

How Fixing Devices Affect Measurement Accuracy in a Experiment of the Submerged Body Flow

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ABSTRACT

When performing the circulating water channel testing of a submerged body, some form of mounting device is inevitably required to maintain the object of interest in a stationary position as the water is circulated around it. However, these devices disturb the local flow field and therefore result in measurement errors. Although various experimental guidelines and compensation schemes have been proposed for minimizing the flow interference effects of these devices, the experimental errors which they induce are still not yet fully understood. Accordingly, the present study performs a series of numerical investigations to examine the effects of two typical mounting devices, namely a vertical rod-like suspension bracket and a flat horizontal stand, on the flow fields induced around two submerged bodies, i.e. a torpedo-like body and an artificial reef block, respectively. The numerical results provide valuable insights into the flow interference effects of the two mounting devices and allow the likely experimental errors to be estimated in both cases. Moreover, the results reveal general experimental guidelines for improving the precision of the hydrodynamic evaluation results obtained from scale-model water tunnel tests.

KEY WORDS: Submerged body; modeling experiment; mounting device; flow interference.

INTRODUCTION

The hydrodynamic and cavitation properties of an object are commonly evaluated by placing the object in a water tunnel and then using some form of visualization technique to observe the resulting flow phenomena as the water is circulated around it. Such tests enable the force, moment and pressure acting on the object to be reliably measured and allow various properties of the flow field around the model, most notably the local velocity, to be evaluated with a high degree of precision. The results obtained from such hydrodynamic tests provide a useful means of verifying the data obtained from theoretical or numerical analyses and provide an invaluable source of information to facilitate both the design of the submerged object itself and that of suitable experimental procedures with which to evaluate its hydrodynamic performance. The hydrodynamic properties of an object

were traditionally examined by constructing a full-scale prototype and then performing extensive experimental testing under realistic flow field conditions. Although this technique provides an excellent indication of the hydrodynamic properties of the object of interest, the costs incurred in manufacturing the prototype model and setting up and maintaining the experimental environment are often prohibitively expensive. Furthermore, such tests are relatively inflexible in the sense that it is difficult to control and evaluate the individual effects of the various flow field parameters. Moreover, exploring the effects of design changes inevitably requires the modification (or even complete re-fabrication) of the prototype model. As a result, traditional full-scale prototype tests have been largely replaced nowadays by the use of laboratory-based experimental techniques utilizing a water tunnel and a scale model of the object of interest.

Compared with full-scale prototype tests, such methods have the advantages of a lower overall cost and an improved flexibility. However, in setting up the experiments, great care must be taken to minimize the effects of experimental errors in order to ensure the validity of the measurement results. Non-dimensional analysis techniques and numerical simulation methods also provide a powerful means of evaluating the hydrodynamic properties of an object. However, their use requires a detailed prior knowledge of the physical phenomena governing the interactions between the object and the flow field. Whilst these interactions are relatively easy to predict for objects with a simple geometrical form, the problem becomes considerably more complicated for objects with complex forms such as ship's propellers, artificial reef blocks, and so forth. As a result, experimental scale-model water tunnel tests often represent the most practical means of evaluating the characteristics of the flow field around a submerged body and of determining the physical quantities acting upon it.

As discussed above, when performing scale-model investigations, care must be taken to minimize the effects of experimental errors. In general, these errors can be attributed to three main sources, namely wall effects, a scale effect and the flow interference effect of the mounting device used to support the model in the water tunnel. To reduce the wall effect, it is necessary to increase the physical size of the water tunnel or to reduce the scale of the model. Clearly, the former approach is impractical since the dimensions of the test section within the water tunnel are fixed. As a result, it is generally necessary to reduce the physical scale of the model in accordance with the