siderations of the roll effect (2) and the propeller revolution effect (related to the main engine characteristics) on the horizontal motions. Referring to the coordinate system shown in Fig.1, the basic equations are written in the following form.

$$\begin{aligned} \text{Surge: } & m(\dot{u}-rv) = X_H + X_p + X_R \\ \text{Sway : } & m(\dot{v}+ru) = Y_H + Y_R \qquad (1) \\ \text{Yaw : } & I_{zz}\dot{r} = N_H + N_R \\ \text{Roll : } & I_{xx}\ddot{\varphi} = K_H + K_R \end{aligned}$$

Propeller Revolution:

$$2\pi I_{pp}\dot{n} = Q_E + Q_P$$

where the terms with subscript H represent the hydrodynamic forces produced by the motion of ship hull (without propeller and rudder) and acting on it, and the terms with subscript R represent the rudder forces including the hydrodynamic forces induced on ship hull by rudder action. The terms X_P, Q_P and Q_E in Eq. (1) represent the propeller thrust, the propeller torque and the main engine torque respectively.

The hydrodynamic forces acting on ship hull are estimated by making use of estimate formulae and charts which were developed with theoretical calculations and model experiments. Especially for the lateral force and the yaw moment the estimate formulae which were proposed by Inoue and one of the authors (3), (4), (5) are used where the hydrodynamic coefficients can be determined by knowing the principal dimensions of ship hull. The rudder forces are estimated with the semi-empirical formula based on the method proposed by "MMG" of the Japanese Towing Tank Conference (6). In this formula the effects of the propeller race and the hull wake on the rudder side force are taken into consideration in the form of the effective rudder inflow speed and the effective rudder inflow angle, and the rudder forces of full-scale ships can be estimated by considering the scale effect on the hull wake with the concept of the wake ratio.

The computed results of the turning motion with 35° rudder for two kinds of ships of a high speed container carrier (Lpp = 202m) and a 380,000-DWT ULCC (Lpp = 348m) are shown in Figs.2 and 3 together with the full-scale trial results. In Fig.4 the results of the 10°- 10° Z-manoeuvre for the above two kinds of ships are shown. In Fig.5 the results of the spiral manoeuvre for five kinds of ships from a general cargo boat of 10,000-DWT class to a 270,000-DWT VLCC are shown in the form of the steady turning performance. It can be seen from these figures that the computed results show satisfactory agreements with the results of the full-scale trials for various kinds and types of the merchant ships and for wide range of the manoeuvring characteristics.

The conclusion is that the calculation method of the present paper is very useful and powerful for the predictions of the ship manoeuvrability at the time, such as the initial design stage etc., when the principal particulars of ship hull, propeller and rudder are known.

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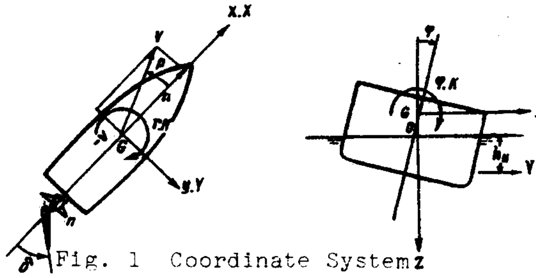

