Synthetic ropes jackets made of polyester and high modulus polyethylene (HMPE): comparison of abrasion wearing behavior.

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ABSTRACT. The application of synthetic ropes has been foreseen, each time more, in projects of oil exploration and production platforms in deep waters. The preference given to this kind of rope is because of its characteristics as excellent flexibility and handling quality, and low linear weight. Even though the jacket does not contribute in the ropes mechanical analysis, it keeps their subropes together and protects them from eventual deteriorations. So, a detailed study of their behavior becomes extremely important. The purpose of this work consists in determine the wear behavior of two kind of synthetic materials to be used like cover jackets and to compare with these materials new and degraded. The specimens, gently supplied to our laboratory by DSM–Holland, consist of two ropes, both with the same internal architecture of High Modulus Polyethylene (HMPE) fibers. One rope was made with polyester jacket and the other one with HMPE jacket. Both jackets were made similarly with the same architecture. The wearing tests were performed for both material specimens, first in tension plus bending and after in tension submerged in tap water. With the results obtained it is easy to see the different performance of the polyester jacket when compared with the performance of the HPME jacket.

KEYWORDS. Abrasion; Wearing; Ropes; Jackets; Synthetic mooring ropes.

INTRODUCTION

The use of synthetic ropes in the naval sector has been increased during the last years. Mooring and movement operations of ship using tugs have became very common because of its handling simplicity.

The architecture of synthetic ropes for oceanic platforms mooring is made of multifilament (yarns) forming subropes and together, in parallel, forming a rope. These subropes are involved in a protection jacket. One important element that composes the rope is the jacket that covers it, giving it an unique characteristic, the subropes are kept together by its involving action. Although the jacket does not contribute to the mechanical strength of the rope, it must have durability characteristics that, during the useful life of the rope, work as a protection against the action of all kinds of external agents.

Usually the jackets are made of the same material of the ropes, which implies an additional cost, considering the following reasons: a jacket does not have structural function or, in other words, it is not considered in the design of the mechanical strength of the rope and, nowadays, it takes near to 20% of the weight of the rope. These jackets can be made of different materials from the one of the rope.

In this work, the analysis of two different materials for jacket is made for ropes with the same diameter, architecture and same subrope materials. The materials tested are polyester (PET, Diolen 855T 1670 Dtex) and high modulus polyethylene (HMPE, Dyneema SK75 1760 Dtex) and, to verify the wearing resistance, they are submitted to abrasion tests. DSM-

Holand sent these ropes. The abrasion tests were performed in at Policab – Stress Analysis Laboratory of the Federal University of Rio Grande, in an abrasion machine.

ABRASION TEST MACHINE

As shown in Fig. 1, this machine was constructed to perform abrasion tests with different work solicitation. Fig. 2 shows drawings of the abrasion tests under tension, abrasion under tension in a fluid environment (tension test submerged in water) and abrasion under tension combined with bending. The abrasion tests in tension were not made due to be too less aggressive to the jacket rope. The machine was adapted to promote uniform abrasion in the jacket ropes in a way that all abrasive elements to have the same characteristic.

The work machine consists in a crankshaft axis moved from an electric motor. This axis movement makes the six pistons go up and down. The union between each piston and specimen is made of a steel cable. The union between specimen with the steel cables and the weights is done for a "Sandwich". The weights calibration is in a precision scale. The number of cycles is mechanically counted, simultaneously, for the three tests for each kind of solicitation.

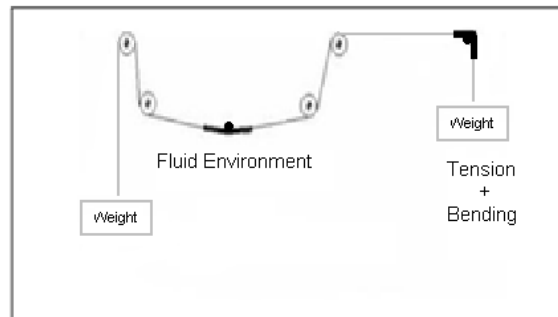Figure 1: Machine used for test the materials

Figure 2: Abrasion under different kinds of tension situations.

TEST PROCEDURES

Specimen preparation

In this work, the specimens are made of a subrope that is wrapped by the jacket which is shown on Fig. 3.

