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Focus

# Sustainable recycling of mooring ropes from decommissioned offshore platforms

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ABSTRACT

Decommissioning offshore *Floating Production, Storage and Offloading* (FPSO) platforms requires extensive technical knowledge, since it generates different post-consumer materials, including mooring lines. These ropes are made from polyester high tenacity yarn, based on polyethylene terephthalate (PET), and their high added value means they should not be discarded as scrap. This paper aims to present a review and technical opportunities, from an economic standpoint, of recycling the mooring lines recovered from decommissioned FPSOs. Studies conducted over the last two years have researched and developed different potential applications for the fibers. These studies include collaborative project initiatives involving technical and management professionals, universities and private enterprises, with a view to achieving a more sustainable destination for these fibers.

## 1. Introduction

The oil and gas sector is facing a sharp rise in decommissioning spending, forecasting an increase from around US$ 2.4 billion in 2015, to almost US$ 13 billion, per year, by 2040 (Correa and Russel, 2017).

Briefly, the decommissioning procedure consists of transporting the platform to an onshore dock, where it is dismantled and the parts removed for future sale and reuse (Dexter and Ghorashi, 2016; Junior Alves and Souza, 2017; Rouse et al., 2018; Montenegro, 2017).

The world's offshore oil and gas structures are aging and becoming obsolete and selecting the optimal decommissioning process is a complex decision involving a number of primarily environmental impacts that are also related to financial and socioeconomic considerations (Kruse et al., 2015; Fowler et al., 2014; Cripps and Aabel, 2002; Schroeder and Love, 2004).

In FPSO decommissioning, and mooring lines specifically, this involves the rope and mooring system suppliers, as well as the FPSO owner and its operators. In this case, ropes made from polyester are not biodegradable (Li et al., 2010) and cannot be disposed of on the seabed or used in artificial reefs, meaning they need to be treated or processed to ensure environmentally adequate disposal.

The FPSO platforms installed along the Brazilian coast in the late 1990s will reach the end of their operating life in the coming year. Furthermore, new units (around 38) are being installed in deeper and deeper water, accounting for around 70,000 tons of mooring ropes (Correa and Russel, 2017).

The aim of this review is to present different techniques for recycling retired mooring ropes, maximizing the value capture of high-performance polyester fibers employed in rope manufacturing. These studies are aligned with the decommissioning process of offshore platforms.

## 2. Performance fibers for deep water offshore mooring ropes

The use of synthetic fiber ropes for deep-water conditions is well established and growing. Despite some initial difficulties with aramid ropes 20 years ago, polyester fiber has become an accepted alternative to steel for this application (Davies et al., 2008; Davies et al., 2002; Rossi et al., 2010; Bastos et al., 2015a; Bastos et al., 2016).

Polyester high-tenacity yarn for mooring ropes is produced by multi-filament melt spinning following by drawing and heat setting in a single process (Fig. 1). The temperature required for melt spinning process is above 270 °C (Bastos et al., 2015b; Ming, 2012). A silicone/wax based "marine finish" is added to the filament surface before

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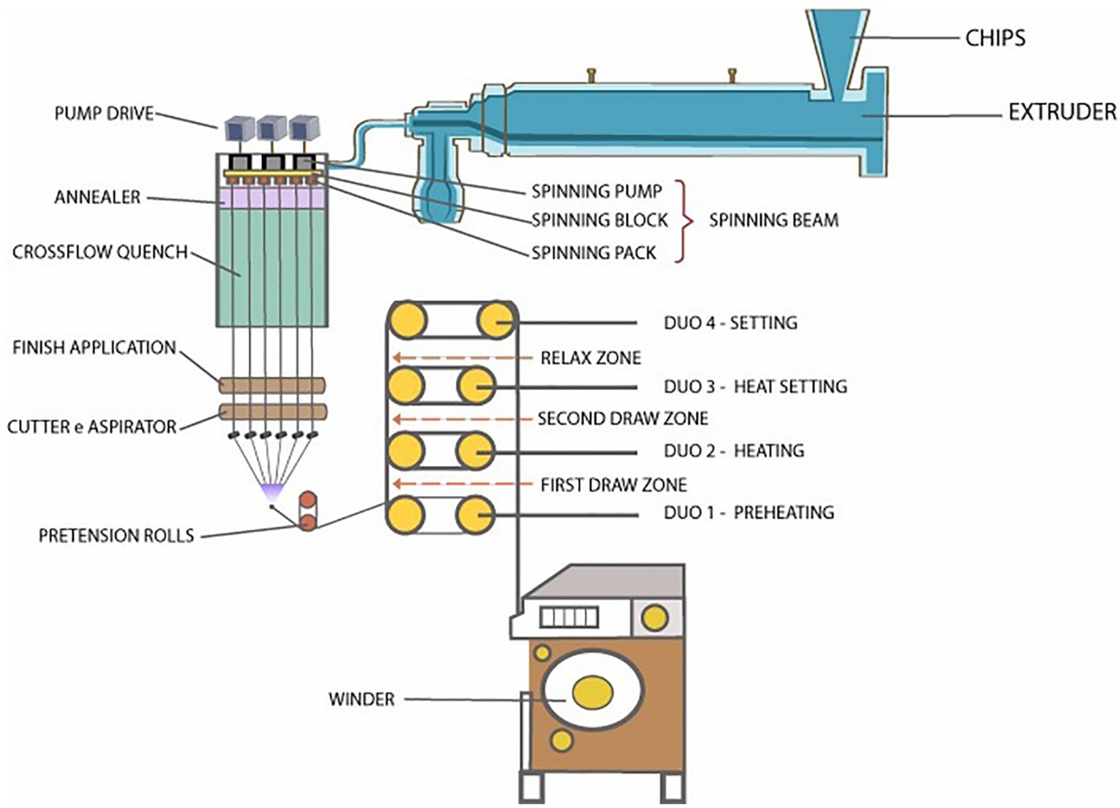


