SESSION ON MOTIONS OF THE HULL
MANOEUVRING
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Discussion of the Report and the draft Recommendations of the MANOEUVRING COMMITTEE

I. DISCUSSIONS

N. NORBIN - Statens Skeppsprovningsanstalt, Göteborg, Sweden

I will thank the Committee for a fine report which I enjoyed reading. I have a brief remark on the Recommendation, and a few comments on items 5 in the review.

Looking one more on the list of recommendations produced by the 14th I.T.T.C., and by the old Committee, to be true, it prevented a formidable task. Quite right, the new set of Recommendations is somewhat less ambitious. I do feel, however, that we must advance work on the complex problems of steering in waves outside the range of the special care of long following seas, important as it may be. Inherent in the review and the concluding remarks is a recommendation to Member Organizations to meet the demands for computer models and pertinent data often raised by "simulator owners" outside our profession. I think we must be very careful not to endanger the proper use of these models, not to encourage the widely spread belief that "computer solution" is an alternative to hydrodynamic theory or scale model experiment.

At the outset of the review it is stated that no significant scientific advances have been made within the field since the last Conference. I feel prepared to name the general introduction of circulatory effects in interaction theory, initiated by Newman, and Tuck and Newman, as a significant advance.

A. POSTUMA - Netherlands Ship Model Basin, Wageningen, The Netherlands

After reading the report of the Manoeuvrability Committee I would like to make the following remarks:

1. One of the recommendations adopted by the 14th I.T.T.C. Conference contains a study of the manoeuvring characteristics and controllability of a ship in backing or other transient propulsion conditions, including modelling and associated scale effect problems. Especially in view of the important part of ship control in which man-ship interaction is concerned and where transient propulsion conditions have to be taken into account for the mathematical modelling of the manoeuvring ship, I wonder why there is no comment on this recommendation in the report.
2. In the report a literature study is presented about the steering of ships in waves. This study gives a good review of the work carried out on this subject, therefore the absence of a conclusion on this topic in the form of a recommendation, is remarkable.

Would the Committee care to comment on these 2 points?

V. KOSTILAINEN - Helsinki University of Technology, Ship Hydrodynamics Laboratory, Finland

This discussion concerns the problems associated with ship handling in confined waters.

The Committee has collected a comprehensive review of this subject under separate headings. There is, however, two points which deserves further emphasis.

1. Discussion on ship handling in confined waters are to often limited to slow speeds only. There are, however, cases in which ships are designed to sail in confined waterways at full speed. Also considering the safety of all ships most dangerous critical situation arise at high speeds, when the kinetic energy of ship is large. High speed means rapidly changing external surroundings which complicate mathematical modelling. On the other hand mathematical modelling and simulations are the only possible way to collect statistical data necessary for probability considerations.
2. High speed operations in shallow waters involve also problems with squat. The squat has neither been handled by the Manoeuvrability Committee, nor any other Committee. At least our Laboratory has made several squat studies and as far as I know there are some other Institutions making squat research.

K. TAMURA - Mitsubishi Heavy Industries Ltd., Nagasaki Technical Institute, Nagasaki, Japan

It is pointed out in the Committee Report that sometimes the directional stability is improved with increasing fulness of model stern and this comes from the occurrence of the two completely different stern flow patterns. The explanation on the two different stern flow patterns, however, is a somewhat vague one and some additional explanation will be necessary.

The same unusual flow phenomena are also treated by the Performance Committee and the results of studies are given in the Committee Report as "flow separation" (pp.374-375). Therefore, we can get clearer view on this phenomena by referring to it. The writer, who took part in preparation of the Report, would like to make some supplementary comments.

It must be pointed out that the flow pattern around model stern of this type becomes unsymmetrical by the action of propeller, even though it is completely symmetrical in the towed condition. The flow separation which is accompanied by the reverse flow as shown in Fig.13 (of the Rep. of Manoeuvrability Comm.) appears sometimes on the starboard and sometimes on the port side. The side force is delivered at the stern toward starboard or port side corresponding to this position of separation zone. Such a phenomenon may be correlated closely to the present problem on directional stability.

The values of thrust and torque delivered by the propeller are also related closely with the positions of separation zone. Thus, the higher and lower values of wake fraction as stated in the present report correspond to them.

The change in the separation zone does not occur periodically; sometimes it is shifted from one side to the other and this may cause the flow pattern unstable.

The flow pattern stabilized by means of fins, as shown in Fig.14, becomes symmetrical, where not only the side force delivered at the stern and the change of wake fraction but also the anomalous steering behaviour disappear.

It is still unclear why such unsymmetrical flow patterns as stated above occurs by the action of propeller. Also it is unclear at what fulness and shape of stern and boundary conditions these phenomena occur. Further joint studies by Manoeuvrability and Performance Committees are desirable.

G. AERTSSEN - University of Ghent, Department of Naval Architecture, Ghent, Belgium (retired)

When IMCO has to establish a minimum capacity for the tanks of segregated ballast tankers, much thought was given, in the ballast condition, no only to immersion of the propeller, but also to course keeping ability in severe seas. IMCO has recommendations both for draught and trim, but the recommendations finally resume in a requirement for minimum draught T_f, T_f and L being in metres:

$$T_f/L = 0.0125 + 2/L \qquad (1)$$

The formula is well built, pitching indeed decreases as ship length increases. IMCO requires that "in no case shall ballast water be carried in oil tanks except in weather conditions so severe that, in the opinion of the Master, it is necessary to carry additional ballast water in oil tanks for the safety of the ship".

In an oblique severe sea, when the forward draught of the ship is too small, the ship pays off to leeward and, unless the revolutions are driven up allowance the ship to be held up in the wind, the ship is broaching-to. Having been involved in at least three of these cases, some information is available to compare with the IMCO standard. From this information it may be concluded that formula (1) applies to any kind of cargo ship more than 100 m in length, with this exception, however, that T_f given by the formula be increased by 25% in sea states beyond Beaufort 9. The allowance should be even 50% for ships having strong windage as containerships.

Cargo-liner BREUGHEL, a sistership of the JORDAENS, at a forward draught of no more than 4.56 m - the IMCO draught with an allowance of 25% was 4.78 m - taking the waves Beaufort 11 at 45 deg port, broached-to and went on drift in this sea state. Finally, the ship drifted far away from her initial route and approaching the coast, captain decided to come up into the wind. He increased the revolutions as high as 100 (normal revolutions being 118), the ship slamming and racing heavily in this Beaufort 11 sea at 45 deg port.

In similar circumstances a Victory ship went on drift in an extreme sea state. As in the case of the BREUGHEL no noticeable damage happened.

Typical is the behaviour in waves of containership DART EUROPE in light-loaded condition - she carried no more the 8800 tons of cargo - during her third westbound crossing of the North Atlantic, the tanks being unadequately filled. The captain only little reduced speed, heading in waves Beaufort 7, accepting 3 slams per 100 pitch oscillations. Then, just before facing a sea Beaufort 9, the ship endured 4 slams, 2 water shipments and 50 propeller emergences per 100 pitch oscillations. To reduce pitching the captain took the waves at 30 deg starboard, hereby rolling heavily (maximum roll angle 35.2 deg, maximum acceleration transversely 0.93 double amplitudes). This manoeuver had eased ship motions at a draught of 30 ft. But now, at a draught forward of 7.02 m - IMCO draught with 50% allowance was 7.09 m - this high windage ship had no course keeping ability in waves of more than 10 m significant height and the manoeuver failed. The containers were endangered and the ship risked to broach-to. To avoid this the captain came again head into the waves, reducing his revolutions to 80, his speed to 8 knots, not too much but just enough to have not too much slams, 5 slams per 100 pitch oscillations, and not too much green seas, 5 water shipment per 100 pitch oscillations, so preventing his ship to broach-to. He was afraid of endangering his containers if he reduced too much (lateral acceleration too high because of broaching-to), on the other hand afraid of endangering his deck fittings if his speed was too high (deck wetness). Incidentally the deck damage of this ship was not unimportant.

In conclusion, a ship at reduced draught gains speed and captain is eager not to spoil this gain. Too often, however, captain, curious enough, pays more attention to chief's demand for a better propeller immersion than to a reasonable forward draught. On the containership a trim by stern, 4 ft, was correct, and to reduce the whipping of the hull girder which was conspicuous, captain added 500 tons ballast fore and 500 tons ballast aft. This trim was rather high on the BREUGHEL, 6 ft, for a 146 m ship.

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1. Aertssen, G.: " Service performance and seakeeping trials on m.v. JORDAENS", Trans. R.I.N.A., Vol.108, 1966.

2.Aertssen, G.: "Service performance and seakeeping trials on a large containership", Trans. R.I.N.A. Vol.114, 1972.

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Department of Naval Architecture, Osaka,
Japan

The recommendation No. 1 as adopted by the 14th I.T.T.C. reads: "test procedure and methods of analysis that may be considered to define the manoeuvrability of a ship should be kept under continued review".

The captive-model-plus-digital-simulation technique has greatly developed in these one decade of years. At the same time, remote control, free-sailing model test has still been used at many places of the world. Indeed it is perhaps the handiest means of manoeuvrability prediction; it takes only a few hours of testing; compact and inexpensive instruments; can be done in a conventional towing tank with a reasonable width (even in a pond); possible to use an ordinary model after the resistance and propulsion tests.

This procedure also makes it possible to define a mathematical model of an actual ship in commission; a great benifit from the practical point of view.

Procedures of analysing free-model experiments should take much care and thought, however. Quite not enough is a mere reproduction of ship's track at the manoeuvre actually done. A proper type of mathematical model should be adopted in the analysis to bring out a few basic characteristics parameters of a given ship through the analysis. Then we will have a general picture of manoeuvrability of the ship, and if the need arises, be able to predict the ship's response to any manoeuvre.

A number of mathematical models and procedures of analysis with them have already been reported /1/. After a good deal of trial and error, however, the writer should like to introduce now that he believes to be very sensible.

The mathematical model to be used is:

$$T_1T_2\dddot{\Psi} + (T_1 + T_2)\ddot{\Psi} + \dot{\Psi} + \alpha\dot{\Psi}^3 = \\ = K\delta + KT_3\dot{\delta} \qquad (1)$$

This equation describes the steering response of a ship up to fairly intense manoeuvre with a good approximation /2/. T_1, T_2 and T_3 are the time constants, K the linear gain and α the non-linear factor. All these characteristic parameters are theoretically composed of mass terms and hydrodynamic coefficients (including non-linear ones), and could be evaluated accordingly from the captive model data.

