# Comments on Reliable Prediction Accuracy

## A HydroComp Technical Report
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### INTRODUCTION

A traditional part of design has been the use of model testing to predict full-scale performance. In the arena of speed and power prediction, however, many designers are finding that predicting vessel performance with contemporary software, such as NavCad or SwiftCraft, is creating opportunities for shorter development cycles and improved designs with a prediction accuracy typically associated with model testing.

The purpose of any performance prediction is to accurately match the as-built delivered ship - not its model - so the historical precision of full-scale craft is a reasonable guide. One author cites deviations in wetted surface of 4% and displacement of 5% to be common [Schneiders, 1989]. Since the ITTC lists standard model test errors at about half of this figure [ITTC, 1978], there is an overall precision in model testing that is significantly better than the typical as-built vessel.

As can be seen from the above evidence, the institutional precision of model testing is quite reasonable, and well developed numerical methods - like those in NavCad and SwiftCraft - share this accuracy. An evaluation of the historical difficulties with numerical performance prediction, and how the software addresses these problems to provide a reliable, technically sound analysis platform will be described below.

### A HISTORY OF NUMERICAL PERFORMANCE PREDICTION

The numerical prediction methods found in the software are based on the statistical manipulation of empirical (test) data where hull, appendage and propeller data are based on "parametric" values. The exact three-dimensional description of the vessel or propulsor is not required. Rather, the data is described by hull parameters such as length on waterline, displacement and wetted surface, or by propeller parameters like diameter, pitch and blade area ratio. (To simplify the following comments, only hull performance - such as resistance and shaft power - will be addressed further since the history and basic procedures for propeller performance prediction parallel those for hull performance.)

The use of parametric prediction actually goes back some hundred years or more [Froude, 1888]. The techniques employed today however - while still utilizing solid fundamentals established long ago - are far removed from the original method of Froude. Advances in basic methodology, test procedures and numerical analysis have greatly enhanced the breadth and accuracy of parametric prediction.

One important contribution was the introduction of the "methodical series" or "statistical series". By testing a series of hull models in a systematic manner, one could assess the effect of particular hull changes on performance. In a typical series - Series 60, for example [Todd, 1963] - a "parent" hull is created that has certain design features, such as sectional area curve, turn of bilge, bow flare, entrance angle, for example. A matrix of models is then built that vary the principal shape parameters (L/B, B/T, Cp, etc.) in a systematic fashion to determine the effect on resistance of each of these principal parameters.

During the historical development of these model test series, prediction methodologies also went through an evolutionary process. One significant example the change in technique is with the friction line. No fewer than four different recommended skin friction lines have been established during the last fifty years [SNAME, 1988]. This may not seem like many, but each different friction line has required a different recommended value for the model scale to ship scale correlation allowance.

Another maturing technique has to do with the analysis of the wave-making (or residuary) component of resistance. This was originally segregated as a two-dimensional residuary resistance [Froude, 1888], and grew into the currently recommended practice of treating this as three-dimensional viscous and wave-making resistances [ITTC, 1978]. Like the different skin friction methods, each of the wave-making approaches utilizes different recommended values for the model-ship correlation allowance.

One significant advance in the parametric prediction of hull performance came with the use of statistical regression as a means to develop the results of systematic series into numerical formula. Since its introduction [Doust, 1959], a broad range of vessel types and tests have been regressed into numerical relationships.

Of course, performance prediction is not complete without the significant "added resistances", so numerical methods have been developed for added appendage, wind, seas and shallow water resistances. These items are often difficult to predict through a model test program and are frequently derived numerically.

## TYPICAL DIFFICULTIES WITH NUMERICAL PERFORMANCE PREDICTION AND PROPOSED SOLUTIONS

Due to less than successful experiences, many designers are justifiably skeptical about the ability to accurately predict performance. However, poor prediction accuracy is generally due to misuse of the methodologies, rather than inherent problems with the methodologies themselves. Some of these typical problems - and how the software addresses and corrects them - are outlined below.

### PROBLEM: Incorrect selection of a parametric prediction model (e.g. series or method)

Without a doubt, the most significant contributor to poor prediction accuracy is due to inappropriate selection of the basic parametric model. For example, it is unwise to use a cruiser-stern statistical series like the Taylor series [Taylor, 1943] to evaluate high-speed, transom-stern displacement vessels. However, many designers do just that.

