Manoeuvrability Committee

Committee Chair: Prof. K. Kijima
Session Chair: Mr. A. Hasle Nielsen

I DISCUSSIONS

Contribution to the Manoeuvrability Committee

by B. Della Loggia
(CETENA - Via Savona, 2 - Genova - Italy)

"SIMSUP: A tool for prediction of ship manoeuvrability performances".

We have appreciated the work done from the committee for the general review of the items connected with ship manoeuvrability.

In our opinion, however, greater attention should be done, to the assessment of tools for ship manoeuvrability prediction.

Those tools are particularly useful to verify, at the design stage, the compliance with the IMO requirements. The activity of IMO recently culminated in the adoption of the interim resolution A.751 (18) on ship manoeuvring performance standards.

To demonstrate compliance with these standards mathematical methods can be used in alternative to scale model tests. To support ship designers in this task, CETENA recently set up the manoeuvring prediction program SIMSUP. To verify the reliability of its prediction, which have to be based on the few data available at the design stage, the program was applied to a sample of 30 ships (20 single-screw, 10 twin-screws) whose characteristics were taken from the ship manoeuvrability data base of CETENA containing, today, more than 300 full scale ship trials related to different ships for size, type, load conditions, propulsion plant, propeller(s) characteristics, rudder type and size, etc. (see figures 1 and 2).

A large number of standard manoeuvres (Turning circle, zig-zag and crash-stop tests) were simulated and the results compared with the corresponding full-scale trial data.

The results of this comparison (see Figures 3 - 8) allowed to obtain information about the SIMSUP reliability.

The analysis was devoted especially to check program limitations and to get warnings and support for the users.

In general, the comparison between full-scale and predicted data was quite good for almost all ship types.

In particular, SIMSUP proved to be able to discriminate between ships with good or normal manoeuvring behaviour and those that do not comply with the IMO criteria. The ship types with higher prediction errors were clearly identified, as to constitute a warning for the users.

Reference

G. Capurro, P. Sodomaco (1996) "Application of the manoeuvring prediction program "SIMSUP" to meet the new IMO standards." MARSIM '96, Copenhagen, September 1996.