Fig. 1 Coordinate System

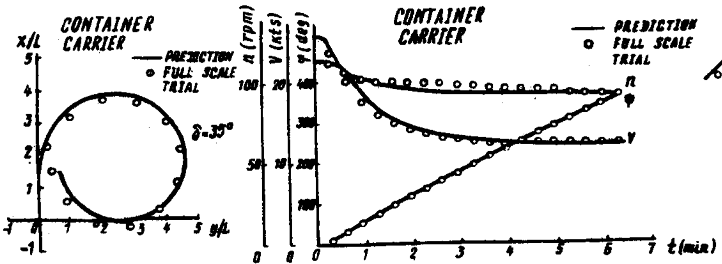

Fig. 2 35° Rudder Turning Motion

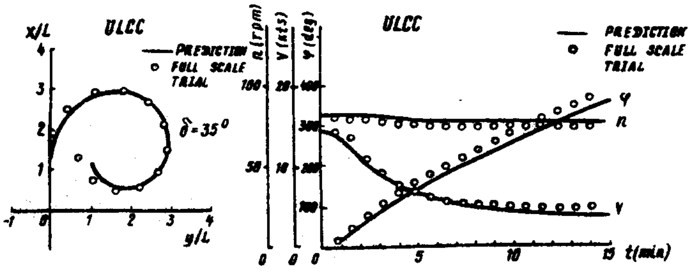

Fig. 3 35° Rudder Turning Motion

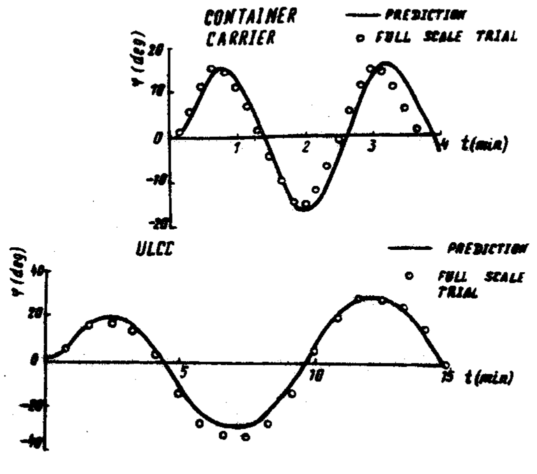

Fig. 4 10°-10° Z-Maneuver Responses

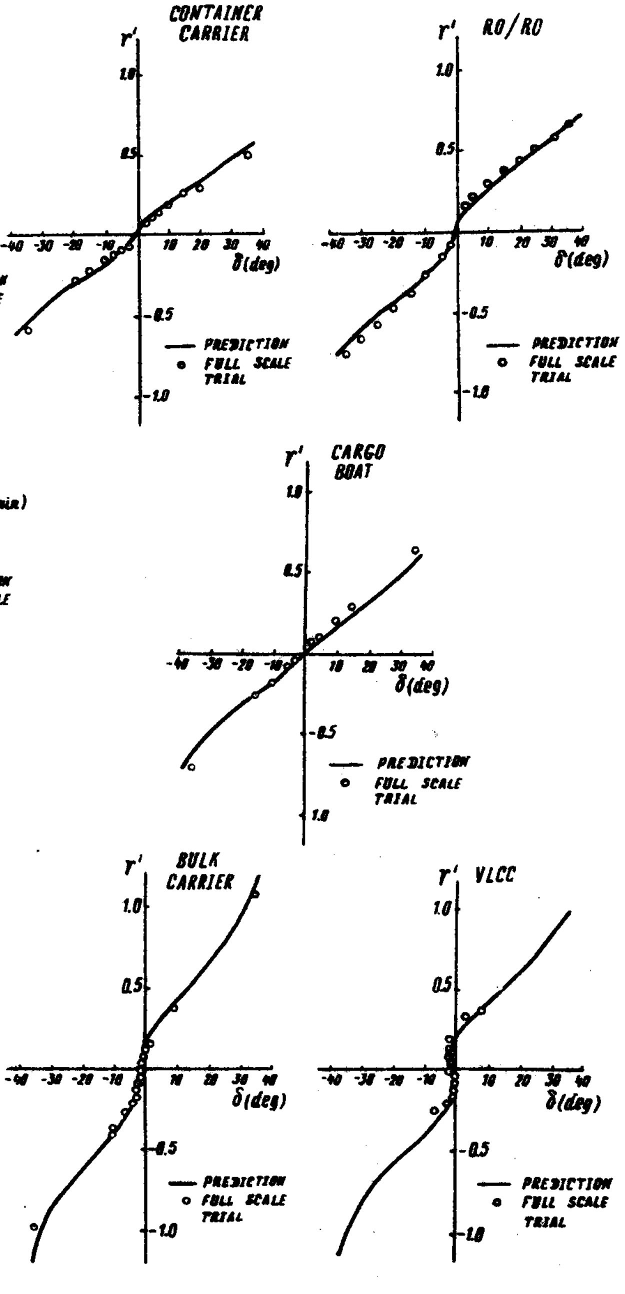

Fig. 5 Steady Turning Performances

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SHIP TURNING TRAJECTORY IN REGULAR WAVES

The study on the manoeuvrability in waves is one of the important subjects to be investigated in the manoeuvrability Committee (1). One typical motion, among many patterns of the manoeuvring motion in waves, is the turning motion in regular waves, and it is of much interest to have knowledge of wave effects on the turning trajectory.

Using a 5.0 m long and self-propelled roll-on/roll-off ship model, the wave effects on the turning trajectory in regular waves were investigated experimentally under wide range of wave conditions with systematic combinations of rudder angle and ship speed. In addition, theoretical approach was also made. Namely an attempt to calculate the turning trajectory in regular waves taking the drifting forces into consideration was made. The computed results were compared with the experimental ones, and the validity of the calculation method was examined. This paper briefly summarizes the results obtained by these investigations (2).

The experimental results of the turning trajectory are shown in Figs.1 - 5 with dotted lines. The turning trajectories in calm water for the cases of the rudder angle of $\delta = -35^\circ$ and -15° with the ship speed of Fn = 0.26 are shown in Figs.1 and 2 respectively. The turning trajectories in regular waves of $\lambda/L = 0.50$ for the rudder angle of $\delta = -35^\circ$ and -25° with the ship speed of Fn= 0.26 are shown in Figs.3 and 4 respectively. In Fig. 5 the turning trajectory in regular waves of $\lambda/L = 0.35$ for the ship speed of Fn = 0.21 with the rudder angle of $\delta = -15^\circ$ are shown.

The experimental results of time histories of the yaw rate and the roll angle from the time of rudder execution in the turning motion in regular waves of $\lambda/L = 0.50$ are shown for the cases of the rudder angle of $\delta = -35^\circ$ and -15° with th(ship speed of Fn = 0.26 in Figs. 6 and 7 respectively.

The results are summarized in Figs. 8 and 9 in the form of the drifting distance S_D, which is defined as the quantity of the deviation of the turning trajectory during one round (360°) turning as shown in Fig. 8.

A ship in waves is generally subjected to the oscillatory forces with relatively high frequency corresponding to the passage of individual waves, and to the second-order steady forces, the so-called wave drifting forces, in addition. From a macroscopic point of view, the deviation of the turning trajectory in regular waves from that in calm water may be considered to depend only on the wave drifting forces, not on the oscillatory forces. Accordingly, based on the motion equations which are usually employed in the analysis of the ship turning motion in calm water, and adding the wave drifting forces to these equations, a calculation of the turning trajectory in regular waves was attempted. The equations of the turning motion in regular waves can be written in the following form including the roll equation (3).

$$\begin{aligned}
&\text{Surge: } \hat{m}\,(\dot{u}-vr) &&= X_H + X_P + X_R + X_D \\
&\text{Sway : } m\,(\dot{v}+ur) &&= Y_H + Y_R + Y_D \\
&\text{Yaw : } I_{zz}\,\dot{r} &&= N_H + N_R + N_D \\
&\text{Roll : } I_{xx}\,\ddot{\varphi} &&= K_H + K_R
\end{aligned} \qquad (1)$$

where the terms with subscript H, R and D represent the hydrodynamic forces produced by the motions of ship hull (without propeller and rudder) and acting on it, the rudder forces including the hydrodynamic forces induced on ship hull by rudder action, and the wave drifting forces respectively.

Assuming that the wave drifting forces are proportional to the wave amplitude squared, the wave drifting force coefficients may be defined as follows.

$$X'_D = X_D \,/\, \tfrac{1}{2}\rho g\, L\, \zeta^2_A$$
$$Y'_D = Y_D \,/\, \tfrac{1}{2}\rho g\, L\, \zeta^2_A \qquad (2)$$
$$N'_D = N_D \,/\, \tfrac{1}{2}\rho g L^2\, \zeta^2_A$$

Some experimental data of the wave drifting forces are available for the drilling vessels. For the estimation of the wave drifting force coefficients in the present calculation, the experimental data reported in the References (4) and (5) are utilized.

