IJNAOE
©SNAK, 2014

*Int. J. Nav. Archit. Ocean Eng. (2014) 6:685~699*
*http://dx.doi.org/10.2478/IJNAOE-2013-0205*
*pISSN: 2092-6782, eISSN: 2092-6790*

# Dynamic responses of a riser under combined excitation of internal waves and background currents

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**ABSTRACT:** *In this study, the dynamic responses of a riser under the combined excitation of internal waves and background currents are studied. A modified Taylor-Goldstein equation is used to calculate the internal waves vertical structures when background currents exist. By imposing rigid-lid boundary condition, the equation is solved by Thompson-Haskell method. Based on the principle of virtual work, a nonlinear differential equation for riser motions is established combined with the modified Morison formula. Using Newmark-β method, the motion equation is solved in time domain. It is observed that the internal waves without currents exhibit dominated effect on dynamic response of a riser in the first two modes. With the effects of the background currents, the motion displacements of the riser will increase significantly in both cases that wave goes along and against the currents. This phenomenon is most obviously observed at the motions in the first mode.*

***KEY WORDS:*** Dynamic response; Internal waves; Background currents; Taylor-goldstein equation; Newmark-β method.

## INTRODUCTION

Marine risers are important equipment for the exploration of oil/gas in deep water, which usually serve as the bridge between an offshore platform and the well head on the seabed (Kaewunruen et al., 2005; Ju et al., 2012). As exploration activities move into deepwater, the long slender risers tend to undergo large-amplitude motions (Xu et al., 2013). Internal waves are believed to be responsible for a great deal of damage. This is because they can create enormous local loads and bending moments on offshore structures. The internal waves have been reported to induce an additional displacement of 200*m* in the horizontal plane and 10*m* in the vertical direction (Chakrabarti, 2005). Therefore, the internal waves should be considered in analysis and design of marine risers.

The internal waves occur frequently in South China Sea where water is deep (Du et al., 2001). At the current stage, most investigations focus on the generation, propagation, transformation and other properties of internal waves, few studies are related to their effects on offshore structures. Cai et al. (2003; 2008) firstly introduced Morison empirical formula and modal separation method to estimate the forces and torques exerted by internal solitons on cylindrical piles. They found that the background currents will modify the properties of internal waves and enlarge both force and torque (Cai et al., 2006; 2008). Ye and Shen (2005) calculated and analyzed the force of internal waves on small-scale cylinder in different frequencies and then

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compared with that of surface waves and currents. Du et al. (2007) found that the maximum total force caused by a soliton of a current with speed of 2.1 $m{\cdot}s^{-1}$ is nearly equal to that by a surface wave with a wave length of 300 $m$ and a wave height of 18 $m$. A lot of studies have been conducted on the effects of internal solitons on marine risers in time domain by experimental, numerical and even CFD methods (Song et al., 2011; Chen et al., 2011; Liu et al., 2011). Jiang et al. (2012) estimated the dynamic characteristics of a Top Tension Riser (TTR) under internal solitary and non-uniform current by mKDV theory in a two-layer fluid. Guo et al. (2013) computed the dimensionless displacement and stress of TTR under combined excitation of internal solitary waves, surface waves and vessel motion in time domain. However, most of these investigations are concentrated on the nonlinear internal waves such as internal solitons and internal solitary waves by using KDV theory, few are on the dynamic response of marine riser under combined excitation of internal waves of high frequency and background currents.

