The Specialist Committee on Azimuthing Podded Propulsion

Committee Chairman: Prof. Mehmet Atlar
Session Chairman: Dr. David Clarke

1. DISCUSSIONS

1.1 Discussion to the 24th ITTC Specialist Committee on Azimuthing Podded Propulsion by Björn Allenström, SSPA Sweden AB, Sweden

On page 555 it is claimed that the pod-housing drag scaling method at SSPA (method c) does not take into account the strut. This is wrong. It is also wrong that the method shouldn't be appropriate for bodies like pod-housing. SSPA method is based on experience from different submerged bodies, such as submarines, and takes into account both pod-housing strut and interference drag, pod-housing-strut according to below:

<u>POD Thrust Correction.</u> The thrust correction for the POD or thruster unit is calculated by comparing the measured POD resistance R_{PODm} with the calculated model resistance $R_{PODcalcm}$. The full-scale POD resistance R_{PODs} is obtained by applying the relation between measured and calculated model scale POD resistance together with the calculated full-scale resistance $R_{PODcalcs}$. The full scale POD resistance R_{PODs} is given by,

$$R_{PODs} = \frac{R_{PODm}}{R_{PODcalcm}} R_{PODcalcs}$$

The calculated resistance is the sum of POD body resistance, fin resistance and interference resistance, i.e.

$$R_{PODcalc} = R_{body} + R_{fin} + R_{int}$$

The calculation of body, fin and interference resistance is described below.

The POD resistance $R_{PODm,sp}$ at the self propulsion water temperature is then obtained using the calculated POD resistance $R_{PODcalcm,sp}$ at the same water temperature and the correction method described above, i.e.

$$R_{PODm,sp} = \frac{R_{PODm}}{R_{PODcalcm}} R_{PODcalcm,sp}$$

POD thrust coefficients in model-scale and full scale are calculated according to

$$C_{TPODm} = \frac{R_{PODm,sp}}{\frac{1}{2}\rho_m V_m^2 S_m} \qquad C_{TPODs} = \frac{R_{PODs}}{\frac{1}{2}\rho_s V_s^2 S_s}$$

The POD thrust correction R_{aPOD} in model scale is calculated as

$$R_{aPOD} = \tfrac{1}{2}\rho_m V_m^2 S_m \left(C_{TPODm} - C_{TPODs}\right)$$

<u>POD Body Resistance.</u> The resistance of the hull is determined as the sum of the frictional resistance of a flat plate (ITTC-57 skin friction line) and a form factor k_{body},

calculated using the parameters introduced by Granville (1956) when evaluating the results of Nordström et al. (1954), and some other results, i.e. $C_B \cdot B/L$.

where,
C_B = block coefficient
B = breadth
L = length

The formula in Granville (1956) is based on the Schoenherr formula for the flat plate resistance. Accordingly, the results of Granville (1956) were recalculated using the ITTC-57 line as a basis and a modified formula was obtained. The material of Nordström et al. (1954) includes results of ship models in the non-wave making range and completely submerged bodies. Thus the formula based on these results can be expected to cover bodies of quite different shape, the parameter B being assumed to be the largest athwart dimension.

The frictional resistance coefficient for the POD body C_{Fbody} is calculated from the ITTC 1957 model-ship correlation line, giving the relation between C_F and Reynolds number R_{nL}

$$C_F = \frac{0.075}{(\log_{10} R_{nL} - 2)^2} \qquad R_{nL} = \frac{VL}{\nu}$$

where,
V is the speed [m/s], L is the length of hull in [m], ν is the kinematic viscosity [m^2/s] (ITTC 1960) and g is the acceleration due to gravity [m/s^2].

The roughness allowance coefficient for the POD body ΔC_{Fbody} is assumed to be

$$\Delta C_{Fbody} = \left[105\left(\frac{k_s}{L}\right)^{1/3} - 0.64\right]10^{-3}$$

where,
k_s is the hull roughness. If $\Delta C_{Fbody} < 0$, it is set to $\Delta C_{Fbody} = 0$.

The body resistance R_{body} can then be calculated using

$$R_{body} = \tfrac{1}{2}\rho V^2 S_{body}\left[C_{Fbody}(1 + k_{body}) + \Delta C_{Fbody}\right]$$

where,
S_{body} is the wetted surface of the POD body and k_{body} is the form factor determined from systematical tests with submerged bodies.

