Engineering Failure Analysis 60 (2016) 137–154

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Abrasion process between a fibre mooring line and a corroded steel element during the transit and commissioning of a marine renewable energy device

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ARTICLE INFO

Article history:
Received 20 August 2015
Received in revised form 15 October 2015
Accepted 16 November 2015
Available online 18 November 2015

Keywords:
Abrasion
Polyester rope
MRE commissioning
Sea trial
OrcaFlex

ABSTRACT

The interaction between fibre rope and steel parts on vessels (fairlead and roller) is technically well understood but not commonly published in codes or practised by mariners. What appears to be a smooth steel surface to the naked eye can still be abrasive medium to synthetic mooring components. There are very few reports of external rope abrasion tests in the literature. The surface finish at the contact between the rope and the steel guide can cause damage and consequently prematurely degrade the exposed yarns of the rope and thus reduces the overall load bearing capacity of the rope. The standard ISO 18692 [1] recommends that prolonged cycling of a rope around rollers should be avoided, however it is specified that occasional bending and running over rollers are allowable. There are two guides to specify surface roughness. MEG 3 [2] states that steel fairleads should be polished to Ra 10, but in practise this may be difficult to achieve or obtain with carbon steel. The US Navy guide also states that the surface of steel should have better than 125 μi or 3.2 Ra [3]. The study presented here discusses the bending of a synthetic rope around a roller during transportation. It relates the motion behaviour of the vessel to rope wear and provides a detailed numerical simulation correlated with post analysis of the rope after the failure. The investigations show that the roughness of the steel roller caused the abrasion of the rope which was exacerbated through the vessel dynamics, resulting in the rope having an estimated residual strength of 14% MBL before rupture. The experimental tests have established a linear relation between strength loss and surface roughness and it was observed that the abrasion mainly occurs in the early stages of load cycling. The presented work recommends the use of lubricated nylon instead of carbon steel rollers to limit abrasive rope wear. The paper also devises a methodology to carefully assess and quantify potential rope abrasion to ensure that the residual rope strength withstands the required load capacity.

1. Summary

This paper brings together two experiences from TTI (Tension Technology International) and the UoE (University of Exeter) and aims to quantify the damage that could be experienced by fibre mooring lines during the transit and commissioning phase of Marine Renewable Energy (MRE) devices.

1. While deploying a new prototype of anchoring system for a MRE device, UoE experienced the failure of a new polyester mooring line during transit to site (90 min duration). A thorough visual inspection supported by Scanning Electron Macroscopy (SEM) analysis and tensile test has established the physical conditions of the fibre rope before its failure.

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http://dx.doi.org/10.1016/j.engfailanal.2015.11.037
1350-6307/

2. Wear testing led by TTI has investigated and established a relation between the degree of abrasion sustained and the residual strength of Dyneema® fibre ropes. The ropes were submitted to friction forces via cycling over a roller and a fairlead with different abrasive surfaces (from 7.6 to 254.3 μm). Negligible wear occurred with the low roughness surfaces and very high wear at the higher roughness surfaces.

The load experienced by the polyester line during the deployment of the anchoring system was simulated with the software OrcaFlex™. Dynamic modelling using representative conditions indicates that the polyester mooring line was loaded between 3 and 20% of its Minimum Breaking Load (MBL) which is well below the design load of the rope.

2. Introduction

To date there are only a few MRE designs which have achieved a pre-commercial development status. Experience in deploying such devices and specific guidance is missing. The approach of designers is thus conservative and based on the offshore oil and gas industry and anecdotal evidence [4].

The use of synthetic fibre ropes for mooring systems has seen a sudden rise in marine applications over the last two decades [5] albeit mainly for deep water mooring [6]. Experience and feedback from the use of polyester ropes for MRE device moorings are still limited in terms of publications produced.

This paper focuses on the commissioning phases of MRE devices, with a specific focus on the deployment of a novel anchoring system. Handling, lifting and rigging of mooring lines could result in damage during transport or installation as discussed in [7] and [8]. The strength of a rope will inevitably degrade from mishandling. Several research programmes have been carried out to investigate the abrasion and twisting damage by rope manufacturers for towing systems. For example incorrect handling during transport could cause significant damage to the rope due to abrasion and the application of sudden high loads is one of the most severe conditions that a rope can experience [9].

Certification standards and specific test methods have been developed to test the abrasion resistance of yarns [10–11]. The abrasion mechanism was described in [12] as a sequence of fibre peeling induced by surface shear forces. However the abrasion resistance of a fibre rope is not determined by standards and knowledge is only based on empirical test data.

The external abrasion resistance of a fibre rope is a function of multiple properties [13]:

— The rope construction (double braided, plaited, etc.)
— The fibre materials (aramid, nylon, polyester, HPME, etc.)
— Fibre and rope lubricants and abrasion protection coatings
— Wet and dry conditions
— The tension in the rope and pressure on the abrasive surface
— The speed of the sliding over the surface

A better understanding of the abrasion effects on the strength loss can potentially reduce performance uncertainties and limit the normal wear damage experienced by MRE mooring components.

3. Fibre rope observation

3.1. Background

The present case study relates the abrasion of a polyester mooring line during the commissioning of a novel type of anchoring system in Falmouth Bay (UK) 1.25 miles away from the coast. The 28 tonnes anchoring system was connected to the deck winch

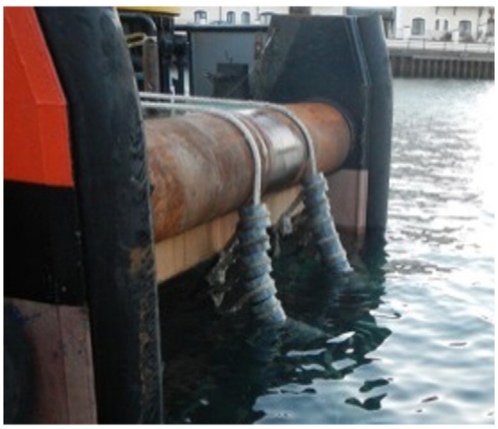

Fig. 1. Anchoring system over the roller when connected to the vessel winch.