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Modelling creep tests in HMPE fibres used in ultra-deep-sea mooring ropes

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ABSTRACT

Due to its low density and high strength, HMPE (high modulus polyethylene) fibres are being increasingly used in synthetic ropes for offshore mooring. Nevertheless, the occurrence of creep at sea temperature can be a shortcoming for its practical use. Creep tests performed at different load levels in a sub-system of the HMPE rope (yarn) are frequently used as a first step to obtain some information about the susceptibility to creep deformation at a given temperature. The present paper is concerned with the phenomenological modelling of creep tests in HMPE yarns. In this macroscopic approach, besides the classical variables (stress, total strain), an additional scalar variable related with the damage induced by creep process is introduced. An evolution law is proposed for this damage variable. The predicted lifetimes and elongations of HMPE specimens in creep tests at different load levels and room temperature are compared with experimental results showing a good agreement.

1. Introduction

Offshore oil drilling and exploration in increasingly deep waters requires the replacement of traditional steel wire rope and chain moorings by synthetic fibre ropes with lesser linear weight. A mooring system with synthetic fibre ropes can be configured as either a catenary or a "taut-leg" system, but generally the last one is the most feasible in deep and ultra-deep waters (Fig. 1, also see the recommended practice for design, manufacture, installation, and maintenance of synthetic fibre ropes for offshore mooring, API-RP, 2001, for instance). Nowadays these synthetic ropes provide the necessary compliance to the taut-leg system by means of the natural mechanical properties of the fibres.

Most fibre ropes comprise a core to withstand tensile loads and an outer jacket, which often has little tensile load bearing capability. Additional protective coatings or wrappings may be applied after rope manufacture. Typical rope construction types suitable for deepwater fibre moorings are wire rope constructions (WRC), and parallel strand types. The main structural levels in a fibre rope, although not all present in every construction, are: (i) textile yarns, as made by the fibre producer and typically consisting of hundreds of individual filaments; (ii) rope yarns, assembled from a number of textile yarns by the rope maker; (iii) strands made up from many rope yarns; (iii) sub-ropes of several strands; (v) the complete core rope assembly; (v) rope, sub-rope and strand jackets.

In the "taut-leg" mooring system, each rope is stretched under tensile load (Fig. 1). Polymer based fibre ropes generally have a rate-dependent nonlinear behaviour. High tenacity Polyester and High Modules Polyethylene (HMPE) are the most common types of synthetic fibres materials used for such kind of offshore mooring ropes. Polyester fibres do not present significant creep at loads and temperatures normally experienced in mooring applications. HMPE is a material with better tensile strength and lower density than polyester, but may present creep even at sea water temperature (Smeets et al., 2001; Chimisso, 2009, for instance). The stability control of the platforms and reliability of the overall mooring system in long term experience with HMPE is a major concern.

It is not the goal of the present paper to goal to discuss the chemical aspects of high modulus polymers neither to investigate the microscopic mechanisms of creep in this kind of material. Such a discussion can be found in other works concerned about the subject. For a general idea of previous studies about this subjects it is suggested the works of Ward and colleagues (Ciferri and Ward, 1979; Ward and Sweeney, 2004; Wilding and Ward, 1981, 1984a,b; Bonner et al., 1999, for instance) and also the papers of Liu et al. (2008) and Kolarik et al. (2006).

Many studies particularly concerned with polymer fibres, ropes and fabrics have also been developed in the last years (Boxman and Cloos, 1998; Smeets et al., 2001; Bles et al., 2009; Ghoreishi et al., 2007; Fernandes and Rossi, 2005; King et al., 2005, for instance). Nevertheless, the mechanisms proposed so far to explain the damage initiation and propagation processes in different geometry/material mooring systems are not able to elucidate all aspects of the phenomenon (Pellegrin, 1999; Sloan, 1999; Hooker, 2000;

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