Ocean Engineering 122 (2016) 1–9

Contents lists available at ScienceDirect

Ocean Engineering

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

Recovery length of high strength tapes in damaged flexible pipes

Junpeng Liu [a], Murilo Augusto Vaz [a,*], Anderson Barata Custódio [b]

[a] Ocean Engineering Program, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil
[b] Petrobras, Cenpes, Rio de Janeiro, Brazil

ARTICLE INFO

Article history:
Received 31 March 2016
Received in revised form
14 June 2016
Accepted 15 June 2016
Available online 22 June 2016

Keywords:
Flexible pipes
High strength tape
Capstan effect
Non-linear friction law
Recovery length

ABSTRACT

The application of filaments wound around damaged high strength tapes (HSTs) in flexible pipes may be one of the simplest methods to reestablish the initial restraint capacity for the armor wires. This paper aims at evaluating the effectiveness of such method observing the recovery length of filaments and investigating the mechanical behavior of both perfect and damaged HSTs. Analytical formulations that depict the restraint ability of undamaged HSTs are derived from a combination of Clebsch–Kirchhoff equilibrium equations and a modified non-linear friction law in terms of normal stress. As a base case, the restraint ability induced by the interaction between original damaged HSTs and filaments is obtained as well as the required recovery length. The solution is presented in non-dimensional form and it is shown that the repair method is feasible. Besides, some important parameters affecting the recovery length are investigated. It is found that the application of tension force at both ends of filament is the most effective way to reduce the recovery length. It is also shown that external pressure has insignificant effect if tension forces at ends are large. In addition, a case study shows that the recovery length grows almost linearly with the increasing radius of tape.
© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

During the past few decades, the rapid expansion of world economy has driven the need for fossil fuels and enabled the oil and gas development in deep waters. Such process has prompted growing demand for flexible pipes, which are constructed by numerous thermoplastic cylindrical and metallic helical layers with special purpose functions. During offshore pipe laying or miscontrolled operation shut down in deep waters, flexible pipes may experience axial compression, which is mainly supported by the tensile armor layers, producing radial expansion that may lead to wire buckling. This phenomenon is commonly known as birdcage failure, and in case of HSTs' rupture the pipe outer sheath itself has insufficient mechanical strength to arrest the wires' expansion. Worse still, a combination of this condition and existing gaps over or beneath each tensile armor allow the wires to twist, bend and buckle, disarranging them. Such failure mode characterized by large localized radial deflection has been investigated extensively (Bectarte and Coutarel, 2004; Braga and Kaleff, 2004; Custódio, 2005; Kraincanic and Kebadze, 2001; Sævik and Thorsen, 2012; Vaz and Rizzo, 2011; Østergaard et al., 2012a, 2012b; Tang et al., 2015). To contain radial expansion, High Strength Tapes consisting of fabric with warp polyamide, as shown in Fig. 1, are often employed in deep water flexible pipes. In some applications, polyethylene terephthalate (PET) or other polyester with weaker strength wound on HSTs may be also used to increase the system strength at reduced cost. The number of superimposed layers depends on the particular application and the estimated load on the warp, but generally lies between 2 and 4. HSTs are slightly wound at small pitch to achieve partial overlap at each turn, and their widths typically vary between 65 mm and 150 mm. The difference in engineering solutions for HSTs provided by flexible pipe suppliers depends on accumulated empirical experience.

According to a predictable mechanism, the dilatation of armor wires mainly induced by compressive loads tightens the HSTs and this interaction propitiates HSTs to immobilize the armors as much as possible. The restraint ability of the HSTs majorly depends on the capstan effect and its own physical properties including material and geometrical configuration. The capstan effect, as a result from integration of distributed friction stresses over/along a contact interface, rules the maximum force above which the HST will slide. For instance, in a common halter system seen in Fig. 2, a small holding force exerted on one side can carry a much higher loading force on the other side and the difference between those forces is equal to the integral of distributed friction forces. Therefore, it can be anticipated that slip phenomenon occurs when the traction force on the tape in tangent direction exceeds the maximum frictional force between HST and armor layer. Also the tape fails if traction force surpasses its limit resistance.

HSTs may be subject to damage due to abrasion, wear or other unpredictable reasons, as shown in Fig. 3. Hence, recovering the constraint capacity in such localized zone is necessary and a

* Corresponding author.
E-mail address: murilo@oceanica.ufrj.br (M.A. Vaz).

http://dx.doi.org/10.1016/j.oceaneng.2016.06.025
0029-8018/© 2016 Elsevier Ltd. All rights reserved.