<u>Fin/Strut Resistance.</u> The total resistance of the POD fin/strut is assumed to be the sum of skin friction resistance of the equivalent flat plate (ITTC-57 line), the form resistance and the surface roughness resistance for the fin.

The fin/strut resistance R_{fin} is then calculated according to

$$R_{fin} = \tfrac{1}{2}\rho V^2 S_{fin}\left[C_{F\,fin}(1 + k_{fin}) + \Delta C_{Ffin}\right]$$

where,
C_{Ffin} and ΔC_{Ffin} is calculated according to equations above.

<u>Interference Resistance.</u> The interference resistance is defined as the total resistance for the body + fin minus resistance of body and fin alone, that is the increase of the resistance due to the fact that the fin is located on a body.

The total resistance thus obtained was compared with experimental values from tests in the towing tank. Based on the results of this comparison the formula giving the interference resistance was adjusted to agreement according to

$$R_{int} = \tfrac{1}{2}\rho V^2 B_{sl}^2 F\left(\frac{B_{sl}}{H_{sl}}\right)$$

where,
H_{sl} is the mean height of fin [m].

The function F is dependent of the ratio $\frac{B_{sl}}{H_{sl}}$.

References.

Granville, P.S., 1956, "The Viscous Resistance of Surface Vessels and the Skin Friction of Flat Plates", Trans. SNAME, Vol. 64.

Nordström, H.F., Edstrand, H. and Lindgren, H., 1954, "On the influence of form upon Skin Friction Resistance", SSPA Publ. No 31.

1.2 Discussion to the 24th ITTC Specialist Committee on Azimuthing Podded Propulsion by Neil Bose, Memorial University of Newfoundland, Canada

The interim procedure for Podded Propulsors prepared by the Propulsion Committee of the 23rd ITTC included options for extrapolation of powering for ships fitted with podded propulsors that included use of both resistance, open water and self-propulsion tests as well as methods using results from load varied self-propulsion tests only. This was done purposely to leave options open for these relatively new propulsion systems because at least one major tank used these methods regularly and because little full-scale trials data were available for validation of methods. The Specialist Committee on Azimuthing Podded Propulsion explains that there is still little data for validation of methods and as a result I am disappointed to see that the new procedure has recommended the use of one of these approaches only, without validation in the open literature. This seems premature and a rather conservative approach that will stultify progress especially as there is evidence (see the Report of the Specialist Committee on Powering Performance Prediction) that uncertainty levels of extrapolations done using load varied self-propulsion data only, may lead to lower levels of uncertainty in ship powering performance prediction. It is a pity that the ITTC procedure for podded propulsors now no longer leaves this option open within the approved procedure.

1.3 Discussion to the 24th ITTC Specialist Committee on Azimuthing Podded Propulsion by Ian W. Dand, BMT SeaTech Ltd, United Kingdom

The Committee's Report is interesting and comprehensive and an important contribution to the techniques of model testing podded propulsors.

While congratulating the Committee, I have one question to ask. It concerns the manoeuvrability of vessels fitted with a mixture of fixed and azimuthing pusher pods. To be specific, the discusser had to deal with a proposed design which had four pods at the stern, comprising two fixed pods (port and starboard) with two fully azimuthing pods (again port and starboard) astern of them. A simulation model was built of this arrangement and it suggested that turning was degraded when all four pods were working, compared to the case when only the two aft azimuthing pods were in operation, with the fixed pods stopped.

This was put down to the course-stabilising effect of the two fixed pods in the turn, brought about by the momentum drag of their propellers. This suggests that, for low speed manoeuvring, it would have been preferable to stop the fixed pods and manoeuvre only with the two azimuthing pods aft.

I wonder if the Committee have any comments?

1.4 Discussion to the 24th ITTC Specialist Committee on Azimuthing Podded Propulsion by Manfred Mehmel, Schiffbau-Versuchsanstalt Potsdam GmbH, Germany

Mr. Chairman many thanks for your sophisticated work in your Committee. Let me make one comment to the problem of IMO Manoeuvring Criteria. From my point of view you have to take in account the different side forces of a single rudder in the behind condition and a podded drive for the same helm angle. From my experience there is a need of about 2.5 times higher angles for a pod for the same side force. This means that comparable results with a single screw, single rudder ship most done with much higher helms angle of the pod driven ship. This is valid for Zig-Zag Manoeuvres especially.

It is clear ITTC should contact IMO for making remarks for pod driven ships.

