Report of the 25th ITTC Seakeeping Committee

17 September 2008

Membership

- Terrence Applebee, Chairman
- Paul Crossland, Secretary
- Gregory Grigoropoulos
- Greg Hermanski
- Yonghwan Kim
- Rumen Kishev
- Koichiro Matsumoto
- Jianbo Hua (until April 2007)
- Dariusz Fathi (July 2007 to the present)

Committee Meetings

- January 2006 – QinetiQ, United Kingdom
- October 2006 – David Taylor Model Basin, United States of America
- May 2007 – National Technical University of Athens, Greece
- December 2007 – Seoul National University, Korea

Why Seakeeping?

Presentation Outline

- Recommendations of the 24th ITTC
- Cooperation with the ISSC
- Conclusions of the Committee
- Recommended ITTC Procedures
- Discussion

Tasking from the 24th ITTC

1. State-of-the-Art Review
2. Update Procedures
   - 7.5-02-07-02.3 Experiments on Rarely Occurring Events
   - 7.5-02-07-02.1 Model Tests on Linear and Weakly Non-linear Seakeeping Phenomena
   - 7.5-02-07-02.4 Validation of Codes in the Frequency Domain
3. Rewrite Procedure 7.5-02-07-02.2 Predicting Power Increase in Irregular Waves Based on Model Experiments in Regular Waves
4. Develop a Procedure for Validation of Codes in the Time Domain
5. Support the Specialist Committee on Uncertainty Analysis
6. Benchmark Data
   - Review Examples of Validation of Prediction Techniques
   - Determine Requirements for Seakeeping Tests in Oblique Waves

Additional Tasking from EC

Identify overlapping subject area(s) and avenues of cooperation with the International Ship & Offshore Structure Congress (ISSC)

specifically,

I.2 Loads Technical Committee

ITTC-ISSC Cooperation

Results of Joint Meeting held at NTUA in Athens in May 2007:

- ITTC Procedures covering Seakeeping Experiments, Experiments on Rarely Occurring Events, and Validation of Seakeeping Computer Codes
- ITTC Ocean Engineering Committee cooperation with ISSC Loads & Environment Committees
- Benchmarking & comparative studies
- Exchange of reference lists, forwarding/review of final reports
- Consideration of future joint reports
- **Common membership**
- **Scheduled joint meeting(s)**

Summary & Conclusions

1. Highlights
2. Developments in Experimental Techniques
3. Loads and Responses in Waves
4. Sloshing
5. Slamming, Deck Loads and Whipping
6. High Speed Vessels and Multihull Ships
7. Increased Powering in Waves Prediction
8. Computational Fluid Dynamics
9. Benchmark Data
10. Uncertainty Analysis
11. Cooperation with ISSC