Fig. 1. High strength tapes used in flexible pipes. Middle: Kevlar. Right: PET.

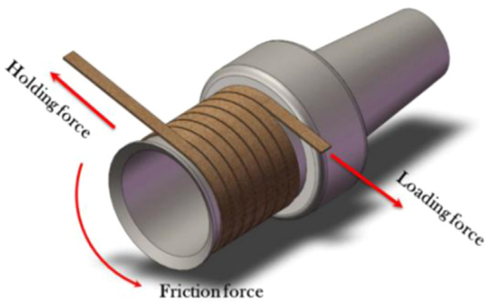

Fig. 2. A common halter system.

Fig. 3. Damaged tape in flexible pipe.

feasible solution is to tightly wind high strength filaments or tapes on the damaged area (see Fig. 4). However, concerns about the process effectiveness and limits have arisen as there are no previously published work and similar engineering applications that can be used as reference.

Therefore, this paper aims at investigating the mechanics of this technique, in special to assess the minimum recovery length in repairs based on filament or tape winding as well as mapping its governing parameters. Furthermore, practical suggestions will be given for engineering implementation. In this paper, firstly a model for predicting the restraint ability of HSTs in an undamaged flexible pipe is developed using a combination of mechanical equilibrium equations and modified non-linear friction law in terms of normal stresses (Brown and Burgoyne, 1999). Such model essentially belongs to the class of capstan problems. Capstan effect has been widely introduced in tribological area (Budinski, 2001; Greenwood, 1985; Tu and Fort, 2004; Tu and Fort, 2004; Werkmeister and Slocum, 2007) and used in analysis of rope rescue systems (Attaway, 1999; Manning, 2000). In addition, the structural response of multi-layered filament-wound composite pipes under different loading conditions has also been investigated (Ansari et al., 2010; Bakaiyan et al., 2009; Xia et al., 2001a, 2001b). The use of filament or tape winding in the repair of flexible pipes is a technological solution deserving deeper study.

In this model, an analytical solution for the maximum tension force is obtained. Therefore, the maximum tension force sustained by filament in a repaired flexible pipe can be calculated, as well as the recovery length for a given condition. The expression for recovery length can be written in non-dimensional form, which is convenient for parametric analysis. A case study is performed and it evidences that three factors affect the recovery length, i.e. tension force at both ends of filament, reference force at repaired filament and external pressure. The first parameter is found to dominate the effectiveness of repair. Some useful suggestions for engineering applications are also presented in view of the repair methodology.

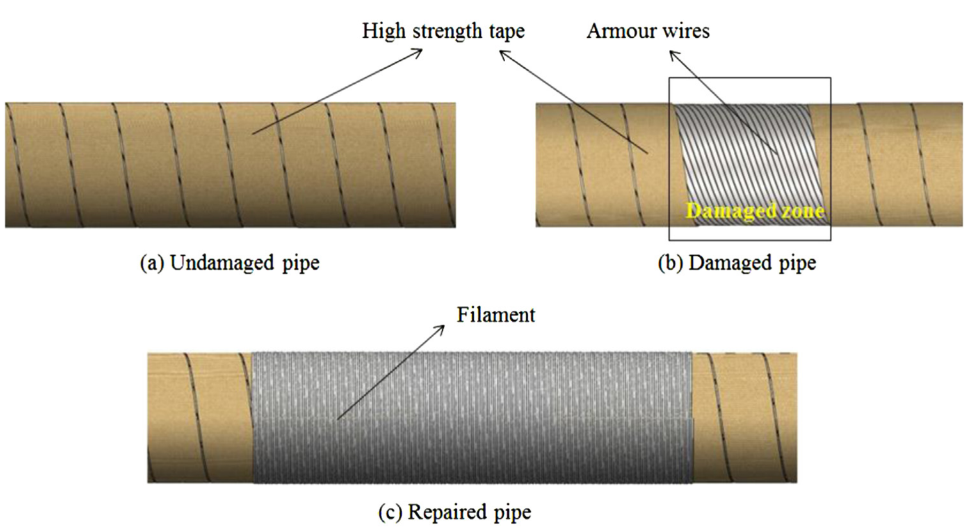

Fig. 4. Schematic diagram of damaged and repaired pipe.

Download English Version:

https://daneshyari.com/en/article/1724992

Download Persian Version:

https://daneshyari.com/article/1724992

Daneshyari.com