1.5 Discussion to the 24th ITTC Specialist Committee on Azimuthing Podded Propulsion by Friedrich Mewis, Hamburgische Schiffbau-Versuchsanstalt, Germany

Dear Mr. Chairman, I would like to thank you and the whole Committee for the work you have done. It is the best collection regarding all problems of azimuting podded drives I have ever seen. I have one question and one comment.

1. The question:

Why do you recommend measuring the system thrust using a two component balance. My experience is: it is nice but there is no need. You can measure the thrust by a one component balance very well.

2. The comment:

In the Report there is a discussion regarding scaling the drag of the pod-housing.

HSVA is using an application of the method used for passive propulsion devices that has been used for more than 20 years. The drag corrections are moderate, in the range of 20% to 40% of the model drag.

In any case we take a plausibility check to avoid mistakes. The best method for this check would be to make RANS calculation both for model-scale and full-scale with the working propeller taken into consideration. If the calculation is well validated it leads to the most believable results, see written discussion Chicherin and Pustoshny. We have done it in a few examples. Unfortunately, this method is both time and money consuming and not very practicable for commercial work.

We are checking the results of the correction calculations in a very simple way. We are measuring the pod-housing resistance without propeller, for different speeds and estimate the drag coefficients. In all cases, more than 20, the drag coefficient is stable at model speeds higher than 2m/s and the coefficients do not differ very much. As the basis of this comparison, we check the correction in each case. From my experience more than a 40% correction is not possible.

Please look at the whole system, the pod-housing drag is only a small part of the whole correction needed for the system, ship model, propeller model and pod model.

1.6 Comments to the 24th ITTC Specialist Committee on Azimuthing Podded Propulsion by Anthony Molland and Stephen Turnock, University of Southampton, United Kingdom

We should like to make a couple of comments on the Report of the Azimuthing Podded Propulsion Committee.

Firstly, when considering propeller rotational effects on the induced drag of the pod-housing, Section 6.3 and strut gap effects, Section 5.3, we would suggest that much useful information can be gained from existing propeller-rudder interaction studies, such as those in Molland and Turnock (1993, 1996 and 2002). These should prove particularly useful for puller type pods and for the validation of CFD analyses.

Second, on the subject of yaw checking and course keeping when propelled by podded propulsors it is apparent that deflection of the podded propulsor is a very inefficient way of producing side force. We believe that the efforts should be directed at investigating secondary means of producing side fore such as flaps on the pod-housing or the incorporation of conventional rudders. It is interesting to note that waterjet propelled vessels can suffer similar problems with course keeping by having to deflect large quantities of water and in many cases, this has been overcome by incorporating small conventional rudders or interceptors.

References.

Molland A.F. and Turnock S.R., 1993, "Wind Tunnel Investigation of the Influence of Propeller Loading on Ship Rudder Performance", Transactions of the Royal Institution of Naval Architects, Vol. 135, 105-120.

Molland A.F. and Turnock S.R., 1996, "A Compact Computational Method for Predicting Forces on a Rudder in a Propeller Slipstream", Transactions of the Royal Institution of Naval Architects, Vol. 138, 59-71.

Molland A.F. and Turnock S.R., 2002, "Flow Straightening Effects on a Ship Rudder due to Upstream Propeller and Hull", International Shipbuilding Progress, 49, No. 3, 195-214.

1.7 Discussion to the 24th ITTC Specialist Committee on Azimuthing Podded Propulsion by Alexander Pustoshny, Krylov Shipbuilding Research Institute, Russia

Initially I've prepared and distributed a short comment (discussion 1.8) in order to illustrate the assumptions from one of the most critical points for the development of a Podded Propulsor Performance Prediction Procedure. But after the Reports of both the Resistance and Powering Performance Prediction Committees it is important to give more general comments.

You may remember that in the discussion on 23rd ITTC Propulsion Committee we, with Dr. Chicherin, offered to scale resistance by applying the relation of model and full-scale viscous resistance, calculated by RANS-code, instead of form factor. The idea was based on the results of analysis of international RANS-code workshop, and was published in 3rd Volume of Proceedings of 23rd ITTC. Also, it was found that the relation of the calculated viscous resistance coefficients was almost independent of the RANS-code version.

In spite of highly promising perspectives, either the Resistance or Powering Performance Prediction Committee did not give their comments or even mentioned such an approach, concentrating on further development of the flat plate model and form factor accuracy. But it is clear that the flat plate model, initially very useful and developed by the best ship hydrodynamics, should have some limitation of the accuracy simply because the hull is not a flat plate.