A series of computations corresponding to the contents of the model experiments were carried out, and the computed results are shown in Figs. 1 - 9 with solid lines. Satisfactory agreement between the computed and the experimental results can be seen for the turning trajectories shown in Figs. 1 - 5. For the time histories of the yaw rate and the roll angle shown in Figs. 6 and 7, the computed results can be seen to explain well the low frequency variation of the experimental results.

Conclusions

(1) Tne deviation of the turning trajectory in regular waves from that in calm water may generally have the tendency to become larger as the wave length becomes shorter with constant wave height. This deviation of the turning trajectory also becomes larger as the rudder angle becomes smaller, or as the ship speed becomes slower.

(2) The experimental results can be explained satisfactorily by the calculation. The calculation method proposed here would be very useful for the analysis of the turning trajectory in regular waves.

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In the report of the Manoeuvrability Committee, the "Unusual Phenomena in Manoeuvring Motion" is reviewed. However, it is not clearly stated in the report at what condition (i.e. full load or ballast condition) it is liable to occur.

On the other hand, in the report of the Peformance Committee it is stated that the

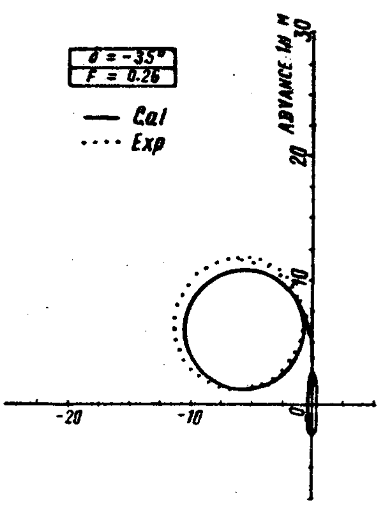

Fig. 1 Turning Trajectory in Calm Water

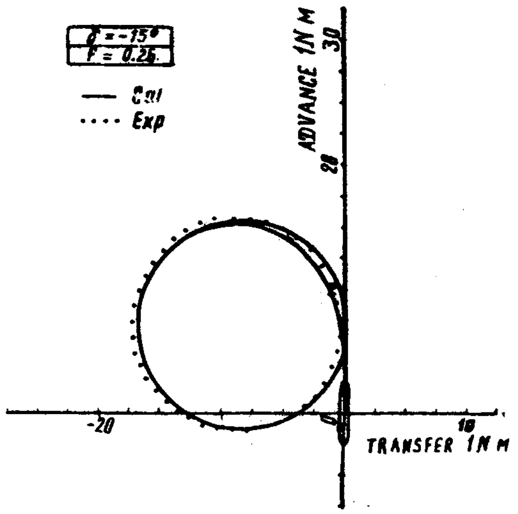

Fig. 2 Turning Trajectory in Calm Water

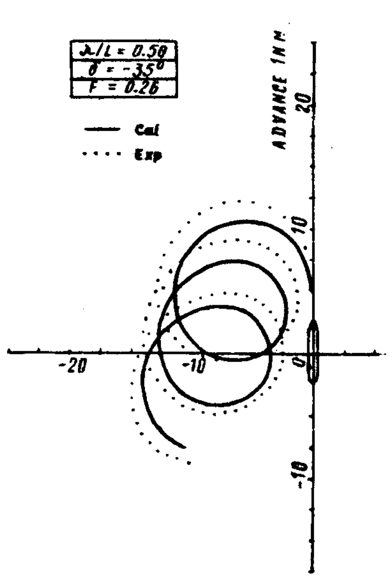

Fig. 3 Turning Trajectory in Regular Waves

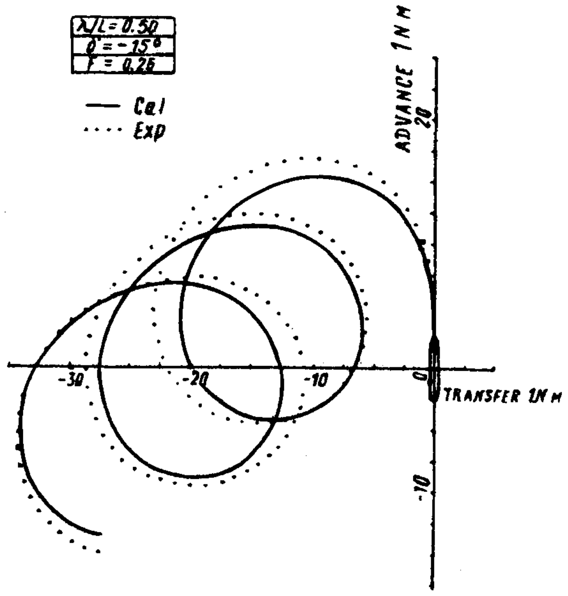

Fig. 4 Turning Trajectory in Regular Waves

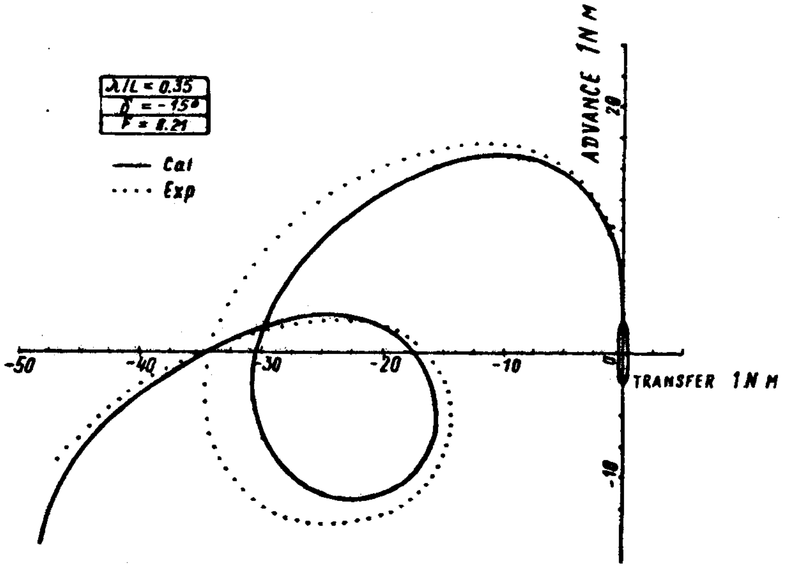

Fig. 5 Turning Trajectory in Regular Waves

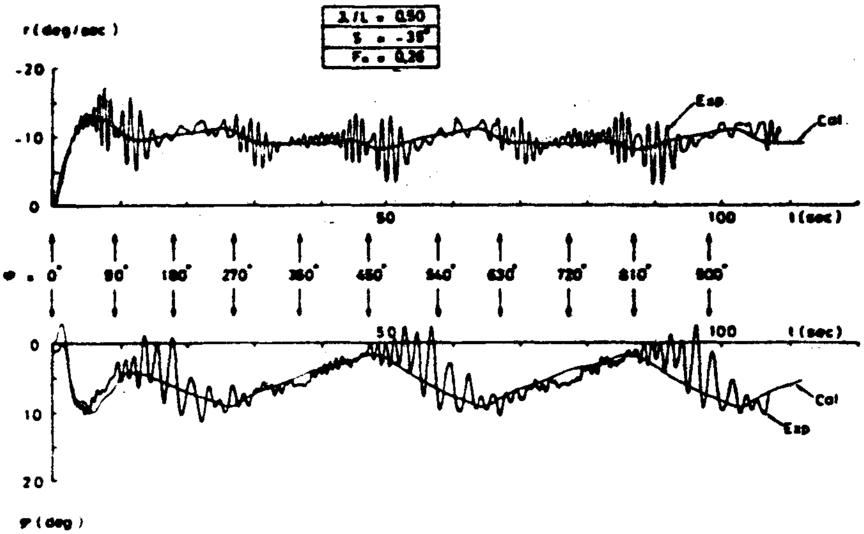

Fig. 6 Time Histories of Yaw Rate and Roll Angle

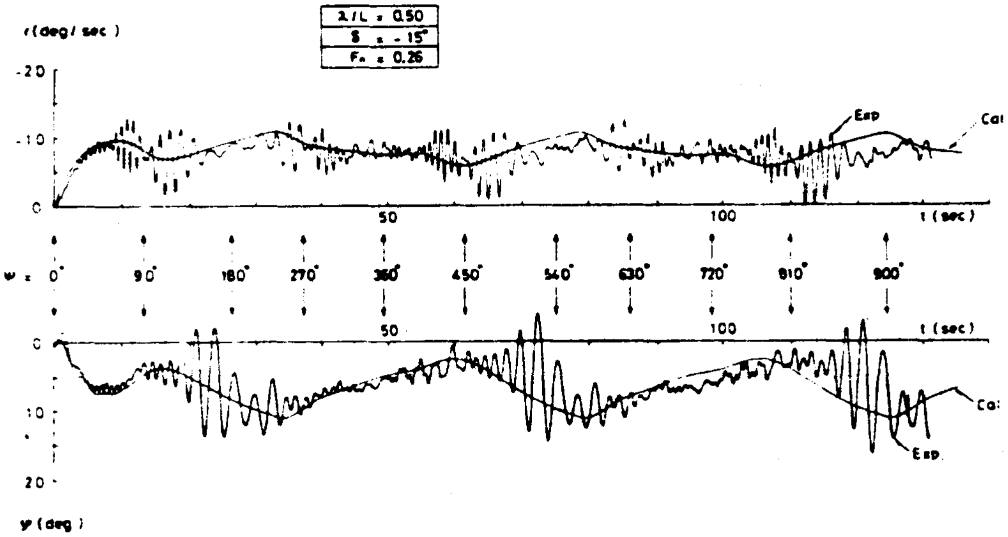

Fig. 7 Time Histories of Yaw Rate and Roll Angle

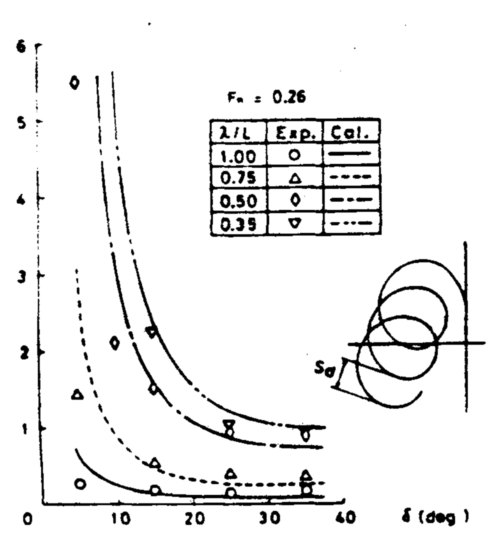

Fig. 8 Drifting Distance as Function of Rudder Angle

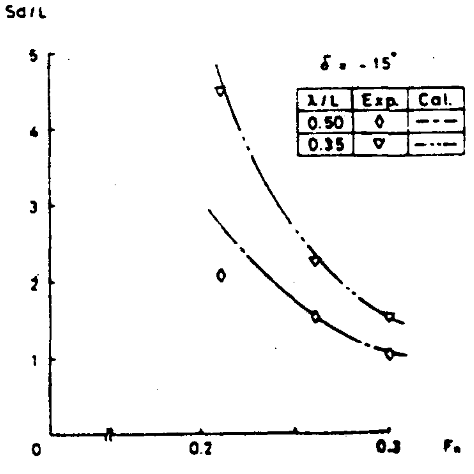

Fig. 9 Drifting Distance as Function of Ship Speed

occurrence af asymmetrical flow in the propulsion tests is liable to occur at the ballast condition.

Therefore, I should like to ask the Manoeuvrability Committee how the Committee thinks on this difference. If, as stated in the report of Performance Committee, the unusual phenomena in manoeuvring motion is liable to occur in full load condition, the further investigation into this difference will be necessary and may lead to more universal understanding of this phenomenon.

The joint study on this point by both Manoeuvrability and Performance Committees is very much desirable.

