ITTC Quality System Manual
Recommended Procedures and Guidelines

Procedure

Quality Assurance in Ship CFD Application

7.5	Process Control
7.5-03	CFD
7.5-03-01	General
7.5-03-01-02	Uncertainty Analysis in CFD, Guidelines for RANS Codes

Disclaimer

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Quality Assurance in Ship CFD Application

1. PURPOSE OF PROCEDURE

To provide a procedure for quality assurance of ship CFD application at organization level.

2. INTRODUCTION

Methodologies for uncertainty analysis of a single solution are described in 7.5-03-01-01. That procedure can be used when validation data exists. The derived uncertainty level is, however, valid for the unique case and condition only. In practical work, validation data does not exist for the investigated cases. For various practical reasons, a full grid convergence study cannot be carried out for every case. Organizations that regularly carry out CFD predictions of cases that are similar to each other can instead use the present procedure for quality assurance.

The procedure contains the following parts: (1) Content of an organization's Best Practice Guideline (BPG); (2) Quality assessment of the BPG methodology; (3) Demonstration of quality.

3. BEST PRACTICE GUIDELINE

The correct way of setting up and executing a CFD simulation depends on the CFD code and the type of prediction. Hence, a general recommended procedure cannot be given. Each organization should formulate their own Best Practice Guideline (BPG). It may be based on the Guidelines given by the code developer. Though this is often a good starting point, it should be noted that the general guideline from the code developer may need to be adjusted for the specific ship applications.

3.1 Best Practice Guideline content

The BPG is a detailed description of how to set-up, run and interpret a CFD simulation for a specific type of prediction and for a required uncertainty. It should contain explicit instruction to the user covering at least the following:

- Code and version
- Ship geometry level of detail (e.g. rudder, appendages and simplification of hull features)
- Ship geometry file preparation and quality assurance
- Definition and selection of input values (e.g. *Re*, *Fr*)
- Degrees of freedom (e.g. sink and trim)
- Turbulence model
- Boundary conditions
- Wall function / wall resolved
- Surface roughness
- Domain size
- Grid topology
- Number of cells, refinement strategy, y^+
- Time steps
- Convergence criterion
- How to assess grid quality and thresholds (e.g. skewness, volume fraction)
- Definition of output values (e.g. force coefficients)

<u>Case Type range</u>

The BPG should give differentiated instructions depending on the type of case and required uncertainty. A case type is defined by:

- Requested prediction; resistance, propulsion power, nominal wake, detailed flow, performance in waves etc.
- Ship type and condition; determining factors are e.g. relative size of resistance components (related to C_B, Fr, Re), propulsion type, unusual hull forms and hull features

4. BPG QUALITY ASSESSMENT

The organization should assure that the BPG is formulated such that it gives the requested uncertainty level for the specified ship applications. If updated, the quality assessment needs to be repeated.

The BPG quality assessment is done in the following steps:

4.1 Numerical and modelling uncertainty

Estimating the numerical and modelling uncertainty following QM procedure 7.5-03-01-01 Section 4 and Section 5 for at least one, preferably several, typical cases. This gives important knowledge when the organization defines their BPG for the various case types e.g.:

- the suitable level of grid refinement, convergence threshold etc. in relation to the required uncertainty;
- which code, model, grid-type etc. is the most suitable for the given type of case.

The Required Uncertainty U_{reqd} in Section 5 of 7.5-03-01-01 must be quantified by the organization. It may vary between different applications and circumstances.

The experimental data should be obtained in accordance with the ITTC recommendations and, in particular, with uncertainty assessment documented. The data may be provided by the own organization, but open benchmark data with published CFD results from other users may also be very useful.

4.2 Assessment of total uncertainty

The uncertainty estimated according to the previous step is valid for the unique cases only. The uncertainty when applying the same CFD process to a similar case is not necessarily the same. Moreover, different users may interpret the BPG differently depending on skill and experience. The BPG therefore needs to be assessed using a large number of samples, all within the same case type definition and preferable by different users in the organization.

The result should be presented in the form of statistics of the comparison error E, given by the difference between the measured data, D, and simulation, S:

$$E = D - S \tag{1}$$

Note that E contains uncertainty of the simulation as well as the measured data.

The comparison error should be based on the same variable and same condition, including scale, as the CFD-simulation aims to predict, i.e. for full scale CFD-predictions, full scale measurements are needed.

The data may be provided by the own organization. Due to the larger number of samples, the precision of each measurement may be less than for benchmark cases. For full scale measurements the precision is often very low. This needs to be considered in the comparison.

The number of cases that are required depends on the scatter of the result and the required accuracy, but in practice, it is limited to the number of available measured data points. The more cases that an organization can include, the higher the confidence they can claim to have in their predictions.

5. DEMONSTRATION OF CFD CONFIDENCE

Organizations that wish to demonstrate their ability to carry out CFD predictions for specified case types may use the following demonstration process. Note that for some applications within the ITTC Recommended Procedures framework a demonstration is *required*. Clients who order predictions may also require this type of demonstration as a purchase condition.

The demonstration document should contain at least the following:

General part

- Definition of the case type range.
- Demonstration of total uncertainty using comparison error, according to section 4.2 above. If the number of datapoints permits, the probability for an error less than the required level can be given. This can be shown in the form of a probability density diagram. Examples of such analyses can be seen in Zhao et al. (2017) and Korkmaz et al. (2021).
- The number of cases used for the statistics of the comparison error.

Case specific part

- Motivation of why the actual case belongs to the case type range.
- State that the actual case prediction is carried out following the same CFD process (BPG) as was used to derive the comparison error statistics. If not, motivation of why this does not deteriorate the confidence level.
- Description of the actual simulation CFD set-up.

Additional information that increases the confidence in the organization's ability

- Verification and validation results using benchmark data.
- Participation in public benchmark workshop.
- Comparison of CFD predictions and blind validation cases.

6. REFERENCES

Zhao, F., Wu, C., Shen, H., "An Innovative Methodology of Confidence Level Assessment for Virtual Test of Ship Hydrodynamics", The 30th American Towing Tank Conference, October 2017

Korkmaz, K.B., Werner, S., Bensow, R., "Verification and Validation of CFD Based Form Factors as a Combined CFD/EFD Method", J. Mar. Sci. Eng. 2021, 9, 75