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Tension-Torsion Behavior of Deepwater Synthetic Mooring Lines

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Abstract

Synthetic fiber ropes are now being used in mooring systems off Brazil and in the Gulf of Mexico, and are being considered for deepwater handling applications. Their behavior under tension loads is well understood but induced torsion effects have received less attention. This paper presents tests to measure induced torque in full size steel, aramid and polyester wire ropes. Results are compared with model predictions and good correlation is obtained. A specially designed torque matched 500 ton break load polyester rope is tested and shown to enable steel wire rope to be used in series with polyester without inducing twist in the system.

Introduction

Following pioneering work by Petrobras large fiber ropes are being widely used in station keeping of floating platforms off Brazil [1,2]. More recently even larger ropes have been installed in the Gulf of Mexico [3,4]. These applications followed extensive development projects [5,6] and sea trials [7-9], and have resulted in a large database of tensile stiffness properties. Tension is clearly the dominant loading in mooring lines but torsion may be present. This can be induced due to the unbalanced construction of some ropes (6+1 wire ropes for example). In this case the coupling coefficients ($k_{\varepsilon\theta}$ and $k_{\theta\varepsilon}$) are non-zero:

$$\begin{Bmatrix} F_z \\ M_z \end{Bmatrix} = \begin{bmatrix} k_{\varepsilon\varepsilon} & k_{\varepsilon\theta} \\ k_{\theta\varepsilon} & k_{\theta\theta} \end{bmatrix} \begin{Bmatrix} u_{z,z} \\ \theta_{z,z} \end{Bmatrix}$$

However, even in a balanced construction, the movement of adjacent unbalanced steel wire loaded in tension may introduce twist. Torsion may also arise during handling or installation operations. A thorough understanding of these phenomena is therefore essential for safe design.

The most detailed work published on torsion effects in offshore ropes to date is that of Chaplin and colleagues at the University of Reading. In a previous OTC paper they discussed torsion effects and presented some results from tests on small ropes [10]. Other small-scale test results have been presented by Yeardley [11] and Huntley [12].

To the authors' knowledge no results from full scale instrumented tension-torsion tests have been published, though some measurements have been made at sea.

The aims of the present work are to:

- Develop tests to measure tension-torsion coupling on large scale steel, aramid and polyester ropes,
- Apply rope models to predict these effects,
- Validate these models by comparison with test results,
- Evaluate a specially designed torque matched polyester design by testing it in series with a steel wire rope.

Two types of test were used, based on those described in the ISO draft document 18692 [13]. The first, measurement of Torque Factor, involved loading 46-meter lengths of rope in tension and measuring the induced torque. The results from these tests will be compared with model predictions. Then the second test, Torsional Compatibility, involved loading equal lengths of steel and polyester to examine induced rotation.

Materials tested

Three materials and four samples, each of nominal length 46 meters, were tested in this study, Table 1.

Material	Construction	Weight kg/m	Nominal diameter, mm	Break load, Tons
Steel	6x49 wire rope	31.0	83	500
Aramid	6+1 wire rope *Araline ™*	3.0	65	205
Polyester	Parallel strand *Integra ™*	11.4	132	500
	6+1 Wire rope *Torque match ™*	11.4	132	500

Table 1. Materials tested

The steel wire was a drilling rig anchor wire, terminated with closed spelter sockets. The aramid (*Twaron 1000*) and polyester (*SeaGard 1W83*) ropes were spliced with soft eyes at both ends.