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Developing reliable methods for the prediction of ship movement on the basis of model tests is an important problem in the field of ship manoeuvrability. Therefore, in the last decade scientists in different countries have been studying scale effect which is specifically noticeable in full-bodied ship model manoeuvring tests. The results of such studies are represented in a considerable part of the Manoeuvrability Committee report. At present there has been accumulated a large stock of data obtained on the models of different sizes and full-scale ships. It appears important to find out the causes of scale effect and work out methods to avoid it while predicting the manoeuvrability of the ships designed.

Tests of tanker models carried out in Krylov Institute basin made it possible to assume that the cause of scale effect in some cases may be an unstable breakaway flow in the area of the bilge. First this assumption was made only on the basis of dynamometric tests of bare hulls of models as represented in (2). Lately we have made experiments of visualizing the flow along the model hull while it was towed on a circular trajectory. These tests enabled us to confirm the hypothesis put out before on the possible cause of the scale effect. To make the flow visible we used dyed oil drops. The tests made it possible to find out some peculiarities of the flow along the model's hull when it was being towed along circular trajectories. As a result of these tests we can suggest a scheme of the development of breakaway flow near a full-bodied ship model. The data obtained showed that angular velocity considerably affects the form of the flow which is not the case with translational movement. In the area of the bilge there develops a breakaway flow with a boundary line whose position on the hull depends on the angular velocity and the drift angle. The cause of the observed breakaway flow may be cross-coupling of two cross flows on the model's bottom, which are directed towards each other. One of them depends on the angular velocity, outwardly directed from the centre of the rotation, and is the result of the centrifugal forces, the other depends on the drift angle, directed from the outer side towards the inner side (as it is in the case of the flow of vanishing aspect ratio airfoil with the angle of attack). The position of the boundary line of the breakaway flow on the width of the model appears to depend on the relative intensity of the two flows. At bigger drift angles the second flow prevails, the boundary line being in the place of conjunction of the bilge and the bottom. When the radius of the trajectory curvature decreases there appear dead water flows (the so-called separation bubbles) on the ship's bottom, first near the extremities. A further decrease of the radius brings about spreading the dead water flows practically over all the surface of the bottom and even to the side of the model which is outer to the circulation. It was in the range of the circulation radii where the breakaway flow on the side of the model was observed that a disruption of the monotonous character of $\bar{Y}(\bar{R})$ dependence in the small model tests occurred (Fig.1).

While studying scale effect in self-propelled model test it is necessary, in our view, to take into consideration an additional lateral force and a moment which arise on the model's hull due to hydrodynamic interaction between the hull, propeller and rudder. Tests carried out in Krylov Institute showed that this force may be of the same order as the forces on the rudder and bare hull and it depends not only on the drift angle and rudder angle, but on the trajectory curvature as well. The dependence of the interaction force on $\bar{R}$ is shown in Fig.2. The force may depend greatly on the scale of the model, which is seen also in Fig.2, which shows test data of two models, two and six metres long. From the figure it is evident that on the tested models the interaction force increases with the decrease of the model length, which explains a better course stability of a smaller sized model. Presenting an interaction force as a separate component makes clearer the appearance of turning curves of an unusual form. Fig.3 and 4 show dependences of interaction force for two tanker models obtained in the basin tests and turning curves corresponding to these dependences obtained on self-propelled models. The Figures show that the unusual turning curves correspond to dependences of interaction force on the circulation radius which have unusual forms. At the same time a monotonous dependence curvature of an interaction force on the radius corresponds to an usual turning curve.

In the study of scale effect greater attention is paid to small rudder angles, as it is considered that scale effect is not so evident at maximum rudder angles. Still there are cases when scale effect is very marked at maximum rudder angles. It may be seen from Fig. 5 which shows turning curves of two trawler models 1.7 and 5.2 metres long ohtained during the tests in Krylov Institute basin.

At present the scale effect which occurs during model manoeuvrability tests is not yet fully explained and studied. Consequently considerable emphasis on this problem in the Committee report may be only approved. Wide support must be given to the Committee proposal to carry out comparative tests of scale effect using the data of "Esso Osaka" full-scale manoeuvrability tests as well as the including of a corresponding item in the draft Recommendations to the Manoeuvrability Committee of the 17th ITTC.

The proposed Recommendations on the whole, in our view, are an excellent basis for a successful work of the Committee in the coming three-year period.

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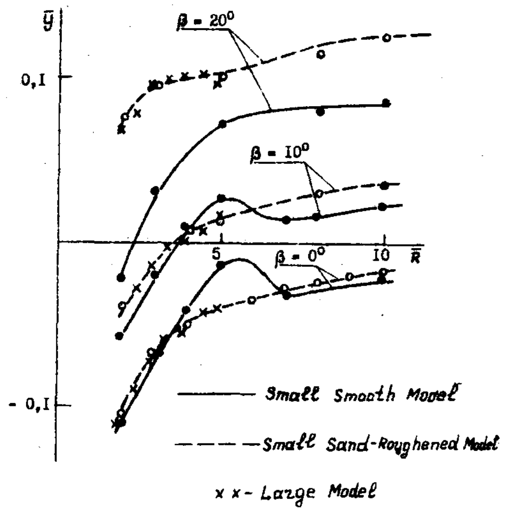

Fig. 1. Change in the Full Lateral Force on Model's Bare-Hull.

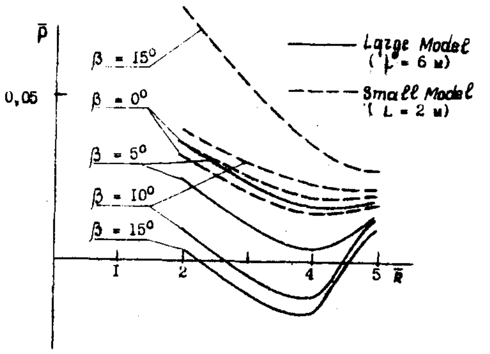

Fig. 2. Influence of Model's Scale on Force on the Hull induced by the interaction of Rudder and Propeller. (δ_R = 0)

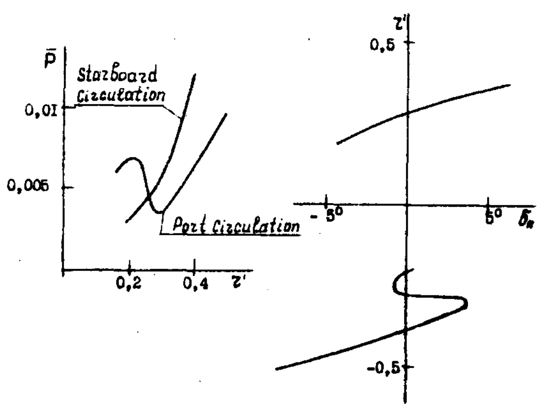

Fig. 3. Force on the Hull induced by the interaction of Rudder and Propeller and Turning Curves of Tanker Model with a Large Width of Deadwood.

