SESSION 1

REPORT OF ADVISORY COUNCIL WORKING GROUP ON VALIDATION

Panel members: Prof. V. Kostilainen (Helsinki University of Technology, Finland)
Dr. W. B. Morgan (David Taylor Research Center, USA)
Dr. M. E. Davies (British Maritime Technology, UK)

Recorder: Dr. I. Watanabe (Ship Research Institute, Japan)

The session started with Dr. Morgan's introduction of motivation and background in preparing the Report. Dr. Davies followed by presenting problems on the uncertainty analysis of the numerical modeling. The first three written discussions were presented by respective authors. Replies and comments for the discussions were made orally by Dr. Kostilainen on behalf of the panel members. Then Dr. English presented his discussion which had been left behind since the panel judged that it was closely related to the Report, although not directly connected. After several additional comments from the floor, the session was adjouned.

1–1 Report of the Working Group

1–2 Written Disscussions

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SOME PROBLEMS CONNECTED WITH THE OBTAINING AND EVALUATION OF EXPERIMENTAL DATA

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SOME COMMENTS ON THE NEED FOR DEVELOPMENT OF VALIDATION TECHNIQUES

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DIFFICULTY OF IDENTIFICATION OF MEASUREMENT RESULTS

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COMMENTS ON "ACCURACIES ENSURED BY TOWING TANK TESTS" BY T. YAMASAKI & T. TSUDA

VALIDATION AND UNCERTAINTY ANALYSIS - AN ITTC ACTIVITY ?

by

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1. INTRODUCTION AND BASIC CONCEPTS

When the first predictions of hydrodynamic phenomena by purely numerical methods saw the light of day, some 12 years ago, those involved were greatly pleased that the results at least qualitatively resembled the phenomenon to be predicted. Pretty pictures were produced in the form of graphical plots and put on the cover of conference proceedings. But off course this was, and is not enough and a long struggle for accurate quantitative results began - a struggle fought both behind computer terminals and in the offices of funding agencies. Good numerical hydrodynamics is both difficult and expensive.

But although we are far from having reached the end of that struggle, now numerical methods are beginning to find introduction in advisory work and this raises the question of the validity in general and the uncertainty in predictions specifically of those methods.

The first development to verification has been comparison with results from either physical model tests or from prototype studies. Some of ITTC technical committees have contributed towards such comparisons. But there are a number of pitfalls associated with such an approach. Some numerical models contain parameters that may be 'tuned' so as to obtain good agreement, often the modeller does not distinguish between a model calibration and model verification; Ideally calibration should be carried out on one set of data and verification on another. As correct and valid model test data or prototype data are often hard to get, comparison is often an affair based on a single case. The universal validity over the full range of variable values within their domain, is hardly proven.

Another problem may be related to the fact that the modeller does not distinguish between uncertainty due to the choice of numerical parameters and uncertainty due to inaccurate knowledge of physical parameters. Proper separation of these two causes of uncertainty is a first requirement for a proper validation.

All this leaves us with a considerable uncertainty towards the use of numerical models in our professional work. As a professional organisation the ITTC must insist that certain standards are met. The ITTC members have devoted long hours to these type of problems in relation to physical model testing, now it is time that the ITTC takes a position on what constitutes a good numerical model and what are proper validation procedures.

Although it is of little comfort, other professional organizations face the same problems. In Section 3 the activities of some of these organizations in response to those problems is briefly mentioned. In general it may be stated that the proliferation of undocumented, unvalidated computer software constitutes a dangerous problem for the scientific-engineering society at large and perhaps even society in general. This represents a challenge to the professional laboratories, which when not properly addressed, may even develop into a serious threat to their existence.

In response to this development the ITTC Advisory Council established at its session on October 21, 1985, an ad hoc Working Group on Validation Techniques, consisting of:

Dr. William B. Morgan,
Prof. Valter Kostilainen,
Dr. Melvyn E. Davies,
Dr. Ing. Antonio Maresca,
Dr. Ir. Gaele S. Rodenhuis - Chairman.

Due to a change of job Dr. Maresca had to leave the group in 1986.

The working group has worked out recommendations to the Advisory Council. The present paper and presentation serves to provide further background to these recommendations.

The Working Group recognized from the beginning that a parallel situation like the one sketched above was developing in physical modelling. There is an increasing integration of physical model testing with the computer calculations in the control of the model test and its analysis.
Laboratories and the ITTC have in the past put great emphasize on correct procedures for model testing. It is important that this attention is now extended to include the total complex of physical model testing and associated computational methods. In order to assess the uncertainty of the end result is is increasingly important to analyse the uncertainty of the individual steps of the total complex.

Although there will be differences in application the Working Group thought it of value to attempt to address both problems under one, feeling that valuable experience with concepts already introduced in the uncertainty analysis of measurements, could be brought to application in the validation of numerical techniques.
In the two following sections the application to the two problem areas will be discussed further.