These characteristic parameters can, however, be obtained also from the free-model experiments. The procedure is:

(1) firstly find K from steady turning data at small rudder angles, normally within 5 degrees. A set of spiral tests or Beck's reverse spiral procedure will be employed. Fig. 1 indicates an example.
(2) Next we take a zig-zag test. Continuous record of yaw rate und rudder angle should be provided. We put the rudder angle record into Fig. 1. The coefficient K is already fixed and the other parameters, T_1 through α, are assumed freely as a set of initial trial value. Numerical integration gives us a "predicted" ship motion, based upon that fixed K and the first trial T_1 through α. Difference between that predicted yaw rate and the observed (recorded) one is the "error", and we modify the trial values of T_1 through α so that the error be as small as possible. A kind of the least square error iteration process is made use of.
(3) Repeating such process with a digital computer results in a set of most

probably T_1, T_2, T_3 and α. We thus obtain all the parameters of Eq. (1) from free-model experiments.

Table 1 gives one of such results for a 4 metre tanker model (the same as one of Fig. 1). We can see that the time constants and non-linear factor α derived from various zig-zag tests result in fairly consistent values. Fig. 2 compares the final "predicted", then best fitted, motion with the one observed at a test.

In the actual computation we use the following equation instead of Eg. (1)

$$T_1T_2(\ddot{\psi}-\ddot{\psi}_o) + (T_1+T_2)(\dot{\psi}-\dot{\psi}_o) + \int_o^t(\dot{\psi}+\alpha\dot{\psi}^3)dt$$
$$= K\int_o^t(\delta-\delta_r)dt + KT_3(\delta-\delta_o) \qquad (2)$$

where $\dot{\psi}_o$, $\ddot{\psi}_o$ and δ_o denote $\dot{\psi}$, $\ddot{\psi}$ and δ at $t = 0$ respectively, and δ_r the neutral rudder angle with which the ship sails straight. Eg. 2 is given by integrating the both sides of Eq. (1), with the neutral rudder angle correction.

The error function is defined as

$$J = \frac{1}{\sigma_r^2}\int_o^{t_F}(\dot{\psi}-\dot{\psi}_m)^2dt + \frac{1}{\sigma_{\dot{r}}^2}\int_o^{t_F}(\ddot{\psi}-\ddot{\psi}_m)^2dt \qquad (3)$$

where $\dot{\psi}$ and $\ddot{\psi}$ denote observed yaw rate and yaw acceleration,
$\dot{\psi}_m$ and $\ddot{\psi}_m$ "predicted" yaw rate and yaw acceleration,
σ_r^2 and $\sigma_{\dot{r}}^2$ variance of observed yaw rate and yaw acceleration

and t_F is the whole period of the test. Observed yaw acceleration data is provided from observed yaw rate through a numerical filtering process whose function is differentiation with data smooting. As for iteration procedure, "Powell method without derivatives" proved most satisfactory /3/.

Incidentally it may look possible to determine all the parameters including the gain K only from a zig-zag test record with the same least square error iteration. The principal obstacle to it is that really considerable variation of the gain K and the dominant time constant T_1 does not give any appreciable effect on the response behaviour, if the two both vary to the same degree. That means that a combination of both large K and T_1 can hardly be discriminated from a combination of both small K and T_1. So we are forced to determine K first from another source.

Fig. 3 tells us the fact. This is an example of the "error-evaluating function" derived from a 10/10 zig-zag test. The parameters T_2, T_3 and α are all fixed. With changing the parameters K and T_1, the error function changes its value. A pair of K and T_1 that corresponds to the minimum value of the function is the answer.

At a glance on the map, we see a notable "valley", starting from the origin and up-rightwards. The "bottom" of the valley is very horizontal. That means that any pair of K and T_1 that has a certain constant ratio corresponding to the angle of the valley line on the map will give the same minimum error, and in turn, any such pair can be the answer. This does not make sense and we need another information source to have an unique answer.

REFERENCES

/1/ Manoeuvrability Committee Reports to 13th and 14th I.T.T.C., Appendices 1 and 2 respectively.

/2/ Nomoto, K.: A Simplified Non-linear Analysis on Ship Manoeuvrability, 12th I.T.T.C. Contribution to Manoeuvrability Committee, 1969.

/3/ Powel, M.J.D.: An Efficient Method for Finding the Minimum of a Function of Several variables without calculating Derivatives, the Computer Journal, 10, 1967.

Expt.No.	Kind of Test	K'	T_1'	T_2'	T_3'	α
59	-15° Z	-11.5	-21.2	0.27	0.63	-81
60	-10° Z	-11.5	-24.1	0.38	0.86	-79
62	10° Z	-11.5	-24.4	0.40	0.83	-57
66	-7.5°Z	-11.5	-25.3	0.41	1.05	-31
70	7.5°Z	-11.5	-27.4	0.37	0.92	-62
117	10°/2°Z	-11.5	-24.8	0.41	0.89	-72

Table 1 - Least square error iteration analysis of zig-zag test for a VLCC model M-2

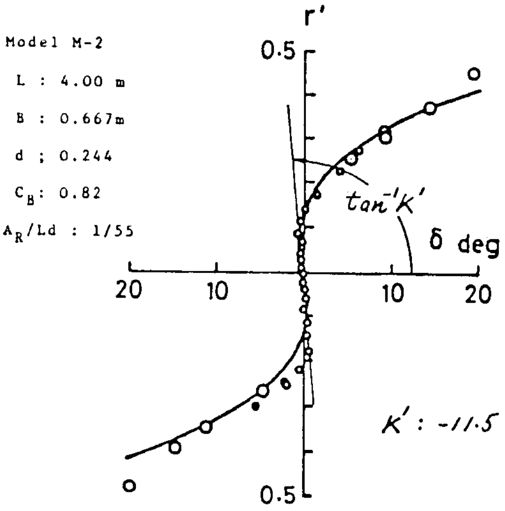

Fig. 1 - Steady turning characteristics of a VLCC model (Spiral test results)

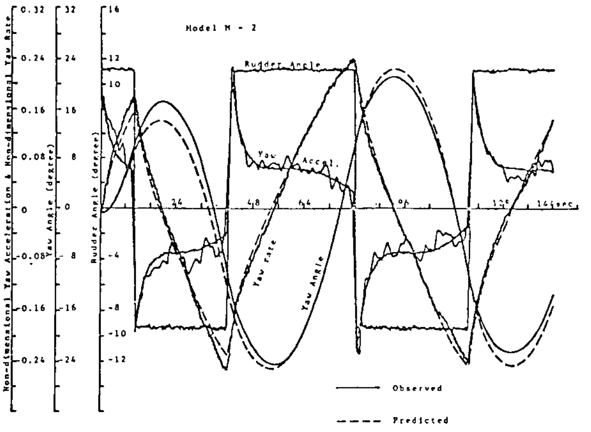

Fig. 2 - Zig-zag test record and its analysis for a VLCC model

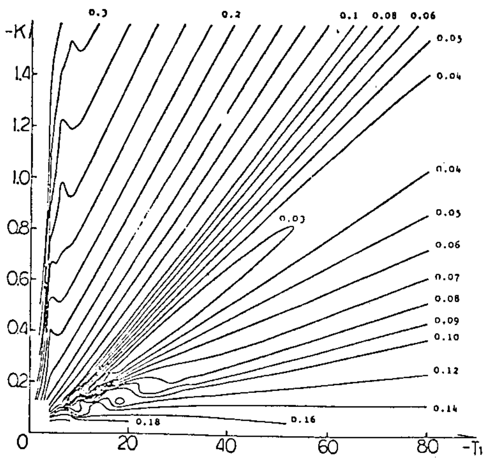

Fig. 3 - Error evaluating function contour (10°/10° zig-zag test, T_2, T_3 and α fixed)

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The Hydrodynamic Derivatives on Ship Manoeuvrability in Even Keel Condition

Introduction

The experiments and the theoretical values of hydrodynamic derivatives on ship manoeuvrability comparatively are more on the case of full load condition and these in the base of ballast condition or other condition are few. On the other hand by the progress of measuring technics these values sometimes are divided into 3 parts, namely bare hull, rudder and their interferences and also the author dealed with the hydrodynamic derivatives in trimmed condition as the ratio of trimmed condition values and even condition values of same displacement /2/. As the estimation of hydrodynamic derivatives on comparatively small even keel draft is needed at that time, these are treated in this paper using new type ship form. If these values are combined with the values in

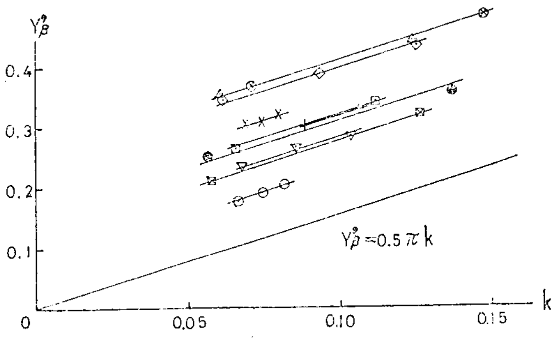

Fig. 1

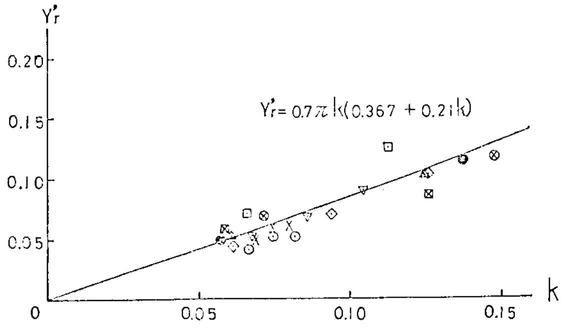

Fig. 3

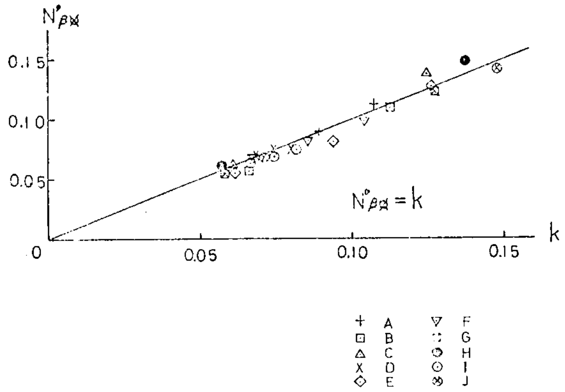

Fig. 2

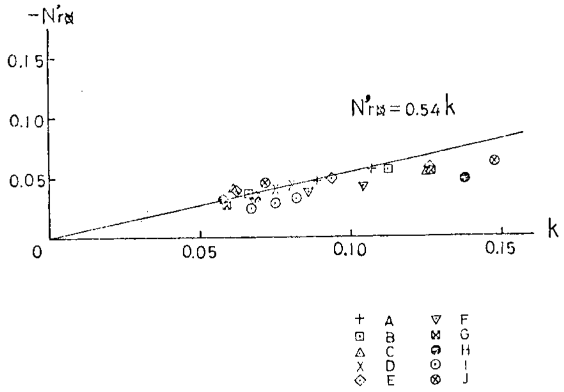

Fig. 4

trimmed condition, it is possible to estimate the values at any conditions.

