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Effects of marine environment on wear mechanisms of polymeric ropes

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Polymeric ropes are widely used in the marine industry, successfully replacing steel wire ropes with superior performance in terms of strength-to-weight ratio and corrosion resistance. However, wear between yarns can reduce their mechanical resistance and life. This works investigates the effects of yarn-on-yarn wear on the tensile strength of polymeric ropes, with particular emphasis on wear mechanisms. Yarn-on-yern tests were carried out under loads corresponding to 4% and 6% of the rupture load obtained from tensile tests. Dry tests were compared with tests under humid and saline atmosphere conditions. For both loading conditions, the number of cycles before rupture of the polymeric yarns was lower under dry conditions. Scanning electron microscopy showed that the worn surface of the yarns was smoother in the presence of water, in particular for the saline solution, apparently due to tribochemical reactions that formed protective tribolayers in the presence of water and NaCl.

Keywords: Wear mechanisms, polyester, polyamide, mooring ropes, yarn-on-yarn wear.

1. Introduction

Despite many advantages of polymeric ropes when compared with steel wire ropes for mooring operations in marine systems [1], the relative movement between yarns can lead to wear, reducing their mechanical resistance and life. Moreover, water and NaCl present in marine atmospheres can affect yarn-to-yarn wear and thus the rope durability. This work uses yarn-on-yarn tests according to ASTM D6611/2002 [2] to investigate wear between yarns, with emphasis on wear mechanisms under different environments.

2. Methods

This work used polyester and polyamide commercial ropes used in marine mooring. For the polyester rope, a previously used rope was also tested in order to analyse the influence of long exposure to real marine atmosphere on the wear between yarns. Initially, tensile tests in multifilaments obtained the load to rupture (Ybl) for the three types of ropes. Then, yarn-on-yarn tests were carried at two loads: 4% and 6% of Ybl. The apparatus presented in Figure 1 was developed according to ASTM Standard D6611/2002. The yarns are subjected to three complete loops, resulting in a total angle of 1080º. The motor attached to a crank mechanism rotated at 65±5 rpm, resulting in yarn-on-yarn relative motion within the loop region. In addition to tests under dry conditions, the multifilaments were immersed in two solutions (water and water + 3.5wt% NaCl) during 1 h before the tests to evaluate the effects of humidity and saline environment on yarn-on-yarn wear. Each condition was repeated 8 times. The yarns were analysed by scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX) to investigate wear mechanisms.

3. Results and discussion

Figure 2 quantifies the number of cycles before rupture of the multifilaments when subject to yarn-on-yarn tests under different environments and loads. As expected, under a higher load the life of the multifilaments decreased. Polyester presented higher durability than polyamide under all conditions tested. At a normal load of 4% Ybl, when new filaments were tested, the life of both polyester and polyamide was much lower under dry than humid conditions; for polyamide, life was so low that it could not be graphically visualized. However, for the previously used rope, the differences under dry and humid conditions were not statistically significant. Under a load of 6% Ybl, the number of cycles were very low under dry conditions for all three filaments, but under humid conditions durability increased substantially. The differences between humid and humid + NCl conditions were smaller and did not show a clear trend.

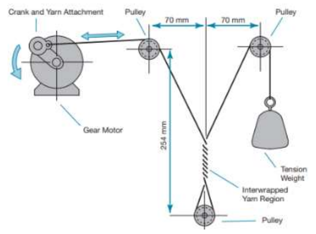

Figure 1 : Setup of the yarn-on-yarn tests.

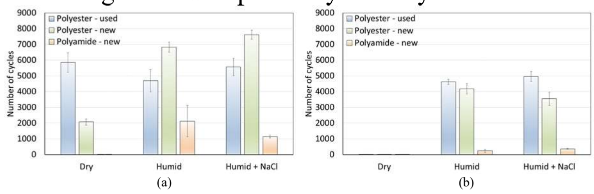

Figure 2. Durability of the filaments in yarn-on-yarn tests: (a) 4% Ybl; (b) 6% Ybl.

Examples of worn filaments are presented in Figure 3 for the polyester rope. Under dry conditions, wear of the filaments clearly involved delamination, whereas the surfaces under humid and saline conditions appeared substantially smoother.

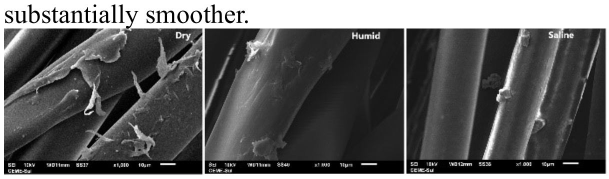

Figure 3: Wear mechanisms via SEM.

4. References

[1] Chimisso, F. E. G. et al., "Modelling creep tests in HMPE fibers used in ultra-deep-sea mooring ropes," International Journal of Solids and Structures v.48, n.1, p 144-152, 2011.

[2] *ASTM Standards, D1776*/2007. ASTM 6611-00 Standard "Test Method for Wet and Dry Yarn-on-Yarn Abrasion Resistance".