The Specialist Committee on Validation of Waterjet Test Procedures

Committee Chairman: Prof. Tom J.C. van Terwisga
Session Chairman: Dr. Stuart Jessup

1. DISCUSSIONS

1.1 Discussion to the 24th ITTC Specialist Committee on Validation of Waterjet Test Procedures by Gilbert Dyne, SSPA and Chalmers university of Technology, Sweden

When reading this ambitious Report I came to think upon an expression I heard when I was a young engineer 50 years ago. One of my colleagues used to say, “Why describe a problem in a clear and straightforward way when you can complicate it so beautifully?”

The prediction method we presented to ITTC in 1996 is straightforward. It is based upon self-propulsion tests and some special pump tests. Resistance tests were not used partly because they were not needed and partly because we regarded the flow conditions at the afterbody so different that a comparison between self-propulsion and resistance tests was meaningless. The number of new symbols introduced was as small as possible and only three efficiency symbols were used.

I do not know how many new symbols there are introduced in the present Report but the number of efficiency symbols is fourteen, six of them being used to determine the propulsive efficiency!

The power prediction of a water jet system is complicated as it is. Why complicate it further by taking also the resistance tests into the prediction procedure? The risk the Committee is taking when doing so is that the procedure becomes so complicated that many Members of ITTC refuse to use it and instead continue to predict the power using their old methods.

1.2 Discussion to the 24th ITTC Specialist Committee on Validation of Waterjet Test Procedures by Thad Michael and Stuart Jessup, Naval Surface Warfare Centre, Carderock Division, USA

Michael and Chesnakas (2004) presented a discussion of waterjet pump loop testing and comparison with a lifting surface/Euler design and analysis approach. A RRNM AWJ-21 mixed flow pump was tested in the NSWCCD 36 inch (914mm) water tunnel.

The pump inlet diameter was 191 mm. To permit the use of available LDV flow diagnostics, the pump was tested in a long duct in the tunnel test section, shown in Fig. 1.1. Interchangeable nozzles were used to vary the mass flow. Smaller flow rate adjustments were made by varying the tunnel speed.

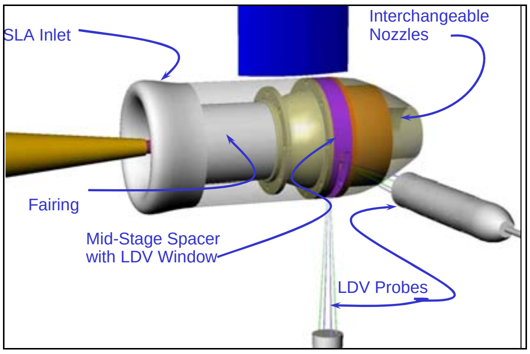

Figure 1.1- Test configuration in water tunnel.

Three component velocity measurements just downstream of the rotor showed a complex leakage vortex structure. The vortex appeared to cross the blade passage into the wake of the following blade. Figure 1.2 shows the leakage vortex structure downstream of the rotor.

Velocity measurements were also made at the inlet, exit, and between the rotor blades. Pressure measurements were made at the inlet, between the rotor and stator, and at the nozzle exit.

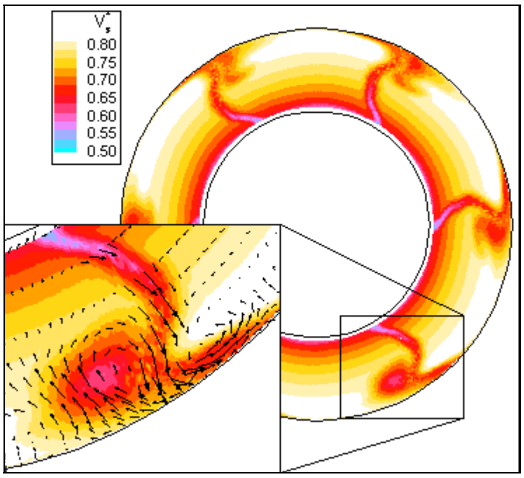

Figure 1.2- Measured flow downstream of waterjet rotor.

The PBD14/MTFLOW analysis is a potential flow based method, with viscous corrections. It has been shown to work well for open propellers.

Tests showed that the PBD14/MTFLOW analysis procedures were not capturing all of the physics. The discrepancies, shown in Fig. 1.3, are believed to be due to insufficient modelling of viscous pump losses not present in open propeller flows.