We used to the tests, ropes of the same diameter with 10 mm and subropes with 12 legs made of HMPE. Two material jackets were tested in accord to Rodrigues et al. (2006): HMPE (Dyneema SK75 1760 Dtex) and Polyester (Diolen 855T 1670 Dtex). The specimens were cut with the same length of 250 ± 1mm (9.84 ± 0.0394 in), without the use of hot blades. The specimens were handled carefully to not modify their external surfaces (jacket).

The specimens were stored for a minimum period of 24h in a controlled environment, with a relative humid air (55 ± 5 %) and temperature within 25 ± 1°C.

The initial mass of each specimen was determined, using a scale with resolution of 0.001g (2.2 10⁻⁶ lb); each specimen was identified with a label, as shown in Fig. 4. Fig. 5 shows a specimen with a "sandwich".

Figure 3: Jacket and subrope.

Figure 4: Identification of the specimen.

Figure 5: Sandwich in a specimen.

Test procedures and wearing analysis criteria for tested specimens on abrasion

To promote a standard for the tests, all preliminary tests (reference test) were made for the two materials, with an initial load of 58.86N (6 kgf) for each solicitation. In these tests, the number of cycles associated with the total damage (the exposure of the subrope or, in other words, the rupture of the jacket) was determined. For each reference test was utilized four specimens.

Each specimen was rigorously carried out through fast stops of the equipment to visualize the wearing of the jacket. It is very easy to note when the jacket is already broken (the total damage is characterized when the subrope appear). When the total rupture happens, the associate number of cycles is obtained. With the number of cycles of each specimen is obtained the average value of each reference test.

To keep the reference cycles to each material, tests changing the load and the solicitation are done. The basic criteria adapted for the abrasion wearing determination, consider the loss of mass of the specimen associated with the mechanical strength loss of the yarns that compose the jacket. Broken yarns and filaments were not considered for the determination of the residual mass of the jackets.

Procedure to determine the mass loss in the reference test

The procedure to find the mass loss, in accord to Rodríguez et al (2006), consists in the follow steps:
1) Separate the jacket and the subrope, as shown in Fig. 6;
2) Unlace the legs that compose the jacket and separate into broken and unbroken, as show Fig. 7;
3) Separate, into broken and unbroken, the multifilaments of the legs, as shown in Fig. 8;
4) All the broken components in the jacket were not considered.
5) For each reference specimen, the mass of the subrope and of the unbroken legs (composed by multifilaments and filaments of the jacket) were determined. Then, the residual mass can be calculated through the Eq. (1):

$$M_r = M_a + M_{nr} \qquad (1)$$

where M_r is the residual mass of the specimen, M_a is the subrope mass and M_{nr} is the mass of the unbroken components of the jacket. So, in this way, it was possible to calculate the percentile loss of mass, using Eq. (2):

$$M_{pr}\,(\%) = \frac{M_{ir} - M_{rr}}{M_{ir}} \times 100 \qquad (2)$$

where M_{pr} (%) is the percentile mass loss of the reference specimen, M_{ir} is its initial mass and M_{rr} is its residual mass.
From the obtained values, the percentile average mass loss of each sample and each kind of solicitation were calculated. These averages were used as reference, considering 100% of damage, for the subsequent abrasion wearing tests.

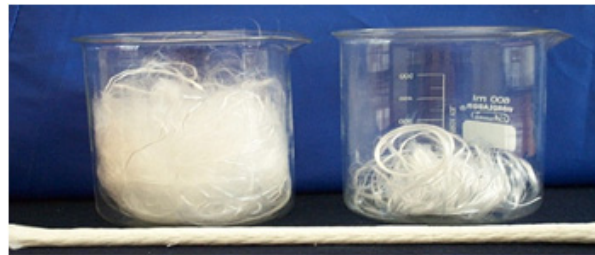Figure 6: Jacket and subrope separated.

Figure 7: Broken legs.

Figure 8: Separated (broken and unbroken) monofilaments.

Procedure to determine the relative wearing

The same analysis was carried out in the specimens of the subsequent tests in order to determine the abrasion wearing evolution, associated with the average load (4.5, 3.0 and 1.5 kgf). The percentile mass loss of each specimen was determined using Eq. (3):

$$M_p(\%) = \frac{M_i - M_r}{M_i} \times 100 \tag{3}$$

where M_p (%) is the percentile mass loss of the specimen, M_i is its initial mass and M_r is its residual mass. The relative wearing, given by Eq. (4), is the relation between the average values of percentile mass loss of the analyzed sample and percentile mass loss of the reference test.

$$\Delta(\%) = \frac{M_p(\%)}{M_{pr}(\%)} \times 100 \tag{4}$$

where $\Delta(\%)$ is the relative wearing.