Conclusions

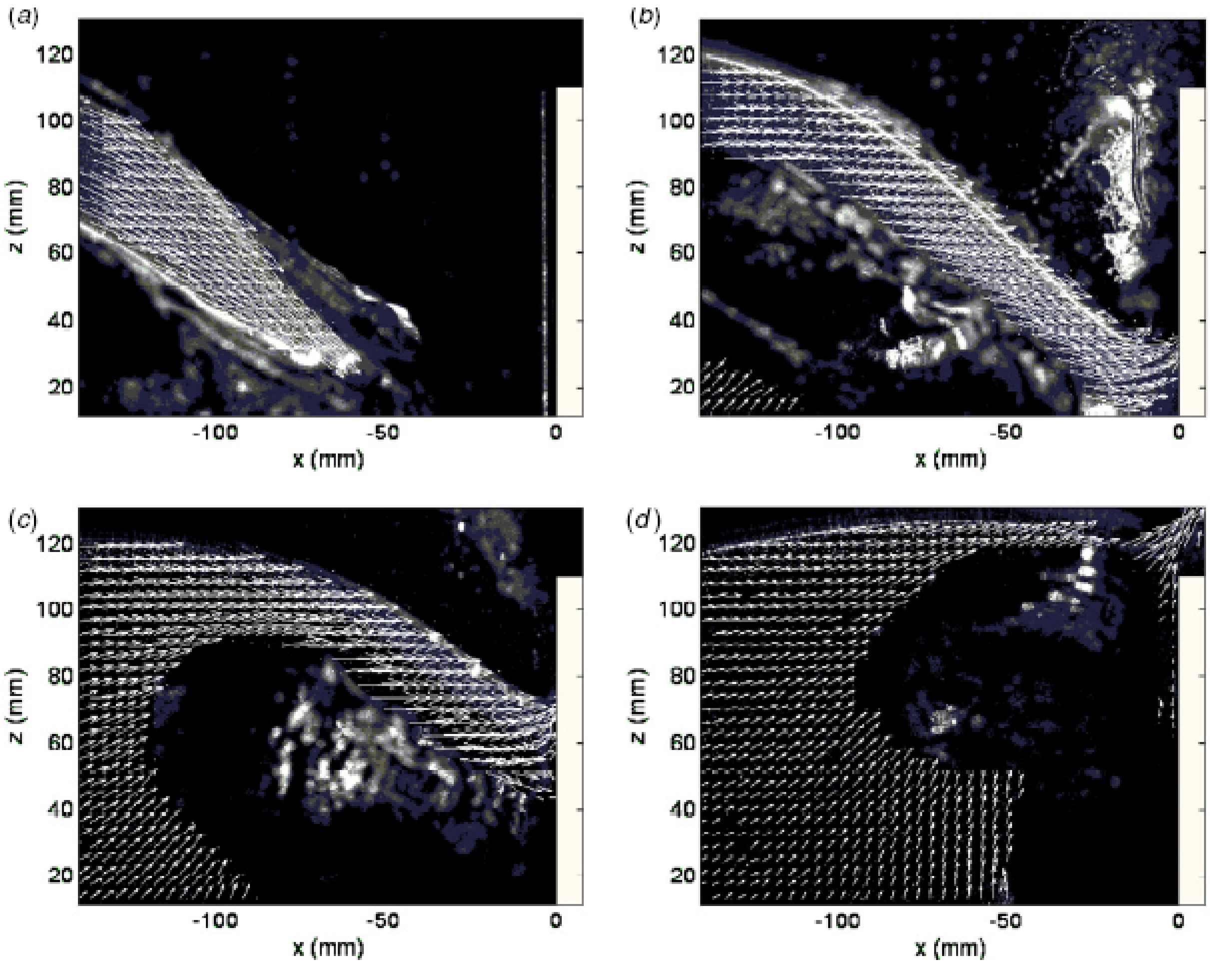
- Highlights:
  - Four Procedures developed/updated for adoption
  - State-of-the-art review included sloshing as an additional area for consideration
  - Review of seakeeping benchmark data resulted in the development of a rigorous definition to be applied to existing and future data sets

Experimental Techniques

- Wavemaking
  - Ring waves for single-pass directional ship responses
  - Generating & absorbing wavemakers to minimize reflection
  - Numerical wave tank modeling for simulations & design improvements
- Nonlinear Model Experiments
  - Large scale models with similar mechanical & structural properties to full-scale, reduction of Reynolds scaling effects
  - Comparisons of nonlinear experimental results to both analytical predictions and full-scale trials, particularly higher order effects
  - Non-conventional ship hull forms
  - Surface pressure and wave impact loading

Experimental Techniques

- Measurement Technologies
  - Bubble Image Velocimetry (BIV) for horizontal green water distribution
- Safety-Driven Experimentation
  - Parametric Roll
  - Dynamic Stability
- Full-Scale Data Acquisition
  - Small & large vessel motions & structural loads
  - Onboard wave, motion, structural measurements for decision making
  - RAO development from full-scale data
  - 3D wave buoy measurements to determine seaway directionality
  - Sea state estimation from ship motions



PIV measurement of plunging breaking wave impinging on structure. The time separation between the panels is 25 ms.

