Marine Structures 63 (2019) 117–137

Contents lists available at ScienceDirect

Marine Structures

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

A simplified multi-layered finite element model for flexible pipes

Dong-Hyun Yoo[a], Beom-Seon Jang[b,*], Ran-Hui Yun[a]

[a] Department of Naval Architecture and Ocean Engineering, Seoul National University, Seoul, South Korea
[b] RIMSE, Department of Naval Architecture and Ocean Engineering, Seoul National University, Seoul, South Korea

ARTICLE INFO

Keywords:
Flexible pipes
Simplified FE model
Nonlinear FE analysis
Ultimate strength assessment

ABSTRACT

A flexible pipe connects offshore platforms to the flowlines and transport gas and oil. It may experience axial compression due to the reversed end cap effect during installation. This can trigger radial buckling or lateral buckling of tensile armor layers. The ultimate strength assessment of the flexible pipe is complicated and time-consuming due to material nonlinearity, large deformation, and nonlinear contact mechanism. These difficulties make the nonlinear analyses difficult to converge. This paper proposes a simplified 5-layered model which can improve the convergence without deteriorating the accuracy. Analytical methods are suggested to determine an equivalent layer to replace inner four layers. In addition, the factor of penetration tolerance (FTOL) of shell element layers needs to reflect the thinning of polymer layers, which makes the axial stiffness equal to the solid element model. Analytical methods are used to determine the factor and a stepwise increasing approach is applied in a numerical analysis.

The 5-layered model with the stepwise FTOL application is verified by comparing with 8-layered model, analytical model and experiment results with respect to axial and bending stiffness. The model is used for an ultimate strength assessment, the failure mechanism and the interaction between layers are investigated in detail with incremental loading.

1. Introduction

Floating offshore structures consist of 3 parts; topside process module, floating platform and subsea modules. Flexible pipes play a role of connecting the platform to flowlines like Fig. 1. They are usually used for dynamic applications that receive various loads cyclically. With respect to mechanical behaviors, they have high axial tensile stiffness and low bending stiffness. The bending stiffness of flexible pipes is known to be about 1/25 of that of steel catenary risers with same diameter. This feature is due to the complex unbonded multi-layers. The flexible pipes consist of metal and polymer layers. The model used in this paper is composed of eight layers. From the inside, carcass, pressure sheath, pressure armor, a pair of anti-friction tapes, a pair of tensile armor layers and fabric tape are laid as shown in Fig. 2.

Each layer has its own function. Carcass, the innermost layer, enables the flexible pipe to withstand strong external pressure. However, the internal fluid can pass through the carcass. Therefore, this layer cannot withstand the internal pressure. On the other hand, pressure armor serves to withstand both internal pressure and external pressure. The carcass and pressure armor have a unique cross-sectional shape like Fig. 3. Therefore, both layers have high radial stiffness and low axial stiffness. Moreover, a pair of tensile armor layers has large axial stiffness and consists of helically wound tendons. The winding directions of these layers are opposite to keep the same torsional strength for both rotational directions. In addition, anti-friction tapes reduce the friction between metal layers. Finally, pressure sheath and fabric tape play roles of insulation and watertight simultaneously.

* Corresponding author.
E-mail address: seanjang@snu.ac.kr (B.-S. Jang).

https://doi.org/10.1016/j.marstruc.2018.08.006
Received 6 June 2018; Received in revised form 25 August 2018; Accepted 25 August 2018
0951-8339/

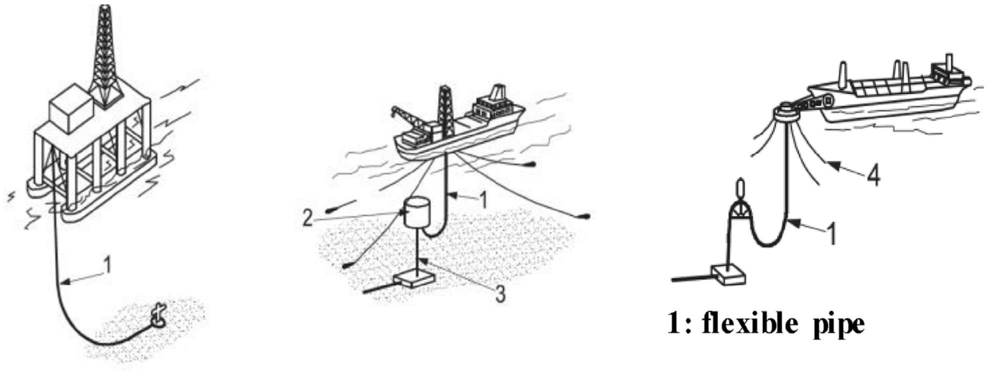

Fig. 1. The concept of flexible pipe.

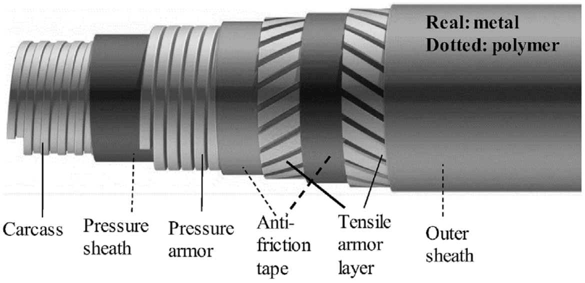

Fig. 2. Composition of flexible pipe.

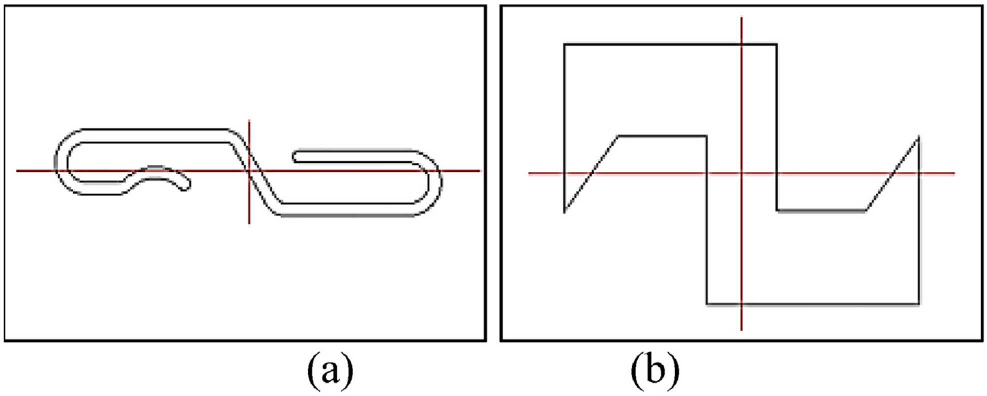

Fig. 3. Cross section of (a) carcass and (b) pressure armor.

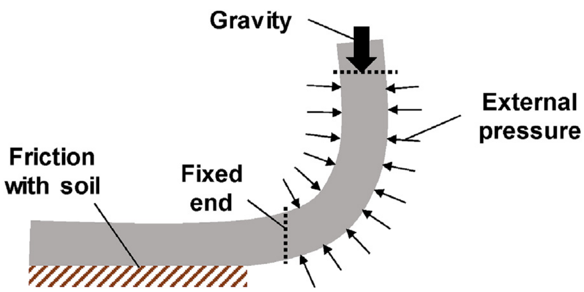

Fig. 4. Occurrence of axial force at TDZ.