In the foregoing and following discussion the notions of validation and uncertainty analysis have been introduced. It is relevant to define these concepts more precisely here:
Validation is concerned with the process of understanding and describing particular aspects of a real world situation, and, at the same time, with the process of establishing how well a model - numerical or physical - produces engineering predictions of the real world situation.
Uncertainty analysis is an activity that establishes the uncertainty or inaccuracy of this prediction. It is a part of the validation procedure, and produces a measureable expression of it.

In brief - validation establishes whether a model is at all a valid description of the real world, uncertainty analysis tells how accurate or inaccurate this description is.

2. UNCERTAINTY ANALYSIS FOR PHYSICAL MODEL TESTING

All measurements are contaminated by error, which can be divided into two groups according to whether or not the error is estimated by repeated measurements. If the estimate of the error can be obtained by repeated measurement, then the error is random. If the estimate of the error must be obtained by reasoning, then the error is bias. The two types of error have an interesting relationship: the bias error is a systematic error that can be converted to a random error if the parameter can be made to be varied. The random and bias errors are added together in some fashion to arrive at the total error. A statement on the total error must include the method by which it is determined. Often the weakest link for accuracy in physical model testing occurs in the calibration mode. The final data will be no better than the calibration data, and it is essential that the experimentalist knows in advance the degree of required accuracy to define the calibration. Another source for error is in the data acquisition process, where the test matrix usually represents a desire to cover as many parameter ranges as possible instead of the necessary needed to conduct replicate measurements to define precision error. Error occurs in data reduction both due to error propagation and due to the fairing of curves through imcomplete data fields.

Multiparameter tests need to recognize an influence matrix to develop a rationale to rank the significant sources of error with a minimum of test time. A list of possible error sources must be compiled, and the error analysis must examine the propagation of error to the final result desired. Pre-test analysis should determine the possible sources of error and a plan by which the minimum amount of data is obtained to satisfy the predetermined accuracy needs. There are benefits to conducting repeat tests: actual random error is directly determined, and there is an opportunity to convert bias error to random error. In the absence of actual measurements, the error source values must be estimated from judgement, and from the results of "similar" measurements.

All techniques for assessing measurement uncertainty are common in the recognition of random and bias error. Differences amount to the definitions and terminology in use, and the method for quantifying the error. As a start, it is desirable to agree on a common definition of the terminology, and a single algorithm to define the error. Using this common base for comparisons, the intuitive methods for placing numerical values on elusive errors, such as for bias, must be developed by example.

A recent ISO standard for specifying the technique for measuring the volume flow in a channel with spatially non-uniform flow is a good example of the proper application of measurement uncertainty methods. In this problem the flow is determined by placing probes at selected positions, determined by the minimum requirements, and using a selectively developed fairing curve to produce measurements of a given accuracy. The standard documents the pre-test planning and the post-test analysis pertinent to developing the accuracy statement. Althoug this problem is not solved with a tow tank, the procedure is illustrative both to show what needs to be done, and to show how a seemingly simple problem can become elaborate.

3. VALIDATION AND UNCERTAINTY ANALYSIS FOR MATHEMATICAL MODELLING

The earlier sections have discussed the basic concepts of uncertainty and described some of the methodologies and initiatives that have been developed to address the quantification of measurement uncertainty.

Numerical modelling is no different in concept and figure 1 shows how both mathematical and physical modelling fit together in the same descriptive framework. (Figures placed at the end of the paper).

In the context of figure 1, measurement uncertainty is normally associated with the right half of the cycle, "Operation", it is presumed that the "correct" experiment is being performed. By contrast attention in numerical modelling has tended to be concentrated on the left side of the diagram, with the general assumption that the numerics solve the equations so developed.

"One of the more important steps, which will make model comparisons more meaningful, will result from a more detailed concern for the numerical problems leading to accuracy of solutions. Only in this way is it possible to distinguish the precision of the physical modelling from the inherent numerical errors related to algorithm and grid".

The quotation was written in 1981 by the Evaluation Committee of the AFOSR-HTTM Stanford Conference on Complex Turbulent Flows as part of their overview of the exercise which produced 1266 numerical predictions of 66 carefully chosen experiments by thirty-five independent groups. Their exhortation was aimed at the next ten years of computing effort, but there is little evidence to suggest that the situation is radically different as we examine the picture in 1987.

Indeed in March 1986 the Journal of Fluids Engineering was moved to address the situation by issuing an editorial statement on the control of numerical accuracy, (appendix) proclaiming that papers reporting numerical solutions would not be accepted for publicationunless systematic error testing and accuracy estimation had been undertaken.

It is well recognised that the tasks involved in meeting such objectives are far from trivial and effective examples are still difficult to find. Nguyen and Maclaine-Cross [4], have complied with the JFE requirement in a meticulous way using three mesh systems and a Richardson extrapolation to zero mesh size for their Navier-Stokes solution of flow in parallel-plate heat exchangers. The techniques may be relatively sophisticated, but the flow is relatively straightforward and the methodology is not available for universal application.