We have met such a situation in the attempts to scale the housing drag for podded propulsion. RANS-code calculations showed that due to the very complicated 3-D inflow, which also includes swirling slipstream of the propeller when we apply a traditional flat plate model, we should operate with form factor equal to 5-8. So, correlation factors between flat plate and a realistic body was 4-7 times higher than the flat plate resistance value, and so, it is unacceptable.

That is why at the T-POD Conference we, together with Dr. Sánches-Caja, have published a scaling procedure based on RANS-code analysis, having in mind that such analysis is more or less accurate, and takes into consideration all particulars of the complicated inflow.

In the distributed discussion (Section 1.8) you can find an analysis of two alternative procedures, one based on non-swirl slipstream with axial propeller induced velocity calculated by formula for ideal propulsor, and another method offers to apply for the housing drag scaling, the results of axi-symmetrical RANS-code for the gondola only.

I hope, the analysis presented will help the future Azimuthing Podded Propulsion Committee to come to the correct decision on housing drag scaling.

1.8 Comments to the 24th ITTC Specialist Committee on Azimuthing Podded Propulsion by Alexander Pustoshny and hicherin, Krylov Shipbuilding Research Institute, Russia

The draft Podded Propulsion Prediction procedure presented in the Azimuthing Podded Propulsion Report refers to five different housing drag reduction scaling procedures. While developing those procedures, different research institutions followed different approaches and that caused certain differences in the final results. Analysing the involved approaches appears crucial for the future development of the final procedure.

So far, we have attempted making the first step and considered approaches embedded in two methods: HSVA and MARIN. As a basis for comparisons, it was natural for us to take results published by Chicherin et al. (2004). That was motivated not by the desire to promote our own results but by some more profound reasons. Those results covered the kinds of thrusters: streamlined and with more blunt shapes. Besides, those results came from different authors who used two different RANS codes but which agreed quite well with each other. Moreover, the application of RANS codes enabled them to account for the physics of the flow around the podded propulsors in the most comprehensive way.

In the HSVA procedure, housing drag extrapolations are based on scaling the friction resistance of the housing and calculations for the portion of the housing that happens to be in the inflow accelerated by propeller induced velocities, which are made with the formula of the ideal propulsor theory. The essence of the approach is that the pressure resistance does not depend on Rn and the propeller impact manifests itself only through the increased velocity in the propeller slipstream. The first of these assumptions has the strongest impact under the discussed approach. It leads to ignoring the housing configuration influence upon the flow pattern, and therefore with the same difference between the model and full-scale Rn numbers the same propeller loading values, scale effects in the housing drag are the same for any housing configuration. However, this contradicts with the physical realities of flow patterns. E.g., according to calculations by Chicherin et al. (2004), for a well-streamlined housing the reduction of the full-scale resistance coefficient compared to the model should be 31% whereas according to the HSVA method it is just 21%. Thus, the HSVA method tends to overestimate the full-scale drag for well-streamlined housings.

In the MARIN procedure, the total resistance is divided into two parts: one should be scaled and the other is independent of Rn. The relation between these two portions is defined by gondola (pod) + propeller resistance calculations using an axis-symmetric RANS code entitled “PARNASOS”. The most significant assumption in this approach is about the possibility to use axis-symmetric results. As far as we can see, the “axis-symmetric version” means no allowance for the impact of the tangential induced velocity and surely no allowance for the distortion of the tangential flow by the strut. Our attempt to apply the MARIN method to well-streamlined podded propulsor discussed in Cicherin et al. (2004) demonstrated that in order to achieve agreement between MARIN and KSRI procedures the former would need taking the

$(R_{RnD}/R_{housing})_{calculated}$ coefficient as 0.58. According to MARIN, however, this value corresponds to a "not well streamlined shape of puller-type pod". For poorly streamlined (blunt) pods, we believe it should be not 0.54 as recommended by MARIN, but 0.25 ~ 0.3. Thus, this procedure may underestimate the full-scale housing drag. Nevertheless, after finding more accurate (in the sense of more precise RANS code calculations) recommended values of the $(R_{RnD}/R_{housing})_{calculated}$ coefficient this method may be considered as an option for the final "simplified" housing drag scaling procedure.

Nevertheless, the authors insist that the most reliable scaling is achieved only on the basis of RANS code calculations.

References.