Models and experimental method

The length of models is 2.5 metre and the kinds of models are a car-carrier, 3 cargo ships, 3 oil tankers, a container ship, a LNG tanker, and a Ro-Ro ship. By the oblique test and the rotating arm test at manoeuvring tank of Kyushu University non-dimensional hydrodynamic derivatives Y^1_β, Y^1_r, $N_{\boxtimes\beta}$, $N_{\boxtimes r}$, are researched.

Analysis of the hydrodynamic derivatives

Y^1_β, Y^1_r, $N^1_{\boxtimes\beta}$ and $N^1_{\boxtimes r}$ are showed in Fig. 1, 2, 3, 4 as functions of $K=2d_m/L$. (d_m: mean draft) Among these, $N^1_{\beta\boxtimes}$, $N^1_{r\boxtimes}$, Y^1_r are

$$N^1_{\beta\boxtimes} = K \qquad N^1_{r\boxtimes} = 0.54\ K$$

$$Y^1_r = 0.7\pi K\ (0.367 + 0.21K) \doteqdot \pi K/4$$

which the author has used formerly. Y^1_β at full load condition can be shown $Y^1_\beta = k_1\pi k$, but on small draft the question arises. As shown in Fig. 1 the slips of each ship's Y^1_β is $\pi/2$ and the value of Y^1_β can be estimated by the addition of constant value f to $\pi/2$ k. $\pi k/2$ is the wing theory value and f is the value by cross flow or Newton's resistance law. f appears as the function of linear β due to the difference of both shipside forces when β is small and is independent of k /1/. Perhaps f relates to the water plane and squar station form near the bow. If f correlates to C_bB/L (C_b; block coefficient; B; ship breadth) in this case, the value of f will be

$$f \doteqdot 1.4\ C_bB/L$$

as shown in Fig. 5.

Results

Y^1_β etc. of bare hulls in even keel condition can be shown, as stated above,

$$Y^1_\beta = \frac{\pi}{2}K + 1.4C_bB/L$$

$$Y^1_r = 0.7\pi K(0.367 + 0.21K)$$

$$N^1_{\boxtimes\beta} = K$$

$$N^1_{\boxtimes r} = 0.54K$$

So we shall be able to estimate the hydrodynamic derivatives in any condition as these in trimmed condition are expressed by the radio of Y^1_β etc. In trimmed condition and Y^1_β etc. in even keel condition.

/1/ S. Inoue: On the turning of ships. The memoirs of the Faculty of Engineering Kyushu University. 1956.

/2/ S. Inoue and K. Kijima: The Hydrodynamic Derivatives on Ship Manoeuvrability in Trimmed Condition. 15th ITTC 1978.

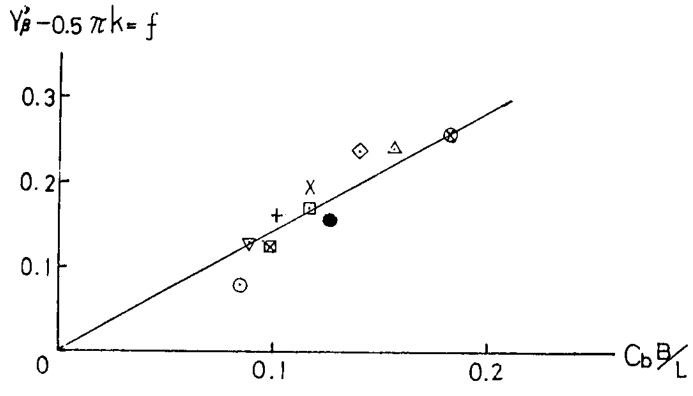

Fig. 5

+	A	▽	F
⊡	B	⊠	G
△	C	●	H
X	D	⊙	I
◇	E	⊗	J

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The Hydrodynamic Derivatives on Ship Manoeuvrability in the Trimmed Condition

Nomenclature

$\vec{v}$: y axis component of velocity vector.

$\vec{n}$, $\vec{\tau}_t$: normal & tangential components on body surface of velocity vector respectively.

p^+, p^- : pressure of upper & lower side on vortex sheet respectively.

U, V : x & y axes components of velocity respectively.

$Y_\beta(0)$, $Y_r(0)$, $N_{\boxtimes\beta}(0)$, $N_{\boxtimes r}(0)$: hydrodynamic derivatives of sway and yaw in even keel condition respectively.

$Y_\beta(\tau)$, $Y_r(\tau)$, $N_{\boxtimes\beta}(\tau)$, $N_{\boxtimes r}(\tau)$: hydrodynamics derivatives of sway and yaw in trimmed condition respectively.

L,B,d : ship length, breadth and draft respectively.

d_m : mean draft.

τ : trim quantity.

ω : vortex strength vector.

Subscript

n, t : normal & tangential component.

Summary

This contribution deals with the hydrodynamic characteristics on ship manoeuvrability in trimmed condition. According to the theory based upon slender body, the hydrodynamic force and moment acting on ship hull in trimmed condition are developed. Simultaneously, the experiment on this problem also carried out, and the theoretical results are compared with that of measuring. By this theory, the approximate formulae for prediction the hydrodynamic derivatives on ship manoeuvrability in trimmed condition are presented.

Introduction

It is primary importance in manoeuvring problems to know hydrodynamic forces acting on ship hull. And we have well known some methods of captive model test or some available theories, in the use of slender body theory or low aspect ratio lifting surface theory, to predict hydrodynamic ones acting on ship hull. Previously, one /1/ of the authors has proposed the theoretical method based upon Bollay's low aspect ratio theory for predicting hydrodynamic derivatives on ship manoevrability in even keel condition.

On the other hand, it is difficult to see some examples of work which dealt with hydrodynamic forces acting on ship hull in trimmed condition, notwithstanding the manoeuvring characteristics of ship will be greatly affected by her load condition.

Then, the relations of this hydrodynamic force and ship's load condition are made clear in this paper. Initially hydrodynamic forces acting on ship hull in trimmed condition are obtained by the theory based upon slender body, and also measured on four types model ship by means of Rotating Arm and oblique towing tests. With these results, the presumption of hydrodynamic derivatives on ship manoeuvrability in trimmed condition are developed.

Foundamental conditions of the flow model

For the flow around ship hull, the following assumptions are here used.

(1) The ship hull has large length compared to her lateral dimensions, so-called "slender body".
(2) The Froude number is sufficiently so small that free surface effects can be ignored.
(3) The fluid is inviscid and incompressible.

In view of the rigid free surface assumption a double-body model can be analysed, and the method to be considered here is the same that of Fuwa /2/.

We may write the following conditions,

basic condition $|L|\, \nabla^2 \phi = 0$ (1)

body surface condition $|B|\, \vec{v}.\vec{n} = 0$ (2)

far field condition $|\infty|\, \vec{v} \rightarrow 0$ (3)

free vortex sheet $|F|\, p^+ = p^-$

$$\vec{\omega} = \vec{n}\,|\vec{v}_t^{\,+} - \vec{v}_t^{\,-}| \qquad (4)$$

$$\vec{v}_n^{\,+} = \vec{v}_n^{\,-}$$

separation condition $|S|\, \vec{v}.\vec{b} = 0$

$$\vec{b} = \vec{n}.\vec{\tau}_t \qquad (5)$$

It should be very difficult to solve the basic formula (1) under the above boundary conditions. We will consider the two parts, therefore, which one is no free vortex field and the other is free vortex field.

On the flow field without vortex

Now, we shall consider initially on the oblique motion of ship. If the flow field about ship hull may be divided into two parts due to the forward motion and lateral motion, the velocity potential will be written,

$$\phi_o = U\,(x + \phi_1) + V\,(y + \phi_2) \qquad (6)$$

Applying here the assumption of slender body on ϕ_1 and ϕ_2 of disturbance velocity potential, we may consider this problem as steady two-dimensional flow in the transverse plane of hull as the first approximation, and the solution in the near field of ship hull by means of conformal mapping may be obtained. In this paper, the lateral section of ship hull is approximated by Lewis form section.

On the flow field due to free vortex

Then, as shown in Figure 2 the free vortex is assumed to leave as straight trailing vortex at some angle to the body surface from keel center line of hull. Noting the point P (x, r, ϕ) on hull surface and the Q (x^1, r^1, ϕ^1) on the free vortex sheet, induced velocity v(P) due to the free vortex at the point P may be written as follows:

$$\vec{v}(P) = \frac{1}{4\pi} \iint_F \frac{\vec{\omega}(Q) \times \vec{r}_{PQ}}{r_{PQ}^3}\, dS \qquad (7)$$

where

$$\vec{r}_{PQ} = (x - x^1)\vec{i} + (r\cos\phi - r^1\cos\phi^1)\vec{j} + (r\sin\phi - r^1\sin\phi^1)\vec{K}$$

$$r_{PQ} = \left[(x - x^1)^2 + r^2 + r^{1\,2} - 2rr^1\cos(\phi - \phi^1)\right]^{\frac{1}{2}}$$

$\vec{i}$, $\vec{j}$, $\vec{K}$ represent unit vector.

And then, after applying some assumptions of slender body and the free vortex, by replacing $\vec{\omega} = (\omega_1, \omega_2, \omega_3)$, we can rewrite the formula (7) as follows:

$$v(P) \cong \frac{1}{2\pi}$$

$$\int_F \frac{\omega_1^* r^* [-\vec{j}(r\sin\phi - r^*\sin\phi^1) + K(r\cos\phi - r^*\cos\phi^1)]}{r^2 + r^{*2} - 2rr^*\cos(\phi - \phi^1)} d\phi^1 \tag{8}$$

where $r^* = r(x, \phi^1)$, $\omega_1^* = \omega_1^*(x, \phi^1)$

We may consider approximately that the velocity induced on the body surface is induced only by the vortex on cross sectional plane of body. Therefore, the integral equation (7) will be solved on each cross sectional plane to decide the vortex distribution. Then, the velocity potential represented the flow field due to vortex sheet is also solved by means of conformal mapping. Simultaneously, after making some assumptions for the separation condition, the total velocity potential represented this flow about ship hull decided.

