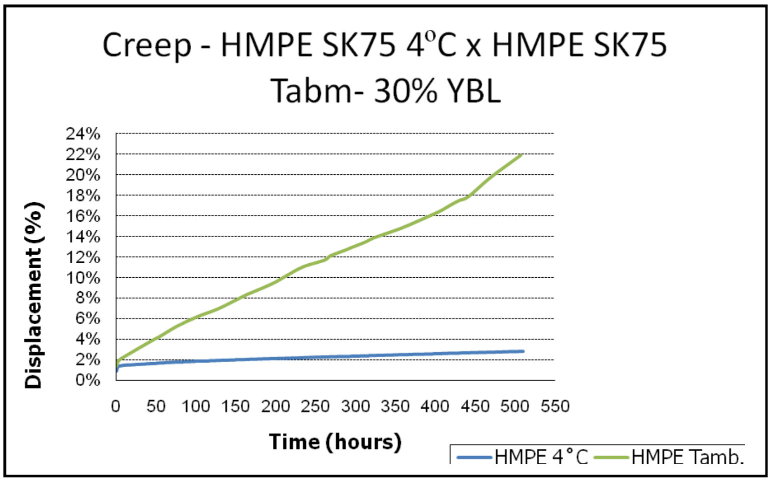

Figure 9: HMPE SK75. Creep at low and room temperature. 30% YBL.

The figure 10 show the creep behavior for 3 test specimens of Dyneema SK78, at low temperature. The 3 tests was stopped with 543 hours and shown an average strain of 1.85%.

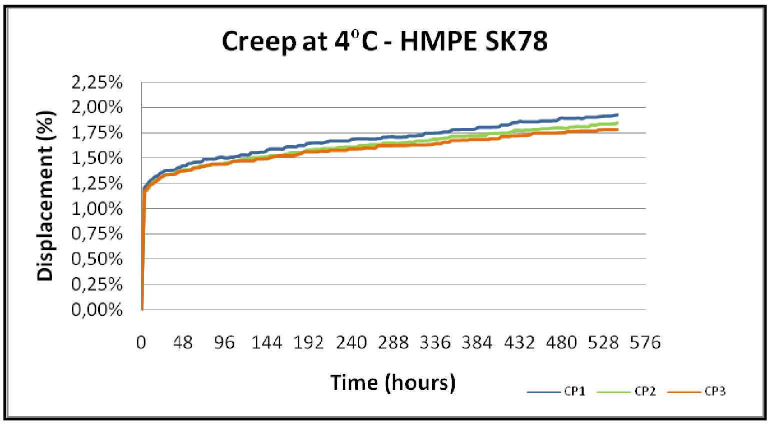

Figure 10: HMPE SK78. Creep at low temperature. 30% YBL.

In the figure 11 was compared the HMPE SK78 specimens creep behavior at room and low temperature test. The test at temperature room was stopped near 543 hours with 6.46% of strain (displacement).

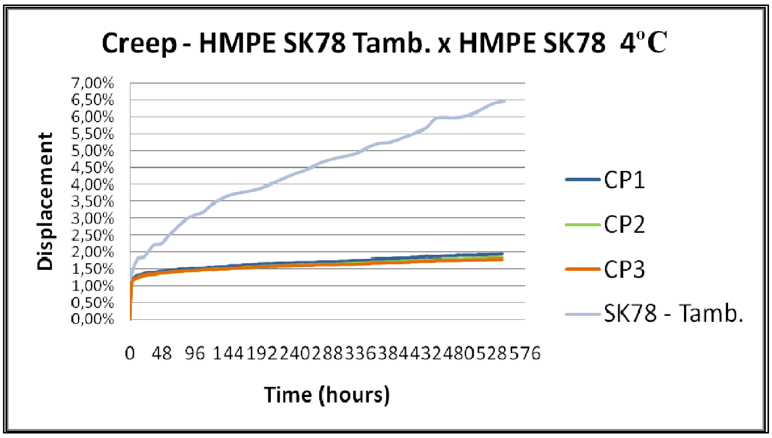

Figure 11: HMPE SK78. Creep at low temperature and room temperature. 30% YBL.

In the figure 12 was compared the creep behavior of both HMPE at low temperature. For sample was taken one specimen of SK 78 with 1.84% of strain for 543 hours of creep test and for the SK 75 was obtained 2.86 % of strain for the same time.

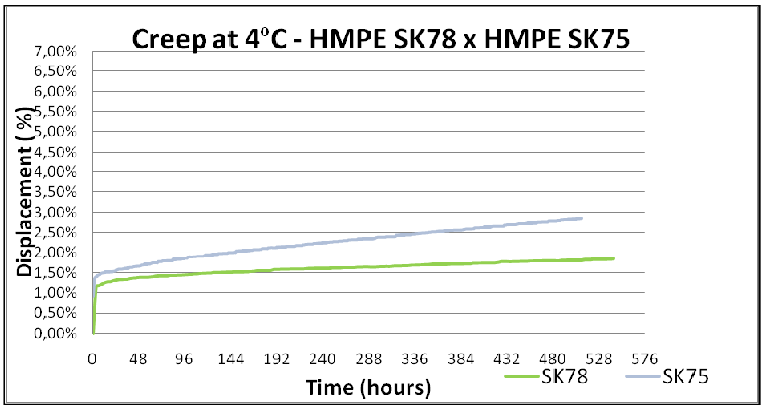

Figure 12: HMPE SK75 x SK78. Creep at low temperature. 30% YBL.

5 Concluding remarks

It is easy to see the best performance for both materials at low temperature, when are simulate the deep sea temperature conditions. The analysis of HMPE multifilament creep behavior at the simulated cold temperature to the deep water show a sensible decrease in strain (with the same load) when are compared with the strain behavior of the same material at environment or room temperature of 20º +/- 2ºC. It is possible to see that in low temperature, HMPE has a better mechanical behavior than the mechanical behavior at environment temperature.

This paper show the preliminary studies that was begin in the earliest months of 2008 [10]. The continuity of this experimental research points to more complete analysis of the same materials to give us parameters and conditions to best evaluate the creep phenomenon at low temperature.

It is important to obtain the complete curve of creep behavior even if expend very long time. Also, find the creep curves at sea water low temperatures for other kind of percentage of YBL (Yarn Break Load) like as 15%, 20% and 25% of YBL to verify other possibilities of mooring ropes use is an important data acquisition. Extend the research to others low temperatures, for sample 8 ºC, 10º C, and consecutively, to determine de variation of strain to temperature for a fixed YBL, turn more complete the experimental research.

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