TESTS AND RESULTS

The results considering the reference tests, in which the total damage of the jackets happens, are shown in Tab.1. Through these results it is possible to observe that the jackets made of HMPE has less wearing than the jackets made of Polyester in all solicitations. The number of cycles of the HMPE is approximately three times the Polyester ones for both solicitations.

Solicitation \ Material	Tension + Bending (cycles/time)	Tension submerged (cycles/time)
HMPE	191	1020
Polyester	63	315

Table 1: Number of cycles to the damage of the jacket.

The following curves show the behavior of the relative wearing for different test conditions. Two types of experiment were made for each material jacket (PES and HMPE). In the first, we imposed tension + bending in dry condition. In the second, we imposed tension in submerged condition. Tests changing load and keeping the same number of cycles for each type of solicitation were made.

Fig. 9 shows the results obtained in the tests performed using specimens with jackets made of Polyester submitted to Tension + Bending (63 cycles) and to Tension submerged (315 cycles). We can observe that the rate of the relative wearing for both solicitations is similar; it is higher for smaller loads, decays in the intermediate loads and grows again in the higher loads. The curve for tension submerged is always below the other one.
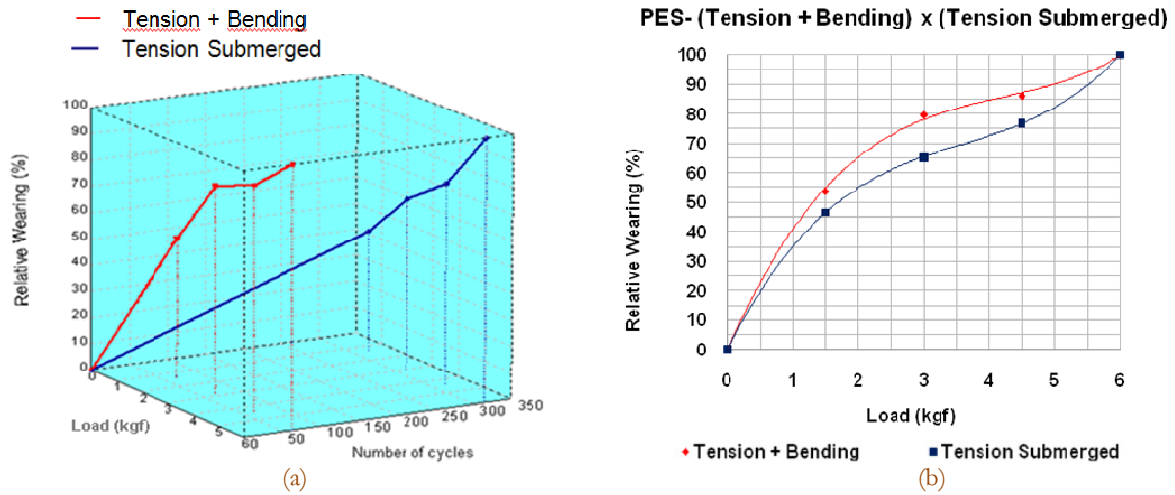

Figure 9: Results obtained for Polyester material jacket.