CETENA FULL-SCALE DATA

IMO Requirements for advance

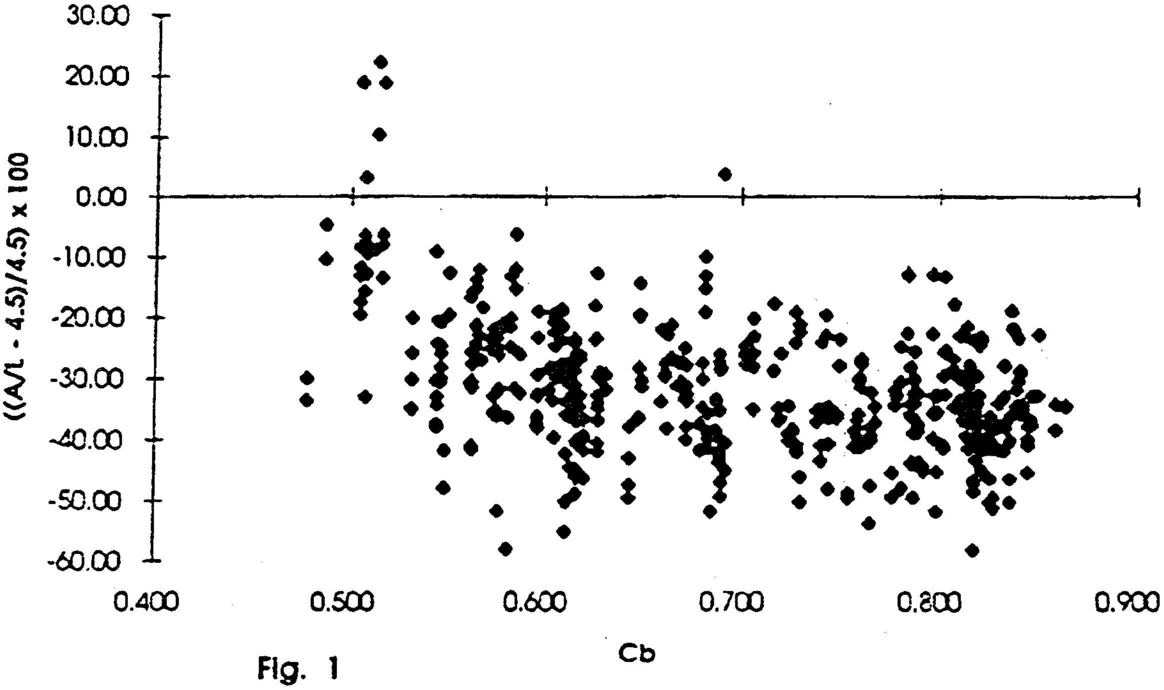

Fig. 1

CETENA FULL-SCALE DATA

IMO Requirements for tactical diameter

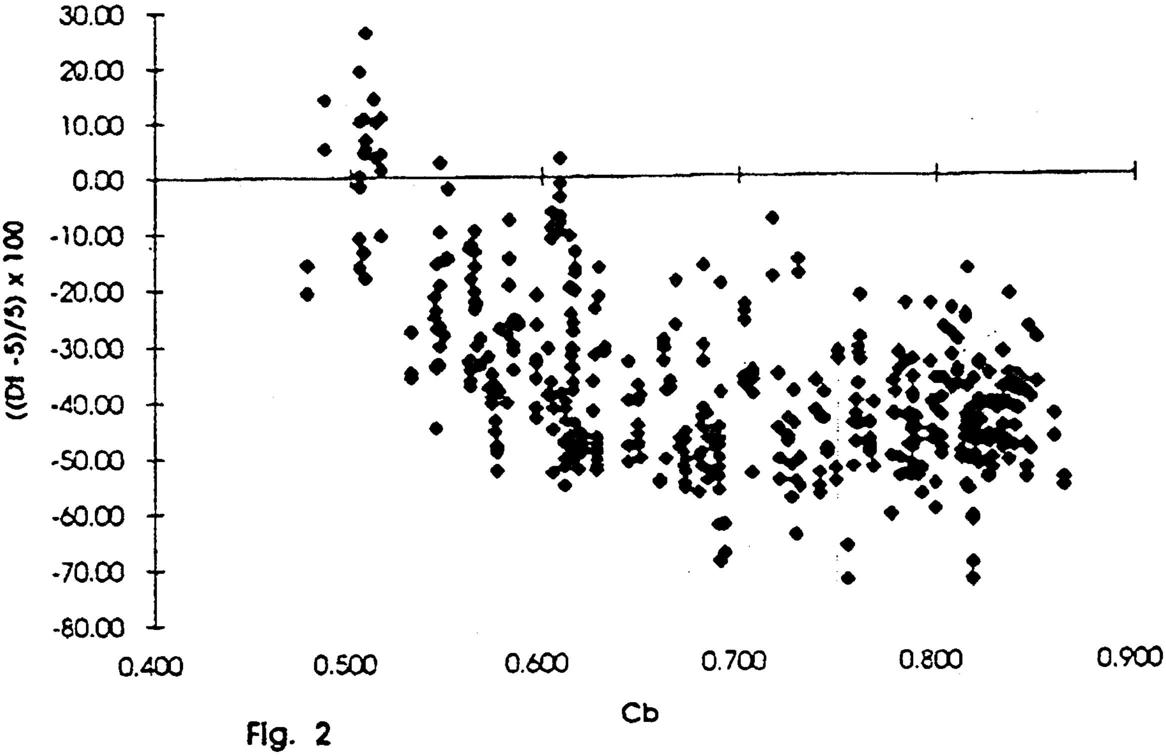

Fig. 2

ONE-SCREW SHIPS
Turning circle tests

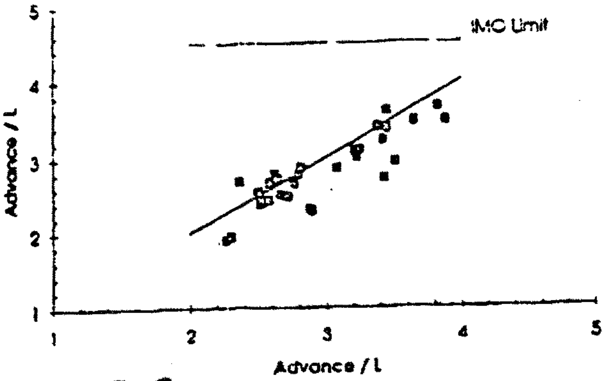

Fig. 3

ONE-SCREW SHIPS
Turning circle tests

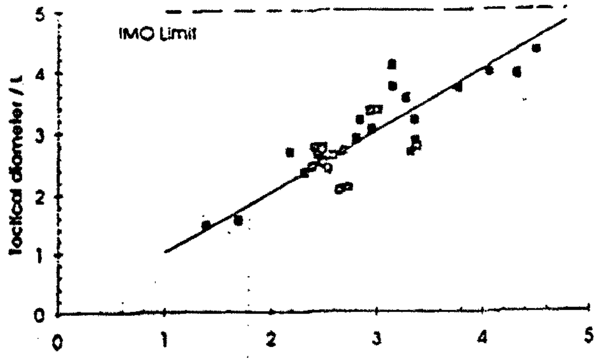

Fig. 4

TWIN-SCREW SHIPS
Turning circle tests

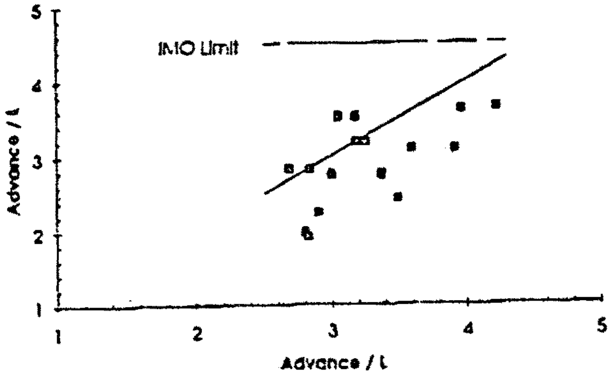

Fig. 5

TWIN-SCREW SHIPS
Turning circle tests

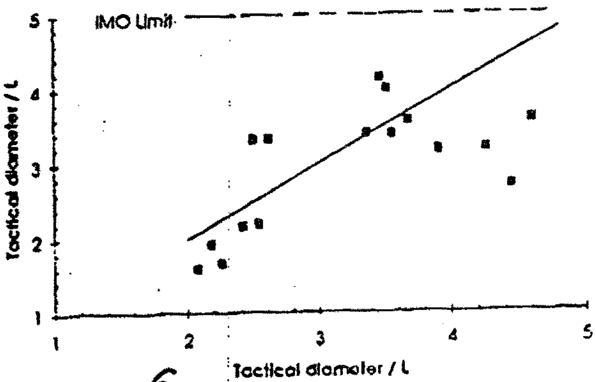

Fig. 6

ONE-SCREW SHIPS
20/20 zig-zag tests

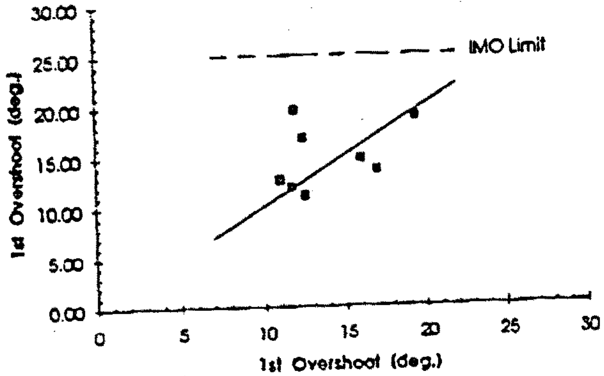

Fig. 7

TWIN-SCREW SHIPS
20/20 zig-zag tests

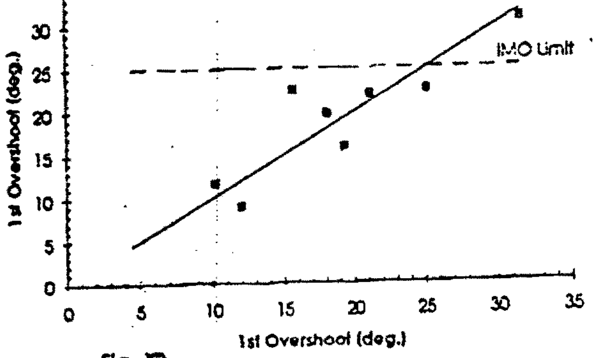

Fig. 8

Discussion of Manoeuvrability Committee Final Report and Recommendations to the 21st ITTC

by Prof. Grant E. Hearn and Dr. David Clarke
University of Newcastle upon Tyne, UK
Presented by Prof. G.E. Hearn

The Committee is to be congratulated on providing a very extensive and clearly presented report. However, may I suggest that those parts of the conclusions indicating shortcomings and needs, be formulated with a set of clear, ranked recommendations in a manner analogous to Section 1.2 of the report concerning the 20th ITTC. Since the Committee has clearly been very industrious it is important that we may readily appreciate and understand the Committee's thinking concerning future work.

With the Committee's permission may we be permitted, to expand the details related to the MOSES research programme (especially Phase II), touched upon in Section 2.3, and then address the topic of control considered in Section 7.2. In passing one might also note that the work of Burcher and Zhang cited in Section 8.3 was partially funded through MOSES Phase I.

Section 2.3

The MOSES Phase I research programme commenced in January 1992 and ended in March 1994. Phase II then ran from June 1994 until June 1996. Whereas Phase I was primarily directed at providing fundamental understanding of the hydrodynamics of a manoeuvring ship, Phase II was required to extend that understanding to shallow water and to provide (as the Committee's report indicates) software to assist with manoeuvring at the design stage, and to deliver a design manual to provide guidance on propeller design and the influence of propeller-rudder-hull interactions. The latter step providing an extension of the work of Molland & Turnock cited in Section 3.4 of the Committee's Report. I am sure Dr. Molland will address this particular aspect himself, therefore I will address the joint work undertaken by Hearn & Clarke at Newcastle University, and Varyami, Incecik and their Research Associates at Glasgow University.

The main outcome of the Phase I theoretical studies at Newcastle was a method of accounting for the effect of stern vortices on the calculation of the linear hull derivatives. To extend this to shallow water conformal mapping techniques were used to provide the added mass terms in shallow water. Using the ratio of added mass in shallow water to that in deep water, a correction factor was developed for flat plate, circular, elliptical sections and also elliptical sections with fins.

Furthermore, these correction factors could be used for more general ship sections. This work indicated that the earlier work of Sheng (1981), now widely used, is in error and underestimates the shallow water effects. Obviously this comment does not apply to the alternative methods of Kijima cited in the Committee Report, Section 3.3.

The calculation of the behaviour of the vortex influence coefficient in shallow water using conformal mapping methods is made extremely complicated by the necessity to consider fluid conditions at off-body points in the fluid flow. This is not necessary in the added mass calculations, since the contour integrals are solved on the body surface. The alternative vortex element method was found to give a satisfactory result more readily.

The result likely to be of most interest to the Committee, and Delegates, is that the Normalised Impulse Position Derivative (part of the vortex influence coefficient) did not vary appreciably in shallow water, unlike the added mass where the variation was more significant, see Figure 1.

To date the strength and path of the vortices have been deducted from the experimental observations made at Glasgow University, with some use of lifting surface theory at Newcastle University. These experiments justified the existence and the extent of the vorticity field, and by combining this knowledge with the theoretical calculations allowed differences between earlier predicted and measured sectional derivatives to be significantly reduced from an underestimation of 30 % to less than 5 %. Therefore future research and understanding should be aimed at providing readily applicable, reasonable estimates of the vorticity fields. Some useful methods were presented at MARSIM'96 as a product of the Japanese programme, but probably more research is required to develop design packages, for use by designers, which incorporate the corrections of added mass due to the existence of vorticity. Having recognised its influence we cannot now ignore its importance.

Regarding the MOSES developed software, the program calculates the ship derivations, then solves for standard manoeuvres of turning circle, zig zag manoeuvre and spiral manoeuvre, and then gives an indication of whether current IMO standards have been satisfied. If necessary it allows modification to the ship geometry until manoeuvring rules are complied with. The task was accomplished using Microsoft Visula Basic on a PC.

Other results will be released as papers in the near future.