Calculation of hydrodynamic forces

We now consider the reference slab into the infinite flow as shown in Figure 3. The hydrodynamic force acting on a cross sectional plane per unit slab is written, as follows, by means of application of momentum theory.

$$\frac{d\vec{F}(x)}{dx} = \rho U \frac{d}{dx} \oint \Phi(x,y,z)\vec{n} dl \tag{9}$$

where Φ represents the disturbance velocity potential. It is shown the hydrodynamic force (Y) and moment (N) acting on ship model as follows:

$$Y = \int_{-L/2}^{+L/2} \frac{dF}{dx} dx = \rho U [\oint \Phi n_y dl]_{-L/2}^{+L/2}$$

$$N_{\boxtimes} = \int_{-L/2}^{+L/2} \frac{dF}{dx} x dx = \rho U [x \oint \Phi n_y dl]_{-L/2}^{+L/2} - \rho U \int_{-L/2}^{+L/2} \{\oint \Phi n_y dl\} dx \tag{10}$$

The above mentioned procedure is restrained on the oblique motion of ship. In the general case of the manoeuvring motion, we must consider the parameters of the both of drift angle (β) and angular velocity (r). If these β and r are no large, the drift angle at x on keel center line of ship hull may be represented as follows:

$$\beta(x) \cong \beta + \frac{x}{R} = \beta + \frac{xr}{V_s} \tag{11}$$

By using of this drift angle we will be able to obtain the hydrodynamic force on turning motion of ship.

Theoretical and experimental results

Characteristics of hydrodynamic force and moment acting on ship hull in trimmed condition are here investigated.

The numerical calculations carried out on the four models of Todd's series 60, of being 4210W(C_b=0.6), 4212W(C_b=0.7), 4214WB-4(C_b=0.8) and LB-5(C_b=0.8). The results are shown in Figure 4 to 11, which represent the condition of trim by stern for positive τ/d_m. Simultaneously measuring also carried out by means of Rotating Arm and oblique towing tests on models of Todd's series 60 as shown in Table 1, and the results are shown in Figure 4,5,8 and 9.

The theoretical results are in close agreement with that of measuring except $N_{\boxtimes\beta}(\tau)$. And hydrodynamic derivatives on ship manoeuvring are greatly affected by trim quantity, however, those are no influence of change of draft at a fixed τ/d_m. These will be also greatly affected the effect of aspect ratio of ship hull.

Here, it will be made a attempt of modification for $N_{\boxtimes\beta}(\tau)$. Hydrodynamic moment due to the horizontal motion generally may be represented by two terms, the one is the term due to Munk's moment and the other is that due to the lift. Now if Munk's moment is no affected by trim quantity, we may consider the modification coefficient in the center of pressure of hydrodynamic force generated by vorticies.

With these results and some assumptions, we may represent the following formulae based upon this theory for predicting a hydrodynamic derivatives on ship manoeuvring in trimmed condition, as shown in Figure 12 and 13,

$$\begin{aligned} Y^1_\beta(\tau) &= Y^1_\beta(0)\left[1 + \frac{2}{3}\frac{\tau}{d_m}\right] \\ N_{\boxtimes\beta}(\tau) &= N^1_{\boxtimes\beta}(0)\left[1 - \frac{0.27}{1_\beta}\frac{\tau}{d_m}\right] \\ Y^1_r(\tau) &= Y^1_r(0)\left[1 + 0.80\frac{\tau}{d_m}\right] \\ N^1_{\boxtimes r}(\tau) &= N^1_{\boxtimes r}(0)\left[1 + 0.30\frac{\tau}{d_m}\right] \end{aligned} \tag{12}$$

where, $1_\beta \equiv N^1_{\boxtimes\beta}(0)/Y^1_\beta\ (0)$

Conclusions

Comparing with numerical and measured results, the following conclusions are reached.

(1) There is greatly influence of aspect ratio of ship hull on ship manoeuvrability.

(2) The hydrodynamic derivatives are affected by ship's load condition, and those are greatly affected by the trim quantity more than the change of draft at a fixed τ/d_m.

(3) The approximate formulae for predicting the hydrodynamic derivatives on ship manoeuvring in trimmed condition may be obtained.

REFERENCE

/1/ S. Inoue: "The Determination of Transverse Hydrodynamic Non-Linear Forces by Means of Steady Turning"; 11th I.T.T.C., 1966.

/2/ "Hydrodynamic Forces acting on a ship in Oblique Towing". J. of the Society of Naval Architects of Japan, Vol. 134, 1973.

Table 1
Main Particulars of Model Ship

MODEL SHIP	Series 60		TANKER
	4210W	4214WB-4	
Length (m)	2.500	2.500	2.500
Breadth (m)	0.333	0.385	0.500
Draft (full)(m)	0.133	0.154	0.183
Block Coeff.	0.600	0.800	0.820

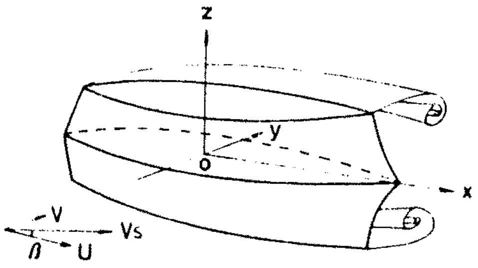

Fig.1 Coordinate System

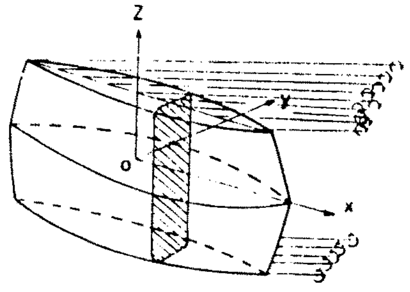

Fig.2 Flow Model

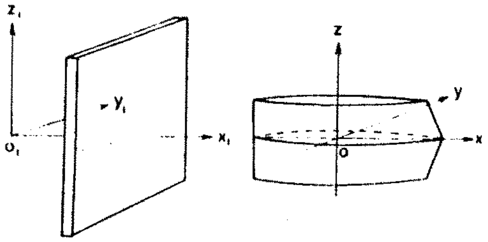

Fig.3 Reference Slab

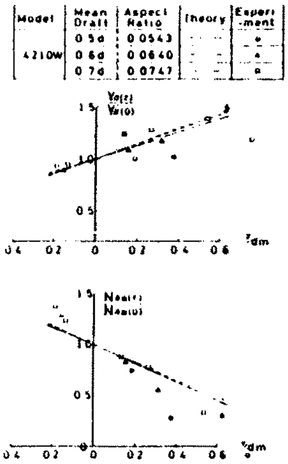

Fig.4
Static Derivatives
in Trimmed Condition

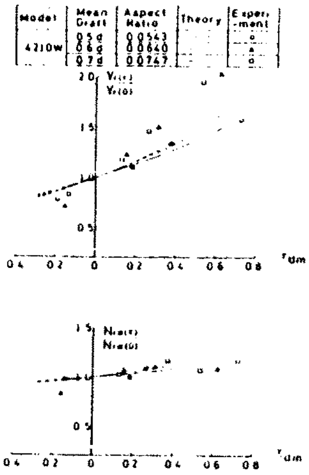

Fig.5
Rotary Derivatives
in Trimmed Condition

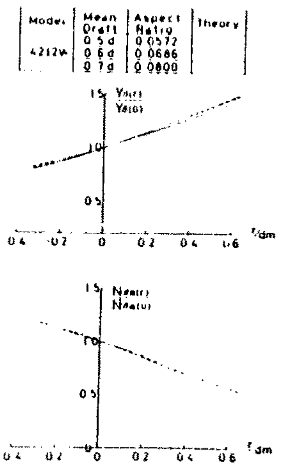

Fig.6
Static Derivatives
in Trimmed Condition

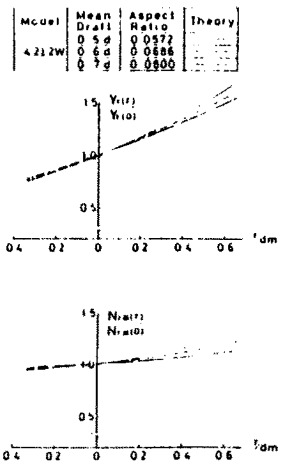

Fig.7
Rotary Derivatives
in Trimmed Condition

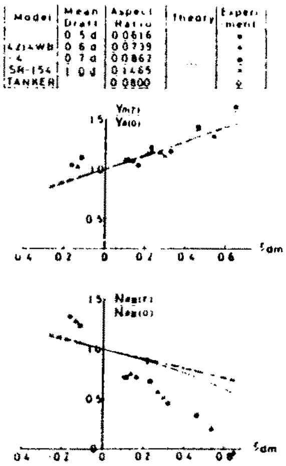

Fig.8
Static Derivatives
in Trimmed Condition

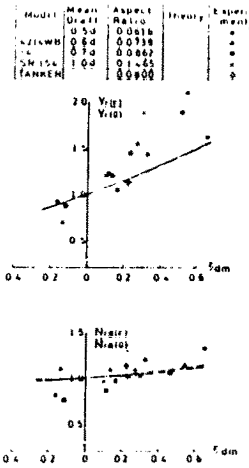

Fig.9
Rotary Derivatives
in Trimmed Condition

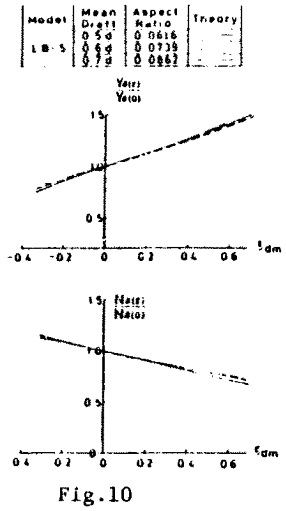

Fig.10
Static Derivatives
in Trimmed Condition

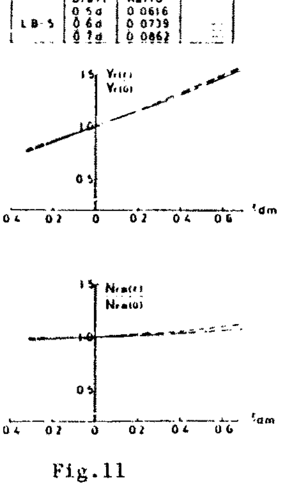

Fig.11
Rotary Derivatives
in Trimmed Condition

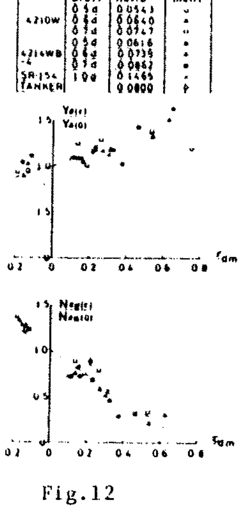

Fig.12
Approximate Expression
of Lateral Force and
Yawing Moment Derivatives
of Oblique Motion in
Trimmed Condition

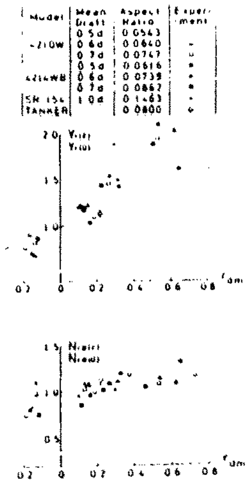

Fig.13
Approximate Expression of Lateral Force and Yawing Moment Derivatives of Turning Motion in Trimmed Condition

K. SUHRBIER - Vosper-Thornycroft Ltd., Porthmouth, United Kingdom

I like to refer briefly to the coupling effects between roll and yaw at higher speeds discussed under "Special Problems" on p.133.