Fig. 10 shows the results obtained in the tests performed using specimens with jackets made of HMPE submitted to Tension + Bending (191 cycles) and to Tension submerged (1020 cycles). We can see the same behavior showed in the Polyester case.
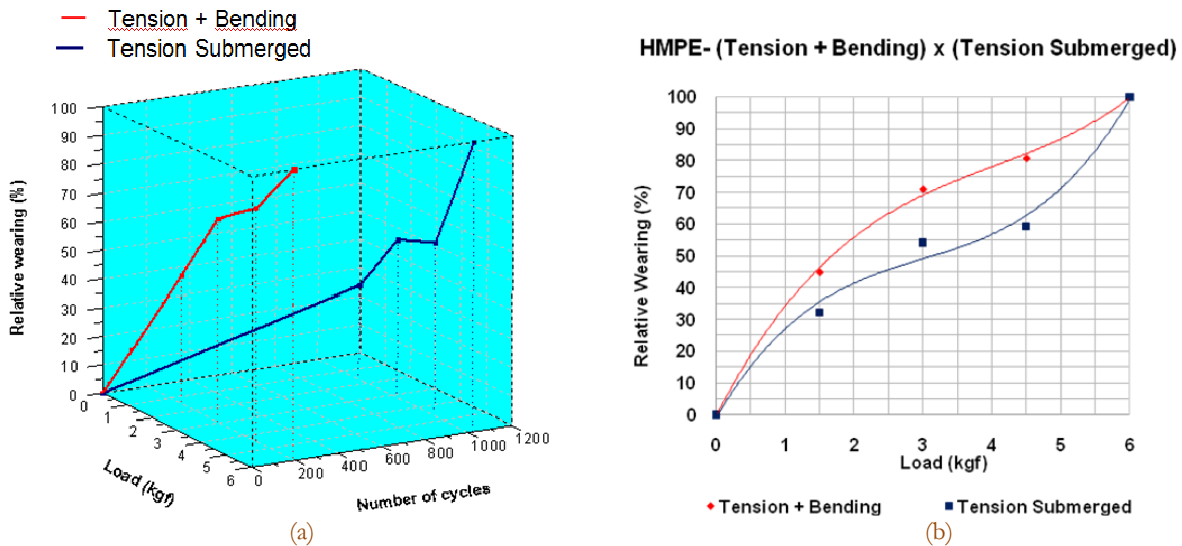

Figure 10: Results obtained for HMPE material jacket.

Fig. 11 shows the results obtained in the tests using specimens with jackets made of Polyester submitted to tension submerged and a comparison with HMPE ones. We observed that the HMPE relative wearing was always lower than polyester ones.

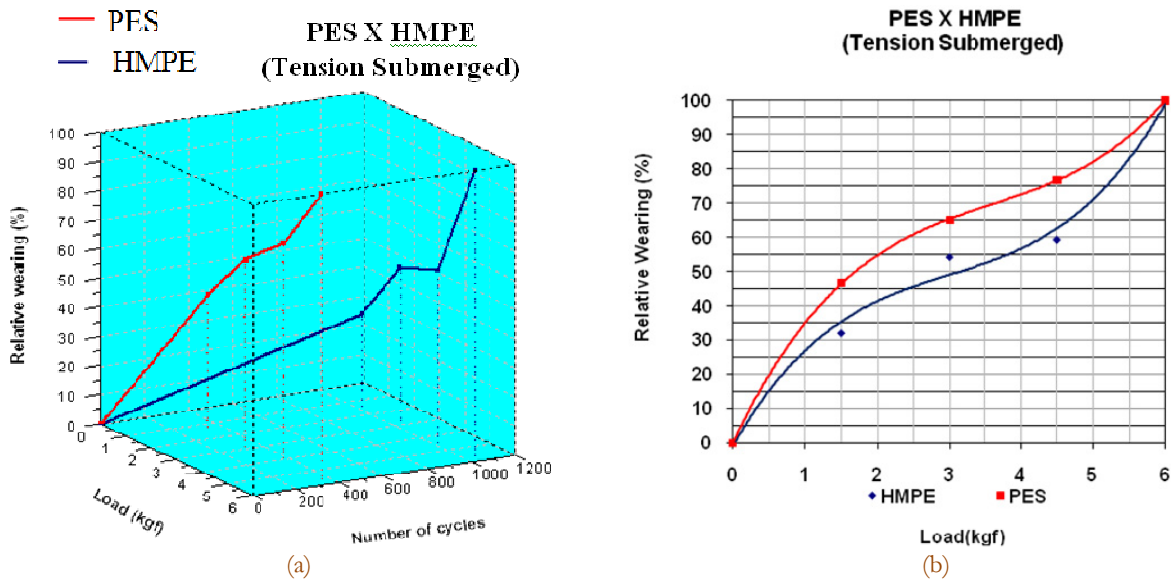(a)   (b)

Figure 11: Comparison between Polyester and HMPE results for wet condition.