Ryu et al.(2007)

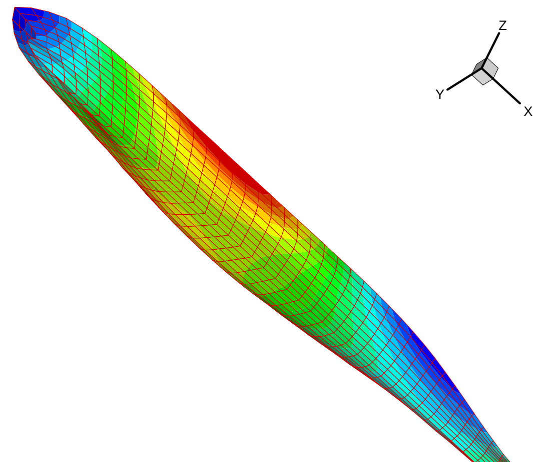
Loads & Responses in Waves

- Linear, weakly-nonlinear analyses continue to improve, with movement to time domain and 3D panel methods, and provide sufficient capability for many ship design issues and practical engineering
  - Use of Green's function approach and Rankine panel method to the 3D problem
  - Coupling of impulse response function approach with strip or panel methods
- Nonlinear problems, such as extreme ship motions & dynamic structural loading, and complex problems, such as multiple body interactions & motions in shallow water, require better accuracy
  - Rely heavily on the Navier-Stokes equation solvers
  - Use of Rankine panel method to remain popular for the linear and weakly-nonlinear as well as strongly nonlinear problems
  - Computational time remains problematic for CFD (viscous flow methods) vice potential flow (inviscid) methods

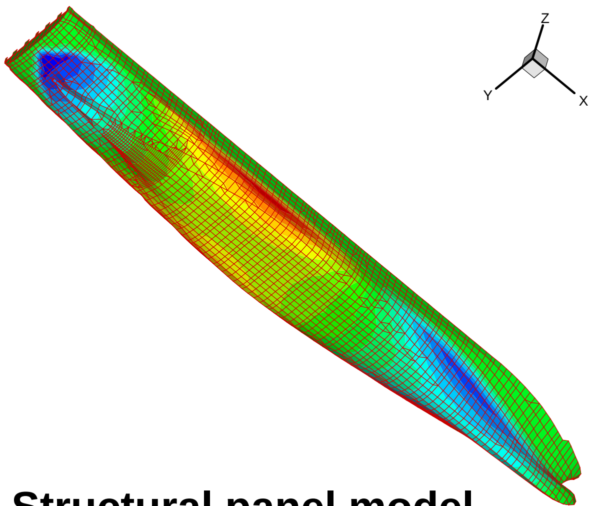
Loads & Responses in Waves

- Propose a workshop for investigating time domain methods
  - Qualify & quantify advantages, disadvantages, accuracy
  - Include nonlinear loads, pressures, motions
  - Provide V&V data
  - Inclusion of experimental results as benchmark data
  - Ultimately will aid in the development of the new nonlinear code V&V procedure
- Results of time domain simulations must provide details (e.g., transom treatment, autopilot coefficients, spatial & temporal discretization, etc.)

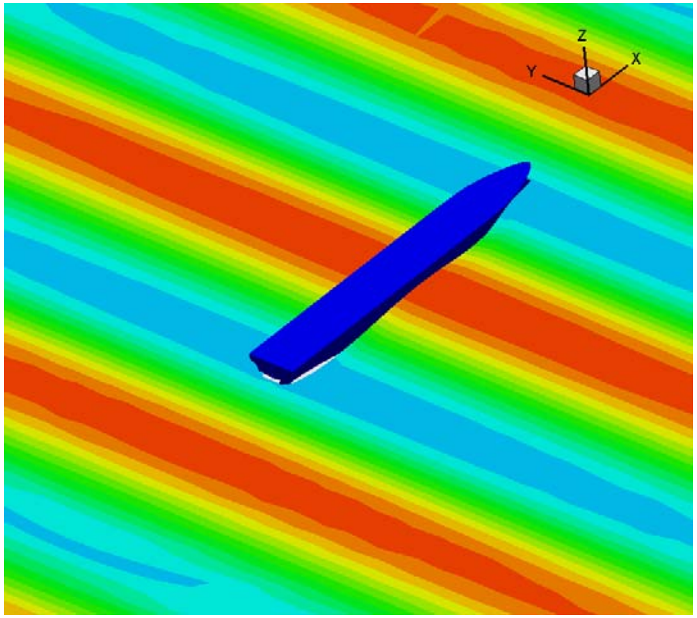
Real Ship Application: Large Containership



