Features of a Near-Surface Tethered body in Waves and Currents

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SUMMARY

This is the final report for the one-year project of "Features of a Near-Surface Tethered body in Waves and Currents", started 1 October 1998 and ended 31 July 1999. The specific goal of the project is to investigate the effects of current and irregular waves upon the characteristics of the short surface-wave patterns by moored near-surface objects. A powerful simulation program, developed for the nonlinear dynamics of a coupled cable-buoy system in waves and currents, is applied. Through systematic simulations, it is found that similarly to the regular wave case (Zhu et al 1999), the result of cable snapping, chaotic body response and the associated amplification of short-wave generation is also obtained under irregular wave conditions and in the presence of current. In particular, it is found that due to the increase of viscous damping, the key effect of the current is to intensify mode switching in cable-buoy snapping responses and increase the threshold value of the incident wave amplitude for the onset of chaotic buoy motions. The study has an immediate implication to the detection of submerged near-surface bodies under realistic coastal wave-current conditions by remote sensing.

SPECIFIC OBJECTIVES

To extend our research on the dynamics of a tethered near-surface buoy to include the effects of irregular waves and current. The primary focus is on the possible effects these have on the cable snapping, the chaotic buoy motion, and the radiated short surface-wave pattern.

APPROACH

A powerful simulation method for the coupled nonlinear dynamics of a submerged moored buoy in the presence of surface waves is extended to include the effects of irregular waves and current. The method is developed based on the coupling of an efficient high-order spectral method for the nonlinear wave-buoy interaction problem with a robust implicit finite-difference method for the cable-buoy dynamics. The numerical scheme accounts for nonlinear wave-wave and wave-body interactions up to an arbitrary high order in the wave steepness and is able to treat extreme motions of the cable including conditions of negative cable tension. This scheme is capable of simulating highly transient snapping motion of the buoy-cable system and quantifying the resulting high-frequency free-surface signature associated with such motions.

WORK COMPLETED

The main work completed includes:

- Extend the coupled wave-cable-buoy nonlinear program to include the presence of currents and multiple-frequency/directional-component ambient waves
- Perform systematic simulations involving realistic near-shore wave and wave-current conditions
- Understand and elucidate the mechanics of quasi-periodic and chaotic responses and the mechanisms of mode switching under multiple wave-current component conditions

RESULTS

Our systematic simulations show that cable snapping and chaotic response of the buoy, which are identified under regular waves (Tjavaras et al 1998), also obtain for irregular waves. Like the regular wave case, the generation of short/high-harmonic surface waves are remarkably amplified once the cable-snapping/chaotic-motion sets in.

Our simulations also show that the presence of a current does not change the fundamental behavior of the cable snapping and chaotic buoy response. *Due to the increase of viscous damping, the key effect of the current is found to intensify mode switching in cable-buoy snapping responses and increase the threshold value of the incident wave amplitude for the onset of chaotic buoy motions.*

Figure 1 shows the time histories of the cable-end tension for a tethered near-surface spherical buoy in surface waves (Zhu et al 1999) with and without a small current. Cable snapping is clearly seen in both cases. More apparent mode switching is shown for the case with the presence of a current. A typical three-dimensional (snapshot) wave pattern over the buoy associated with chaotic buoy motion in the presence of a current is shown in figure 2. The radiated/diffracted waves are out-weighted by short waves both radially and circumferentially. Compared to the zero current case (Zhu et al 1999), the short surface wave patterns are slightly shifted downstream.

IMPACT/APPLICATION

The finding of this study is of immediate importance to the detect-ability of wave/wave signatures of underwater moored objects under realistic coastal conditions. Also, the finding has a significant implication to the design and analysis of oceanographic mooring systems.

TRANSITIONS

The present study can be used to determine detectable short surface-wave patterns for the detection of submerged moored objects with remote sensing. In addition, the computational method developed in this study can be readily applied to the general nonlinear problems of moored bodies in waves.

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Zhu, Q., Liu, Y., Tjavaras, A.A., Triantafyllou, M.S. and Yue, D.K.P. "Mechanics of nonlinear short-wave generation by a moored near-surface buoy," *Journal of Fluid Mechanics*, 381, pp.305-335, 1999.

