Ocean Engineering 86 (2014) 68–81

Contents lists available at ScienceDirect

Ocean Engineering

journal homepage: www.elsevier.com/locate/oceaneng

Uncertainties in seakeeping analysis and related loads and response procedures

Yonghwan Kim [a,*], Greg Hermansky [b]

[a] Department of Naval Architecture and Ocean Engineering, Seoul National University, 599 Gwanak-Ro, Gwanak-Gu, Seoul 151-744, Republic of Korea
[b] National Research Council Canada, Ocean, Coastal and River Engineering Portfolio, Arctic Avenue, St. John's, Canada

ARTICLE INFO

Article history:
Received 7 June 2013
Accepted 8 January 2014
Available online 4 March 2014

Keywords:
Uncertainty analysis
Seakeeping analysis
ITTC procedure
Uncertainty sources
ISO UOM

ABSTRACT

This paper presents the uncertainties in seakeeping analysis and the related International Towing Tank Conference (ITTC) procedures for loads and responses for waves. One of the emerging issues in ITTC activities is uncertainty analysis. ITTC (2008) has published a report with recommendations for uncertainty analysis for ship model testing, which summarized the fundamentals and examples of uncertainty analysis. Furthermore, a specific description focusing on seakeeping experiments was introduced by the Seakeeping Committee (2011) in their procedure, 7.5-02 07-02.1 Rev. 4, ITTC – Recommended Procedures and Guidelines: Seakeeping Experiments. This procedure is based on the International Organization for Standardization Guide 98-3, Uncertainty of Measurements – Part 3 (2008). In this paper, the uncertainties in seakeeping analysis are considered, and technical issues regarding the related ITTC procedure for motion responses and loads are introduced. Next, the background of uncertainty analysis in the ITTC procedure 7.5-02 07-02.1 Rev. 4 is described in detail. The types and primary sources of uncertainty in seakeeping analysis are also described, and an appropriate procedure is proposed. Some existing representative studies on uncertainty, which were carried out with respect to seakeeping analysis, are introduced. Furthermore, this paper includes several technical issues with numerical seakeeping and loads analyses.

1. Introduction

The measurement of uncertainty is an essential element for evaluating the accuracy of experiments or measurements, including seakeeping experiments. The primary purpose of uncertainty analysis is to quantify errors and to obtain an objective index that can be used to evaluate the confidence level of measured data. In addition, the results and findings from uncertainty analyses also help to improve the quality of other experiments. In mechanical and aerospace engineering societies such as the American Society of Mechanical Engineers (ASME), American Institute of Aeronautics and Astronautics (AIAA), and American National Standards Institutes (ANSI), uncertainty analysis has been of great interest for many years and the observation of confidence levels has been discussed for both experiments and computational studies. However, in the fields of naval architecture and ocean engineering, uncertainty analysis has not been a substantial focus until recently.

Concerns relating to uncertainty in seakeeping experiments have been described by the 15th and 16th International Towing Tank Conference (ITTC) Seakeeping Committees, and their reports (ITTC, 1978, 1981) indicated that the experimental data of seakeeping test are significantly scattered. Hirayama et al. (1988) introduced an analysis on the accuracy of seakeeping experiments and the possible sources of uncertainty. However, they did not perform a systematic uncertainty analysis. Later, ITTC (1990) revisited the issue of uncertainty in ship hydrodynamic experiments and computational studies. Based on the approach of ANSI and ASME (1985), (ANSI/ASME PTC, 1985), simple analyses were introduced for a few example studies, including wave resistance experiments. Himeno et al. (1990) improved the simple analysis for ship propulsion experiments. Yum et al. (1993) introduced a more systematic study on uncertainty analysis in seakeeping experiments. They carried out a series of towing-tank experiments to measure the heave and pitch motions of S175 hulls in waves, and a systematic uncertainty analysis based on ASME's approach was performed. They also introduced the sensitivity of physical parameters in motion responses.

In the ITTC 2008 conference, the International Organization for Standardization (ISO), Guide to the Expression of Uncertainty in Measurements, 1995 (ISO-GUM) was recommended for uncertainty analysis for the ITTC community and its members' organizations. The ISO-GUM's recommended method groups uncertainty components into two categories, type A and type B, based on the

* Corresponding author. Tel.: +82 2 880 1543; fax: +82 2 876 9226.
E-mail addresses: yhwankim@snu.ac.kr (Y. Kim), greg.hermanski@nrc-cnrc.gc.ca (G. Hermansky).

0029-8018/$ - see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.oceaneng.2014.01.006

method by which they are evaluated. The type A uncertainty represents the category of random uncertainty, which is evaluated by statistical methods based on repeated measurements. The type B components are estimated by a means other than repeated observations. Following the ITTC, the Seakeeping Committee adopted the ISO-GUM for their procedure, 7.5-02 07-02.1 Rev. 4 (2011), to measure uncertainty in seakeeping experiments.