It is clear that treatments of validation and uncertainty will need to be individually tailored to particular numerical schemes and to their appropriate domain of application. It was a clear conclusion at Stanford in 1981 that "no method had any significant unversality" and separately this observation was graphically borne out in McQuaid [5] where the spread of a number of model predictions of a dispersing gas cloud (figure 2) warns starkly of the difficulty of applying models outside their range of previous validation.

The difficulty in determining mathematical model validity and quantifying uncertainty is of course very general, but the desirability is increasing steadily with the growing power of computational methods offering the prospect of effective predictive capability.

In aerospace, the NATO advisory group 'AGARD' will hold a symposium on 'Validation of Computational Fluid Dynamics' in May 1988. Their goal for CFD development is a 'fully mature design and analysis capability that is user friendly, cost effective, numerically accurate and fully verified by detailed experimental comparisons.' Our tasks are essentially the same and it is appropriate for ITTC to play a major role in the fields of hydrodynamics and marine vehicle design.

Tasks such as validation and inter-comparison are familiar to the ITTC Technical Committees and they remain the ideal vehicles to review the detailed specific methods covered by their technical brief. However, a greater formality is called for and will need to be developed by a special panel. Its challenge would be to brigde the gap between the high level Quality Assurance procedures (e.g. Figure 3) for software design and the narrow consideration of particular convergence or sensivity tests.

With the growth of attention to the subject in hydraulics, aeronautics and general fluid engineering and the cooperation of the ITTC technical committees it should prove possible in one term to outline appropriate standards for ITTC endorsement, backed by specific examples for major ITTC subject areas.

REFERENCES TO SECTION 2:

[1] "Measurement Uncertainty -- Part 1: Instrumentation and Apparatus". ANSI/ASME PTC 19.1-1985; supplement to ASME Performence Test Codes.

[2] "Liquid Flow measurement in Open Channels-- Velocity--Area Methods-- Collection and Processing of Data for Determination of Errors in Measure ment", ISO 1088-1985(E).

[3] "Liquid Flow Measurement in Open Channels-- Velocity-Area Methods--Investigation of Total Error,"ISO/TR 7178-1983(E).

REFERENCES TO SECTION 3:

[4] T.V. Nguyen and I.L. Maclaine-Cross:
"Incremental Pressure Drop Number in Parallel-Plate Heat Exchangers" To be published in the journal of Fluid Engineering (ASME)

[5] J. McQuaid and B. Roebuck:
"Large Scale Field Trials on Dense Vapour Dispersion". Report no. EUR10029. Commission of the European Communities, Brussels, 1985.

[6] AGARD Symposium on "Validation of Computational Fluid Dynamics" to be held in Lisbon, Portugal 2-5 May 1988.