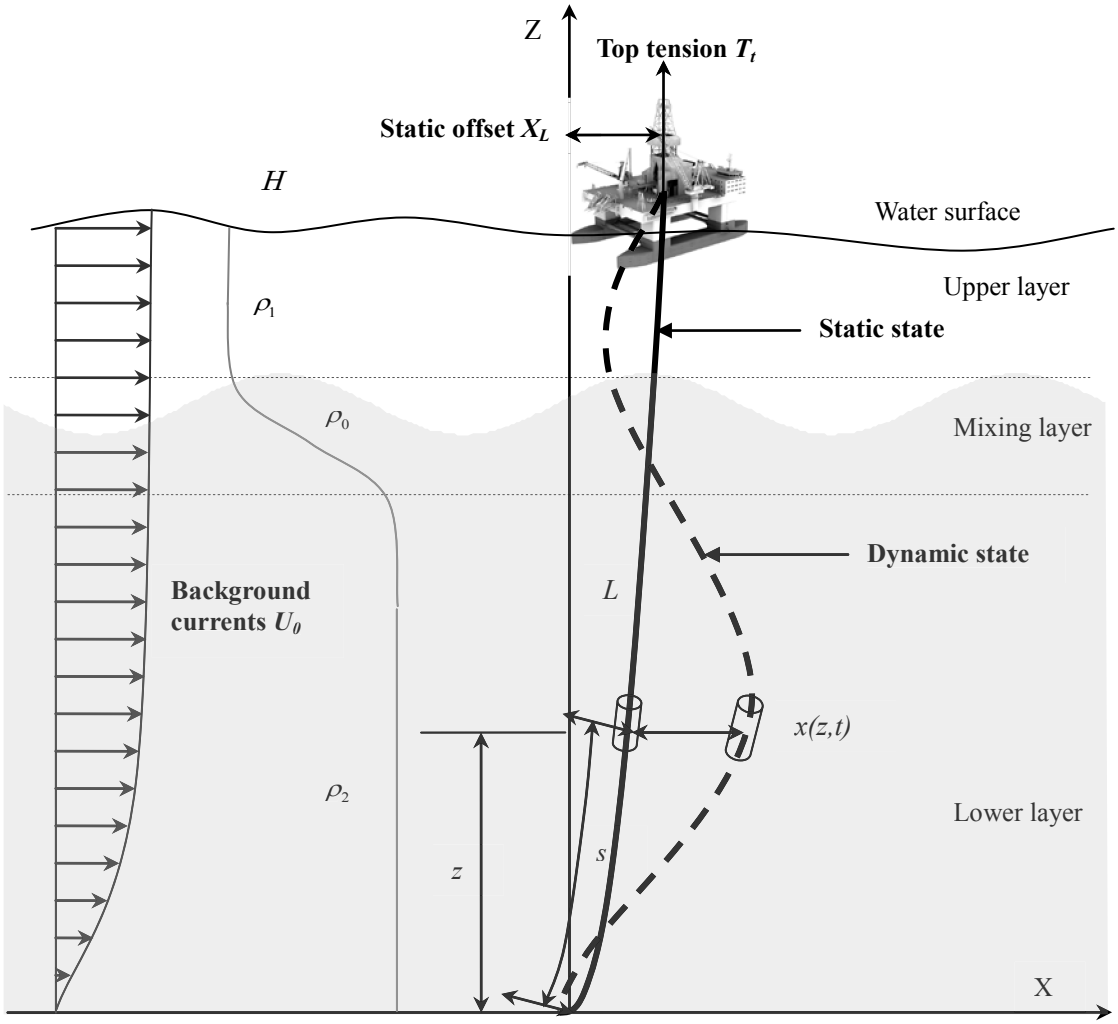


Fig. 1 Sketch of a riser under the combined excitation of internal waves and background currents.

In this study, the finite element method is applied to calculate the dynamic response of a marine riser conveying fluid subjected to internal waves and background currents. The basic equations of internal waves should be modified if background currents are considered. Thus, it is instructive to demonstrate the effect of background currents on the dynamic response exerted by internal waves on a supposed riser for comparison with no current case. The schematic diagram for a marine riser conveying fluid in internal waves and background currents is shown in Fig. 1. In sections 2 and 3, the governing equation of internal waves, the differential motion equation of a marine riser and the solution methods are presented. The computational results of different cases are discussed in section 4 and the conclusion is given in section 5.