By some model tests carried out with a captive and a radio-controlled free-running model of a semi -displacement craft, we were able to demonstrate the strong influence of roll on yaw, i.e. the roll-yaw instability, in calm water.
It could be shown that at higher speeds ($F_n > 0.6 .....0.8$) directional instability or even severe broaching can occur if the initial roll stability is lost due to forward speed.
In such conditions the manoeuvring characteristics are clearly also dependent on the transverse stability of the ship or model. It is therefore worth emphazing that attention must be paid to the characteristics determining the roll behaviour, particularly the metacentric height, when conducting trials or model tests at higher Froude numbers, or when comparing such data.

REFERENCES

K.R. Suhrbier: "An Experimental Investigation on the Roll Stability of a Semi-Displacement Craft at Forward Speed". Symposium on Small Warships and Security Vessels, RINA March '78 (to be published).

NB.: Paper discusses roll-yaw stability problems and broaching in calm water.

H. EDA - Davidson Laboratory, Stevens Institute of Technology, Hoboken, U.S.A.

Yaw-Roll Coupled Instability

When a ship is proceeding at a high-speed in a seaway, serious rolling motions are frequently observed in actual ship operations and in model testing in waves. Anomalous behaviour of rolling and steering was clearly evident, for example, in full-scale tests of a high-speed container ship during cross-Atlantic operations.

Certain high-speed ships have the following hull form characteristics which have major impacts on ship performance, in particular, manoeuvring and rolling behaviour:

(1) High speeds with large ℓ/B ratio and relatively small GM.
(2) Fore- and-aft asymmetry.
(3) Relatively large rudder.

This particular hull form characteristics introduces the possibilities of Fairly significant yaw-sway-roll-rudder coupling effects during high-speed operations.

Recently, a high-speed ship was extensively tested in the rotating-arm facility of the Davidson Laboratory, with inclusion of roll motion effect. Test results clearly indicated fairly significant couplings between yaw-sway-roll-rudder motions. Accordingly, a mathematical model was formulated on the basis of these experimental results combined with analytical estimations.

Asymmetry in Underwater Hull Configurations due to roll

Figure 1 shows two curves which indicate the distance of CG of the local sectional area from the longitudinal centerline at roll angle ψ = 0 and 15 degrees. The curves can be considered to be equivalent to camberline of the wing section.

When roll angle is not zero, the camberline is not straight line, as shown in these figures introducing hydrodynamic yaw moment and side force. This trend is pronounced by the fore-and-aft asymmetry of hull form, in particular, during high-speed operation.

Figure 2 shows, for example, captive model test results of yaw-roll coupling effect, indicating hydrodynamic yaw moment to port introduced by roll angle to starboard.

When roll extinction curves were obtained in simulation runs in equations of roll-yaw-sway coupled motions, important results were shown in rolling and yawing behaviour. Roll-yaw coupled instability was clearly indicated in test runs. Figure 3 shows time history of roll and yaw motions starting on a straight course with an initial roll angle of 10 degrees. Subsequent roll and yaw motions are divergent, indicating roll-yaw coupled instability. When an autopilot is adequately included in these yaw-sway-roll coupled motions, stability characteristics of the ship system are improved as shown in Figure 4, where the above mentioned roll-yaw instability is eliminated.

Predictions of Manoeuvring and Roll Behaviour

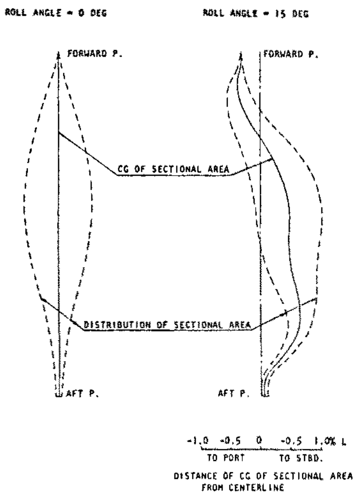

FIGURE 1 LONGITUDINAL ASYMMETRY DUE TO ROLL (HIGH-SPEED CONTAINER SHIP)

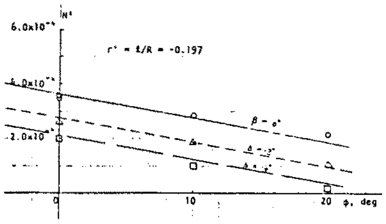

FIGURE 2 YAW MOMENT COEFFICIENT DUE TO ROLL ANGLE

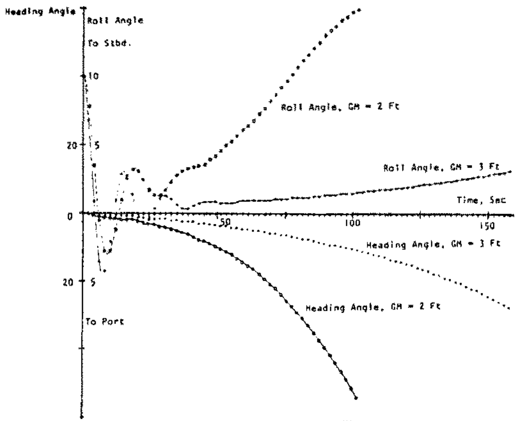

Figure 3 ROLL-YAW INSTABILITY (WITH 10 DEG INITIAL DISTURBANCE)

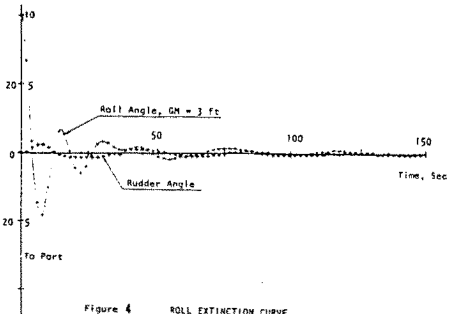

Figure 4 ROLL EXTINCTION CURVE (WITH AUTOPILOT)

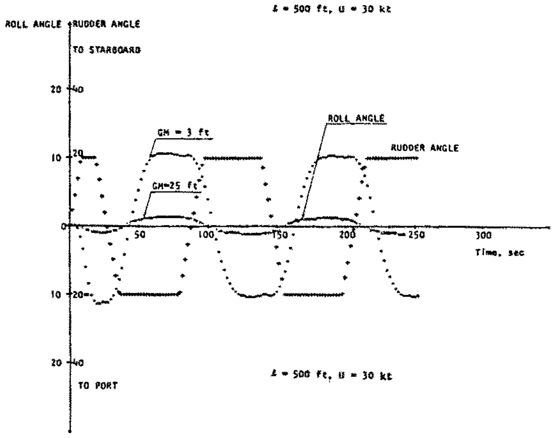

FIGURE 5 ROLL DURING Z-MANEUVER

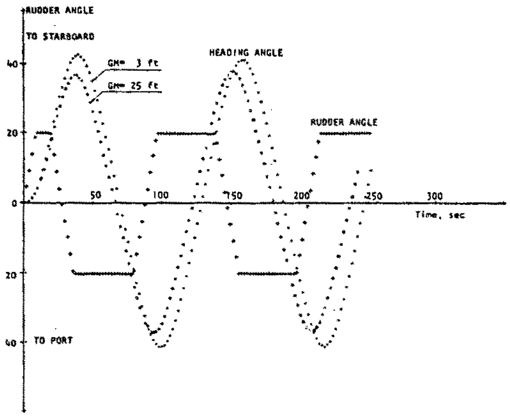

FIGURE 6 Z-MANEUVER RESPONSE

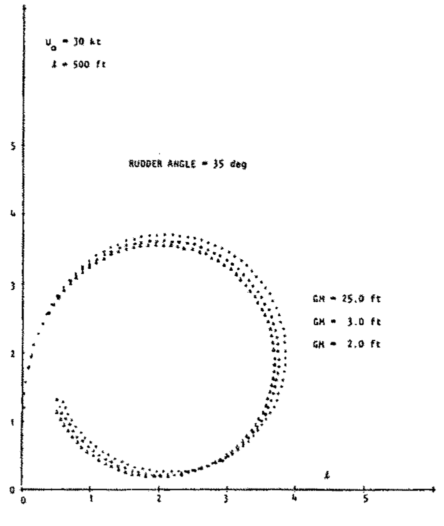

FIGURE 7 TURNING TRAJECTORY

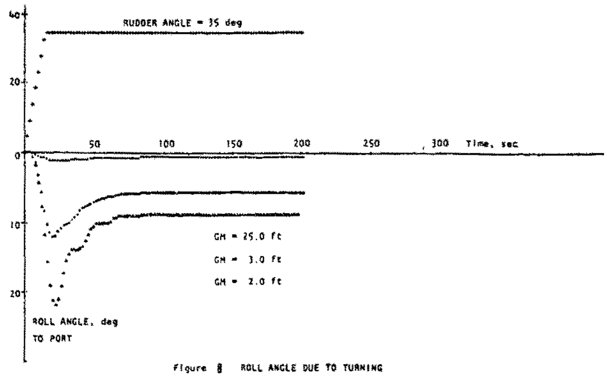

Figure 8 ROLL ANGLE DUE TO TURNING

Figures 5 and 6 show response to 20°-20° Z-manoeuvre with changers in GM. A comparison of heading angle response clearly indicates a greater overshoot angle with a smaller GM. It is clearly evident in this figure that course stability characteristics are deteriorated with reduction in GM. Figures 7 and 8 show turning and rolling characteristics. When the ship is proceeding on a straight course, a certain external disturbance (e.g., the roll moment due to beam wind) is given stepwise to the ship. When the ship is rolled to the starboard, for example, due to beam wind from the port, an asymmetry is formed in the underwater portion of the hull as shown in the previous figure (i.e., Figure 1). As a result, hydrodynamic yaw moment is generated to deviate the ship heading angle deviation. This starboard rudder angle produces the roll angle further to the starboard. Under this condition, the possibility of instability exists in the ship system. Figure 9 shows, for example, the unstable response characteristics due to the stepwise roll moment. This instability can be eliminated by an increase in GM or by a refined autopilot characteristics as shown in Figures 10 and 11, respectively.

Serious rolling problems frequently observed during high-speed operation in waves can partly be due to inherent yaw-roll instability (or marginal stability).