As numerical computation becomes increasingly popular, the ITTC is progressively concerned with uncertainty measurements for computation results as well as experiments. One of their primary interests related to uncertainty for numerical computations is a verification and validation (V&V) process. Because the V&V process is essential for assuring the accuracy and repeatability of computational results, the uncertainty of the results can be measured as a part of the V&V process. However, uncertainty measurements of computational results are not in a fully developed state. Guedes Soares (1991) introduced the observation of uncertainty for different theories of wave-induced motions and loads. In this pioneering work, the uncertainties of computational models were assessed from comparisons with model experiments. Additionally, linear regression models were developed to quantify the models' uncertainties and their effect on short-term prediction was assessed by first-order and second moment methods. Later, a work similar to that of Guedes Soares (1991) was introduced by Sagli (2000). More recently, Irvine et al. (2008) presented towing tank experiments and numerical computations of coupled pitch and heave motions for a surface combatant advancing in regular head waves. A test program was undertaken to provide a validation data set for unsteady Reynolds-averaged Navier–Stokes and other computational fluid dynamics (CFD) codes. Their study included a rigorous uncertainty assessment of the experimental results following standard procedures. Recently, the ITTC carried out a comparative study on the parametric roll of a large container ship (2011).

This paper introduces the details of the ITTC's procedure for the uncertainty in seakeeping experiments and in computational seakeeping analysis. For seakeeping experiments in a towing tank or a seakeeping basin, the ITTC procedure 7.5-02 07-02.1 is applicable. In this paper, the general concept of the ISO-GUM for the application of uncertainty analysis of seakeeping experiments and the primary sources of uncertainty is introduced. Furthermore, this paper communicates the uncertainties in computational analyses of seakeeping problems. Although a systematic method is not developed yet, the general concept of uncertainty measurements is introduced. This paper includes some examples that were chosen from previous studies. These examples enable the understanding of the current status of uncertainty analysis in seakeeping problems.

2. ITTC procedure for uncertainty analysis in seakeeping experiments

2.1. Uncertainty in seakeeping experiments

Although it is obvious that uncertainty analysis can improve the accuracy and confidence of experimental results, it is not a simple task for seakeeping experiments because of the high expense, amount of time, and limited capacity of facilities. Moreover, uncertainty analysis in seakeeping experiments is more complicated than other ship hydrodynamics problems because measurements of multiple variables are needed in most cases. For instance, in a ship resistance experiment, only one quantity, i.e. the resistance of the ship, is of primary concern. However, seakeeping experiments are normally carried out to obtain the motion responses in multiple degrees of freedom (DOF) and the corresponding structural loads on the ship structure in different wave conditions. That is, there are many variables affecting the measurements and the number of experimental conditions can be significantly large. Consequently, uncertainty analyses require a significantly large number of repeated experiments, and therefore have a large cost and require a large amount of time. Furthermore, the relevant variables are strongly or weakly coupled; hence, error sources can strongly influence each other. Such difficulties are the barriers of uncertainty analysis in seakeeping experiments.

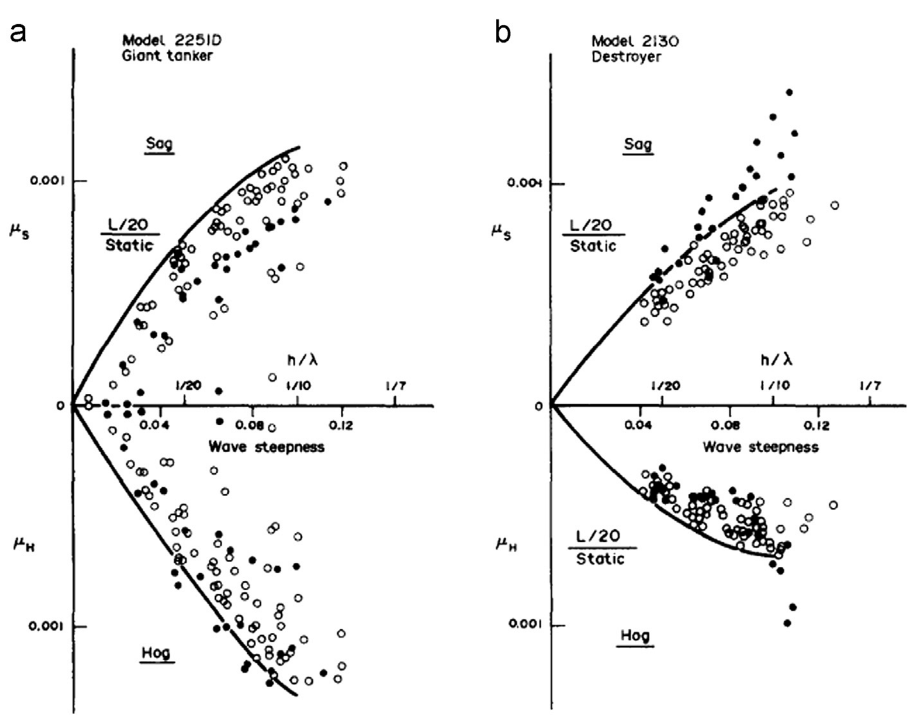

Fig. 1. Example of scattered data of wave-induced bending moment from two ships (Guedes Soares, 1991, originally from Dalzell's experiment). (a) Tanker and (b) Destroyer.