Chicherin, I., Lobatchev, M., Pustoshny, A. and Sánches-Caja, A., 2004, "On a Propulsion Prediction Procedure for Ships with Podded Propulsors Using RANS-Code Analysis", 1st International Conference on Technological Advances in Podded Propulsion, University of Newcastle, UK

2. COMMITTEE REPLIES

The Committee is grateful to all those who discussed their Report; their contribution have added significantly to its value.

2.1 Reply of the 24th ITTC Specialist Committee on Azimuthing Podded Propulsion to Björn Allenström

In his written discussion Mr. Allenström includes a helpful statement regarding the approach and definition of the pod-housing drag scaling method used at SSPA. In this statement he indicates that the Committee's review of the SSPA method (on page 555 of the Report) is not correct on two accounts: in contrary to the Committee review, firstly, the method takes into account the effect of the strut; secondly, the method is appropriate to represent modern pod-housing shapes.

The Committee is very pleased to see this helpful statement, which has not been available to the Committee before this written discussion and the Committee therefore could only make reference to whatever was available in the open literature, in this case the only reference is Sasaki et al. (2004) which does not make reference to the effect of the strut. Based upon Mr. Allenström's statement it appears that the effect of strut is taken into account through the steady-state resistance component of the pod-housing at two stages: in the first stage, a towing test is carried out to measure the model pod-housing drag; in the second stage, this measured value is corrected for the full-scale by using the estimated pod drag for the full- and model-scale based on a semi-empirical approach. In this approach, the pod-housing drag is assumed to be decomposed into the lower pod-body, fin (presuming that this can also represent the strut) and the interference component. In this assumption the lower body of the pod-housing and the fin/strut drag are estimated mainly based on the simple flat plate resistance coefficient and suitable form factors based on experience used for different submerged bodies such as submarines while the interference drag is estimated based on a suitable interference factor which is obtained on the basis of the towing tank experiments of bodies with and without fins/struts, and represented as the ratio of the chord to span ratio of the fin/strut.

Within the above framework the Committee makes a correction on their statement that the effect of the strut has been taken into account in whatever approximate way the method is. The Committee however points out that the pod-housing drag correction is based on the steady drag component using the form factor approach and neglects the effect of propeller loading. This method is therefore still open to question due to the dependency of the form factor on the propeller loading as well as on the

Reynolds number. In addition it is still debatable how realistic it is to rely on the experiences with the submerged bodies, like submarines which have a typical length to beam (diameter) ratio is far greater than for a typical pod (at least 3-4 times), similarly they have a ratio of the lateral area of the sail/fin to that of the main hull which is far smaller than for a typical pod. In this regard the Committee feels that such experience is not completely transferable to modern pod-housing shapes, particularly neglecting the effect of propeller loading. In addition, the circulation forces acting on the pod-strut are dependant on quite different origins from those acting on a submarine sail. The relative size of the submarine sail to the body means that the circulation forces acting on the sail are best described by assuming that a double-body effect is induced by the connection between the two. In contrast, the predominant double-body effect associated with a pod is relevant to the connection between the pod-strut and the ships hull. In fact, the connection between the pod-strut and the pod-lower housing is better likened to the increase in aspect ratio derived for aircraft wing tip tanks.

References.

Sasaki, N., Laapio, J., Fagerstrom, B., Juurma, K. and Wilkman, G., 2004, "Full Scale Performance of Double Acting Tankers "Mastera & Tempera", 1st International Conference on Technological Advances in Podded Propulsion, 14-16 April, University of Newcastle, UK, p. 155-172.

2.2 Reply from the 24th ITTC Specialist Committee on Azimuthing Podded Propulsion to Neil Bose

Prof. Bose makes reference to the option for power prediction method based on the load varied self-propulsion tests, which may lead onto the lower level of uncertainty of extrapolation in ship powering performance prediction, as demonstrated in the Report of the 24th ITTC Specialist Committee on Powering Performance Prediction (ITTC, 2005). By assuming this Committee have disregarded this option, he expresses his disappointment that the ITTC procedure for podded propulsors now no longer leaves this option open within the approved procedure.

This Committee points out that Prof. Bose is not correct in his assumption. On the contrary, in Section 6.1 (pa: 5) and Section 6.5 (pa: 3) of the Committee Report, particular emphasis is made to the attractive nature of this optional method and the Committee encourages to pursue this option in the long term, due to the current lack of full-scale data to demonstrate the validity of this method for podded propulsors. In their statement the Committee also notes the fact that, in spite of the obvious attraction of this option, they are not aware of any validation of this method using one of the well-known unconventional propulsors such as ducted propeller or others. Furthermore the proposed extrapolation procedure by this Committee is still not an approved procedure and this option is therefore still as open as others.