Section 7. Ship Operation & Safety, IMO Standards

May I now be permitted to address another topic, that of ship control as addressed in section 7.2 (page 372) of the Committee Report. The work cited by Zhang et al. (1993) and Hearn et al (1994) has now been extended to the provision of neural network on-line controllers for course keeping, track keeping and automatic berthing. Permission to test these controllers with a 4.3 m length tanker model on a reservoir has recently been granted, together with another company agreeing to provide a ship to test the controllers. Here it is important to stress that we are using on-line controllers, not off-line trained neural networks.

This approach to control clearly begs a question. Traditionally the work of the Manoeuvrability Committee has been concerned with assessment and improvements in manoeuvrability. Given the aircraft industries capability to design unstable craft which are then controlled by computer (fly by wire), and assuming there might be some commercial advantage in designing vessels which do not conform with IMO standards, why not permit such vessels provided they have suitable controllers which compensate for the inherit "weaknesses" of the design, as judged by conventional thinking. Hence might this sort of less conventional approach to design and manoeuvrability also be made the business of this Committee?

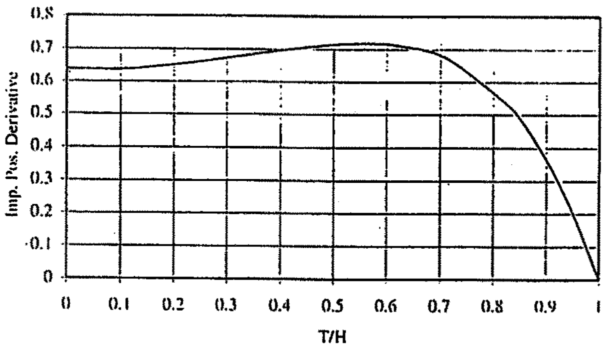

Fig. 1 The variation of the Impulse position Derivative with Depth, H.

Inclusion of free surface effects in the modeling of ship dynamics

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A complete modeling of ship dynamics, especially when high Froude numbers are considered, demands a coupled approach to manoeuvrability hydrodynamics and to those aspects traditionally more connected with the seakeeping of ships. In fact, though the main forces relevant to ship manoeuvres are connected to the vorticity field generated by the hull, experiments and numerical tests put in evidence the role of the free surface in determining the actual value of the hydrodynamic loading. As an example, for the simple case of a flat plate in steady yaw motion, Landrini & Campana (1996) show how the lateral force and the yaw moment change significantly as the Froude number increases from zero up to one. Hence, in our opinion, at least when large variations in the speed are expected, a proper modeling of the fluid forces requires the inclusion of Froude number dependence.

Furthermore, when dealing with manoeuvring in waves, the classical concept of *quasi-steady dependence* of forces upon the hull motion appears to be inadequate. In fact, it is well known that both the wave effects and, to some extent, the vortex shedding introduce a dependence of the instantaneous force values upon the history of motion. The inclusion in the equations of motion of first order seakeeping theories as discussed in the Committee Report (page 360) may be effective. However, it must be stressed how it is difficult to assess the general validity of a simple superposition of *wave forces* with those related to the vorticity field, which primarily determines the *low speed* hydrodynamic forces. Actually, due to the low aspect ratio of ships, the behaviour of the shedding of vorticity along the hull is highly nonlinear and, also within a linearised approach to the free surface problem, the effects induced by this moving boundary on vortex induced forces are in principle nonlinear.

In this framework, an attempt to a global modeling of free surface and vortex shedding phenomena appears promising and, in our opinion, it should be one of the topics of future research activity.

M. Landrini, E.F. Campana, 1996. 'Steady waves and forces about a yawing flat plat', to appear on *J. of Ship. Res.*

The effects of After-Body Appendages on the Manoeuvrability of a Container Carrier.

by H.Y. Lee and D.J. Yum
Hyundai Maritime Research Institute,
Ulsan, Korea

International Maritime Organization adopted the interim standard A.751(18) for ship manoeuvrability in November 1993 for the purpose of protecting marine environment and improving ship stability. The proposed standard will be reviewed for 5 years of practical experience as an interim period. In order to meet the manoeuvring standard well, it is required for a ship designer to have tools to accurately predict the ship manoeuvrability at the preliminary design stage of a vessel. And, without doubt, developing tools for the prediction of ship manoeuvrability will be one of major roles of ITTC community.

For the discussion, the authors intend to briefly mention the causes of directional instability of a medium size container carrier and the effects of changing after-body appendages on the manoeuvring characteristics of the vessel.

In general, container carriers are known to have good manoeuvring characteristics because of the fine hull form with small block coefficient and large length to beam ratio. But as mentioned in Oltmann (1993), container carrier can show some degree of directional instability and even be in excess of IMO interim standard when it has extremely small GM value.

As a ship designer's point of view, the container carrier is characterized by very small GM value and negative lcb, which means the location of lcb after midship. Both of these characteristics have unfavourable effects to a vessel's directional stability. When these characteristics are combined with small length to beam ratio and barge type after-body hull form, a container carrier can be more unstable than any other full-form ships. Furthermore, in applying IMO standard, container carriers which are usually faster than other types of vessel, are subject to severe criteria in $10^0/10^0$ zig-zag overshoot angles due to low values of L/V.

For the improvement of the manoeuvrability of a medium size container carrier, various types of after-body appendage are considered. Figure 1 shows the appendages considered for the study. Case 1 is the original hull without appendage. The appendages of Case 2, 3, 4 and 5 are skeg-below-transom, increase of rudder area, skeg-below-stern-bulb and skeg-below-stern-bulb and increase of rudder area respectively. The experimental investigation has been carried out at the deep water towing tank of Hyundai Maritime Research Institute. For the manoeuvring simulation, surge-sway-yaw coupled equation of motion is solved (Lee and Yum (1996)). The hydrodynamic coefficients in the equation of motion are obtained based on Abkowitz model, also called as the whole ship simulation model. Ogawa's method (1978) is adopted for model/full-scale correction. The model is free in heave, pitch and roll at static tests to consider the effect of heel for manoeuvring simulation.

Table 1 shows dynamic stability lever for each case. The stability levers are improved 2.8 % (Case 2), 29.8 % (Case 3), 47.4 % (Case 4) and 62.7 % (Case 5) in comparison with that of Case 1. Figure 2 shows turning circles with rudder angle of 35^0 to starboard. They are nondimensionalized by LBP. It is clearly shown in this figure that turning performance definitely decreases with the increase of rudder area and attachment of skeg. Figures 3 and 4 show comparative plots of the time histories of heading angle for the $10^0/10^0$ and $20^0/20^0$ zig-zag manoeuvres, respectively. These figures with the results in Table 1 show that the skeg-below-stern-bulb is the most effective means in improving the dynamic stability of an unstable vessel. The effect of skeg-below-transom seems marginal and that of rudder stands in the middle. Table 2 shows the comparison between results of PMM tests and sea trial for zig-zag manoeuvres. This table gives an indication of good agreement between PMM tests and sea trial. The vessel's loading condition for the results in this table is design draft condition whereas the condition for the previous results is scantling draft condition.

From the present study, the following conclusions can be made. Firstly, container carrier with fine hull form can be directionally unstable due to the combined effects of several design parameters and constraints. Secondly, the effects of skeg-below-stern-bulb is much larger than those of any other types of appendages in improving directional stability of an unstable ship.

References

Oltmann, P., 1993, "Roll - An Often Neglected Element of Manoeuvring". MARSIM '93, St. John's, Canada.

Lee, H.Y. and Yum, D.J., 1996, "The Theoretical and Experimental Study to Predict Manoeuvring Performance", HMRI-96-06-S106.

Ogawa, A. and Kasai, H., 1978, "On the Mathematical Model of Manoeuvring Motion of Ship", Vol. 25, International Shipbuilding Progress.