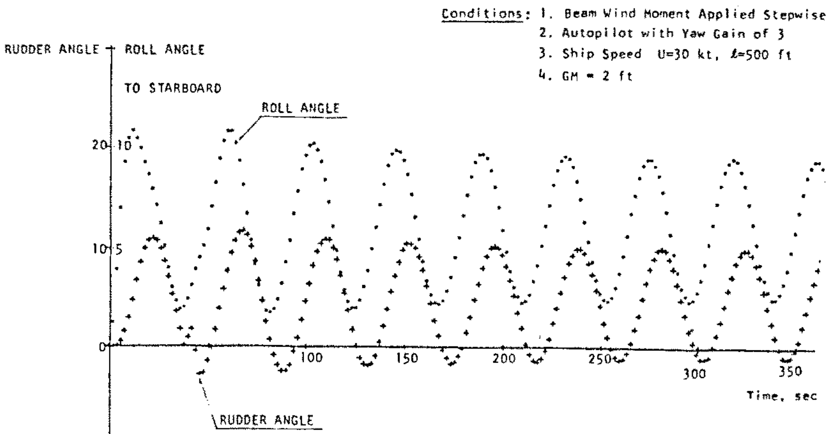

FIGURE 9 ROLL-YAW-RUDDER COUPLED MOTION

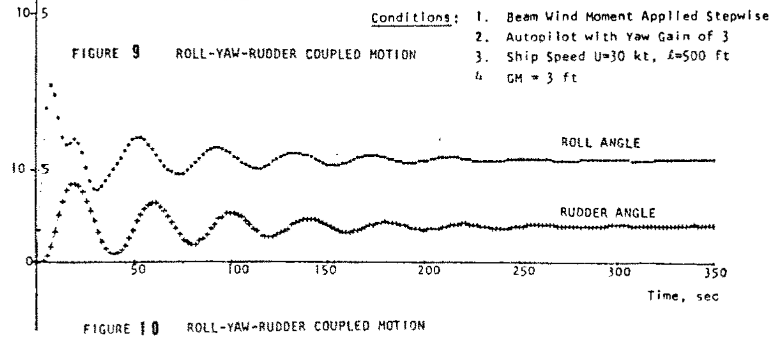

FIGURE 10 ROLL-YAW-RUDDER COUPLED MOTION

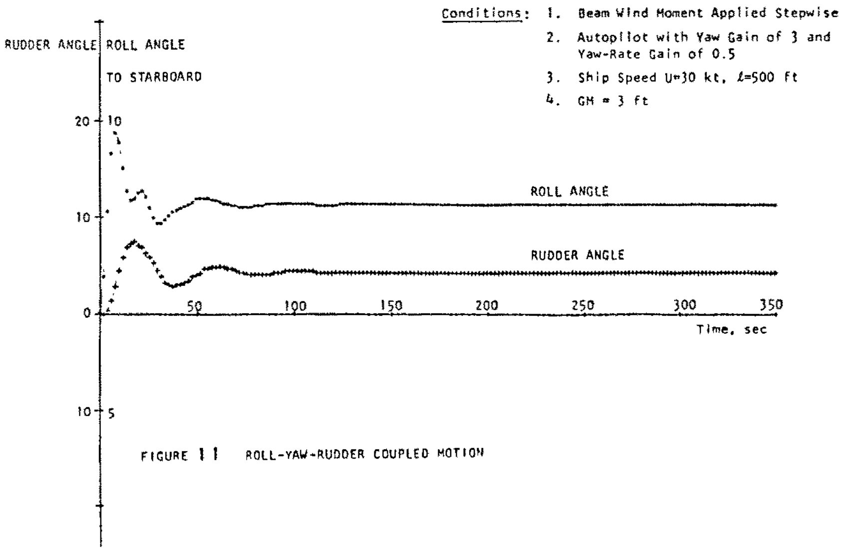

FIGURE 11 ROLL-YAW-RUDDER COUPLED MOTION

E. NIKOLAEV - Krylow Ship Research Institute, Leningrad, U.S.S.R.

Estimating the Manoeuvrability Committee report I can not agree with the view point expresses by Dr. L. Wagner-Smit, that small progress in the field was made by the Committee during the last three years. A new problem, a very complicated one, was studied. I mean the problem of closed-loop ship control. The appropriate part of the report is very good.
It contains a new approach to the problem, some new ideas and interesting results and it stimulates further research.

The Committee has proposed good recommendations for the next three year period. From my view point items 2 and 6 are very important. I only pity that Term special purpose marine craft in item 6 does not comprise high speed marine crafts such as hydrofail-boats and air-cushion vehicles.

M. NAKATO and K. KOSE - Hiroshima University, Faculty of Engineering, Department of Naval Architecture, Hiroshima, Japan

On Quasi-Steady Treatments of Transient Motions

In the Manoeuvrability Committee report, it is stated that during periods of transient motion, the validity of the usual quasi-steady description of the forces and moments acting on the ship must also be questioned.$^{1)}$ We would like to report some experimental results concerning to this point.

On a transient motion in a straight course, the equation

$$(m + m_x)\dot{u} = T(1-t)-R \qquad (1)$$

is often used accompanying the concepts of added mass m_x and effective thrust $T(1-t)$. Supposing a model ship under forced surging motion with a certain period by means of PMM, which is mounted on the towing carriage running at a constant speed, and the force F required for the surging motion can be measured.

Assuming that the change of ship resistance depends linearly on the change of velocity at or near the velocity, the equation of motion becomes:

$$(m + m_x)\dot{u} = F-(R_o+R_u\, U) \qquad (2)$$

In this case u and $\dot{u}$ can be written with the surging amplitude a, and the surging frequency ω as follows:

$$u = \alpha\omega \cos \omega\tau, \quad (3) \qquad \dot{u} = -\alpha\omega^2 \sin \omega\tau \quad (4)$$

Putting the above equation into equation (2), we get

$$F-R_o = -(m+m_x)\alpha\omega^2 \sin \omega\tau + R_u\alpha\omega \cos \omega\tau \quad (5)$$

Integrating both sides in the range of $0 \sim \pi/\omega$, it becomes

$$m+m_x = -\frac{1}{2\alpha\omega}\;{}_{o}^{\pi/\omega}\;(F-R_o)\,d\tau \qquad (6)$$

In Fig. 2, the added mass thus obtained is presented. The particulars of model ship used are shown in Table 1. From the figure, the m_x seems to be not dependent on the frequency in such a low range of frequency.

Next, it will be shown that the effective thrust $\dot{T}(1-t)$ also not depend on the acceleration. Again supposing the tests which are just as the same as previously mentioned but the only difference is having a rotating propeller behind the hull. The equation of motion in this case is,

$$(m+m_x)\dot{u} = F + T(1-t) - (R_o+R_u\, u) \qquad (7)$$

With Taylor's expansion, the thrust term becomes,

$$T(1-t) = \{T(1-t)\}_o + \{T(1-t)\}_u\, U + \{T(1-t)\}_{\dot{u}}\, \dot{U} \qquad (8)$$

Putting equation (8) into equation (7),

$$F + \{T(1-t)\}_o-R_o = \{(m+m_x) - \{T(1-t)\}_{\dot{u}} + \dot{U} + \{R_u-\{T(1-t)\}_u\}U \qquad (9)$$

where the suffix "O" indicate the steady state values at a certain speed u and the suffix "u" and "$\dot{u}$" indicate the partial differentials. Equation (9) can be integrated with the same procedures as previously, and the following expression is obtained corresponding to expression (6).

$$(m+m_x)-\{T(1-t)_{\dot{u}} = -\frac{1}{2\alpha\omega}\int_o^{\pi/\omega} \{F+[T(1-t)]_o-R_o\}dt \qquad (10)$$

$$(m+m_x) = -\frac{1}{2\alpha\omega}\int_o^{\pi/\omega} (F-R_o)\,dt \qquad (6)$$

If the right hand side of equation (10) and (6) are equal, the contribution of

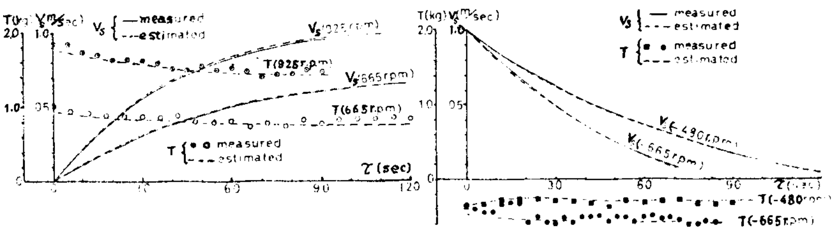

Fig. 1

Comparison of accelerating and decelerating motions between estimated result and experimental result (ship T)

		Ship T
Hull	L (m)	4.500
	B (m)	0.701
	d (m)	0.270
	∇ (m^3)	0.689
	C_B	0.810
	L_{CB}(%)	2.07 Fore
Propeller	section	Aero-foil
	Z	5
	D	0.1207
	R.A.	9° 58′
	B.T.R.	0.647
	E.A.R.	0.575
	P.R.	0.730
	B.R.	0.189

Table 1 Particulars

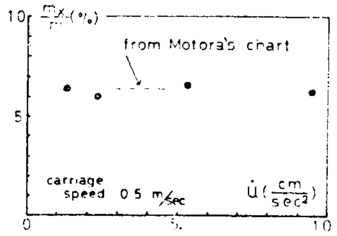

Fig. 2 Added mass of ship T obtained by forced surging (const. motion)

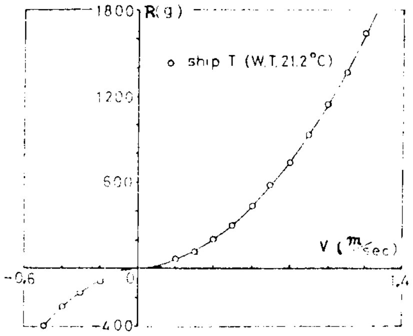

Fig. 3 Resistance curves of model ship

$\{T(1-t)\}_{\dot{u}}$ must be neglible and then the term T(1-t) does not depend on the acceleration $\dot{u}$.

Practically the integration of the right hand side of equation (10) and (6) can be obtained directly from the measured data by some electric circuit.

The above mentioned fact is examined with the model ship. The test condition is $a = 50_{cm}$, $\omega = \pi/10$, $\pi/20$ and $n = 7.67$ rps. It is found that the contribution of $\{(T(1-t)\}_{\dot{u}}$ is nearly negligible and within the experimental errors.

Then we can treat the transient motion in a straight course as a quasi-steady problems.

To estimate transient motions in a straight course practically, the following procedures are available.$^{2)}$

(a) To get m_x by the experiment as mentioned in this paper or by the chart published by Prof. Motora./3/

(b) To obtain thrust T and thrust deduction factor (1-t) by over/under-loading tests in the required range of J_s or to get them from the data of sister ships.