References.

ITTC, 2005, "The Specialist Committee on Powering Performance Prediction, Final Report and Recommendations to the 24th ITTC", 24th ITTC, Vol. II, p. 600-638, Edinburgh.

2.3 Reply from the 24th ITTC Specialist Committee on Azimuthing Podded Propulsion to Ian W. Dand

Dr. Dand reflects on his interesting experience during the turning simulation of a proposed design which comprised two fixed and fully azimuthing pusher pods. He enquires if the Committee can make any comments on degraded turning performance of the vessel when all four pods were working, compared to the case when only two aft azimuthing pods were operational.

As rightly suggested by Dr. Dand himself, the Committee are also of the opinion that degraded turning performance can be attributed to the extra course-stabilising effect provided by the slipstream momentum of the two fixed pod propellers. The study referenced within the Committee Report demonstrates that the IMO manoeuvring criteria provide equivalent information about the manoeuvring performance of pod driven ships as for conventionally propelled ships. This does not however dismiss the fact that the IMO criteria do not give a complete picture of manoeuvring performance but only approximate some relevant characteristics to prevent the building of ships that do not meet with the criteria. It is also important to put into context, the meaning of the term "degraded" manoeuvring performance; as an improvement in manoeuvrability is usually at the expense of course-stability and vice-versa. In the case of pod driven ships the predominant difference in manoeuvring performance is the significant loss in speed when manoeuvring, not accounted for by the IMO criteria manoeuvres; due in part to some proportion of the thrust being used for control and in part by the larger induce drift angles that result. When turning a ship with all four pods the control force is very large and the subsequent loss in speed is significant (often resulting in total loss of forward motion). Then, comparing a manoeuvre predominantly composed of pure yawing motion with the conventional idea of Advance and Tactical diameter parameters becomes somewhat spurious. It is also important to point out that the "improved manoeuvring" often quoted about pod applications is more related to improved control in harbour. Reduced port time can be offset by a reduced sea-speed for the same overall turnaround time; offering valuable fuel savings. While it is true that pod driven ships do have different, and in most cases advantageous, manoeuvring characteristics at sea; it is sufficient that, at a minimum, they meet the IMO criteria while still offering the improved harbour performance.

2.4 Reply from the 24th ITTC Specialist Committee on Azimuthing Podded Propulsion to Manfred Mehmel

Dr. Mehmel makes comment on the differences of side forces between a single rudder behind a propeller and a podded drive for the same helm angle. He also makes useful reference to his experience which indicates that a pod should be put at much higher helm angles (approximately 2.5 times) to provide comparable performance, such as zig-zag manoeuvre, results with a single screw single rudder ship. He therefore believes that the ITTC should contact to IMO for comments on pod driven ships.

As it is clearly stated in Section 9.5 (pa: 1) of the Committee Report, the Committee is aware of the importance of the differences pointed out by Dr. Mehmel though no indication has been provided in terms of the relative magnitudes of applied helm angles as this will very much depend on the main particulars of hullform and propulsors as well as other factors. In this respect Dr. Mehmel's experience with the relative magnitude of helm angles is very interesting and useful. However this cannot be generalised for all podded ship types and arrangements requiring further investigations.

The zig-zag manoeuvre attempts to obtain a simplified result from a complex and interdependent dynamic interaction of phenomena. It should also be remembered that the zig-zag manoeuvre is only an approximation of the true dynamic situation; which is more realistically described in terms of the Phase and Gain of the system. The IMO considered the concept of Phase and Gain to be too complicated to apply and chose instead to use the zig-zag manoeuvres as a close and practical alternative. Subsequently, the overshoot criteria when using 10/10 and 20/20 tests, have been shown to approximate well, acceptable Phase and Gain limits for convention ships and now for pod-driven ships. So, to approximate acceptable Phase and Gain limits using the zig-zag manoeuvres the 10 degree and 20 degree helm angles must be applied as required by the criteria. If a more detailed understanding of the manoeuvring performance is needed then the use of a more conventional control engineering approach is required.