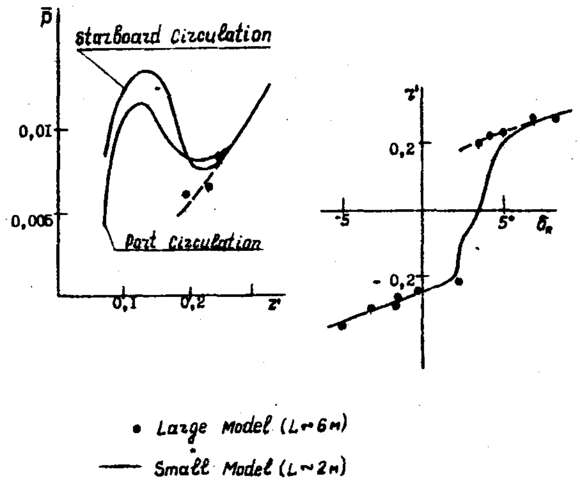

Fig. 4. Force on the Hull induced by the interaction of Rudder and Propeller and Turning Curves of Tanker Models with a Small width of Deadwood.

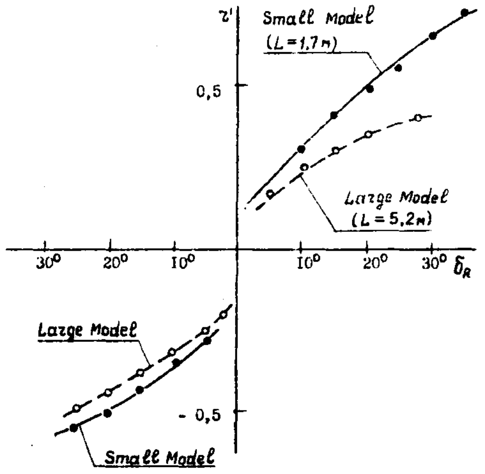

Fig. 5. Comparison of Turning Curves of Trawler Models

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INTERACTION FORCE AND MOMENT BETWEEN SHIPS IN SHALLOW WATER

The hydrodynamic interactions between ships has been receiving a great deal of attention in recent years. Especially this is of importance for ship manoeuvrability in confined water such as canal, harbour or bay because potential hazards of collision and grounding are evolving in such waters.

In this short paper, I would like to show the shallow water effects on hydrodynamic interactions between two identical ships during meeting and passing by experimental results and numerical calculations using matched asymptotic expansion (1). The model ship used here is a cargo ship of $L = 2.5$ m, $L/B = 5.967$ and $C_b = 0.698$, and the test was carried out in Kyushu University.

Figures I to 6 show the instantaneous lateral force (Y') and yaw moment (N') for two identical ships approaching each other. By moving along the abscissa denoting the stagger from left to right, we can see these curves as the time history of the interaction force and moment between ships. And we understand that during the approach each ship experiences initially a repulsive force and a bow-outward moment. Just as the lateral force becomes attractive the yaw moment becomes bow-inward. This corresponds to a highly dangerous situation as far as collision is concerned.

After the midships have crossed, the yaw moment changes to bow-outward again. The peak of this lateral force and yaw moment in each situation experiences large value as decreasing the water depth (H/d) and lateral clearance between the two ships (S_p). We can get the same results in also passing condition. This dangerous situation will be serious problem in passing condition because of much longer time of proximity manoeuvre than in meeting condition.

From the computed results on interaction force and moment, Figures 7 and 8 show the critical regions in controllable situation by the maximum helm angle to avoid the collision. In these figures, the ordinate represents the lateral clearance (S_p) between ships and abscissa the stagger. Inside of the lines represents the uncontrollable condition being very dangerous. We understand that this dangerous region will be extended as increasing the speed differnce between ships, and from these curves the slower ship experiences a larger force and moment than the faster one.

From these results, it may be concluded as follows;

1) In two ships moving in close proximity, there is a very dangerous situation concerning the collision such as the lateral force becomes attractive the yaw moment becomes bow-inward Espesially, in shallow water this tendency is remarkable.
2) In passing condition, the slower ship experiences a lager force and moment than the faster one.
3) The peak points as the time history of the interaction force and moment may be seen at almost some fixed staggers in any water depth and in any lateral clearance between ships.

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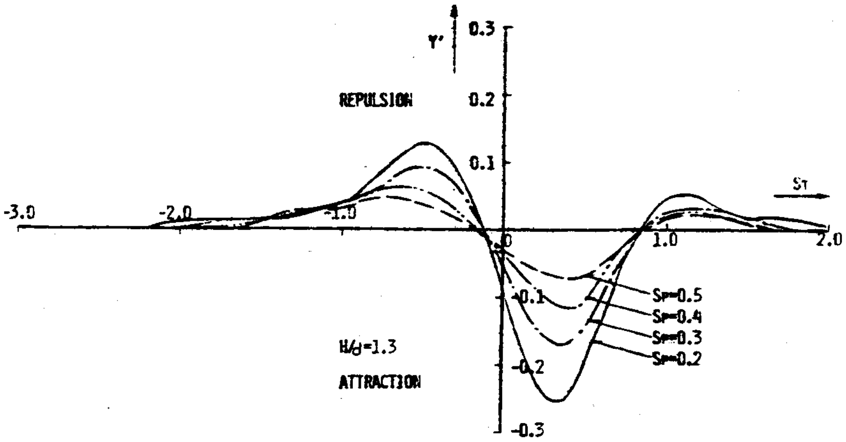

