VIV Analysis of a Riser under Top Excitation Conditions with a Numerical Method

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ABSTRACT

The object of this study is to develop the tool to analyze VIV (vortex-induced vibration) of a slender marine structure which may vibrate in inline and cross-flow directions due to the vortex shedding on the condition of top excitation with a period and an amplitude. KC (Keulegan-Carpenter) numbers distributed along the riser length excited at the top end are calculated and the riser is assumed to be excited with the vortex shedding frequencies corresponding to different KC number along the riser length. In the case studies, vortex-induced lift force with three kinds of vortex shedding frequencies and an exciting frequency excites the riser in the cross-flow direction. The riser, by vortex-induced lift forces with the vortex shedding frequencies corresponding to different KC number along the riser length, vibrates in complex behaviour characteristics. Although the riser is excited with only one vortex shedding frequency at a point of the riser it showed to response in several frequencies component. That is caused by the structural wave propagation along the riser length. This research can contribute the prediction of fatigue and design life for a riser.

KEY WORDS: VIV; top excitation; riser; numerical analysis; Keulegan Carpenter number; FDM;

INTRODUCTION

Vortex-induced vibration (VIV) is a vibration phenomenon created by fluid shedding around a slender marine structure. At a low Reynolds number, a structure vibrates at the inline direction due to symmetric vortex shedding, but as the flow speed gradually increases, the vortex sheds asymmetrical to the structure, creating a cross-flow vibration (Blevin, 2001). VIV induces a dynamic vibration despite a constant static-flow condition, and has a large influence on the lifespan of a structure.

The oscillating pressures cause a structure to vibrate in the cross-flow direction even under wave or top excitation conditions. While a slender structure sheds vortices symmetrically along the length of the structure under a constant flow velocity, the VIV in an oscillating flow or top excitation grows more complex along the length of the structure. The wave particle trajectory varies, has the maximum amplitude on the sea surface, and decreases as the water gets deeper. The VIV effect on a vertical slender structure is generally shown to be minimal. Depth-varying water particle velocity causes different amplitudes and frequencies in VIV along the length of a structure in the oscillating flow, resulting in very complicated VIV characteristics under the wave or top excitation conditions.

An offshore structure, like a riser, is connected to the upper structure, and the movement of the upper structure is applied as forced excitation at the end of the riser. The external force that applies to the top end of the riser excites the entire riser.

The VIV characteristics of a riser by top forced excitation are similar to those by waves. The top excitation of a riser gives rise to inline vibration with a different amplitude along the riser length according to the excitation condition.

The characteristics of the vibration of a riser excited with the amplitude and frequency can be determined by the KC number (Keulegan-Carpenter number). The different KC numbers distributed along the riser length according to the excitation condition result in the multiphase frequencies of the response in VIV originating from the different KC numbers. Therefore, if a riser vibrates in the inline direction by waves or top excitation, the VIV analysis in the cross-flow direction should be based on the consideration of the KC numbers distributed differently along the length of the riser. Park et al. (2004) explained this phenomenon with a forced-vibration test on a free-hanging riser with the experimental study. They found that several different VIV frequencies were generated identically along the length of the riser, and that the energy induced by the VIV behavior propagates along the length of the riser. There have been researches on the VIV of a slender marine structure (Jauvitis & Williams, 2003; Riveros et al., 2009). Jauvitis and Williams evaluated the inline and cross-flow vibration phenomenon in quantity through an experimental study.

This study was conducted for the purpose of analyzing the characteristics of the VIV behavior in the cross-flow direction of a riser excited at the top end in the inline direction, using numerical analysis. The inline displacement along the riser length was evaluated, and the KC numbers at all the nodes of the riser were calculated. A vortex-induced lift force with a frequency according to the KC number was applied to each node of the riser in the cross-flow direction.

KC NUMBER AND VORTEX-SHEDDING FREQUENCY ON THE RISER UNDER TOP EXCITATION CONDITIONS