As far as Dr. Mehmel's plea for the ITTC to get in contact with the IMO is concerned: The Section 9.4 of the Committee Report, based on the recent study (Woodward, 2005), argues that the operational limits proposed by the IMO manoeuvring criteria provide a perfectly good operational envelop; regardless of how the control force is applied. The study then demonstrates direct equivalents between applied helm angle for both pods and conventional rudders. Ultimately, the study demonstrates that, within the validated limits, the IMO criteria provide equivalent information about the manoeuvring performance of pod driven ships as for conventionally propelled ships; and can thus be applied directly to prevent the building of ships that do not meet the criteria. The study did identify some critical issues for pods, related to both structural loading and snap rolling induced by manoeuvring. These issues do not compromise the risk of collision and are thus not applicable to the IMO manoeuvring criteria; but are certainly of interest to the designers of pod-driven ships.

<u>References.</u>

Woodward, M.D., 2005, "Control and Response of Pod-Driven Ships", School of Marine Science and Technology, University of Newcastle, PhD Thesis, 219 p. [Commercial in Confidence]

2.5 Reply from the 24th ITTC Specialist Committee on Azimuthing Podded Propulsion to Friedrich Mewis

Dipl. Ing. Mewis enquiries about why the Committee recommend measuring the system thrust using a two component balance instead of a single component. He also makes comment on the scaling of the pod-housing drag based on the long experiences in HSVA for passive propulsion devices and points out that the pod scaling issue is a small part of the overall power scaling problem and one needs to look at the whole system.

With regards to Dipl. Ing. Mewis' question, this Committee appreciate that the unit thrust can be measured using a single component balance in principle. However it is strongly recommended to use, if possible, at least a two component balance for the following practical reasons:

1. To check any misalignment that may exist and to check on possible asymmetries in the pod-housing;

2. To be able to test podded propulsors of twin pod ship model at helm angles without having to redirect the force balance for each angle. Propeller and unit thrust should always be measured in a direction parallel to the propeller shaft.

The experience of some of the Committee members in measuring the unit thrust by means of a single component balance between the vertical drive shaft and the ship model indicated an undesirable effect on the balance caused by the thrust and torque effects between the shaft and motor which is simply fitted to the bottom of the model.

With regards to the discusser's comments on the use of RANS, the Committee is pleased to hear of the use of RANS calculations, at least, for the plausibility checks for the drag corrections estimated based on their experience. The discusser nevertheless points out rather large time and cost implications and hence impracticality of the RANS based approach for commercial work. The Committee disagrees with this view, in particular within the current circumstances, since there is hardly any full-scale data published and collaboration activities to justify the reliability of any practical, semi-empirical method based on experience. Within this framework RANS based scaling procedure at least represents the physics of the phenomenon.

The Committee respect Dipl. Ing. Mewis' worthy comment that the pod-housing drag correction, indeed, may be a small part of the whole corrections needed for the entire system and therefore it would be extremely worthwhile to quantify its relative value compared to the whole corrections applied. However, this correction still appears to be an important design issue, as claimed by one of the major pod manufactures and illustrated in Fig 3.1 of this Committee Report to be estimated accurately.

2.6 Reply from the 24th ITTC Specialist Committee on Azimuthing Podded Propulsion to Anthony Molland and Stephen Turnock

Prof. Molland and Dr. Turnock refer to their earlier work on the propeller-rudder interaction effects and claim that this work can provide a useful basis for the induced drag of the pod-housing and strut gap effects, particularly for puller-type pods and validation of CFD analyses. Furthermore they draw attention to the need for effective yaw checking and course keeping of pod-driven ships by the possible use of steering-flaps or conventional rudders instead of deflecting the whole pod.

The Committee are aware of the fundamental importance of the work referred by the discussers as well as the similarities/difference between the conventional rudder/propeller and podded propeller systems. The ability to place the propeller at an angle of attack, the effect of the modified propeller race on the pod-body and the increase in the relative aspect ratio of the pod-strut due to the presence of the nacelle, all require close attention. In fact, in the initial stages of formulating an appropriate numerical model to account for these effects, we did in fact use the highlighted papers by Prof. Molland and Dr. Turnock; to validate the initial assumption. And, these papers did prove very useful.

As far as the strut gap effect is concerned, as discussed in Section 5.3 of the Committee Report, this effect appears to be very small in the model scale and not a real concern in the extrapolation procedures.

Although the combined use of steering flaps or conventional rudders was not included in the current Committee tasks and also has not been a regular feature of the application in service so far, the Committee are aware of the potential benefits of these devices and agrees with the discussers for their use for effective steering in particular for high-speed applications. Some of the Committee Members have been involved in the exploitation of the steering flaps for high speed applications through collaborative European projects, such as FASTPOD (2001) and they realised that the use of steering flaps is not an option but necessity for high speed steering.