(c) By resistance tests or by some charts, resistance R is estimated.

(d) Puting the above value into equation (1) and integrating it numerically.

The examples of estimated results together with measured results of R, K_T (= T/ρnD), (1-t) are shown in Fig. 1, 3, 4 respectively.

Finally, it must be emphasized that the apparent advance ratio J_s(=V_s/nD) seems to govern not only the longitudinal forces but also the lateral forces acting on a hull in transient motions.

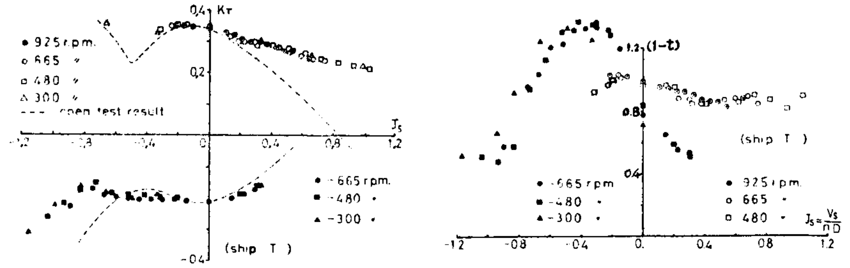

Fig.4 Over/Under-Loading tests results

And with J_s, the manoeuvrability during a transient motion may be described in quasi-steady methods.

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1) Report of Manoevrability Committee, ITTC 1978, p. 122.
2) NAKATO, M., KOSE, K. et al: Experimental Study on Accelerating and Decelerating Ship Motions. Journal of the Society of Naval Architects of Japan, vol. 140, 1976.
3. MOTORA, S.: On the Measurement of Added mass and Added Moment of Inertia for Ship Motions (Part. 2. Added Mass Abstract for the Longitudinal Motions). Journal of the Society of Naval Architects of Japan, vol. 106, 1960.

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Propeller Loading Effects on Course Stability

Propeller loading effects on ship manoeuvrability is an essential problem in transient motions. In this short report, we would like to show the effects on course stability of a ship by experimental results. The model ship used is a Series 60 type of $C_B = 0.70$, and $L/B = 7.0$, and by a PMM oblique, pure yawing and pure swaying tests were carried out in Hiroshima University towing tank. The principal dimensions and the test conditions of the model are listed in Table 1.

As a propeller working effects on a hull and on a rudder are different from each other, it is reasonable to separate the lateral forces acting on a ship (Y) into the two parts, the rudder force (R_R) and the total-less rudder force (Y_{HP}), remainder. According to the mathematical model of manoeuvring motion /1/ proposed by a working group MMG inJTTC, and assuming the motion be small, the lateral force and the moment acting on a hull may be written as the following expressions by usual notations.

$$Y=Y_{HP}+Y_R=(Y_{HP})_{\dot{v}}\dot{V}+(Y_{HP})_{\dot{r}}\dot{r}+(Y_{HP})_{v}V+$$
$$+(Y_{HP})_{r}r+(X_{HP})_{\dot{u}}ur+(1+a_H)F_n\cos\delta$$
$$N=N_{HP}+N_R=(N_{HP})_{\dot{v}}\dot{V}+(N_{HP})_{\dot{r}}\dot{r}+(N_{HP})_{v}V+$$
$$+(N_{HP})_{r}r+(X_R+a_Hx_H)F_n\cos\delta$$

In the equations, a_H is a interference coefficient of rudder force on the hull and x_R, x_H are shown in Fig. 2. The last terms in the expressions indicate rudder force including the interference effects on the hull, and the others show the total less rudder forces which should be coincide with the measured results without the rudder.

In Fig. 1, the variation of total-less rudder forces versus the apparent advance ratio J_s(= V_s/nD) which represents propeller loadings are shown. The process obtaining these forces are explained diagrammatically in Fig. 3. In Fig. 1, the test results of without rudder are also plotted by darkened marks and naturally they are in good coincident with the total-less rudder forces.

As well known, the course stability of a ship is discriminated by comparing two positions which are the center of damping force of turning motion and the center of damping force of drifting motion, and if the former is in forward position (bow side) of the latter, the ship may be stable. If the distances from the midship to the positions above mentioned are represented by l_γ for turning motion and l_υ for drifting motion respectively, they will vary according to the propeller loadings. They are shown in Fig. 4.

In this figure, the stable range corresponds to $l_\gamma > l_\upsilon$, and dotted lines indicate the case of without rudder.

From this figure, it may be concluded as follows:

1) The loading of propeller is responsible for the course stability of ship. That the weakend slip stream of propeller makes the damping forces around a ship change and naturally the effectivness of rudder decrease, it is the reasons why the course stability of ship turns to worse in a decelerating motion.
2) The working effects of rudder also can be seen in Fig. 4.
   The critical J_s of course stability is represented by the intersection of solid lines (J_s=1.2) in a ordinary case but removing the rudder as indicated in dotted lines, the intersection is shifted to J_s = 0.8.
3) Separating the force acting on a ship into two parts, as stated in this report, is also available to the correlation research of manoeuvrability, because a propeller loading effects on each are different.

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Hull		Rudder	
L (m)	4.000	λ	2.17
B (m)	0.571	AR/Ld	1/66.7
d (m)	0.229	Propeller	
∇ (m^3)	0.366	D (m)	0.160
CB	0.700	P.R.	1.100
LCB	0.5%Fore	E.A.R.	0.500
kzz	0.25L	Z	4

Table 1 Principal particulars of the model

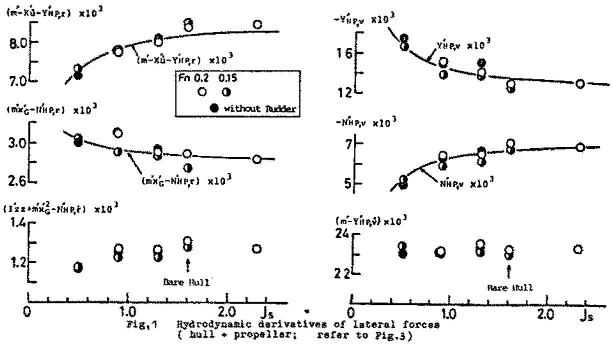


Fig. 1 Hydrodynamic derivatives of lateral forces (hull + propeller; refer to Fig.3)

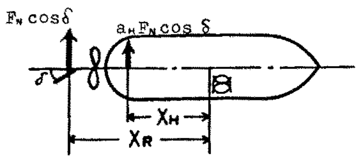


Fig.2 Explanation of x_R , x_H and a_H

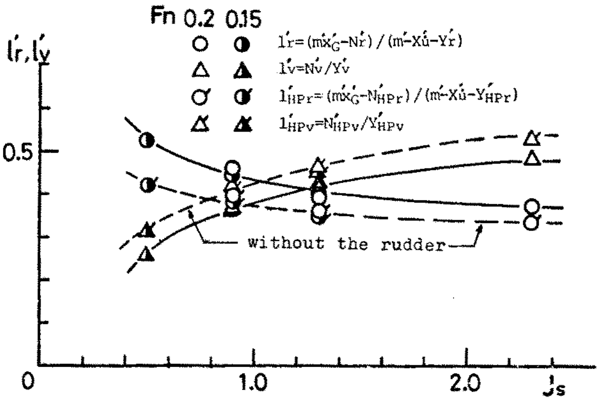


Fig. 4 Propeller load effects on course stability

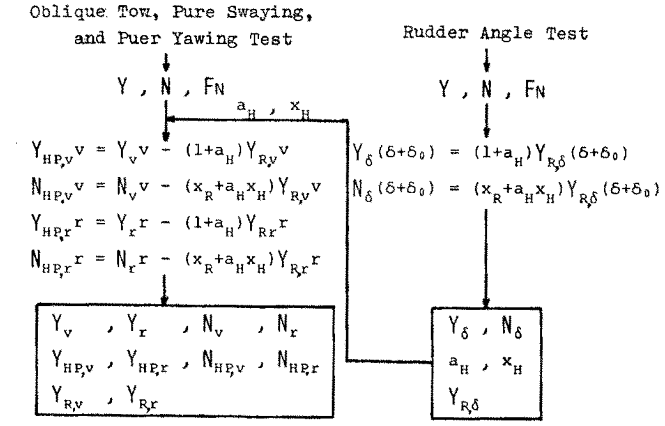


Fig. 3 Flow chart to identify hydrodynamic derivatives

G. AERTSSEN - University of Ghent,
Department of Naval Architecture, Ghent,
Belgium (retired)

I was somewhat puzzled by Fig. 9 tugs deployment for towage of large floating structures. The tug power totalize to 76000 HP representing a total pull of about 500 ton. I compare this figure with 2 other figures:

1) Belgium has a coastal port Zeebreugge berthing the containerships of the third generation. The total pull needed for them is 120 ton. Usually divided among 4 tugs, two at the forebody, two aft.
2) I once travelled on an ore carrier of 60000 tons. Half a dozen of tugs totalizing about 250 ton pull helped the ore carrier from the sand bank.

I admit that fig.9 is a nice deployment of exceptionally strong tugs, but cannot the Wageningen tank precise somewhat better what is meant by the "extremely accurate positioning" attained by this deployment.