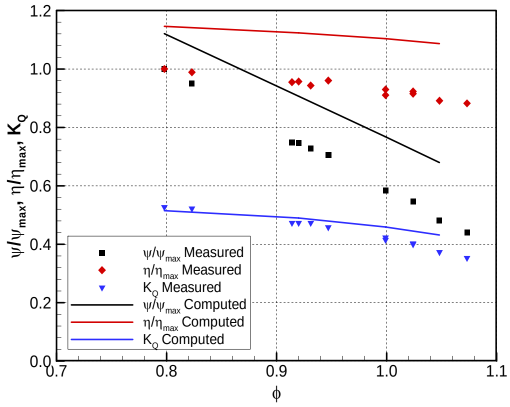

Figure 1.3- Pump performance: calculations and measurements. Both ϕ and ψ are normalized by the highest value measured with the original rotor.

Viscous corrections for blade drag, casing drag, and tip leakage flow have been added. However, the current empirical tip leakage model relies on many approximations, particularly regarding the induced velocities from the leakage vortex.

We would like to ask the Committee their opinion on the importance of considering the details of the tip flow in predicting performance, particularly the trajectory of the leakage vortex.

Also, the current prediction method does not consider large scale secondary flows in the blade passage. We would also appreciate an opinion on the importance of these flows. Comments on the pump loop test procedure used in this study would also be welcomed.

References.

Michael, T.J. and Chesnakas, C.J., 2004, "Advanced Design, Analysis, and Testing of Waterjet Pumps", 25th Symposium on Naval Hydrodynamics, St. John's, Newfoundland and Labrador, Canada.

1.3 Discussion to the 24th ITTC Specialist Committee on Validation of Waterjet Test Procedures by Anton Minchev, FORCE Technology, Denmark

I would like to thank and congratulate the Committee for its excellent and well presented Report. My point of discussion is the unusually high scatter of the bare hull resistance tests results comparison. This is reported to be about 7% to 8% as far as the non-dimensional drag (resistance) coefficient is concerned. Reference is made to Fig. 4.1 in the Report, which presents the actual measured resistance force. It seems that the scatter is somewhat less, compared with the scatter of the non-dimensional drag coefficient. The behaviour of the latter as shown in Fig. 4.2, suggests that the model has exceeded its critical speed ($F_n \approx 0.5$) and reached the semi-displacement mode. At such high relative speed some dynamic lifting force is already contributing to the change of running trim and wetted surface.

Hence my question is whether the still water or the running wetted surface was taken into consideration when calculating the model resistance, or drag coefficient. If the institutions involved in the comparison study had applied difference interpretation of the running wetted surface, then naturally the derived drag coefficient will exhibit enhanced scatter, proportional to the scatter of the calculated wetted surface.

The Committee could, therefore, be advised to re-analyse the data by comparing directly the measured model resistance force with subsequent careful check of the way the non-dimensional drag coefficient is calculated. This will probably help to reduce the observed scatter and improve the correlation between the different tank results.

2. COMMITTEE REPLIES

2.1 Reply of the 24th ITTC Specialist Committee on Validation of Waterjet Test Procedures to Gilbert Dyne

The Committee highly values Prof. Dyne's philosophical comments on the matter as well as it values his contributions to previous work on waterjets and to ship propulsion issues in general.

Although the prediction method of the 1996 ITTC method may appear to be straightforward, it shows a number of anomalies:

- First, it fails to find the relation and the mechanisms for the difference between waterjet thrust and bare hull resistance. Instead, only the change in momentum flux is used. This makes it difficult to relate the waterjet thrust to the bare hull resistance, quantities the ship designer often uses to select a proper waterjet system in an early design stage. By not explaining the relation between "change in momentum flux" on the one hand, and thrust and resistance on the other, it is also difficult to verify or falsify an experimental result. An activity that is not regarded as merely a luxury, given the complexity of flow rate measurements and the many sources of bias errors that can affect the measurement.
- Secondly, a fundamental flaw was introduced by using spatially averaged energy velocities in momentum fluxes.
- Through a lack of systematic approach in the theory behind the experimental analysis, the analysis was necessarily limited as a diagnostic tool in identifying the sources for energy losses.