**Fig. 1.** Industrial polyester melt spin-draw diagram.

winding into cardboard tubes.

Since the 1990s, the MBL (minimum breaking load) in rope construction has been 320 tons-force to 2000 tons-force, with an external diameter of 106 to 265 mm. Construction involves a number of parallel sub-ropes made from twisted and/or braided multifilament polyester high tenacity yarn with a marine coating. A nonwoven polyester filter is used wrap the sub-ropes. Finally, a jacket is made from twisted and braided polyester yarn with no special finish and includes color-coded yarn to identify the supplier and indicate the torsion allowed during deployment and installation, as shown in Fig. 2 (Davies et al., 2014; Ayers and Renzi, 2010; Weller et al., 2014; Brasil, 2010a. Law 12.305, 2010).

## 3. Collaborative innovation projects

Collaborative innovation projects are the best and most cost effective way of handling future FPSO decommissioning operations and, specifically, the challenges involved in treating and processing technical waste such as scrapped mooring ropes. These inter-organizational relationships (IORs) are voluntary partnership agreements between legally autonomous organizations (Albers et al., 2015) to conduct a variety of interdependent projects with a view to achieving common goals (Mishraa et al., 2015) in rope recycling economics.

From an economic standpoint, rope recycling is structured similarly to PET bottle recycling, since it is based on the same polymer material: polyester terephthalate, also known as PET. The main concern in PET bottle recycling is the thermal energy costs, which affect the carbon footprint. This includes the high energy consumption needed for grinding, melting, lamination, extrusion and solid state post-condensation to increase intrinsic velocity (IV).

The melt spinning and drawing process to produce yarn requires high energy consumption. The priority of rope recycling is to use the fibers already formed in a downstream process that is not energy demanding and benefit from the fiber properties obtained.

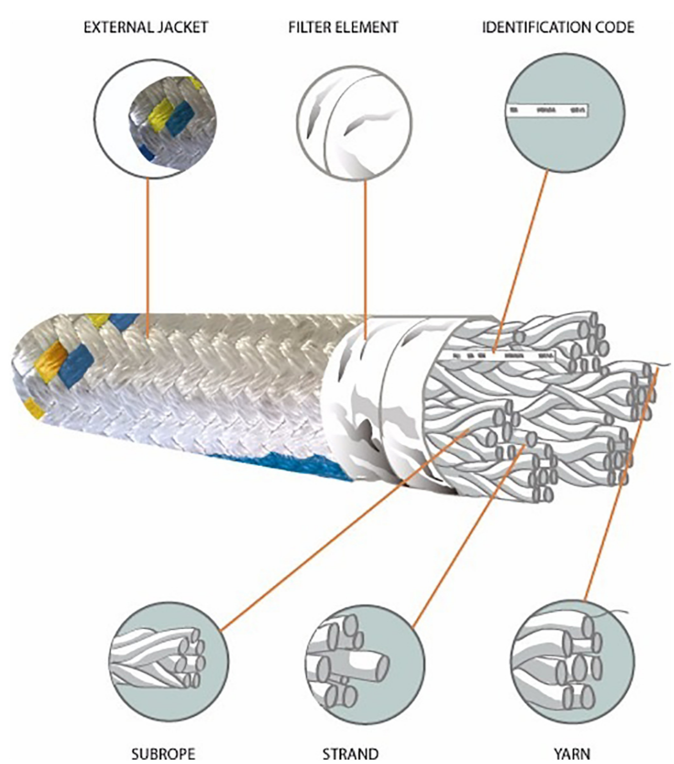


**Fig. 2.** Mooring rope representation [Adapted from Davies et al., 2014].

The other alternative is to grind and melt these fibers and produce a molten polymer that can be extruded in order to make high value added products based on the high-tenacity polymer the fibers are made from. This route involves much higher energy costs, but is still economically feasible because used ropes are sold at the same price as scrap steel