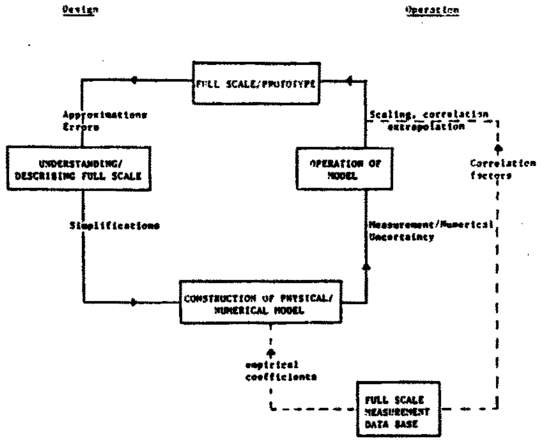

Figure 1

Construction and Validation of Physical and Numerical Models

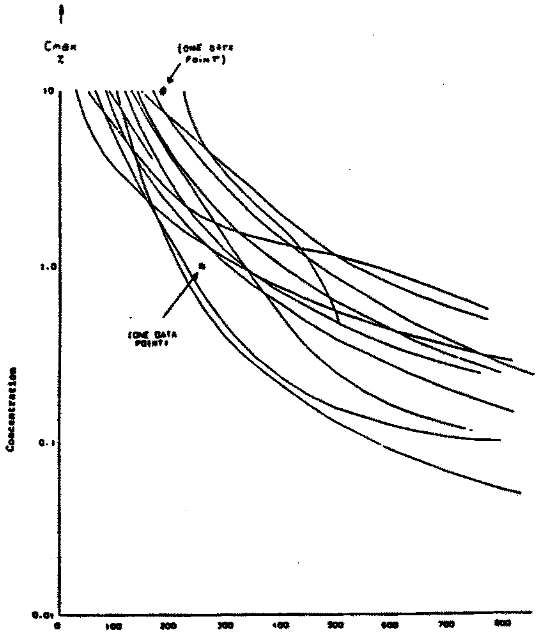

Figure 2

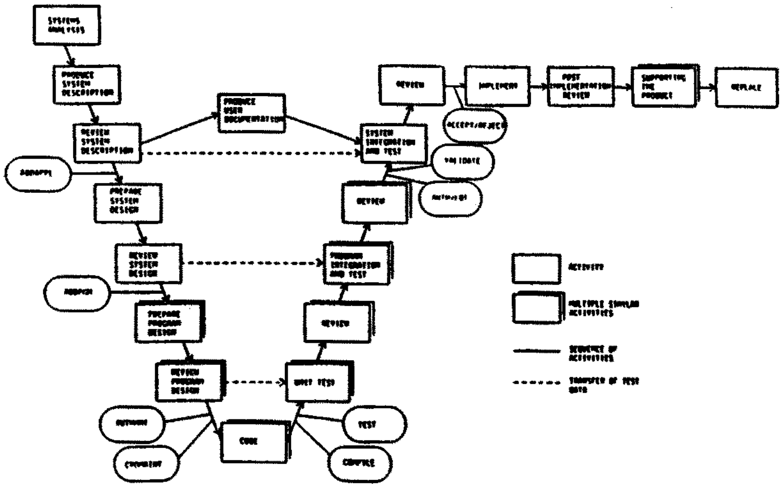

Figure 3 Configuration and Change Control Breakpoints within the Software Lifecycle

APPENDIX

Journal of Fluids Engineering

EDITORIAL

EDITORIAL POLICY STATEMENT ON THE CONTROL OF NUMERICAL ACCURACY.

A professional problem exists in the computational fluid dynamics community and also in the broader area of computational physics. Namely, there is a need for higher standards on the control of numerical accuracy.

The numerical fluid dynamics community is aware of this problem but, although individual researchers strive to control accuracy, the issue has not to our knowledge been addressed collectively and formally by any professional society of journal editorial board. The problem is certainly not unique to the JFE and came into even sharper focus at the 1980-81 AFOSRHTTM-Stanford Conference on Complex Turbulent Flows. It was a conclusion of that conference's Evaluation Committee that, in most of the submissions to that conference, it was impossible to evaluate and compare the accuracy of different turbulence models, since one could not distinguish physical modeling errors from numerical errors related to the algorithm and grid. This is especially the case for first-order accurate methods and hybrid methods.

The practice of publishing comparisons based on coarse grid solutions, without systematic truncation error testing, may have been acceptable in the past.

Certainly ten to fifteen years ago any calculation was of interest, and much of the exploratory work deserved publication, as many researchers lacked the computational power or funds to do a thorough and systematic error estimation. We are of the opinion that this practice, however understandable in the past, is outmoded and that, with powerful computers becoming more common, standards should be raised. Consequently, this journal hereby announces the following policy:
The Journal of Fluids Engineering will not accept for publication any paper reporting the numerical solution of a fluids engineering problem that fails to address the task of systematic truncation error testing and accuracy estimation.

Although the formal announcement of this journal policy is new, it has been the practice of many of our conscientious reviewers. Thus the present announcement is not a change in policy so much as a clarification and standardization.

Methods are available to accomplish this task, such as Richardson extrapolation (when applicable), calculations with a high- and low-order method on the same grid, and straightforward repeat calculations with finer or coarser grids. As in the case of experimental uncertainty analysis,"any appropriate analysis is far better than none as long as the procedure is explained".
Whatever the authors use will be considered in the review process, but we must make it clear that *a single calculation in a fixed grid will not be acceptable,* since it is impossible to infer an accuracy estimate from such a calculation.

Also, the editors will not consider a reasonable agreement with experimental data to be sufficient proof of accuracy, especially if any adjustable parameters are involved, as in turbulence modeling.

We recognize that it can be costly to do a thorough study, and that many practical engineering calculations will continue to be performed on a single fixed grid. However, this practice is insufficient for publication in an archival journal.

Patrick J. Roache
Kirti N. Ghia
Frank M. White
JFE Editorial Board

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SOME PROBLEMS CONNECTED WITH THE OBTAINING AND EVALUATION OF EXPERIMENTAL DATA

In the report of the working group on validation submitted to the Consultative Council in April 1987 it is pointed out that the problem of covering the investigations results is an important one, though not of primary importance. In view of the tasks posed for solving before the Validation Panel, we consider this problem should not remain outside our attention, since it to a great extent affects the terminal goal — the prediction.

In the first place, the measurements' uniformity and accuracy — a state in which the measurement results are expressed in the officially adopted measuring units, and the errors can be determined with preliminarily specified probability — play an exceptionally important role in hydrodynamic investigations with respect to their reliability and possibility to adopt correct solutions in the design.

On national levels the problem is solved to one or another extent, but its posing and discussion in close connection with hydrodynamic experiment peculiarities would contribute to the increase in the effect from the comparative investigations and the prediction reliability in general.

In the field of scientific experiments, the usage of computers and measuring technique intellectualization should ensure more extensive information for the experimenter on the phenomena under investigation and the conditions in which they are observed.

Now that all tanks dispose of computer technique, consideration should be taken of their application not only for data acquisition but also for application of modern methods for processing of the measurement information obtained.