Table 1 Linear Hydrodynamic Coefficient and Stability Lever

	Case 1	Case 2	Case 3	Case 4	Case 5
Y'_V ($\times 10^5$)	-1939.994	-2016.937	-2038.742	-2172.366	-2240.686
N'_V ($\times 10^5$)	-1005.099	-1056.590	-998.586	-1033.427	-998.020
$Y'_r - m'$ ($\times 10^5$)	-1325.904	-1256.526	-1258.433	-1213.948	-1269.593
$N'_r - m'x'_G$ ($\times 10^5$)	-465.329	-454.133	-468.870	-470.764	-486.448
lv	0.5181	0.5239	0.4898	0.4757	0.4454
lr	0.3510	0.3614	0.3726	0.3878	0.3832
l	-0.1671	-0.1624	-0.1172	-0.0879	-0.0623

Table 2 Results of 10°/10° and 20°/20° Zig-Zag Manoeuvres

Description of Manoeuvre		PMM		Sea Trial	
		1st O.A	2nd O.A	1st O.A	2nd O.A
10°/10°	Port	22.6	35.4	22	34
	Stbd.	17.0	41.9	20	33
20°/20°	Port	33.5	28.1	35	27
	Stbd.	31.5	31.5	25	28

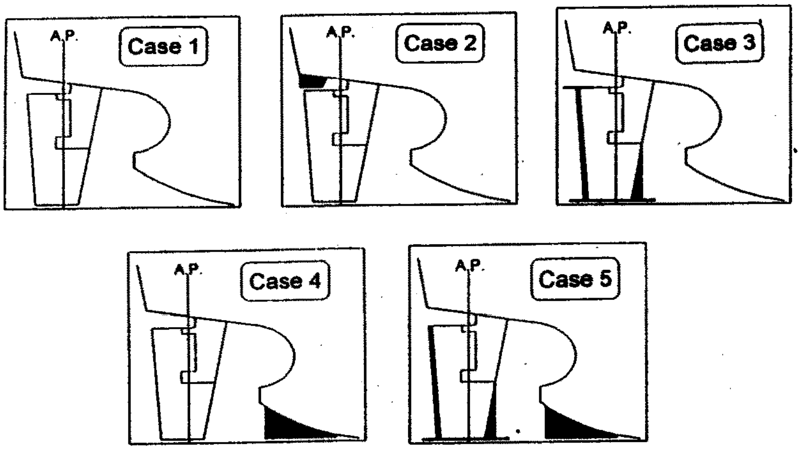


Fig. 1 Stern, Skeg and Rudder Profile

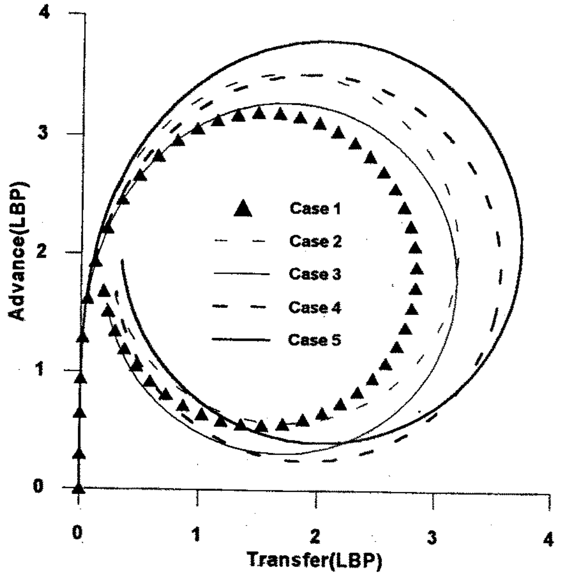


Fig. 2 Turning Circles with Skeg and Rudder Variation.

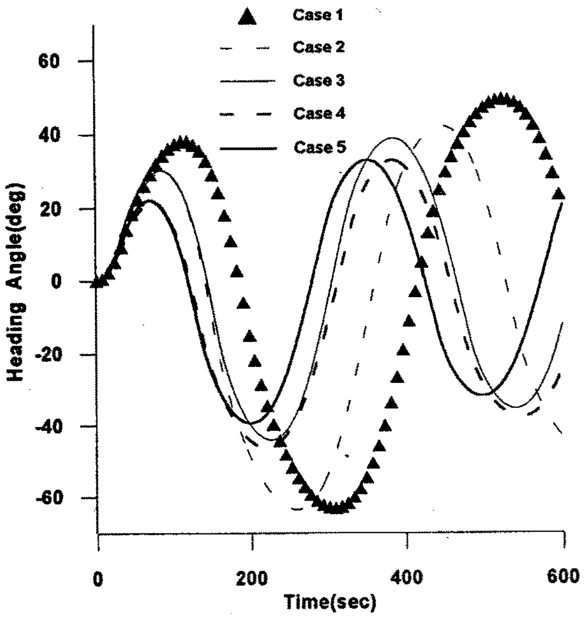


Fig. 3 $10^0/10^0$ Zig-zag with Skeg and Rudder Variation

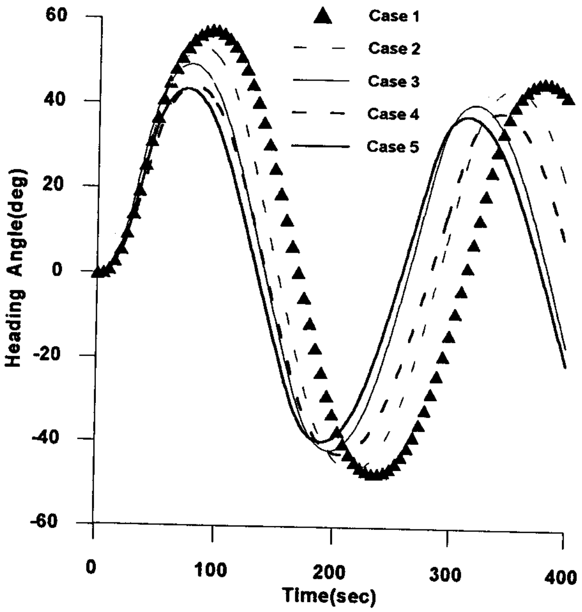


Fig. 4 $20^{0}/20^{0}$ Zig-zag with Skeg and Rudder Variation

Contribution to the Manoeuvrability Committee

by Dr. A.F. Molland
University of Southampton, UK

I should firstly wish to commend the Committee for a good Report on the current status of manoeuvrability research.

My own interests in manoeuvrability tend to concentrate on the aft end of the ship, and the problems of rudder-propeller-hull interaction. It is on this topic that I should like to make some observations.

The Report, Section 4.2, mentions that a crucial requirement for modular simulation models is the ability to accurately predict rudder-propeller-hull interaction, and I would of course agree with that statement. The first point I would make is that I believe it should be emphasised that in order to develop correct theoretical models of these complex interactions we must firstly develop a thorough understanding of the physics of the fluid flow. Propeller induced axial and rotational effects on the rudder have received some attention, but rudder-propeller induced effects on the hull are also asymmetric in nature and the correct prediction of the magnitude of these effects is not straightforward. I believe these points to be important whether one is considering detailed rudder design, modular simulation models or whole-ship simulations.

The Report cites some of our work at Southampton, which forms part of the UK managed programme of manoeuvring research, MOSES, described earlier by Professor Hearn. Using large wind tunnel models we have continued, in Phase II of the MOSES Programme, to concentrate on improving our understanding of the physics of the rudder-propeller-hull interaction problem and establishing detailed experimental data for design and validation purposes. We have now carried out more experimental work with a truncated Mariner hull upstream of the rudder-propeller combination. We have also used a skeg rudder and gathered the usual force data together with LDA velocity measurements and measurements of the pressure distributions on the rudder and hull for different cases of hull drift angle and propeller thrust loading.

For the record, I should like to mention that we have also been carrying out theoretical work using a panel method to model the rudder-propeller interactions, together with their interaction with the hull. The model currently uses a truncated hull model (replicating our experimental work) whereby the influence of the hull on the rudder and propeller and the rudder-propeller combination on the hull can be estimated. A description of the basic rudder-propeller part of the theoretical model is described in Ref. A. The results to date are very promising and we believe this approach offers a useful way forward for predicting the influence of the rudder and propeller on the hull and the potential for investigating the influence of stern shape in this context.

The comments I have made relate directly, and have applications, to modular simulation models. In the case of whole-ship simulation models the same complex physical flows at the aft end obviously still apply. I should like to ask the Committee how important it considers the need to model these aspects at a detailed level in the whole-ship approach to simulation.

Ref. A. Turnock SR, Molland A.F. and Wellicome J.F. "Interaction Velocity Field Method for predicting Ship Rudder-Propeller Interaction". SNAME Propeller/Shafting Symposium '94, Virginia Beach, USA, 1994.

Discussion of the 21st ITTC Manoeuvrability Committee Report

by Nils H. Norrbin, Gøteborg

The kind invitation to comment on the Report of the Committee is much appreciated. Reading the detailed review of recent literature and the recording of current research within various groups is a must for he who works remote from the centre, but it should be so also for any young "model basin" member - not necessarily an ITTC delegate - who much too soon may turn too narrow a specialist in the midst of the busy team.