Hydro panel model



Structural panel model

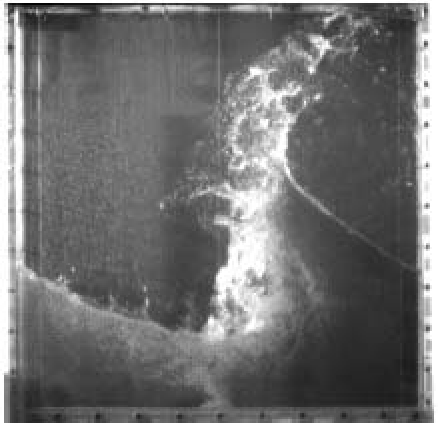


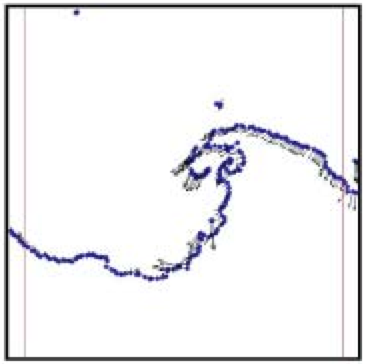
Nonlinear Ship Motion Simulation (Rankine Panel Method, Kim et al, 2007)

Sloshing

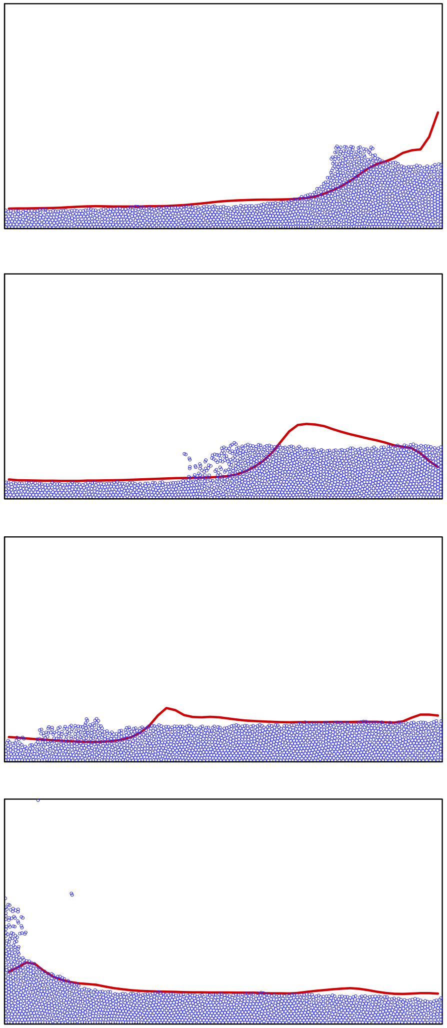
- CFD techniques have been used to simulate sloshing flows
  - Problems arise with numerical diffusion with some methods, and computation time remains an issue
- Coupling with linear time domain motions has been attempted
- Experimental validation is key & requires modern measurement techniques (e.g. PIV)
- Overall, reasonable accuracy for pressures & free surface profiles has been predicted
- Some effort has been made for scale-up law of sloshing pressure, but no breakthrough yet

Sloshing experiment for very large model tank (DNV, 2007)





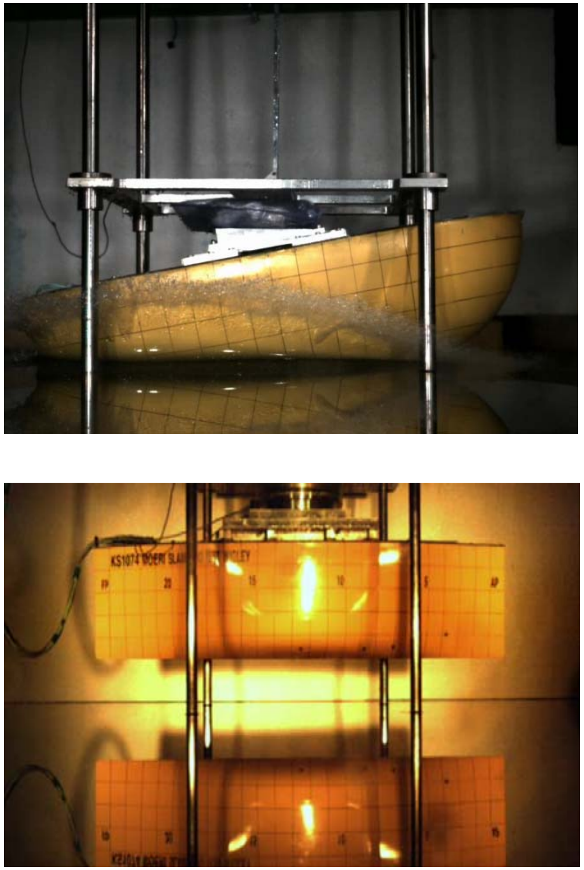
Sloshing experiment and SPH Simulation (Coragrossi et al., 2007)