We think that part of the problems to which the special Validation Panel should pay attention are the problems related to obtaining and evaluating of the reliability of the experiment information in carrying out of model tests. In this connection, it is our opinion that:
— experimental procedures for carrying out of comparative and model tests should be developed, with the purpose of comparing the results obtained from the various towing tanks, and for eliminating maximally the concrete conditions in the separate towing tanks;
— the character of the signals measured (values measured) should be investigated, so that the experimental results should be paid due attention and discussed from the viewpoint of validity, first of all taking consideration of the performance of straight course and calm water tests, as for how much the results obtained from those tests reflect directly both in the carrying out of the remaining tests (manoeuvring, seakeeping, etc.), as well as the correlation to full scale;
— the possible sources of disturbances and the peculiarities of carrying out those tests should be investigated, in view of determining the influence of:
— the final tank length;
— the measurement period;
— the initial moment of measurement;
— the dynamic characteristics of the experimental facilities; and devices used;
— the external sources of disturbances — vibration, etc. of the towing carriages, the railway, the cavitation tunnel, etc., on the precision and reliability of measurement;
— the results from the investigations should be presented besides in the conventional way, also by applying interval estimates (confidence intervals), which may provide a possibility for a more expedient utilization of the data obtained, in the development of optimum plans of the experiment, in the fairing of the results from

systematic (series) model tests and in the development of numerical models.

In this aspect at BSHC investigations are carried out and there is certain positive experience gained, enabling the minimization of errors from measurements by applying methods of real time mathematical statistics.

It is our opinion that such kind of investigations are carried out in other towing tanks as well, and that it should be advisable if the results from those tests be published and discussed, experience be exchanged and recommendations and experimental procedures be developed in future for carrying out of experimental investigations guaranteeing, on the one hand, higher precision and reliability of the results obtained from model investigations and, on the other, for more precise comparison of the experiment results obtained from the different towing tanks.

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SOME COMMENTS ON THE NEED FOR DEVELOPMENT OF VALIDATION TECHNIQUES

During the past 5−6 years BSHC intensely develops and applies in its research programme computational methods for optimization of the design parameters of ships and marine structures and for automation of the engineering activities (computer−aided engineering) and of the experimental facilities. Here, it follows that consideration should be taken of the fact that BSHC deals with research and development activities, as well as with designer's activities which require precise model manufacturing (CAM) as well. Some main achievements in this field are described in Ref.1.

Only the combination of physical with mathematical and numerical modelling is in a position to attack the complicated phenomena in ship hydrodynamics; moreover, it can turn them into a means for practical design and application. This task cannot be accomplished properly without mutual validation of the physical, mathematical and numerical models used.

There are many examples of BSHC activities illustrating the tendency of shifting the purpose of model tests from evaluation to validation, as was pointed in Dr.Morgan's and Dr.Lin's discussion on the subject at the Ⅳth IMAEM Congress [2]. For instance, a series of axisymmetric bodies has been tested in the cavitation tunnel to validate the computational method developed for the evaluation of the wall effect in testing bodies in tunnels. Another recent example is a highly skewed propeller series developed for validating the lifting line and the lifting surface methods, specially developed for propellers of complex geometry. Afterwards, it became clear that the conventional cavitation tests are not sufficient to validate the methods. Additional detailed measurements of the flow are needed in order to improve the physical model adopted. In other words, we agree that the future or even today tests should become more sophisticated if we expect to make a greater use of the computational methods for prediction and design purposes.

In many cases it is not possible to find out an analytical solution even for simple geometries to verify the computational method. Joint effort in this field, especially when 3−D geometries are investigated, can be very useful for example by comparing different methods of similar physical assumptions. This was tried for instance, for the two different methods based on lifting surface theory without viscous corrections which are in use at BSHC.

Many problems needing detailed investigation arise for the validation of computational methods for effective velocity field predictions. The highly simplified physical models used now cannot be compared successfully with full scale or model tests of ships, so that special test arrangements and equipments have to be prepared.

In using numerical techniques for solving computational fluid dynamics problems our experience has shown that without error estimation and sensitivity analysis the numerical results obtained can be very erroneous. For instance, in ideal flow solution, most commonly used in practice, the direct solution of Laplace equation leading to the solving of the matrix of algebraic equations without special care can become singular, or when using integral equations techniques with quadratures, the singular behaviour of the kernel function can alter considerably the numerical solution.

More examples can be presented in the field of seakeeping, manoeuvring, resistance, etc., proving that special attention has to be paid to validation problems in order to spread the use of computational methods to ship design and evaluation as well as to experimental activities.

References

[1] BOGDANOV P.A., HAIMOV A.J.,: "Application of Computing Methods in BSHC Research Activities," to be presented at ICCAS'88, Shanghai, China.

[2] MORGAN W.B., LIN W.C.,: "Computational Fluid Dynamics, Ship Design and Model Evaluation," Proc. Ⅳ IMAEM Congress, Varna, BSHC, 1987.