Fig. 1 Instantaneous Lateral Force between Ships in Meeting Condition

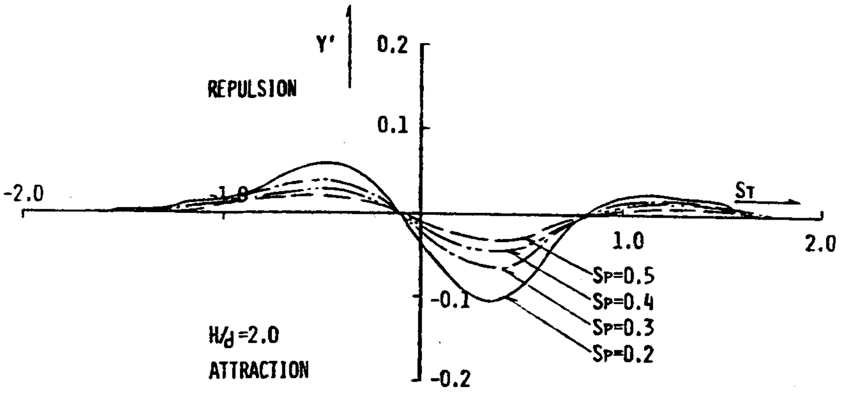

Fig. 2 Instantaneous Lateral Force between Ships in Meeting Condition

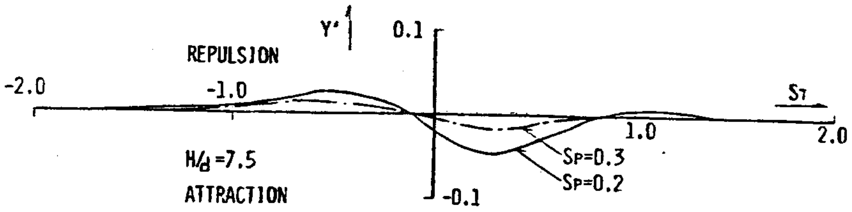

Fig. 3 Instantaneous Lateral Force between Ships in Meeting Condition

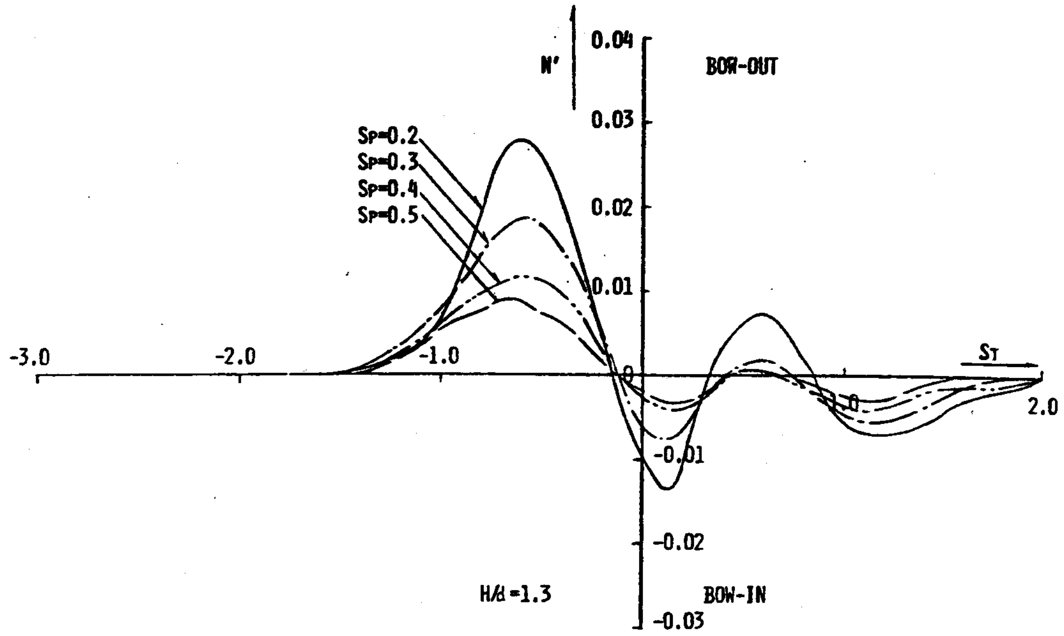

Fig. 4 Instantaneous Yaw Moment between Ships in Meeting Condition

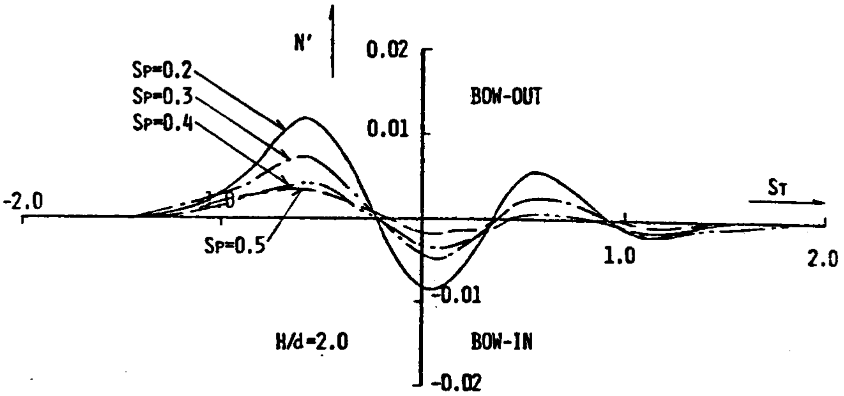

Fig. 5 Instantaneous Yaw Moment between Ships in Meeting Condition

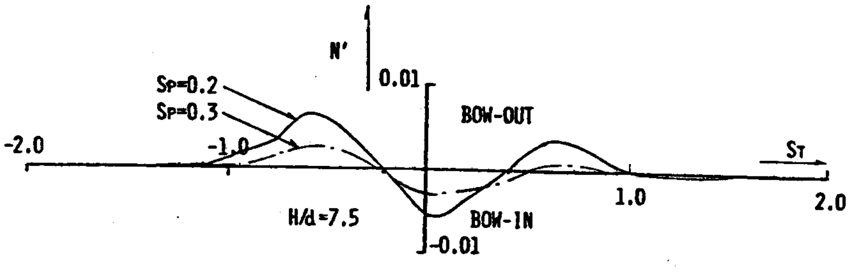

Fig. 6 Instantaneous Yaw Moment between Ships in Meeting Condition

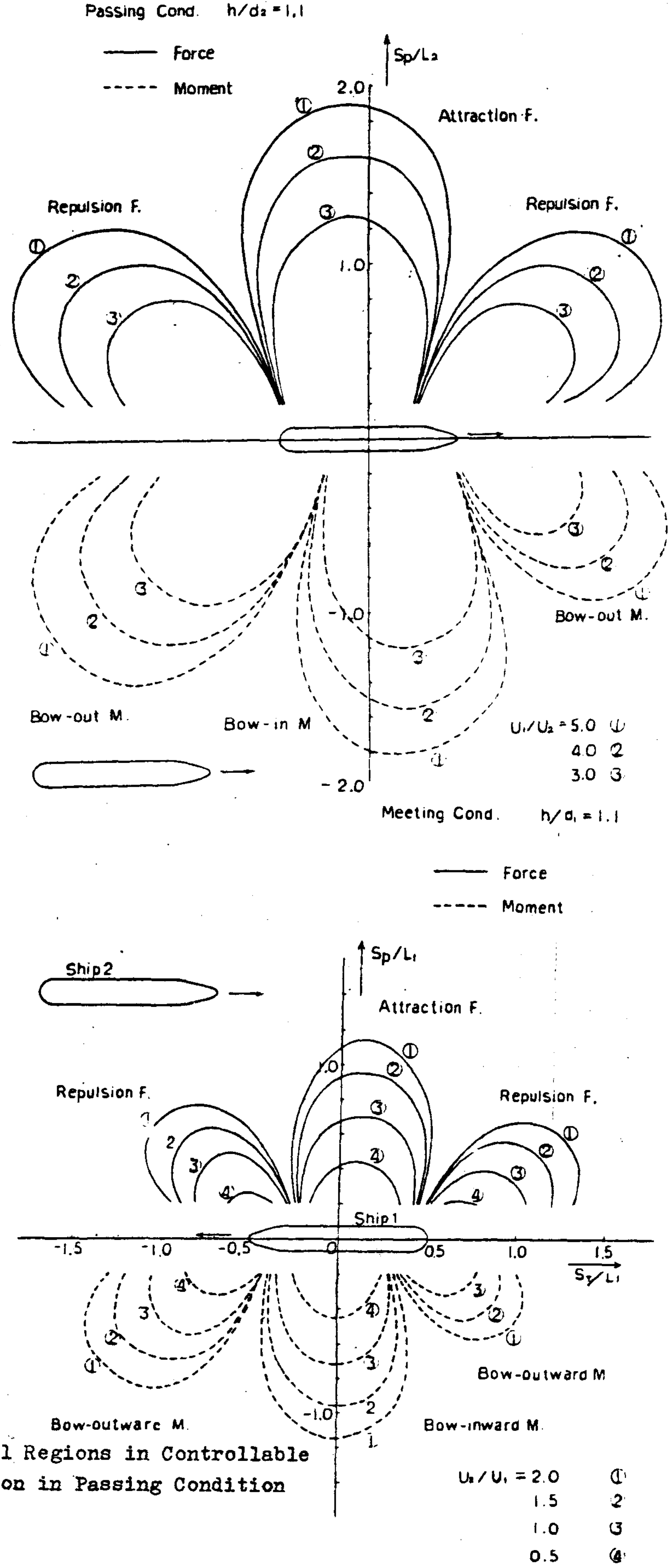

Fig. 7,8 Critical Regions in Controllable Situation in Passing Condition

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HYDRODYNAMIC FORCES DISTRIBUTED ON A HULL

Attempts have been made to calculate the hydrodynamic force acting on a hull under manoeuvring motion by the slender body theory. FUWA[1] calculated the lateral force and yaw moment on a hull under an oblique motion according to a flow model which presentes the ship's wake field as free vortex sheets and showed that the calculated results corresponded exactly with the results measured during the model test. INOUE and KIJIMA et al[2], simplified FUWA's method on the generating point and shedding condition of free vortices and applied the simplified method in estimating hydrodynamic derivatives of a hull in the trimmed condition.