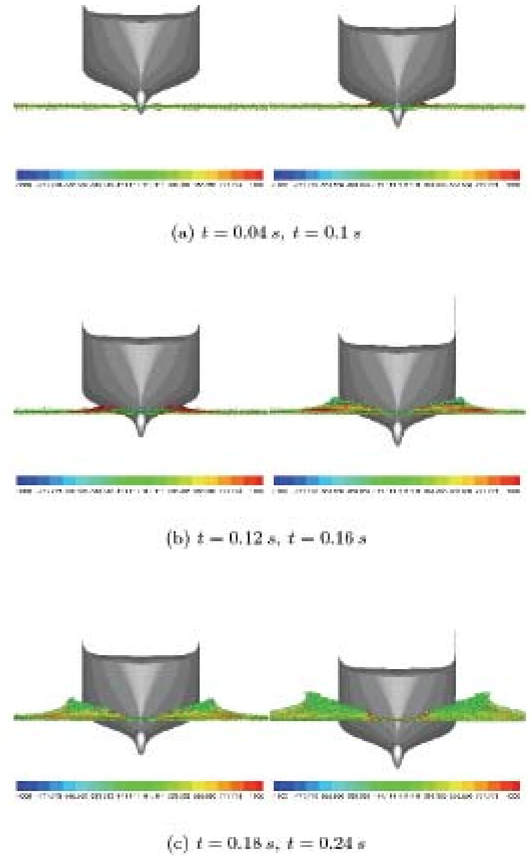
Sloshing simulation at shallow filling: SPH vs. FDM (Kim, 2007)

Slamming, Deck Loads and Whipping

- Multi-stage approach of combining traditional ship motion prediction techniques & CFD methods have been used to derive “cause & effect”
  - For example, relative motion computations predict freeboard exceedance; RANS representation predicts the horizontal and vertical loads
- Application of Smooth Particle Hydrodynamics (SPH) in the treatment of violent free-surface flows and the occurrence of green water loading and slamming impact loads



Slamming Experiment for 3D Bodies (SNU-MOERI, ONR Project,2007)



SPH Simulation for Ship Slamming (Orger et al,2007)