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DIFFICULTY OF IDENTIFICATION OF MEASUREMENT RESULTS

We recognize the rapid development of computational fluid dynamics (CFD). Morgan and Lin state in their recent paper[1] that CFD is having a strong impact on both ship design and model test evaluation. Especially the impact on ship model basins is occurring in various ways. One of them is a request for detailed and extensive flow measurement experiments which must be accurate enough for verification of CFD results. With increasing detailed experiments, the laboratory automation is spreading including sophisticated data processing. As a consequence, researchers in some places are losing the opportunity to look into the experiment or isolated from the raw data. The discusser considers that these circumstances accelerate the necessity of "uncertain analysis"(UA). Problem is then how we proceed to get reliable experiments with UA.

With respect to UA of experiments, we consider usually repeating tests to obtain a most probable result. However, since the experimental conditions change day by day or place to place in a strict sense, simple mean of these experimental results does not always give a meaningful solution, as is shown for example in the resistance measurement of Series 60 hull conducted under a cooperative experimental program of the present resistance and flow (RF) committee (see Fig.4, page 53 of Vol.1). Difficulty is the identification of measurement results or to discriminate between "difference" and "scatter". Another example is shown in the same RF committee report regarding the mean sinkage. The mean sinkage of four institutions noted as B−group (see above continuing Fig.5) indicates a good coincidence. Yet difference seems to appear among them. The data of HMRI and SHI are obtained under blockage $m \geqq 0.004$, while the data of ALM(L), IHI under blockage less than 0.0022. So the committee reports that small differences in sinkage of the B−group may be related with blockage. This statement might not be added if the committee was not encouraged by an another blockage effect study as seen in a serial Fig.13 (page 58).