The Recommendations of the 20th ITTC were fairly general in nature, and they are only weakly traced in the Conclusions of the Report. It is observed that this Committee Report, unlike each one of the other, does not include a formal set of Recommendations to the present Conference or to the new Committee, perhaps because the new Committee Structure identifies the Manoeuvrability Committee as a General Technical Committee with these same general responsibilities.

The need for advice to IMO is recognized, but the Committee feels that a revision of the 1993 Interim Standards should await more than the five years of trials foreseen. This is probably true in general, and especially when it comes to the adjustment of the detailed numerical criteria. The wording on the stopping ability and its interpretation should be seriously considered once more, however. The present reading was the result of a sequence of compromises within the IMO Working Group and the Sub-Committee, accepting also the general ideas that all criteria should be valid for all the ships covered by the Standards and that all the different trials should be performed at essentially the same test speed. This speed shall be at least 90 % of the ship's speed corresponding to 85 % of the maximum engine output. (From the ITTC 1975 Manoeuvring Trial Code it is worth citing: "Whereas the crash-stop manoeuvre from full-ahead may often be required as an acceptance test a stopping test at a low speed of approach is here recommended.")

The naval architect is likely to know that the ship will hardly stop on a straight course, but that the track will stay inside some "mushroom figure", and he seems to accept this fact. The mariner usually knows that he can not control the ship's heading during a crash stop manoeuvre, and he rightly wonders why it should be like that. While we ask the designers to device a ship stopping system, which allows a safer stopping, we must try to identify a reasonable criterion not only for the maximum track reach accepted but also for the lateral reach then likely to occur. For ships that are apt to turn away form the original course more than usual it may be necessary to place restrictions on the stopping procedure to be used in the trial; the real emergency situation has no use of rules. As an alternative, it may be recommended to introduce a new test procedure involving controlled slowing-down and stopping. These questions must be subject to further analysis within the ITTC.

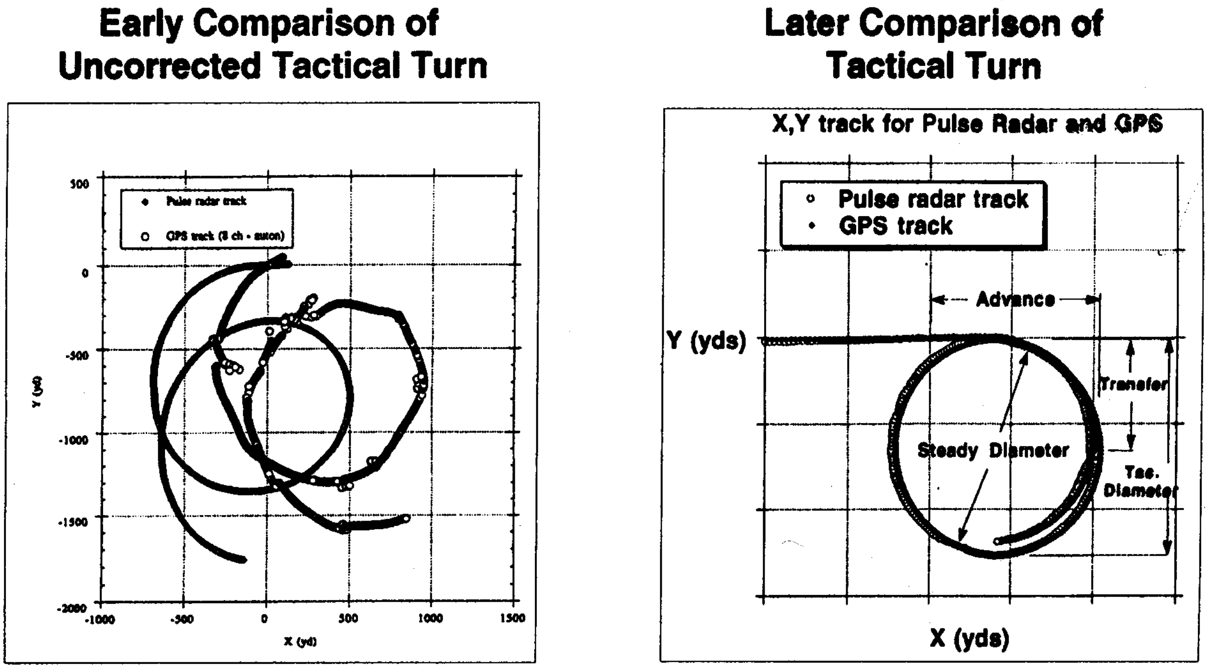
Contribution to the Manoeuvrability Committee

by R. J. Stenson
David Taylor Model Basin

The Manoeuvrability Committee is to be congratulated on an excellent report. I would like to comment on section 6 of their report "validation, scale effects, and full scale trials". In this section they discuss a problem specifically related to ship manoeuvring data and state that "very few full-scale manoeuvring trials are carried out at a scientific level that makes them suitable for validation purposes". This is analogous to the findings of the Powering Performance Committee regarding speed/power trials and correlation work. They further state that "the level of accuracy obtainable in model tests and full scale trials differ typically by an order of magnitude". I would propose that the scientific quality and level of accuracy can be significantly improved by the use of new technologies such as high speed/high capacity/portable computers, and the global positioning system. I would like to present a few examples of definitive manoeuvres conducted with the GPS.

Fig. 1)	Two tactical circles
Fig. 2)	Zig-zag manoeuvres
Fig. 3)	Spiral manoeuvre
Fig. 4)	Tactical turn.

I would also point out that fig. 5.7 in their report "tactical diameter of swath vessel" was derived from trials using GPS. I hope that the newly formed specialist Committees on Trails and Monitoring will address the conclusion of the Manoeuvrability Committee that "there is a need for more accurate full scale data for validation purposes". Again I wish to congratulate the Committee for their fine report.