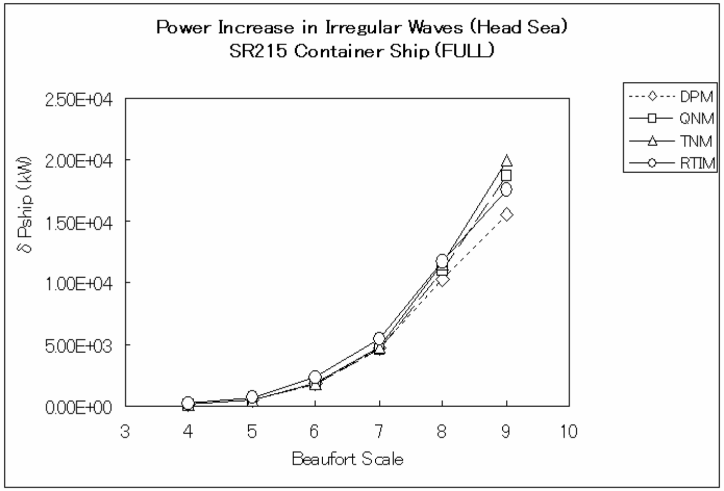
High-Speed and Multihull Vessels

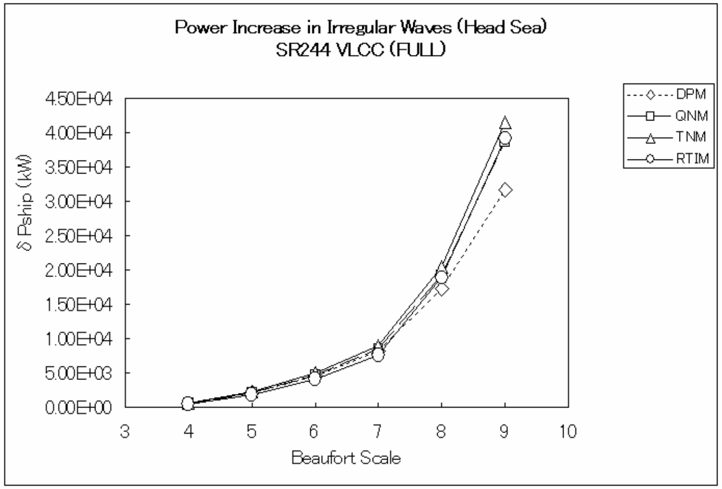
- Model and full-scale experiments reported for high-speed vessels, including systematic tests of planing catamaran hulls
- Nonlinear seakeeping codes have been compared to high-speed and multihull tests primarily in head seas
- Oblique wave conditions are noticeably absent from evaluations of both high-speed and multihull experiments
  - Obvious tank restrictions make such testing problematic
  - Suitable test procedures must be devised to provide appropriate benchmark data

Increased Powering in Waves Prediction

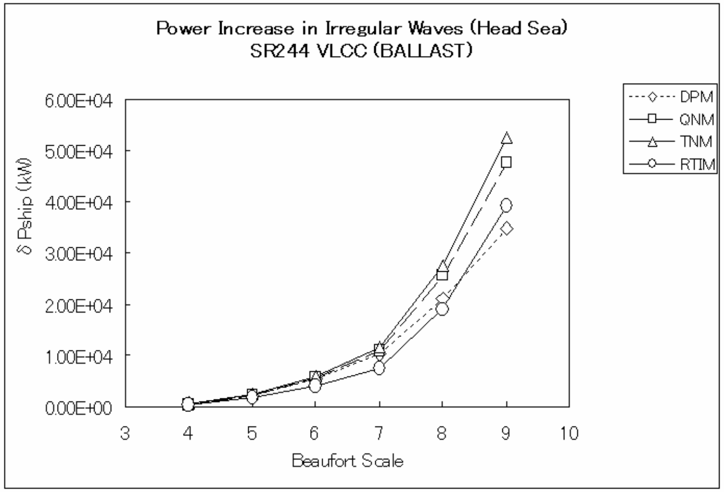
- Four methods to predict increased powering in irregular waves from model tests in regular waves were investigated:
  - Torque and Revolution Method (QNM)
  - Thrust and Revolution Method (TNM)
  - Resistance & Thrust Identify Method (RTIM)
  - Direct Power Method (DPM)
- Comparison of results for various ships at full load shows very close agreement of all but DPM

Increased Powering in Waves Prediction





Comparison of power increase in irregular waves for the four methods



Increased Powering in Waves Prediction

- Based on these results, DPM has been removed from the procedure
- Results are less conclusive for the ballast condition, and further validation of these methods from model and full-scale tests in irregular waves is desirable
- RTIM considers all added resistance components (e.g., waves, wind, hull fouling, maneuvering, etc.)

Computational Fluid Dynamics

- CFD methods for seakeeping analyses are still in the early stages for practical use, but provide the promise of developing accurate solutions to the nonlinear problems (motions in severe seas, green water & slamming, sloshing, etc.)
- Computational time and verification of results remain hurdles
- Finite difference/volume methods for solving Navier-Stokes equation and Constrained Interpolation Profile (CIP) method have been used for large amplitude ship motions, and particle methods, particularly Smooth Particle Hydrodynamics (SPH), have been used for motion-related phenomena (sloshing, green water, etc.)

Benchmark Data

- Tasking to determine required benchmark seakeeping tests for oblique wave conditions, esp. for high-speed vessels, evolved into a larger issue:

What qualifies as benchmark data?