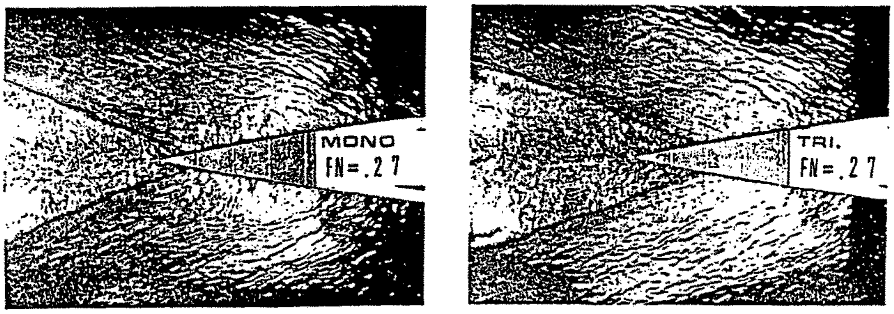

Fig.1 Observed Stern Waves 2.5m Wigley Models

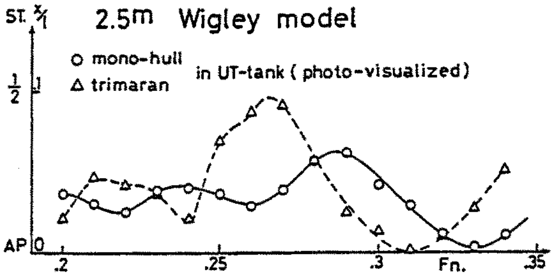

Fig.2 Starting Point of Stern Waves

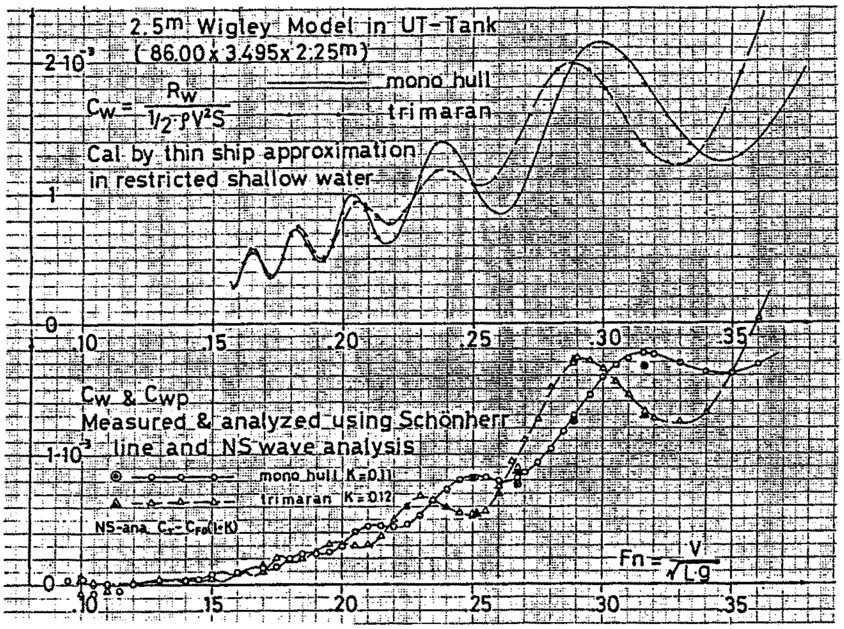

Fig.3

In order to get reliable data or to get a meaningful result, full consideration, well observation and systematic approach of experiments seem to be important with UA. This means that one should be educated by experiments. On this aspect the discusser would like to introduce his experience which happened at a combined study of stern flow with restricted water effect. For this purpose using Wigley hulls we conducted both mono−hull and trimaran experiments by which the blockage is tripled. We actually photographed the stern waves in UT−tank in the Fn range from 0.2 to 0.34 with 0.01 intervals. We carried out resistance tests and wave analysis. Fig.1 is an example of the photographed stern waves at Fn=0.27. The starting point of stern waves is summarized in Fig.2, while wave resistance coefficients Cw and wave−analyzed Cwp are given in Fig.3. We learn first that the generating point of stern waves moves up and down periodically depending on Fn. The movement is closely related with the phase of Cw−curves. Its detail is not given here because of the out of scope of the discussion. However there must be a dramatical interaction between bow waves and viscous boundary layer around stern. The discussion point is the instability of flow around the stern when the stern waves are generated most advanced. In this case, the initiating point of stern waves fluctuates fore and aft even within a single test running. Accordingly the measured total resistance or wave resistance coefficient are sometimes bifurcated at this Fn. This two different results of Cw of the trimaran at Fn= 0.267 are an example, which is not due to a measurement error but due to a definite unstable stern flow. The instantaneous resistance on the dynamometer increases with advancing of stern waves and decreases with delaying of stern waves. If the discusser did not watch the stern flow with the movement of resistance dynamometer, he might treat these two values as experimental error.

We appreciate the great development of CFD which may be exemplified by such as applications of Rankine source method, Reynolds averaged Navier−Stokes equation and Direct NS equation methods. We expect that uncertainty analysis or validation technique is also applied for the development of CFD which simulates the above experimental flow and resistance characteristics.

Reference

[1] W.B. MORGAN and W−C LIN,: "Computational Fluid Dynamics, Ship Design and Model Evaluation," 4th Conference of IMAEM, Varna, 1987.

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COMMENTS ON "ACCURACIES ENSURED BY TOWING TANK TESTS" BY TO YAMASAKI & T. TSUDA

The authors are to be congratulated on the extensive and methodical manner of considering the various factors that contribute to the uncertainty in R & P testing. However, when they combine these in an attempt to calculate what they term the 'accuracy' of measurement I have a difference of opinion with them.

1. The words 'accuracy' and 'error' are frequently abused by native English Language speakers, and therefore the authors of this paper cannot be criticised for the common but incorrect usage of these words. In the context of measuring unknown quantities the words 'accuracy' and 'error' imply that the true value of the unknown quantity being measured is known, when clearly it is not. They should be talking about uncertainty in a measurement and in the different components of uncertainty, or in the confidence that can be placed on the measurement.

2. The authors are attempting to combine uncertainty in model measurements and uncertainty in

model/ship extrapolation in one process. These are distinct processes which should be evaluated separately. If an attempt to combine them is made to estimate the overall uncertainty this should be performed later using a defined method.

3. The authors refer to the 'resolution' and/or 'repeatability' of various transducers when tested in the calibration mode. They then assume that the resolution of the R & P experiments will arise from the proper summation of these isolated individual resolutions. This procedure neglects interactions that can occur in testing in the tank when the actual experiment can be quasi unsteady. This is likely to arise in propulsion tests in the measurement of the towing force F and the difficulty of separating model inertia loads from the true towing force. On this subject I refer the authors to Ref.80 of the Report of the Powering Performance Committee at this ITTC. It will be seen from this reference that uncertainties arising from this interaction can dominate the uncertainty level of propulsion tests.

4. The determination of thrust from a model resistance and propulsion experiment is crucial when using the accepted methods of analysing experiments. There is random scatter on R, F and T and the following method is the one I use to determine the uncertainty in $(1-t)$ when using the load varying test technique in the propulsion experiment.

From observation of experimental results it appears likely that the scatter on F is independent on the scatter on T, then the uncertainty in $(1-t)$ can be determined by combining the individual uncertainties in $(1-t)$ in quadrature. Referring to Fig.1 the 95% confidence limits on the least squares lines of $(R-F)\upsilon T$ and $T\upsilon(R-F)$ are shown. Then using a calculated value of $(R-F)$, say $(R-F)p$ as the point of entry the uncertainy in $(R-F)p$ can be found as $\Delta(R-F)$. With Tp known the uncertainty can be found as ΔT. Then we have the two components of uncertainty due to the uncertainty in $(R-F)$ and T as,

$$\Delta(1-t)_{1'} = \pm\frac{(R-F)p}{Tp-(R-F)p}\cdot\frac{\Delta(R-F)}{(R-F)p}$$

$$\text{and}\,\Delta(1-t)_2 = \pm\frac{(R-F)p}{Tp-(R-F)p}\cdot\frac{\Delta T}{Tp}$$

Combining these in quadrature or root−sum squaring leads to,

$$\Delta(1-t) = \pm\sqrt{\Delta(1-t)_{1'}{}^2 + \Delta(1-t)_2{}^2}$$

Calculating the cofidence limits on $(1-t)$ this way for a set of good data mentioned in Ref.80 of the Powering Performance Committee Report leads to the information given in Fig.3. It will be seen from this that the 95% confidence limits on $(1-t)$ are very much larger than the value of the maximum deviation given in Table 2 of the authors' report.

