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Mechanical Properties of Polyester Mooring Cables

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ABSTRACT

The work presents expressions to deal with the stiffness nonlinearity of polyester mooring cables. The study is based on two efforts. One basic effort is a comprehensive set of model cables tests performed. The other effort has been completed by the analysis of the acceptance tests performed with actual full-scale cables with 5-in (0.127-m) or thicker diameters. For the parallel construction cables under analysis here, a weak dependence on the frequency has been detected, while the mild to significant dependence on the average load and load amplitude has become clear. A theoretical consideration is made through the Maxwell model. Finally, suggestions on how to deal with the expression in a mooring design are also addressed.

INTRODUCTION

The use of polyester in mooring lines of floating structures is a very recent issue due to the oil exploitation in deeper and deeper water. It is nevertheless a reality. After several years of research and field evaluation, PETROBRAS decided to use polyester lines in several floating production systems (FPS) in Campos Basin, offshore Brazil. Two of them were installed in 1997 and others are planned for 1998 and 1999.

The basic research that sustained the feasibility of the lines has been consolidated in Del Vecchio (1992), where a comprehensive series of testing and analysis is summarized. Typical yarns and small-diameter (less than 1 in) cables were then studied. Later on, several acceptance tests as required by PETROBRAS were also performed. Both of these activities yield a fundamental basis for the understanding of the polyester rope's mechanical behavior. The highly nonlinear characteristics have come up clearly, as shown in Fernandes and Castro (1997) and summarized below.

SPECIFIC MODULUS OF ELASTICITY

The axial stiffness of a line is usually expressed as:

$$k = \frac{EA}{\ell_0} \tag{1}$$

where E is the Young Modulus, A is the cross-sectional area of the polymer cable, and ℓ_o is the initial line length.

This expression works fine whenever the area is not changing too much. For the polyester lines, at least at the investigation stages, it makes more sense to work with another quantity that follows after rearranging Eq. 1:

$$k = \frac{E}{\rho}\frac{A\rho}{\ell_0} = \frac{E}{\rho}\frac{d}{\ell_0} \tag{2}$$

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where d is the mass per unit length and ρ is the polymer specific gravity. The referred quantity is E/ρ, which is called the specific modulus of elasticity.

Following the textile industry, the usual unit for E/ρ is N/tex, where 1tex = 10^{-6}kg/m. Note therefore that 1N/tex = 10^6m^{2}s^{-2}. The advantage of assessing this quantity is that it depends on material properties, cable construction and the type of loading (as shown next), but it does not depend on the possibly varying cross-sectional area. The other ratio in Eq. 2, d/ ℓ_o , will come into the calculations at later stages.

COMPREHENSIVE SMALL-DIAMETER LINE TESTING

In Del Vecchio (1992), yarns and small-diameter polyester cables were tested in a systematic manner, furnishing a lot of information on the cable's mechanical behavior, within the present scope. Once the breaking strength was fixed, the line specimen was excited longitudinally with different percentages of average load (L_m), different load amplitudes (L_a) and different excitation periods (T). Note that in the present text, L_m and L_a are expressed in terms of percentage of the maximum breaking load (MBL). Table 1 shows all the imposed values during the tests with the small-diameter cables.

The regression analysis of these tests conducted to the following expression (Del Vecchio, 1992):

$$\frac{E}{\rho} = \alpha + \beta L_m - \gamma L_a - \delta Log(T) \tag{3}$$

where the Greek letters on the right-hand side are 4 constants whose values are shown in Table 2 for two types of cables. The first was a parallel sub-rope construction, with fourteen 3-strand sub-ropes, half "z" and half "s" laid, enclosed in a braided jacket. It is important to say that this was a model rope, specifically made by Marlow Ropes in the United Kingdom, a model similar to typical full-scale mooring line construction. The other was a parallel strand construction, also torque-balanced, with 34 strands and an overbraid. Brascorda in Brazil made this rope.