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The Effect of Unsteady Motion on the Drag Forces and Flow-Induced Vibrations of a Long Vertical Tow Cable

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ABSTRACT

Drag coefficients and flow-induced vibrations of a long vertical tow cable are measured under steady and unsteady towing conditions. The steady-state drag coefficients range from 2.2 to 2.5. For unsteady towing conditions, the drag coefficient was lower by as much as 40%, depending on the frequency content of the planar ship motion. For purely oscillatory motion, the drag coefficient decreased as the frequency of motion increased. The reduction in the drag coefficient may be related to the amplitude modulation of the flow-induced vibrations of the cable, which are magnified during unsteady operations. When the surface ship changes speed, differences in the normal component of the velocity along the cable are present because of time delays in the response of the bottom of the cable to inputs at the top. The longer the cable, the greater are the delays. This creates large velocity gradients in the oncoming flow which are responsible for the intensification of the amplitude-modulation above the level that is observed during steady-state towing conditions. The overall effect of the amplitude modulation is a reduction in the hydrodynamic drag forces.

INTRODUCTION

In this paper, we present the results from full-scale experiments of the quasi-static and dynamic behavior of a long vertical tow cable during steady and unsteady towing operations. The overall motivation for the experiments was to improve performance in the positioning of towed vehicles, for example, ARGO — the Deep Submergence Laboratory's search and survey system.

The data were collected in two separate experiments. The first experiment (Yoerger, Grosenbaugh, Triantafyllou and Burgess, in press; Grosenbaugh, Yoerger, Triantafyllou and Hover, submitted) took place in the spring of 1987 at the U.S. Navy's Atlantic Underwater Test and Evaluation Center (AUTEC) in the Bahamas. The second experiment was carried out in the summer of 1988 in the Tyrrhenian Sea.

The studies show that the drag coefficient of the cable is lower during *unsteady* towing operations (by as much as 40%) than during *steady-state* operations. We believe that the reason for this is related to the observed amplitude modulation of the flow-induced vibrations of the cable which are magnified during unsteady operations (Grosenbaugh, Yoerger, Triantafyllou and Hover, submitted).

When the tow ship changes speeds (e.g., during maneuvering operations), there are differences in the normal component of the velocity along the cable because of the presence of a time delay in the response of the bottom of the cable to inputs at the top. The longer the cable, the greater are the delays. This creates large velocity gradients (in addition to those that already exist due to the ambient shear currents).

Triantafyllou et al. (1988) and Howell (1989) have shown that velocity gradients in the oncoming flow are responsible for the formation of beats in the flow-induced vibrations of long marine cables. Howell assumes that, because of fluid damping, the cable is infinitely long, and so it does not have natural transverse frequencies. Instead, the cable vibrates locally at whatever frequency it is being forced, in this case, the local Strouhal frequency. The local response creates transverse waves that travel along the cable and interact with the motion at nearby locations. In a shear flow, the forcing at a nearby location of the cable will be at a slightly different frequency, and thus the interaction of the traveling waves produces beats. These in turn propagate along the cable and modulate the amplitude of the cable response. Modulation of the vibration amplitude acts to lower the root-mean-square (RMS) of the motion, an effect which leads to a lowering of the cable drag coefficient (Triantafyllou and Karniadakis, 1989).

Previous experiments have shown that the drag coefficient for towed cables and cables moored in currents can vary greatly (Vandiver, 1983; Skop, Griffin and Ramberg, 1977; Ivers and Mudie, 1973; Kim, Vandiver and Holler, 1985). The results, presented here, help to explain the large variation in drag coefficients that exists in the literature by showing just how important the time history of the flow conditions are to the magnitude of the drag forces.

AUTEC EXPERIMENT

These experiments took place at AUTEC and made use of the wide area precision acoustic tracking capabilities of the facility. The AUTEC range provided continuous tracking of a set of acoustic pingers placed on the ship, aboard the vehicle, and along the length of the cable. In addition to the acoustic pingers, a set of instrument packages which contained a triaxial accelerometer, a set of inclinometers, a compass, a data logger, and batteries was placed along the cable. Currents were measured with drifting acoustic pingers (bounce pingers) and expendable current probes (XCP). A complete description of all the instrumentation is given by Yoerger et al. (1988).

A total of four separate runs was performed, three steady-state runs using different length cables (RUN 1, RUN 2 and RUN 3) and a transient run which consisted of measuring the cable response during the acceleration to steady-state (RUN 4). Fig. 1

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KEY WORDS: Marine cables, hydrodynamic drag, flow-induced vibrations.