From a manoeuvring point of view, as commented above, the benefits of pods are most apparent when considering slow speed harbour manoeuvring. The application of large helm angles when at sea-speed can produce excessively large control forces, which must be resisted by the structure and bearings, and which serve to slow the ship excessively. In addition, the high precession moments produced by the pod-motor when yawing, can be prohibitive. To resolve this problem, additional control flaps are desirable for many pod applications for sea-speed course-keeping and steering.

References.

FASTPOD, 2001, “Fast Ship Applications For Pod Drives”, Annex 1, Description of Work, European Commission RTD FP5 Project, University of Newcastle upon Tyne (Co-ordinator), GRD2-2001-50063.

2.7 Replies from the 24th ITTC Specialist Committee on Azimuthing Podded Propulsion to Alexander Pustoshny and I. Chicherin and Alexander Pustoshny

Although the discussions included in Section 1.7 and 1.8 are presented separately, the basis of these discussions is common and the Committee therefore present a common reply to them in the following.

In the first discussion (Section 1.7), Dr. Pustoshny refers to their general argument with regards to the limitations of the prediction for the viscous resistance component of ship hullforms based on the flat plate and form factor approach. He makes emphasis to the weaknesses of this approach based on their written discussion to the 23rd ITTC Propulsion Committee, Chicherin and Pustoshny (2002) where they recommend replacing this approach by a more direct method of predicting this component. Their proposal involves the introduction of a correction factor to the measured viscous resistance component of model hull, a so-called “proportion coefficient” which is defined as the ratio of the full-scale to the model viscous resistance component predicted by using RANS based calculations. He recalls that the same argument applies on the pod-housing drag prediction even with a greater degree of flow three dimensionality, further complexity caused by the swirling effect of the propeller race on puller-type pods and unacceptably high values of form factors of various types pod geometries.

In the second discussion (Section 1.8) Dr. Chicherin and Dr. Pustoshny refer to this Committees’ investigation on the five different methods for the pod-housing drag correction and they provide further discussion why the CFD (RANS) based approach is the most reliable amongst these methods based on the comparison with the HSVA and MARIN procedures. They indicate that the HSVA procedure neglects the Reynolds number dependency effect of the viscous pressure drag, which overlooks the effect of pod shape on the flow pattern, as well as the neglect of the swirling effect of the propeller slipstream. Their computations with a well-streamlined housing indicate that the neglected effects can result in 32.2% less reduction of the full-scale pod resistance coefficient and hence overestimation of the full-scale drag. In their comments on the MARIN procedure, they draw attention to the use of axis-symmetric RANS solver to take into account the effect between the scaled and the Reynolds Number independent parts of the pod-housing drag computations. The use of the axis-symmetric model will neglect the effect of strut and tangential induced velocities. Their attempt to demonstrate the results of the simplification imposed in the MARIN procedure for a “well-streamlined puller-type pod” indicates that the procedure may provide a misleading drag ratio, which is more appropriate for a “poorly-streamlined puller-type pod”, when it is compared with the results of their RANS computations with a more complete treatment of the pod geometry. The discussers, nevertheless, believe that the possible underestimation in the full-scale housing drag estimation by the MARIN method can be improved by the use of more complete housing geometry and the use of RANS code computations is the way ahead for the most reliable scaling.

The comments raised by Dr. Chicherin and Dr. Pustoshny present further support to this Committee’s investigation on the issue of the pod-housing drag scaling included in Section 6.3 and 6.4 of the Committee Report. The support is provided by their discussions of the results on two different shapes of puller-type pods based on the various assumptions and simplifications made in the HSVA and MARIN methods and by comparing these results with the results based on the more complete RANS computations by the discussers. As is included in the final remarks (Section 6.5) of the Committee Report in the short term, this Committee clearly recommends utilising RANS based prediction methods for pod-housing drag correction as these represent the physics of the phenomenon in the absence of full-scale data. Within this framework the discussers' comments are extremely complementary to this Committee's view. However, this should not be interpreted as the scaling method based on the RANS is the ultimate. There are other practical and more attractive methods, which may not even require scaling of the pod-housing drag separately. For these methods to become established in their own right, it is necessary to collect reliable long-term full-scale data.

References.

Chicherin, I.A. and Pustoshny, A.V., 2002, "Some Comments to the "Form Factor Prediction" from the Gothenburg 2000 Workshop" and "Development on the Formulation of the Flat Friction Line", Written Discussion to the Propulsion Committee, 23rd ITTC, Vol. III, Venice.