International Journal of Offshore and Polar Engineering
Vol. 5, No. 4, December 1995 (ISSN 1053-5381)

The Viscous Damping of a Submerged Pontoon Undergoing Forced Combined Motions in the Presence of a Weak Current

M. J. Downie, J. M. R. Graham
Department of Marine Technology, University of Newcastle upon Tyne, United Kingdom

Y.-D. Zhao and C.-Y. Zhou
Department of Aeronautics, Imperial College, London, United Kingdom

ABSTRACT

The paper describes experiments carried out on a submerged pontoon-like body, using a Planar Motion Generator. The body was forced to sway and heave, in turn and in combination, in still water and in the presence of a weak current. The rectangular model was tested with sharp and rounded edges. The results have been compared with those of two numerical models and good agreement was obtained. The investigation showed that a transverse mean current has a significant effect on the damping. Also, there can be strong interaction effects on the damping for combined motion with mixed frequencies.

INTRODUCTION

Viscous flow phenomena are of importance in many problems relating to the fluid loading of offshore vessels and fixed or floating offshore structures. Examples range from the prediction of the fluid loading on jackets, risers, tethers and pipelines, to the roll damping of ships, the slow-drift oscillation damping of moored structures and the high-frequency damping of TLPs (Faltinsen, 1990). One aspect of viscous flow phenomena that has been identified as a particular problem is that of viscous damping (Staunton-Lambert and Barltrop, 1992).

A common denominator in the solution of problems in which viscous effects are significant, insofar as they are capable of solution, is that the analysis techniques employed rely heavily on empiricism. The data required are obtained through experiment, where possible, and on the basis of best estimates where it is unavailable. Viscous damping in many cases can be attributed largely to flow separation and vortex shedding from the surface and appendages of the body in question. In what follows, the term viscous damping will be used to describe damping arising out of flow separation from the body. A means of predicting damping of this nature on a purely theoretical basis has been developed by the authors for the case of a body floating in waves at zero Froude number (Downie, Graham and Zheng, 1990). The method is currently being developed further to accommodate low forward speeds and weak cross currents (Al-Hukail, Bearman, Downie, Graham and Zhao, 1994). The experiments described in this paper were carried out partly as a means of validating the theory, and partly to explore further the phenomena involved.

The particular geometry was chosen because it is commonly used offshore for such varied applications as semisubmersible and TLP hulls, and because relatively little data are available relating to the fluid loading of submerged bodies of this type. Some work has in fact been carried out on semisubmersible hulls by Le Marchand et al. (1988) also using the GMP (to be described later) but they restricted their experiments to heave motions. The case of a pontoon section in circular orbiting flow has also been treated by Chaplin (1993). Otsuka et al. (1993) have conducted experiments on circular cylinders and semisubmersible hulls oscillating at low frequency in regular waves.

The present experiment was designed to explore a number of issues, some of them explicitly for validating the theory, and some because they are of a more general interest. The theory referred to above is capable of calculating the viscous damping for bodies with sharp or rounded edges, although the former is easier. The model in the experiment was equipped with interchangeable sharp and rounded edges for the purpose of validating this aspect of the theory. The model was subjected to forced motion because viscous damping of this type of body has been found to be a function not only of its geometry but also of its roll centre (Downie, Bearman and Graham, 1988). Constraining the motion to forced motion simplifies the analysis and eliminates one more possible area of uncertainty, although the theory can in fact accommodate freely floating bodies in waves. The experiments were carried out at three different depths at which the flow approximately simulates flow around a barge, a semisubmersible pontoon and a TLP pontoon, respectively.

The model was tested in pure heave and in pure sway, and also with heave and sway combined. In the combined case the model was forced to undergo large amplitude sway with a relatively small higher-frequency heave motion superposed, similar to the motions experienced by a TLP. Measurements were also made as the model described circular and elliptical orbits. The combined motion tests were intended to investigate the effect of mixed frequency motion on the force coefficients. Finally, certain selected tests were repeated in the presence of a weak transverse current.

EXPERIMENTAL EQUIPMENT

The experiments were carried out in the wave basin of the Fluid Mechanics Laboratory of the Ecole Centrale, Nantes. The basin is 18 m in length by 9.5 m in width and has a mean water depth of 2 m. At one side of the tank there is a wave generator, and at the other a beach. The tank is spanned by a bridge supported on rails running along its length. The bridge can be used as a rudimentary

Received January 24, 1994: revised manuscript received by the editors June 21, 1995. The original version (prior to the final revised manuscript) was presented at the Fourth International Offshore and Polar Engineering Conference (ISOPE-94), Osaka, Japan, April 10-15, 1994.
KEY WORDS: Viscous damping, combined motions, mixed frequencies, submerged pontoon.