Early Comparison of Uncorrected Tactical Turn

Later Comparison of Tactical Turn

Fig. 1 Tactical Turn Comparison

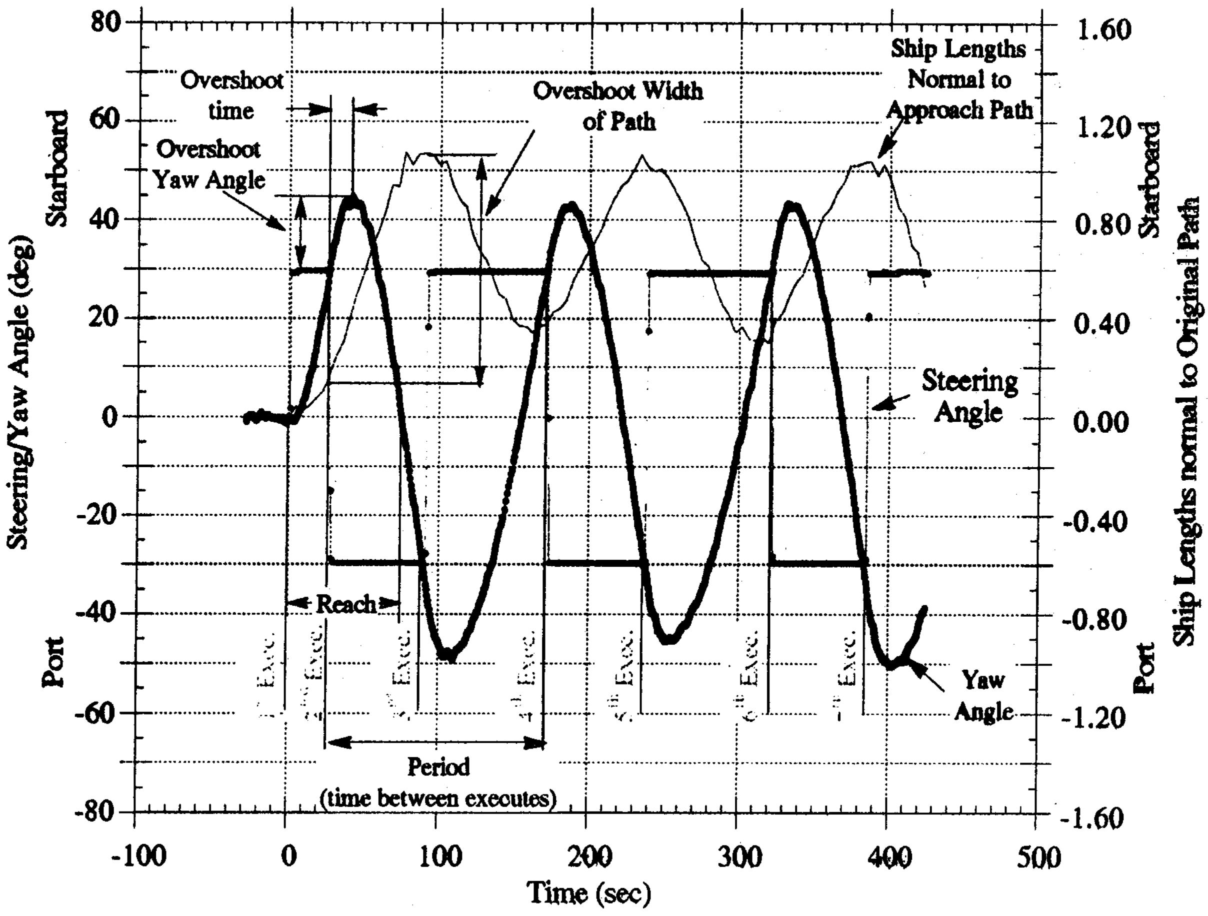


Fig. 2 Horizontal Overshoot Trials Using GPS

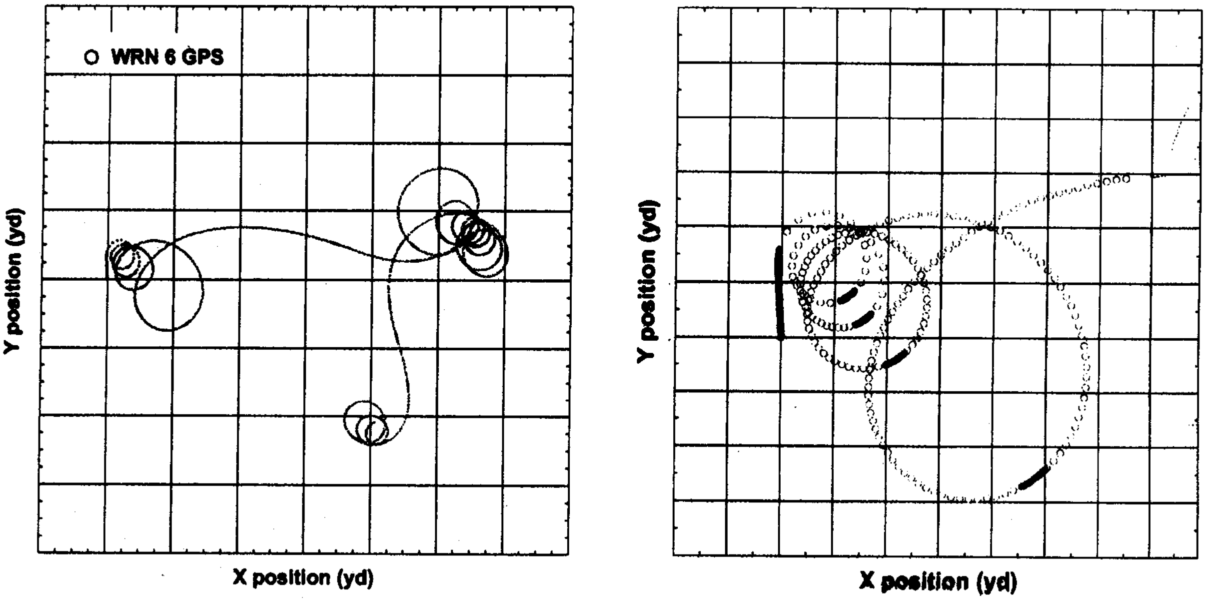


Fig. 3 Dieudonne's Spiral Manoeuvre

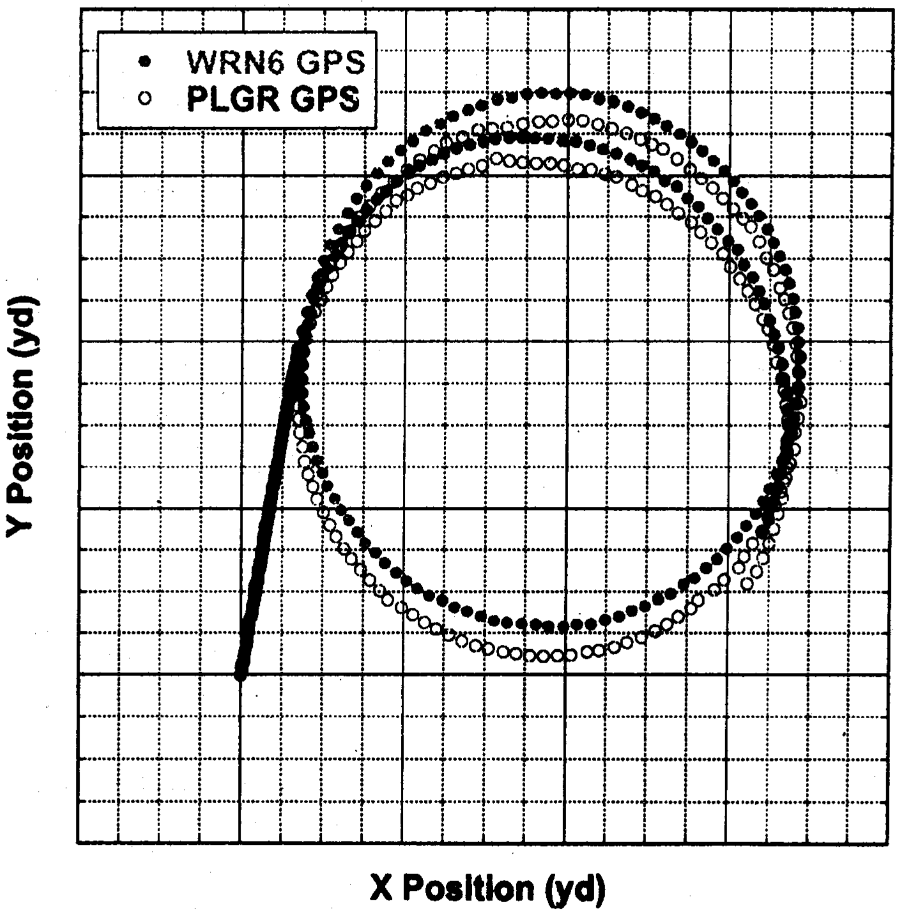


Fig. 4 WRN 6 and PLGR GPS Tracking Systems

Discussion of Manoeuvrability Committee Final Report and Recommendations to the 21st ITTC

by Willem van Berlekom
SSPA, Gothenburg, Sweden

The Committees report is of great interest, however I have two comments/questions.

1. Simulation of dynamics (Section 4)

When I read the report I get the impression that there is only one method including 6 degrees of freedom. To my knowledge there exists a number of 6 DOF models and surely this must be the way ahead as ship manoeuvring in waves will be more and more important.

2. Evolution of model testing methods (Section 8)

No mention is made of tests with free-sailing model tests. Could you explain why, as we consider tests with free-sailing models are very important for assessing manoeuvring characteristics as well as the hydrodynamic coefficients.

Discussion on the Prediction of Ship Manoeuvrability with a Flapped Rudder

by Yasuo Yoshimura
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1. Introduction

Recently, the powerful high-lift type rudder such as a flapped rudder is widely used in order to improve a steering quality or to achieve the reduction of labour cost in ship operations. For the prediction of manoeuvrability with such ships, very few papers have been presented. The prediction has been done by means of employing some empirical amplification factor in the calculation of rudder normal force. This factor, however, has some problems. It differs depending upon rudder angle especially when the flap angle is not proportional to the rudder angle. It is not also proper when a ship is swaying and yawing because the inflow angle to the rudder changes depending on the ship motion, but the flap angle is kept unchanged. These facts may cause the miscalculation of the manoeuvrability.

In this paper, the mathematical model is proposed to predict the manoeuvrability of the ship that has a flapped rudder. Then the model is validated by free-running model tests.

2. Open Characteristic of Flapped Rudder

Naturally, the rudder normal force of the flapped rudder should be expressed by two parameters which are inflow angle to rudder and flap angle. According to the research of flapped wing or rudder, the lift coefficient C_L can be simply described as the following within a certain range.

$$C_L = a\alpha + b\delta_f \tag{1}$$

where, α: inflow angle to rudder
δ_f: flap angle (see Fig. 2)

a is almost equal to that of the conventional non-flapped rudders. It is well predicted using the aspect ratio of the rudder. b depends on the flap area and the gap between flap and main rudder. Fig. 1 shows the results of wind tunnel test with the flapped rudder whose aspect ratio is 2.0, flap area is 25 % and section is NACA-0012. It is confirmed from this figure that C_L can be approximated by eq.(1) within the inflow angle of 15^0 and the flap angle of 20^0.