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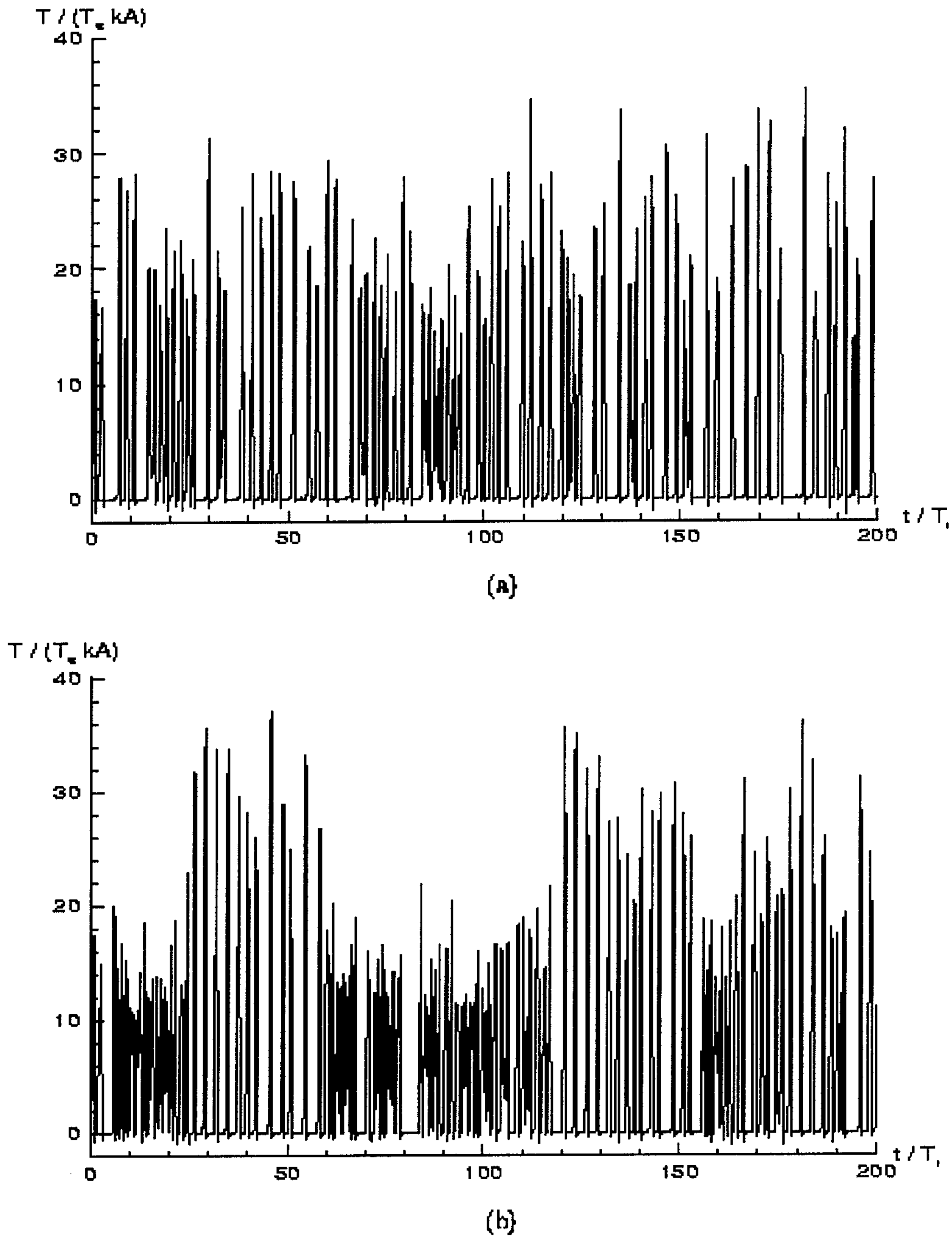

Figure 1: Time history of the top-end cable tension $\boldsymbol{T}$ ($\boldsymbol{t}$), normalized by the static tension of the cable $\boldsymbol{T}_s$, for incident wave steepness $\boldsymbol{kA}$=0.13 and period $\boldsymbol{T}_i$=5 and current speed $\boldsymbol{U}$=: (a) 0; and (b) 0.2 m/s.