*SOLUTION: A broad selection of parametric models*

In a setting where only a few parametric models are used and designers apply these few methods to a broad range of hull types, it is easy to see how errors can occur. In a comprehensive software, designers need not make compromises that lead to such errors.

HydroComp software provide the largest commercially-available library of prediction methods for a wide range of hull types and parameters. By appropriately selecting a method from the dozens of displacement, semi-displacement, planing, barge train, sailing yacht and catamaran routines, a designer can eliminate errors derived from using an unsuitable method. This software also aids in the selection of a parametric model by providing parameter range windows that display limits of the available methods in relation to the subject hull.

### PROBLEM: Using incompatible components

Too often, designers incorrectly mix prediction routines which are incompatible with each other. For example, in an attempt to employ a recommended contemporary approach, a designer will predict frictional resistance with the newer ITTC friction line [ITTC, 1957]. This designer will then use a frequently quoted correlation allowance of "0.0004", which was derived from analyses with the older Schoenherr friction line [Schoenherr, 1932] and is incompatible with the ITTC recommendations.

*SOLUTION: Compatible components are readily available*

With properly developed software, the calculation process naturally guides the designer toward the appropriate choice of compatible prediction components. For example, either the ITTC or ATTC friction lines may be used. Then, to insure compatibility, the software offers a selection of correlation allowance estimates with suitable values for either friction line.

In another instance, the software offers specific propulsive coefficient predictions for various hull types and propeller configurations. A designer is not forced to use an open-wheel figure if a ducted propeller is being installed, for example.

### PROBLEM: Forgetting necessary components

Wind, appendages, seas and shallow water all contribute to the real performance of the vessel at sea. Many times, however, designers will neglect some or all of these, or base added resistances on simple guesses. As these contribute significantly to total resistance - appendages for fast craft or the effect of shallow water can be as much as 25% of the total, for example - it is apparent that poorly defining these added resistances can greatly reduce prediction accuracy.

*SOLUTION: A complete analysis environment*

One source of prediction error is simply to forget one or more important parts of the picture. By placing all of the necessary routines in front of a designer, the software helps to insure that no part is accidentally omitted.

A designer has complete control over the analysis. No assumption is hidden and no pre-set methodology or calculation path is needlessly forced on a user. In every possible way, the software offers complete freedom to run the predictions and analyses in any manner the designer chooses. To further aid the designer in preparing a complete and error-free evaluation, the software has a comprehensive error and data checking system that helps to discover potentially hidden errors.

The help system places a complete library of methodology, data definitions and descriptions of the parametric models in the hands of the designer. Included in this help system are comments by users and industry experts that help a user to choose the best methods and to guide a designer toward an accurate prediction.

**PROBLEM: Using poorly developed regression methods**

Simply because a regression formula is based on model tests is no guarantee that the developed numerical regression will generate accurate results. Occasionally, methods are presented that do not follow a well-planned statistical development, leading to what is termed an "unstable" formula. These unstable relationships may quite accurately predict the original test data points, but fall apart between points and in extrapolating beyond the data set. A well-developed regression, on the other hand, accurately forecasts the trends across the range of data, as well as for the test data itself.

*SOLUTION: The nature of statistical analysis*

The very nature of the statistical manipulation of test data can help insure good results with the software. Two features of the regression process add to prediction reliability.

First, regression helps to smooth the effect of any one test into the results of the remaining tests of the series. While the results of any one particular model or test may be suspect, the regression process is "self-regulating" and the series as a whole remains well-behaved and of good quality.

Second, HydroComp has reviewed the available statistical prediction methods, and only those that are technically valuable to a designer and were appropriately developed are included in the software.

**PROBLEM: Using outmoded methodologies**

Evolutionary changes in hull form have demanded that numerical methods keep pace. Many designers, however, do not have enough time or interest to keep abreast of contemporary methodologies which are suitable for these newer hull forms and speed regimes. For example, the two-dimensional (Cf-Cr) structure produced acceptable results while vessels remained fairly slow, where friction was the major contributor and wave-making was well-behaved and consistent. As vessels became faster and new hull performance characteristics emerged, the two-dimensional approach proved unsuitable, and gave way to the three-dimensional form-factor method [ITTC, 1978] and to recent enhancements on this theme [Holtrop, 1988].