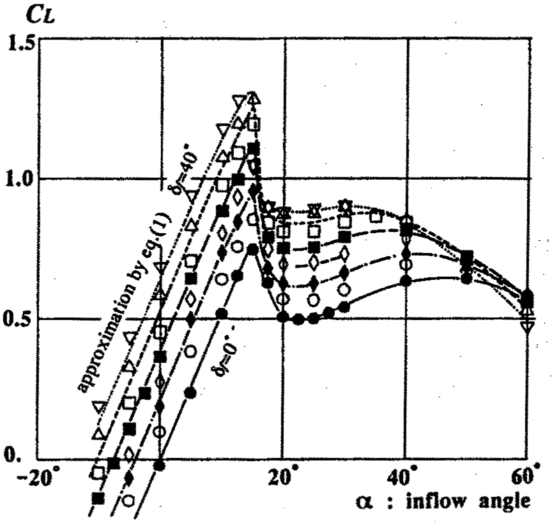

Fig. 1 An example of the open characteristic

3. Mathematical Model for Rudder Normal Force of Flapped Rudder.

According to the MMG's modular type mathematical model, the rudder normal force is described as the following form.

$$F_N = (\rho/2)A_R U_R^2 a \sin\{\delta - \gamma(\beta + cr')\} \tag{2}$$

where, γ is the flow straightening factor induced by propeller and hull. $\gamma(\beta + cr')$

represents the reduction of inflow angle due to the manoeuvring motion. This produces the damping of ship motion and contributes to stabilize the course keeping quality of ship.

As for the flapped rudder, F_N is conventionally multiplied by the amplification factor k_f.

$$F_N = (\rho/2)A_R U_R^2 a\, k_f \sin\{\delta - \gamma(\beta + cr')\} \qquad (3)$$

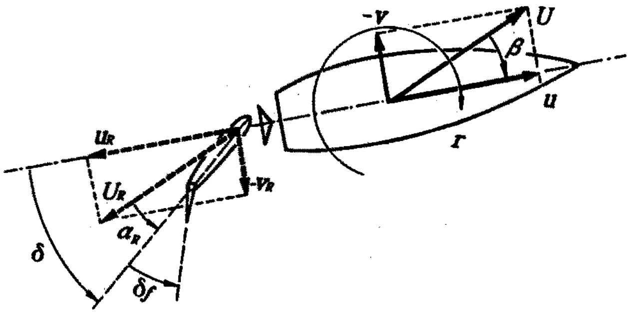

Fig. 2 Co-ordinate systems

This expression, however, should be altered since the lift coefficient of a flapped rudder is described by eq.(1). The altered formula is

$$F_N = (\rho/2)A_R U_R^2 a\,[\sin\{\delta - \gamma(\beta + cr')\} + (k_f - 1)\delta] \quad (4)$$

where, conventional amplification factor by a flap: k_f can be written as,

$$k_f = 1 + (b/a)(\delta_f/\delta) \qquad (5)$$

When the flap angle is proportional to the rudder angle, k_f may become constant. However, it differs depending on rudder angle and flap angle. An example of measured k_f is demonstrated in Fig. 3.

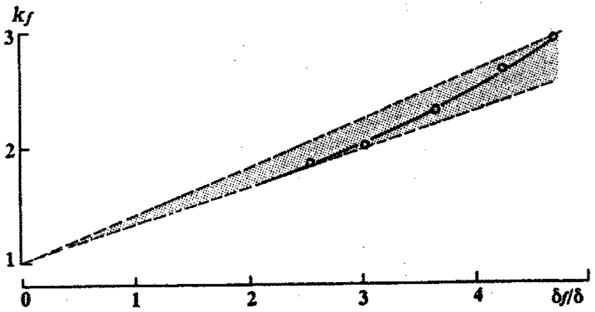

Fig. 3 An example of measured k_f.

Eq.(4) also indicate that the increment of rudder normal force: $(\rho/2)A_R U_R^2 a(k_f-1)\delta$ is kept unchanged even in the swaying and yawing. This fact means that the flap itself does not contribute to the course stability of ship in spite of the strongly magnifying of the rudder force.

4. Results of Simulation

The above mentioned mathematical model is applied to the ship model that has a flapped rudder. Fig. 4(a) is the comparison of spiral characteristic between predicted by MMG's model using eq.(4) and measured by free-running model test. In this figure, it is found that the predicted result is well explained by eq.(4). On the contrary, the dotted line in Fig. 4(b) shows the conventionally predicted spiral curve by eq. (3). The predicted r' at the small rudder angle shows the over-estimation to the stable side in course keeping quality.

The comparison of Z-manoeuvre is also performed, where the almost the same as the measured ship motion can be seen in the altered prediction.

5. Conclusion

From the results of the altered prediction it is shown that the prediction accuracy is successfully improved. Furthermore, it is found that the flap itself does not contribute to the course stability of ship.

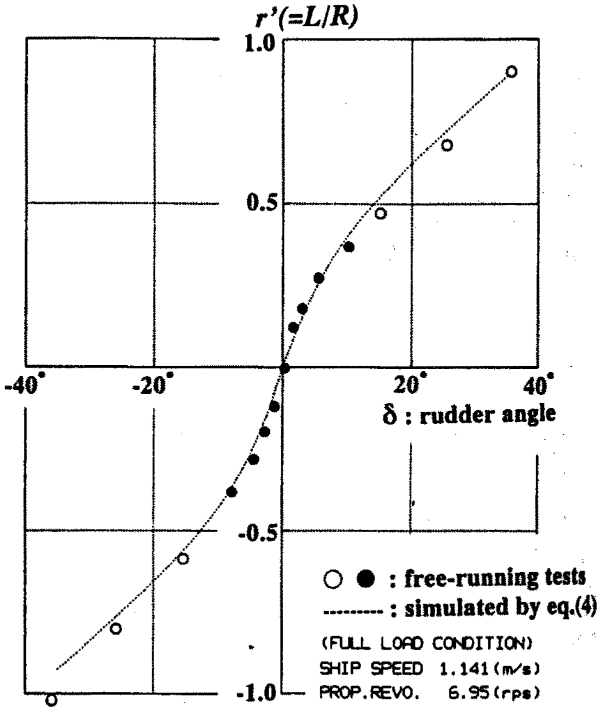

Fig. 4(a) Comparison of spiral curve (eq. (4))

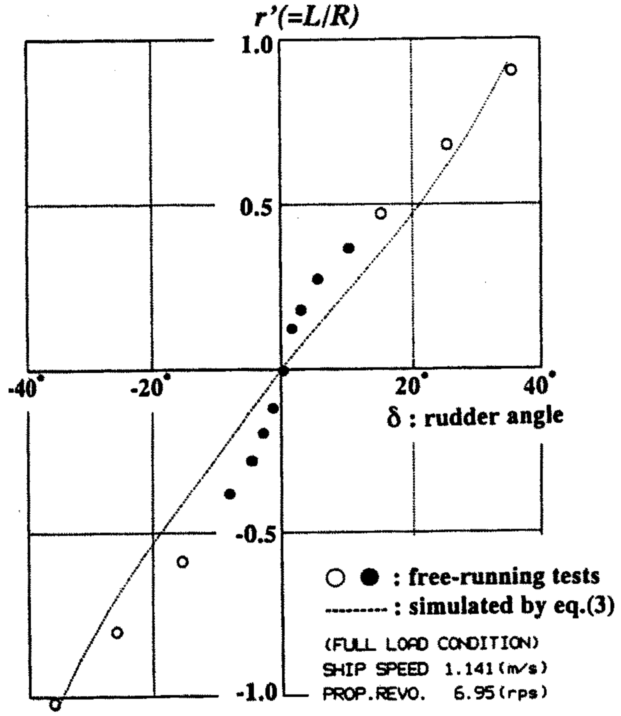

Fig. 4(b) Comparison of spiral curve (eq. (3))

II REPLIES

Reply to the discussion by Dr. B. Della Loggia

We thank Dr. Della Loggia for his comments. He wishes that the Committee had paid greater attention to the assessment of tools for predicting ship manoeuvring performance. The past three years have seen the publication of many papers describing such methods, many of which are intended for use in assessing new ship compliance with IMO Interim Standards. However, most of these methods have been only broadly described and adequate validation of few have been provided. The Committee has thus had no rational basis for, or reason to, make a critical assessment of these methods. Among the methods reviewed and referenced by the Committee was SIMSUP, as described in a 1995 paper by Giovanni Capurro, a member of this Committee. We have had no opportunity to review the new paper by Capurro and Sodomaco referenced by Dr. Della Loggia. The next Committee can evaluate recent progress report by this new paper.