- A working definition for benchmark data has been proposed
- Continued review of past and future data against this criteria is recommended for inclusion as benchmark data
- Recommended long term goal: A repository of experimental particulars and digital data for meaningful comparisons

Benchmark Data

- **Definition**: Benchmark tests are those that generate experimental data, both model and full-scale, that are presented in a way that makes the results reproducible both numerically and experimentally. Benchmark data are to be used for the validation of numerical methods and the verification of experimental procedures. These data should be fit for the intended purpose, should include uncertainty analysis, and should be publicly available.

Benchmark Data

- **<u>Criteria</u>**: Reported parameters forming a minimum set of information required to reproduce the experiment
  - ***Ship/model condition***; i.e., hull form, model scale, appendage definitions, mass/displacement, draft/trim, hydrostatics, mass distribution, radii of gyration, center of gravity, natural periods
  - ***Ship***; i.e., ship speed and heading
  - ***Waves***; i.e., wave amplitude, frequency and wave slope; type of spectrum, significant wave height, modal period, and spreading
  - ***Test Details***; i.e., free running/towing arrangement, control laws, run duration/number of wave encounters, wave measurement (fixed or encountered), and facility parameters
  - ***Presentation of Data***; i.e., units/sign convention, reference system, definitions of presented data, tabular data preferred, and uncertainty analysis

Benchmark Data

- Much of the current referenced benchmark data does not conform to the definition or criteria
- Not surprisingly, high-speed vessel data, particularly for oblique wave conditions, is extremely limited
  - Restricted or proprietary hull designs/data exacerbates the problem
  - Public release of past test efforts; cooperative/joint experiments

Uncertainty Analysis

"The Seakeeping Committee concluded that the work of the Specialist Committee on Uncertainty Analysis be continued until practical and useful techniques are provided for assessing and reporting experimental uncertainty."
Development of uncertainty analysis techniques for dynamic testing is recommended for consideration by the 26th ITTC Specialist Committee.

Cooperation with ISSC

- Communication is Key
  - Common membership
  - Scheduled joint meetings
- ITTC Seakeeping and ISSC I.2 Loads
- ITTC Ocean Engineering and ISSC I.1 Environment & I.2 Loads
- Benchmarking and comparative studies

Recommended Procedures

7.5-02-07-02.1 Seakeeping Experiments

- Minor modifications to standardize text & formulae
- Discussion and recommendations for spectral cut-off frequencies, test run duration, and time interval between runs
- Removal of numerical simulations from validation reference list (benchmarking)
- No changes to uncertainty analysis section at this time

Recommended Procedures

7.5-02-07-02.2 Predicted Power Increase in Irregular Waves from Model Experiments in Regular Waves

- Three methods produce comparable results and can be recommended for use, the choice depending on test tank specifics
- The Direct Power Method (DPM) is removed based on results comparing the four methods to experiment, as presented in the Committee report
- Comparison of advantages & disadvantages of these methods is provided

Recommended Procedures

7.5-02-07-02.3 Experiments on Rarely Occurring Events

- Extensive modifications are provided to address extremes, including local, but not global, loads
- Relies on Procedure 7.5-02-07-02.1 Seakeeping Experiments for basic test preparation
- Updated sections include
  - Measurement techniques for each phenomena & the parameters to be measured
  - Run duration
  - Presentation of the data

Recommended Procedures

7.5-02-07-02.4 Verification and Validation of Linear Seakeeping Computer Codes

- Replaces earlier procedure to include **both** frequency and time domain linear seakeeping codes
- Clear definition of verification and validation provided
- Requires thoroughly documented benchmark data
- Eventually should extend to nonlinear codes

Thank you for your attention.

Response to Discussion

Topic: Uncertainty Assessment
Discussers: Longo, Simonsen, Stern

From the Seakeeping Committee:

The 25th ITTC Seakeeping Committee thank the authors for preparing their discussion on Uncertainty Analysis for seakeeping tests in head seas and the derivation of the methodology for estimating the *Fr* for maximum pitch and heave response. Because of the work of the UA Specialist Committee, the Seakeeping committee chose not to specifically address uncertainty analysis to any great degree in its report. However, we feel that this work represents an excellent, systematic attempt to tackle the problem of uncertainty in the measurements of the dynamic response of a ship and that the committee encourages researchers to extend their efforts in this area. Since the references themselves are beyond our Committee's timeline for reviewing publications we feel that it is more pertinent that the 26th ITTC Seakeeping Committee should consider this work in more detail.