Despite the impression raised by Prof. Dyne, the Committee would like to emphasize that a major goal of their work is to provide a simple, yet complete, and robust procedure to determine the powering characteristics of waterjet driven craft. To ensure that the theory behind the procedure is complete and robust, a rigorous systems breakdown of the waterjet-hull system was made in terms of energy flows and losses through the total system. The various sources for energy losses were subsequently acknowledged and new terms were introduced only where this could not be covered with existing terminology. Care was thereby taken not to introduce unnecessary new symbols. The systematic nature of the identification of sources for energy losses is believed to assist in the analysis and the optimization of waterjet-hull systems, as all terms introduced are associated with identified physical processes.

Finally, the Committee would like to state that to their belief, it is up to the individual institutes to make simplifications or to collapse terms into one efficiency. This Committee has attempted to provide the rigorous framework that allows for simplifications in a rational manner.

2.2 Reply from the 24th ITTC Specialist Committee on Validation of Waterjet Test Procedures to Thad Michael and Stuart Jessup

The Committee would like to thank Dr. Michael and Dr. Jessup for drawing our attention to their very valuable contribution.

As to the importance of the reported leakage vortex in the wake of the impeller, there are two aspects: A possible tip leakage vortex on the pump used during the propulsion tests, and the tip leakage flow in the prototype pump.

The tip leakage vortex in the model pump used for the propulsion tests, will contribute to the non uniformity of the discharged jet. If the tip leakage vortex would have the same strength and position during the flow rate calibration and during the propulsion tests, it would not affect the flow rate calibration. It is however, likely that both the position and the strength are affected by the pump loading condition, and that there is a slight difference in velocity profile for the both conditions. Depending on the reference pressure measurement technique that is used during the propulsion tests, this will contribute to the bias error in the flow rate measurement. This observation emphasizes the importance to measure the reference pressure at multiple locations, so that small changes in velocity distribution are at least in part, accounted for.

With regard to the effect on the prototype pump, the hypothesis is suggested in the contribution, that the secondary vortex is responsible for at least part of the discrepancy between computed and measured head and torque coefficient. The effect of the tip leakage vortex should clearly be taken into account, when the model pump of convenience is substituted by the prototype pump. It is therefore good to be aware of this physical phenomenon, which does affect the discharged momentum and energy fluxes, and therefore the pump characteristics.

The pump loop test set-up in this procedure seems to meet the requirements of a uniform inflow and controlled pump head. This is confirmed by the marginal scatter in experimental data.

2.3 Reply from the 24th ITTC Specialist Committee on Validation of Waterjet Test Procedures to Anton Minchev

The Committee thanks Dr. Minchev for his comment on the scatter in bare hull resistance results. They share the astonishment expressed by Dr. Minchev about the large scatter in results. It is a serious concern to the Committee, as the resistance test is probably the most common test performed by any towing basin. This Committee did some investigations on the differences, but given the scope of their mission and the “double blind” method of reporting, information on facilities and some of the details of resistance test procedures were not available.

Although the Committee agrees that, in principle, the scatter in resistance coefficient could be somewhat reduced when the actual wetted surface would be taken into account, they believe that this is not the major cause for the scatter. Since the maximum Froude number is approximately 0.7, where dynamic lift is still limited, the Committee does not believe that a speed dependent wetted surface correction would improve the scatter in experimental data noteworthy.

It is noted here that in the derivation of the resistance coefficient from the dimensional resistance values in Fig. 4.2 of the Report, the same wetted surface was taken for all test cases, irrespective of speed, and irrespective of the differences in displacement, which showed a maximum deviation of 3.5% from the design displacement. This deviation in displacement corresponds roughly to a deviation in wetted surface of some 2.3%. Applying the wetted surface corrected for displacement (speed 0) will take away some, but will still leave an undesired scatter.

The Committee has not made a rigorous attempt to analyse the cause for the remaining differences in measured resistance. Yet, they have identified a number of possible sources that are considered responsible for deviations in measured resistance:

- Risk of change of displacement during resistance test due to leakage in the waterjet inlets.
- Blockage caused by the finite dimensions of the towing tank.
- Carriage interference effects on the water surface (induced waves) and air induced drag on the model.
- Change of model condition. There appeared however to be no correlation between time and model condition, and the resistance. Model 2 split on shipping, but the results of the repaired Model 2 compare well with Model 1's first test.
- Differences in method used to tow model. The effect of towing method is seen most dramatically in the running trim data. Some facilities used a single tow point, others use a twin staff towing apparatus. This is likely to introduce differences in trim and measured drag.

Given the focus of this Committee on Waterjet Test Procedures, it would like to gently pass this unsettled problem through to the Resistance Committee, who has a special assignment to look into the scatter of resistance results.