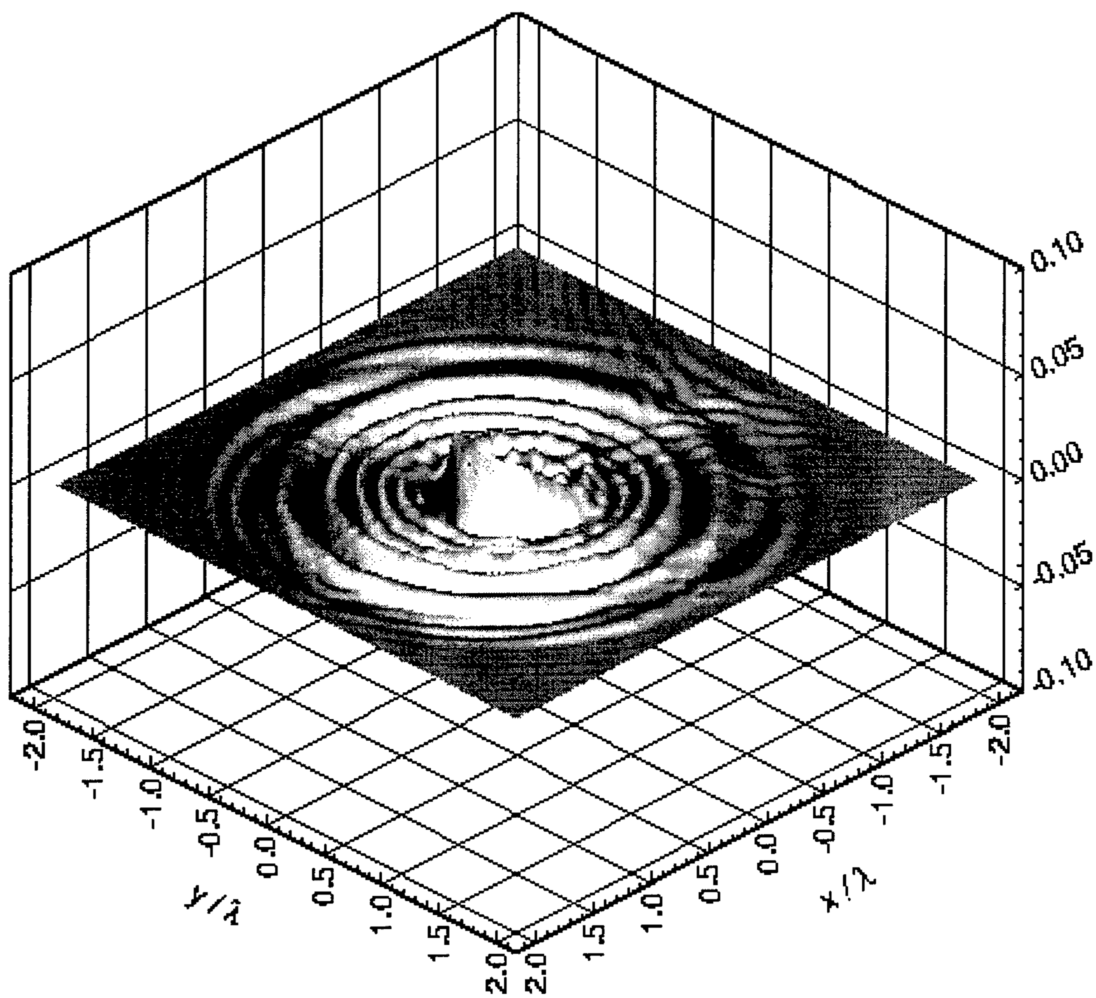

Figure 2: Instantaneous three-dimensional free-surface wave elevation (normalized by incident wave amplitude A) at time t/T_i=23 for incident wave steepness kA=0.13 and period T_i=5 s and current speed U=0.2 m/s. The incident wave itself is subtracted. Both the incident wave and current are in the $+x$ direction.

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14. ABSTRACT
The goal is to investigate the effects of current and irregular waves upon the characteristics of the short surface-wave patterns by moored near-surface objects. A powerful simulation program, developed for the nonlinear dynamics of a coupled cable-buoy system in waves and currents, is applied. Through simulations, it is found that similarly to the regular wave case, the result of cable snapping, chaotic body response and the associated amplification of short-wave generation is also obtained under irregular waves and in the presence of current. In particular, it is found that due to the increase of viscous damping, the key effect of current is to intensify mode switching in snapping responses and increase the threshold value of the incident wave amplitude for the onset of chaotic buoy motions.

15. SUBJECT TERMS
Wave, current, near-surface. tethered body, cable snapping chaotic response, short-wave generation.

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