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A comprehensive study on composite risers: Material solution, local end fitting design and global response

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ABSTRACT

Two up-to-date composite riser solutions, specifically, the thermoset and thermoplastic based ones are studied in a global-local framework to examine their technical feasibility for offshore applications. At the local scale, the riser pipe body with multi-layered structure is homogenized through an analytical approach, obtaining equivalent material properties of the riser string model for the global analysis. The metal-composite interface (MCI) end fittings between the riser body and standard connector are examined using finite element (FE) simulations to understand their load-transfer mechanisms for both solutions. At the global scale, an in-house analysis code is performed to study the risers' static and dynamic response in a certain sea condition due to top-tension, current drag and vortex induced vibration (VIV). The analyzed parameters include the resulting riser deflection, axial stress, tension and bending moment distributions. Following that, an integrated analysis utilizing the global results and the local failure envelopes is performed to determine if the maximum stress states of the riser exceed the equivalent structural strength boundary. It is concluded that composite risers exhibit a larger safety margin than traditional steel riser under the same sea condition.

1. Introduction

Offshore engineering is generally divided into surface water, shallow water (< 500 m), deep water (between 500 and 1500 m) and ultra-deep water applications (> 1500 m). Oil and gas exploration and production are currently moving from shallow water into deeper waters, with numerous proven results in regions such as the Gulf of Mexico and Campos Basin of Brazil. The riser, transporting oil and gas from the subsea wellhead to the production platform on the surface is an indispensable component. Its capacity and performance directly determines the economic efficiency of the field.

For typical top-tension risers (TTRs) which are widely used for tension leg platforms (TLPs) and spars, a lifting force is applied by the top-tensioner to eliminate compression at the bottom and help keep it vertical. Traditional TTRs are usually made of high grade steel and few key components are made of titanium. The low strength-to-weight ratio of these metallic materials makes them unfavorable for deeper applications. Carbon fiber reinforced polymers (CFRP), which is widely used in the aerospace industry, may serve as a potential solution due to superior properties such as lightweight, high specific strength, corrosion resistance, high thermal insulation, high vibration dampening and excellent fatigue performance [1–3]. The application of CFRP would significantly benefit the oil platform in many ways, such as lower top-tension load requirement, which leads to cost savings by using a smaller tensioner and decreasing platform size and mooring system [4]. However, with these potential advantages that the use of composite risers may

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Table 1
A summary of previous joint industry projects on composite risers. P denotes production riser and D denotes drilling riser.

Year	Project/Country	Riser type	Length /m	ID /m	Thickness /mm
1985–1987	Joint Industry Program (JIP) by Institut Francais Dupetrole/France [5,6]	P	4 and 15	0.2286	9.57 (carbon) 7.28 (glass) 1.1 (inner layer)
1994–2000	NIST Advanced Technology Program/US [7–11]	P&D	2.286	0.255/ 0.496	Not specified
1995–2001	Heidrun/Norway [12]	D	14.585	0.536	Not specified
2009	Part of NIST Advanced Technology Program by University of Texas/US [13]	D	4.57	0.540	30.5
2008–2011	RPSEA/US [14]	D	10	0.508	25.4 (liner) 53.3 (composite)
2011	Magma/UK [15,16]	P&D	Up to 27.4	0.047–0.6	7–39

present, three are inevitably some challenges that come alongside the use of composite risers. One such challenge is the added complexity in performing realistic analysis on such systems, both within the material itself and also between the numerous components present in the riser.

The idea of using composite materials for risers emerged some two decades ago and the interests have been increasing since then. Table 1 summarizes some major joint industry projects.

In addition to the major JIP projects, there have also been more recent works looking at various aspects of a deepwater riser structure. They include studies on the risers with varying properties [17–19], local investigations of flexible riser components [20–23], and VIV predictions [24–27].

Fig. 1 shows a typical composite riser configuration with structural details on joints. The riser is a long string of many pipe segments joined together using flange-bolt, clamp or thread connections. Within each pipe segment, the middle tubular body is attached to the end connector via the metal-composite interface (MCI) end fitting. The end fitting is a critical region for the load transfer between the connector and the riser body. A reliable end fitting is vital for the joint, with equal or even higher importance than the tubular body.

This paper is organized as follows. Firstly, the homogenization scheme dealing with the riser body and two types of end fitting designs are analysed at the local scale. Following that, a series of parametric simulations are performed at the global scale to study the static and dynamic behaviours of composite risers, as well as a traditional steel riser as a benchmark. Results from the global model and the locally developed failure envelopes are then employed to assess the riser design. Finally, point-based findings and suggestions for further development are provided in the conclusion.

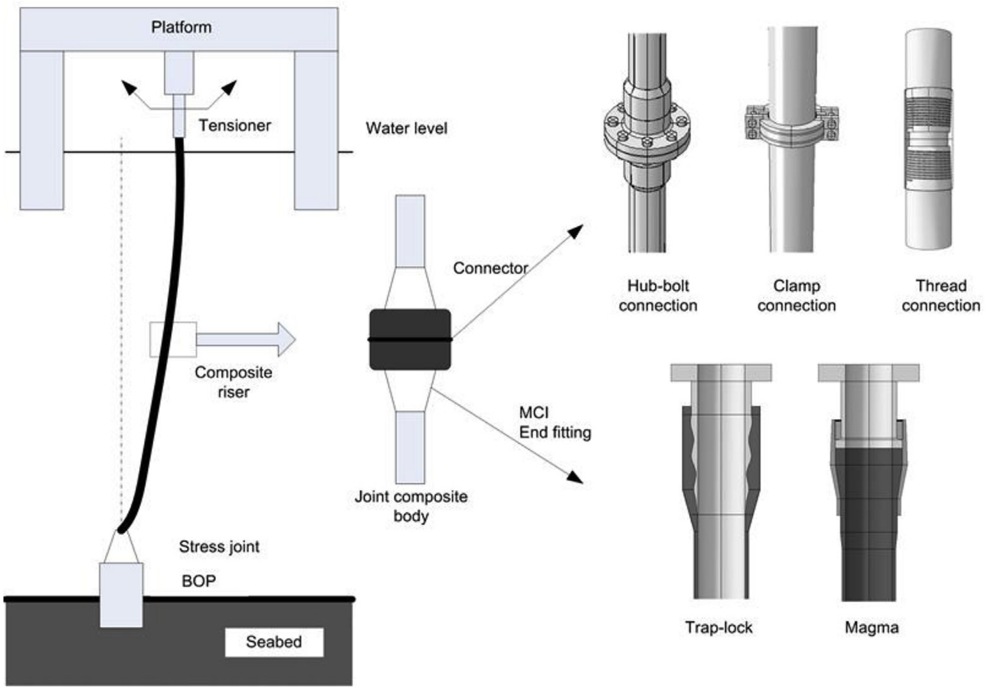

Fig. 1. A typical composite riser configuration.