I think that the Performance Committee have been a little hasty in not recommending the use of the Linear Regression Analysis (LRA) method described in Ref.80 on the grounds of economy in testing and apparently without regard to the quality of the result, or at least some knowledge of the confidence that can be placed on it. It is still possible, however, to employ the LRA method in a limited way by combining it at one speed, say, with the traditional 'Continental' method, as shown in Fig.3. This would then permit the Tank to provide confidence limits on the results at this speed, which could be the expected service or trial speed, together with obtaining the other advantages consisting of,

− different analysers producing the same result

from the same raw data,

− the use of parameters to indicate the quality of the data

− the closure condition 'n_T should equal n_Q'

as a check on the answer

The significant advantage of the LRA method, Ref.80, is when comparing results form similar models when small changes have been made. These could be changes to the hull form or the addition of so-called propulsion efficiency improvement devices. It is time, in my opinion that such comparisons were made in a more scientific manner.

Reference

[1] Yamasaki, T., Tsuda, T.: "Accuracies Ensured by Tank Tests", Symposium on Hull Form Development and Towing Tank, JTTC, 1983

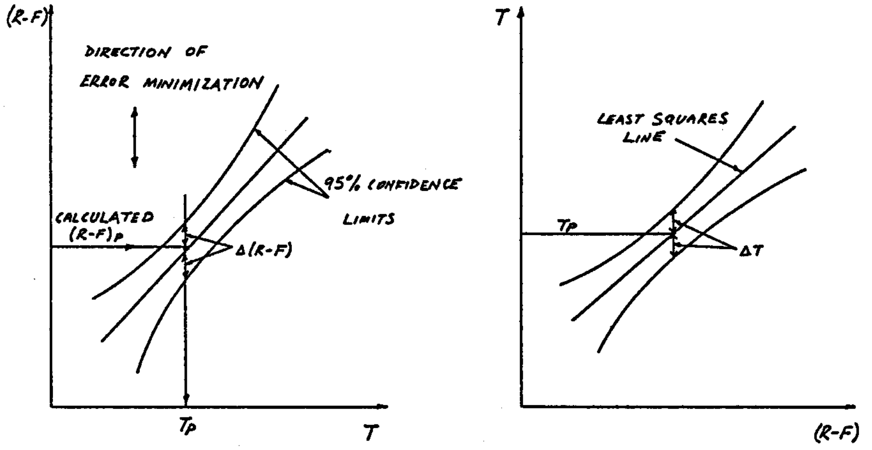

Fig. 1

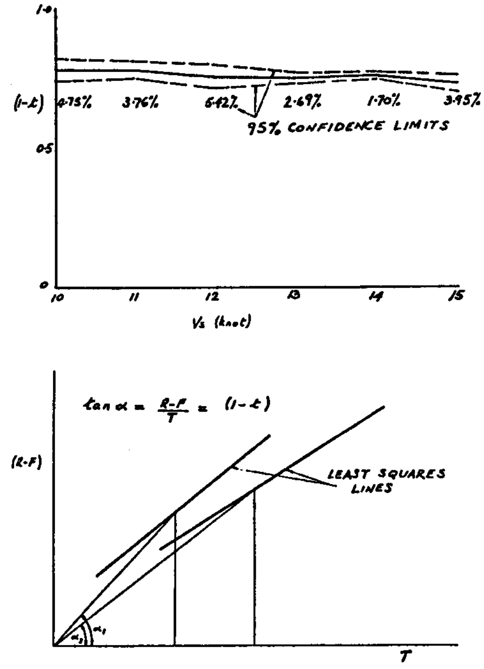

Fig. 2 Variation of Thrust Deduction with Speed (Bulk Carrier, C_B=845, HMRI)

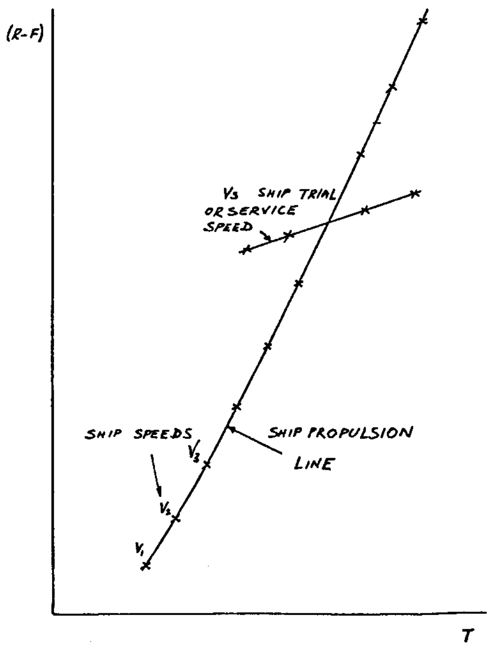

Fig. 3