*SOLUTION: State-of-the-art methodologies*

Most of the methods in the software are based on collections of model tests, so the mathematical accuracy is comparable to that of model testing. Many of the routines also include the results of sea trials, thereby enhancing the ability to predict values more in line with full-scale vessels. They includes these newer parametric models and insures their best use as described in the following examples.

- Some of the available methods are based on older techniques, such as the two dimensional Cr approach. To take full advantage of current recommended practices (like the recent ITTC three-dimensional form-factor method) the software numerically recreates model scale results via the original tested model length and friction line. Then, the software allows the user to build these results to full-scale based on the designer's preference to utilize traditional approaches or to fully exploit contemporary practices (two-dimensional or three-dimensional, ITTC or ATTC friction line and correlation allowance).
- For planing craft, the software extends the simple prediction of bare-hull resistance into an equilibrium trim analysis. Here the effect of hull, flaps, propulsor, appendages and wind are resolved into an equilibrium sum of all forces and moments at each speed, resulting in a true dynamic trim. Each component is then evaluated at this trim, insuring realistic, not simplified, results.
- The shaft power analysis offers the use of a wake fraction scale correction [ITTC, 1984], and establishes equilibrium state propeller RPMs for both fixed and controllable-pitch propellers in a manner similar to self-propelled model tests. Open-water propeller efficiency is determined at these equilibrium RPMs, thereby presenting true system efficiencies and powers, not a value derived from a rudimentary formula.

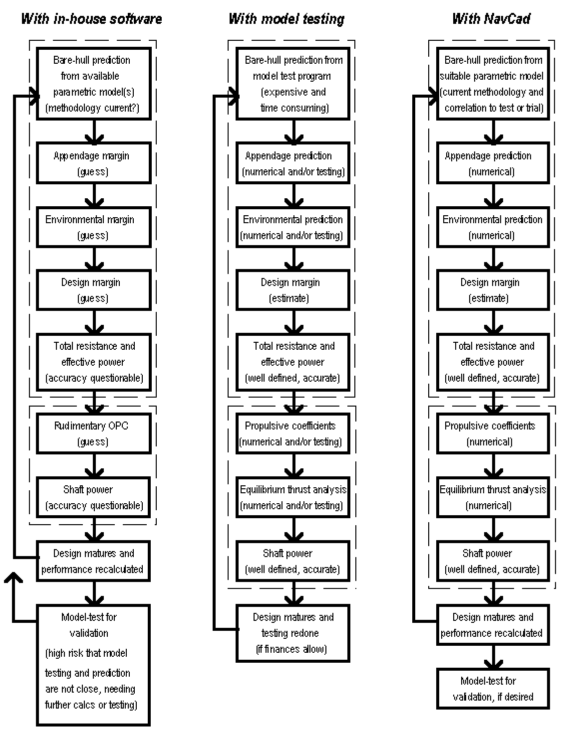
 

## ANCHORING TO REAL-WORLD DATA

Even though NavCad offers a comprehensive collection of prediction methods, a designer may encounter a vessel that does not neatly fit into one of the available parametric models. In these cases, a designer typically has had few options but to accept the results of the closest method with some margin to cover the differences. It is possible in many of these design situations to improve prediction accuracy by using NavCad's ability to correlate a resistance prediction to a model or full-scale test of a design variant or suitable "family" hull.

Without going into great detail, this feature "realigns" a prediction to suit a particular set of test results. In other words, NavCad first sees how well the prediction fares against the model and then applies a correction to the prediction of the subject hull based on this information. The resulting resistance values then reflect the basic resistance "magnitude" of the selected parametric method, in concert with the hydrodynamic "character" of the correlated model.

**Typical resistance and shaft power prediction scenarios**




## CONCLUSION

HydroComp software clearly offers an extremely cost-effective means to predict performance with an accuracy comparable to model testing - especially when aligning to test data as described above. With a) complete control of the methodology in the hands of the user, b) the ability to rapidly evaluate many design options and c) a modest one-time capital investment, the software can be a valuable alternative to a design-oriented model test program - particularly during early and intermediate design stages.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