Fig. 12 shows the results obtained in the tests using specimens with jackets made of Polyester submitted to Tension + Bending compared with HMPE results. We observed the same behavior obtained in the tension submerged condition, e.g., HMPE presented lower relative wearing than polyester.
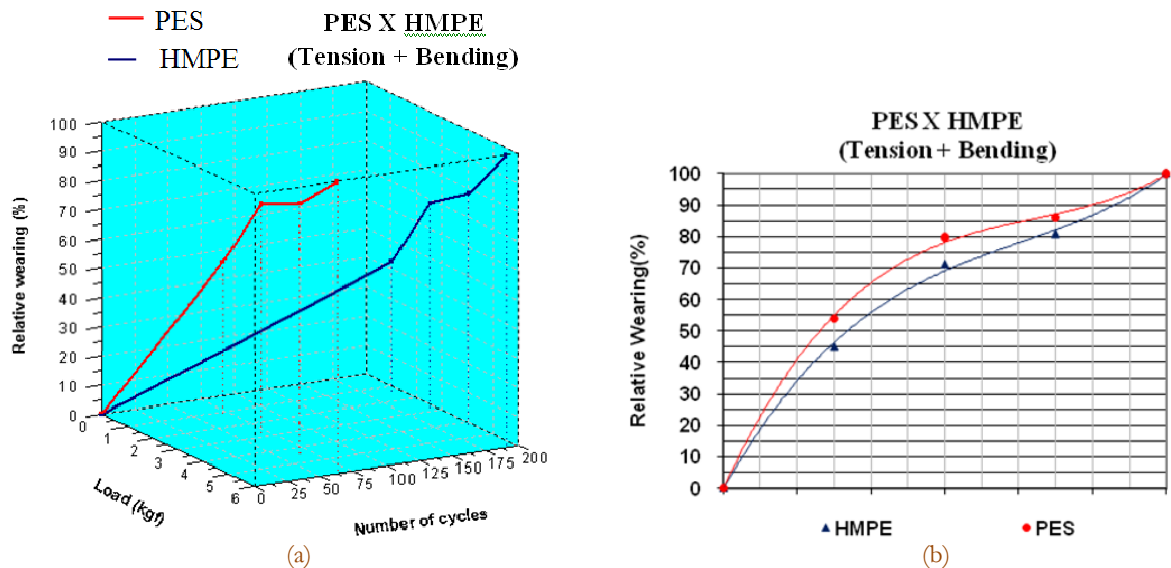

(a)   (b)

Figure 12: Comparison between Polyester and HMPE results for dry condition.

We compared the number of cycles to the jacket damage developed at POLICAB (Tab. 1) with that presented by DSM. The last, carries out two types of wearing tests for the HMPE and polyester materials. The first test was a static abrasion, submitting specimens to the tension + bending in dry and wet conditions, and in the second test specimens were submitted to the wire test in a dry condition. Table results and pictures of these tests are shown in Appendix.

Concerning the tension + bending solicitation, according to POLICAB measurements, we can observe that the wearing abrasion resistances of HMPE, in terms of number of cycles, were three times the polyester ones. Whereas, according to DSM, for the same solicitation, this relation was equal to fifteen.

The same discrepancy was observed if we compare the results to the tension submerged condition measured at POLICAB with the results to the wet static abrasion condition measured at DSM. Whereas, at POLICAB, the relation between the abrasion resistances was approximately three, at DSM this value was equal to thirty nine.

CONCLUSIONS

This paper showed the procedures, the tests and the results to obtain the abrasion resistance of the jackets made of HMPE and polyester. Two types of conditions were imposed: the first was tension + bending in dry and wet environment and the second was tension in wet environment.

We observed that HMPE presented better wearing resistance than the jacket made of Polyester in the all type of solicitation. Comparing abrasion resistance of these two materials according to POLICAB and DSM measurements, we can see some discrepancies. POLICAB measurements indicate lower resistance relation in favor of HMPE than DSM ones.

APPENDIX

Material	Nr. of cycles		
	Static abrasion (dry)	Static abrasion (wet)	Wire test
Dyneema® SK75	120	39	153
PES	8	1	14

Cover abrasion test results to Dyneema SK75 (HMPE) and PES.
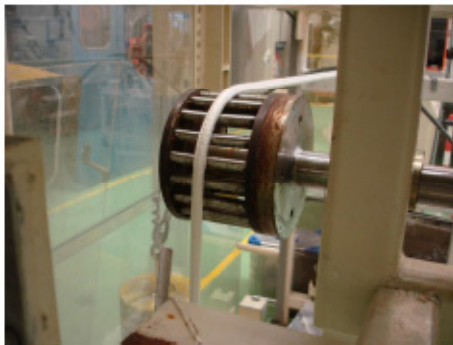
Picture 1: Static abrasion test (wet + dry)

Picture 2: Wire test (dry)

ACKNOWLEDGEMENTS

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