REPLY OF THE MANOEUVRING COMMITTEE

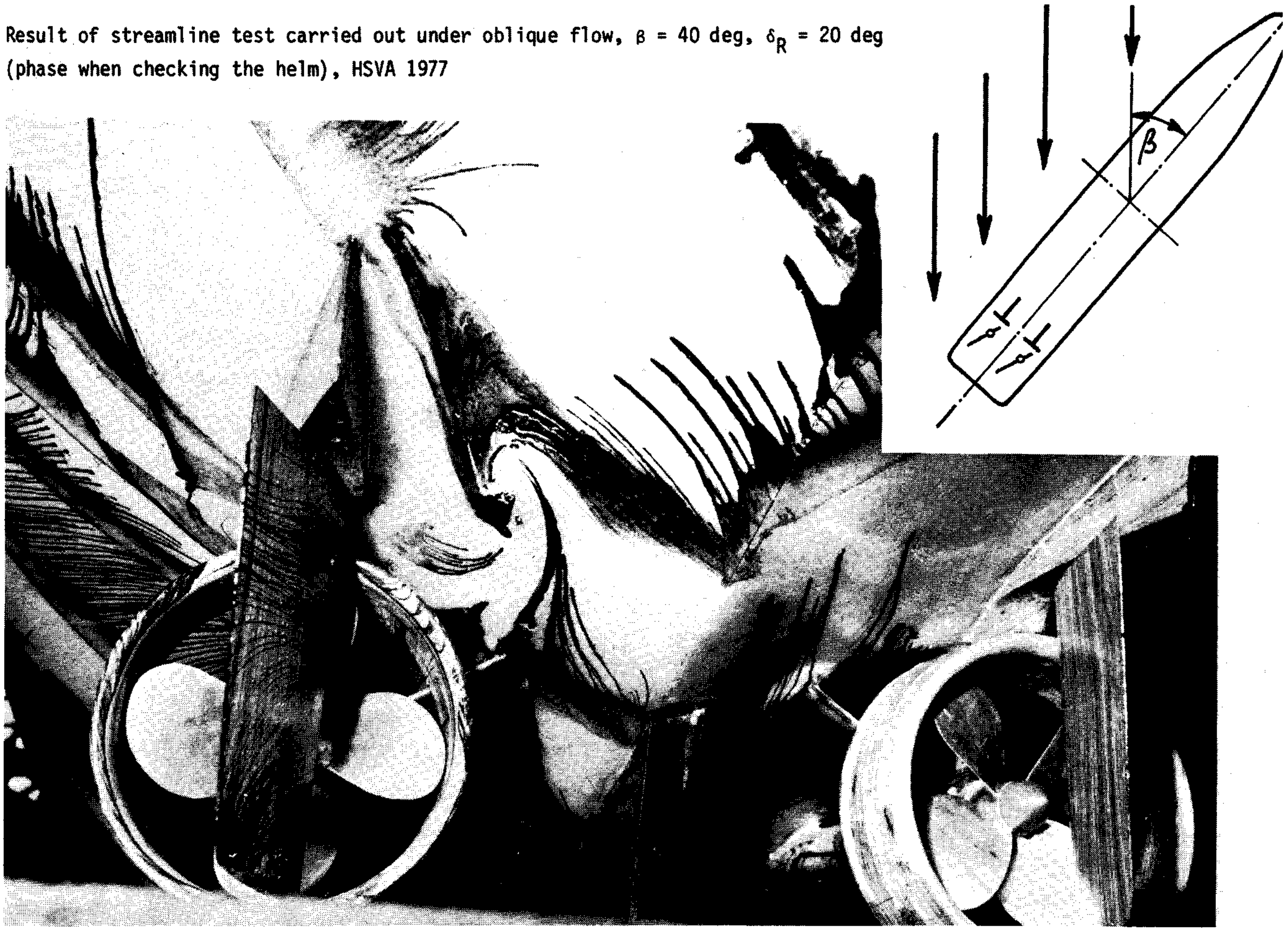
The Manoeuvrability Committee would like to express their appreciation to all those delegates who took part in the discussions, whether by means of a formal submission or by informal remarks.

The Committee was particularly pleased to hear the comments made by *Dr.Norrbin*, regarding the proper use of manoeuvring simulation. We would like to draw particular attention to the relevant paragraph in the concluding remarks of the Report,

> "The Member Organizations of the ITTC may contribute significantly to ship controllability and manoeuvrability studies by co-ordinating such combined exercises involving ship, waterway and human or automatic controller. They may also play a significant part themselves in such studies, by working towards an adequate representation of the important hydrodynamic effects, whether it be for physical model tests or simulator studies."

In the opinion of the Committee, the ITTC Member Organizations must make an effort to ensure that any mathematical models, or other data supplied by them, are not used beyond their intended scope. The Committee agree with Dr. Norrbin that the theoretical studies of Newman and Tuck have lead to a better understanding of interaction theory.

Mr.Postuma suggests that the Report does not follow one of the Recommendations of



Result of streamline test carried out under oblique flow, β = 40 deg, δ_R = 20 deg (phase when checking the helm), HSVA 1977

14th ITTC, which requested a study of transient manoeuvres. In this respect, his attention is drawn to the work of the Mathematical Modelling Group of the Japanese Towing Tanks, mentioned on page 122 of the Report.

In his remarks on high speed manoeuvring in shallow water, *Prof.Kostilainen* highlights the problems facing mathematical modellers in this complex area. The Committee do not wholly agree with his suggestion that squat has been neglected. The changes in hydrodynamic forces and moments in a representative mathematical model implicity account for the effects of squat on manoeuvring. This is provided that the original model, on which the measurements were taken, was free to heave and squat. The work of Dand, who has done a great deal on shallow water problems, is referred to in the Report.

In reply to *Dr.Tamura* concerning his remarks on unusual flow phenomena, the Committee would like to point out that both full bodies and slender ships are prone to the influence of unsteady cross-flow on course stability. The effect is increased if a small drift angle appears due to some disturbance, and some corrective rudder action is taken. A photograph of a streamline test carried out at HSVA is shown below, which clearly shows this extremely complicated cross-flow phenomenon. In the photograph, the model has been subjected to a small oblique flow and has a 20 deg. rudder angle.
This subject was covered in much greater detail at the last Conference, but is clearly an area where more work is required to understand the nature of the phenomena.

The Committee expresses thanks to *Prof. Aertssen* for his contribution to the discussion and for his very interesting observations concerning actual ships. The IMCO minimum draft rule mentioned by Prof.Aertssen was produced for tankers in the ballast condition, and it is clearly shown by the examples he gives in his contribution that the minimum forward draught recommended by IMCO is not sufficient for faster ships, such as cargo-liners or container ships in strong oblique seas. The Committee keeps in touch with IMCO regulations and is aware of the relevant IMCO documents on ship manoeuvring and ship handling. Normally, an increase in forward draught improves the turning ability, but decreases the course stability and the yaw checking ability. The influence of the rolling motion on the manoeuvring properties will be discussed later in the replies to the comments of Dr. Eda and Prof. Bucher.

The Committee is grateful to Prof. Aertssen for having given his experience relative to actual ships in extreme sea conditions.

The Committee would like to thank *Prof. Nomoto* for his contribution, which describes a method of finding mathematical model coefficients from free running model tests. The approach proposed is very similar to a technique developed earlier at BSRA /1/, for analysing full-scale manoeuvring tests and later used for model tests. Prof. Nomoto is correct in his formulation of an error function based on the sum of the squares of the observed motion variables, where the weighting of each term is dependent on the accuracy of the measurements. It is important to use independent measurements from separate transducers, such as a heading gyro and a rate of turn gyro, since problems can arise by making use of differentiated values, when the weighting factor must be reduced, since the variables are not statistically independent.

Prof. Nomoto uses the Powell search technique, which was found to be inferior and more time consuming than the more direct minimisation technique used in the above mentioned study /1/.

The Committee would like to draw his attention to the parametric differentiation method of Chapman and Kirk /2/, used in the above study /1/, which is an extremely efficient method of minimising the error function, since it in effect uses the first and second derivatives of the slope of the error function.

The applicability of the second order yaw-rate equation with a simple non-linearity, pioneered by Prof. Nomoto and Dr. Norrbin, should not be overlooked in our search for more sophisticated methods of analysis.

In order to predict the manoeuvrability of a ship, it is often desirable to obtain the hydrodynamic derivatives from a simple calculation. In an earlier contribution to the 11th ITTC, *Prof.Inoue* proposed a theoretical method to obtain these values, for an even keel condition, based on Bollay's low aspect ratio wing theory. In this contribution he has developed this method to give hydrodynamic derivatives for a ship in a trimmed condition.

His semi-empirical approach is of course exactly what the Committee were trying to achieve in their study, as shown in Fig.2 of the Report. *Prof.Inoue* gives an empirical equation for the velocity derivative Y'_β, shown on the last page of his paper, which represents the same mathematical form as that suggested by the line fitted to the questionnaire data in Fig. 2. His simple trim correction terms for the hull derivatives are extremely interesting and are similar to the correcting terms given by Fedyaevsky and Sobolev in Ref. 8 of the Report. Since this topic will be of continued interest to the new Committee, in Recommendation 3, it is hoped to produce the emphirical design information suggested by Prof. Burcher and Prof. Loukakis in their informal discussion. It is also hoped that Prof. Inoue will be able to continue his work in this area.

In their various contributions, *Mr.Suhrbier*, and *Dr. Eda* clearly indicate that the possibility of a significant roll-yaw coupling effect exists for certain types of ships when operating at high speed. This coupling effect may have a significant effect on seakeeping and manoeuvring performance.

Several Contributors expressed surprise that the Committee had no specific recommendation regarding steering in waves. The Committee, however, intended that all steering and control problems whether in calm water or waves would be implicit in the original Recommendations. Accordingly the wording of the relevant Recommendation has been altered to explicitly include steering in waves.

It should be noted that the direction and the magnitude of the roll-yaw coupling effect depends to a large extent on the ship type, for instance whether it is a displacement type or a planing type.

Dr. Eda points out in his discussion that roll-yaw coupled instability introduces excessive rolling motion during high-speed operations in a seaway. A definite need is indicated for further studies in the area of steering in waves. This was pointed out by Dr. Nikolaev and Mr. Postuma, and is also one of the Committee's recommendations.

Dr. Nikolaev made a plea for work on the manoeuvrability of high speed boats, which is an important area, highlighted by the formation of a new High Speed Panel. However, as already pointed out, the Committee intend all forms of craft and environmental conditions to be within their scope, without necessarily having to make overt reference to them.

In their contributions, *Prof.Nakato* and *Dr. Kose* provide useful information on the quasi-steady treatment of transient motion. They suggest that this quasi-steady approach can be used for the calculation of surge motions in deep water at moderate Froude Numbers, a finding supported by the eralier work of Wagner Smitt and Landsburg, in a contribution to the 13th ITTC /3/. However, the Committee would like to draw attention to the cautionary notes given in this previous work, in particular that the quasi-steady approach may be quite inadequate in confined waters or at higher frequencies in a seaway. A further problem was pointed out by Jaeger and Jourdain /4/, who showed that for a decelerating ship at high Froude Numbers, frequency or memory effects may be quite substantial, when the ship is caught up and overtaken by its own wave system.

Prof.Nakato and *Dr.Kose* also discussed the effects of propeller loading and slipstream on course stability, in support of other earlier findings. The Committee would like to compliment their colleagues in the Mathematical Modelling Group of the Japan Society of Naval Architects, and to draw attention to their attempts to break up the total forces and moments into their various components. It is hoped that this extremely valuable work is continued in the future.

Some concern was expressed by *Prof.Aertssen* regarding the total power of the tugs indicated in Fig.9 of the Report. The reason for this enormous power is that the entire structure must be moved from a safe anchorage out to its intended station and accurately positioned in as short a time as possible. This task can only be performed during a certain calm weather "window". The use of these high powered tugs is not necessary for accurate positioning but since they are used for the towage phase they are also used for the positioning operation.

Several mistakes in the text require correction, but the Committee would like to express their apologies to Prof. Nomoto for erroneously siting his simulator, in Table II No.7. The location should, of course, be Osaka University and not the Ship Research Institute.

Finally the Committee would like to extend their warm thanks to the several people who forwarded working papers to the Committee which greatly assisted the oreoaration of the Manoeuvrability Committee Report.

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