Reply to the Discussion by Prof. Hearn

The Committee appreciates Prof. Hearn for his interesting information on the detailed program and products in the MOSES project. Although the Committee had made an efforts to collect as detailed information as possible with regard to the MOSES project, available material was very limited at the time of preparing the final draft of our Committee report. In the MOSES Phase 1, theoretical studies for the linear hull derivatives have been made, in which a method has been developed to account for the effect of stern vortices on the calculation of linear hull derivatives. This method has been extended to the case of shallow water in the MOSES Phase 2. The method developed by Prof. Hearn may greatly contribute to the ship manoeuvring prediction with high accuracy.

The Committee likes to look forward to seeing the publication for the products of the MOSES project both for Phase 1 and Phase 2 in near future.

Reply to the discussion by Prof. Grant E. Hearn and Dr. David Clarke.

The Manoeuvrability Committee appreciates the research carried out by Prof. Hearn and his team on on-line training based neural controllers, and looks forward to publications on this subject with great interest.

The idea of permitting vessels which do not conform with IMO Standards, provided that their shortcomings are compensated by means of controllers, is certainly worth a discussion. The principle on which this idea is based is in fact not really new: it is, for instance, well known that a directionally unstable vessel may acquire straight-line stability if it is controlled by a well tuned simple PD-controller. Doubtlessly, more sophisticated modern controllers will have the capability to compensate more adequately for other shortcomings.

On the other hand, there are several reasons to be reluctant to this idea.

Firstly, some parameters mentioned in the IMO Standards are a reflection of the physical restrictions, or the operational boundaries, with which any human or artificial control system has to take account. Turning circle characteristics, for instance, cannot be improved by means of a controller.

Secondly, the behaviour of a ship-controller combination should only be considered as relevant if that combination is not only used in routine situations, but also- and especially - in emergency situations.

These are only two technical arguments, which could be completed by a list of non-technical objections, concerning responsibility, traffic organization, local situations, etc. Nevertheless, approaches as described by Prof. Hearn should certainly be followed by the Manoeuvrability Committee. His comment also gives the occasion to reflect the discussions within the Committee about the limits of its task. The ITTC Manoeuvrability Committee should mainly be concerned about manoeuvring hydrodynamics, about research meant to reveal the physical mechanisms ruling a ship's manoeuvrability, but should also, to some extent, follow up trends in the applications of manoeuvring hydrodynamics, such as simulation, control, safety of shipping traffic, training, etc.

Reply to the discussion by Dr. M. Landrini and Dr. Coppola.

We thank Dr. Landrini and Dr. Coppola for their discussion on the question of Froude number dependence. The important role of free surface effects when considering the manoeuvrability of relatively high and high speed vessels has been recognized by the Committee as described in the report. Consequently we agree with the discussions on that point.

Although we do not have access to the unpublished reference cited by the discussers, we would like to emphasize that the Fn effects in manoeuvrability are characterized by modification of the pressure distribution due to free-surface deformation on a flat plate in yaw as alluded to by the discussers, but also, in the case of a floating body, the introduction of roll and pitch.

It should be recognized that this latter point generally implies non linear free-surface and body boundary conditions in numerical model, and 6DOF simulation models.

The discussers describe problems associated with prediction of manoeuvring in waves, as did our Committee Report. We have chosen to emphasize recent work and progress in this area rather than to reiterate the difficulties. As it remains difficult to adequately validate manoeuvring prediction methods for use in calm environment, we can hardly disagree with the discussers' comments about validation. The Committee has taken note of the need, in some situations, to include "memory effects". Finally, we would certainly encourage development of new approaches to the difficult problem of manoeuvring in waves.

Reply to the discussion by Dr. Lee and Dr. Yum.

The Committee welcomes the comments from Dr. Lee and Dr. Yum. We agree strongly that prediction of ship manoeuvrability is important, and that it will be one of the major roles of the ITTC community in the future.

The committee agrees with the discussers that the effect of $\overline{GM}$ can be important in the manoeuvring of certain vessel types. In fact, one of our conclusions was that the need for inclusion of the roll equation into the model for special cases has been recognized.

The committee notes with interest the effect of the stern shape on the directional stability of the containership reported by the discussers. One of our conclusions in the report was that this is an important effect which is not fully, understood and we welcome the discussers' additional information in this area.

The discussers state that the simulation has been based on the surge-sway-yaw coupled equations and we are a little confused as to the effect of roll in this case. As they stated, this is important for this type of vessel, and we believe it would have been useful to have included $\overline{GM}$ on their figures.

Reply to the discussion by Dr. A.F. Molland

We thank Dr. Molland for his interesting discussion.

We certainly concur that a full understanding of the complex physics of propeller-rudder-hull forces and interactions is required.

We welcome his review of recent MOSES work, which we were largely unable to obtain and review for our report. We unfortunately missed the referenced 1994 paper, perhaps because we desired to "manoeuvre" around propellers and shafts as one of the few topic areas we thought we might safely leave to others.

We look forward to a chance to review data from the truncated model tests. We wonder what limitations may exist on the applicability of results from such tests.

With regard to propellers-rudder-hull interaction representation in whole ship models, we note that:

1) Whole ship models must adequately reflect the physics associated with such interactions;
2) Tests with propellers and/or rudders temporarily removed can and are conducted to help confirm the adequacy of propeller-rudder-hull interaction modelling;
3) Test variables and their ranges of test values must be carefully chosen to ensure that the propeller and rudder performance is adequately modelled;
4) Experience from modular tests can and should be applied in developing and refining whole ship models.

Reply to the discussion by Dr. Norrbin

The first part of your comment is that our committee report does not include a formal set of Recommendations to the Conference. As we mentioned in the presentation of the report, the Committee agreed the Recommendation to the Conference. But in the Proceedings of 21st ITTC, the part of our Recommendation has been eliminated by, may be, the suggestion of the Advisory Council. A similar recommendation has been inserted in the Chapter 4 of the Appendix 2, New Structure of ITTC in the proceeding.

On the second part in your comment, the Committee agreed to support the technical part of the IMO Interim Manoeuvring Standards. The standards are to be included interim for a period of 5 years from the date of their adoption. This means we need experience to apply and to predict ship manoeuvring characteristics at design stage. Although the prediction of a ship manoeuvrability is developing, it seems the precise prediction method taking into account the ship's detailed data is not established yet. More work is needed in this field.

On the third part, it is in fact said that the mariner cannot control the ship's heading during a crash stop manoeuvre. Generally speaking, in the stopping manoeuvre, the trajectory of ship will be affected by the potential energy at the moment of just execution of propeller reverse, and also by the disturbances such as wind and waves. Therefore, the ship will turn to starboard or port during a stopping manoeuvre, and then, as you pointed out, the trajectory of a ship may stay inside such "mushroom figure". From this point of view, the Committee support that it may be recommended to introduce a new test procedure to assess the stopping characteristics in the future.

Reply to the discussion by Dr. Willem van Berlekom

The Committee can only agree with Dr. Willem van Berlekom on the importance of the subjects mentioned. However, the Committee has of necessity been able to mention only the most representative new research works published during its working period. Certainly a number of 6 DOF methods are currently in use, and such methods are clearly required for accurate prediction of manoeuvring in waves. Mention of tests with free-sailing models was not made because there does not appear to have been any significant new developments in this area during the past few years.

Reply to the discussion by Dr. Yoshimura

Dr. Yoshimura provides useful information on the manoeuvring prediction for a ship with a flapped rudder. A practical approach to predict rudder forces acting on the flapped rudder is proposed in his contribution.

Nowadays such an advanced rudder as a flapped rudder has increasingly been adopted for many ships to improve their steering quality in a congested sea such as a harbor area. Further efforts to develop the rudder force prediction for other types of advanced rudder will be awaited with interest.