In this paper, the calculated hydrodynamic force acting on each part of a hull by the latter method are compared with that which were measured using the separated ship model. Judging from the good coincidence between both results, it is proved that the simplified method is practically valid for the calculation of hydrodynamic forces acting on a hull.

Principal particulars of two ship models used in the calculation and experimental tests are given in Table 1.

Each ship model is constructed with the segments which correspond to the square stations of each ship.

Oblique and circular towing tests were carried out at the Tsu ship model basin of NKK.

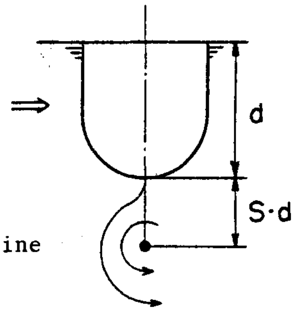
Input data necessary for numerical calculation are the form and motion of a ship and the generating point of free vortices. Following the INOUE and KIJIMA method, the free vortices were to be generated at a distance from the keel line. KASHIWADANI[3] showed empirically the relation between the distance and Lpp/d or Cb and suggested that in the future it should be possible to determine the distance based on the principal particulars of a ship.

Table 1 Principal particulars of ship models

		Container Ship	Tanker
Lpp	(m)	3.000	3.000
B	(m)	0.435	0.524
dm	(m)	0.146	0.196
Trim	(m)	0.017	0.0
Cb		0.562	0.825
l.c.b.		1.8% Lpp fore	2.8% Lpp aft
Scale ratio		1/58.33	1/104.67

The distanse was determined in such a way that the calculated lateral force acting on a hull under oblique towing at $|v'|$ being not more than 0.2 corresponded to that measured at the tests. As a result, the following values were derived for the two ship models.

Container S=0.008
Tanker S=0.013



$$S = \frac{\text{distance from keel line to generating point of free vortex}}{\text{draft at each section}}$$

The comparison of the lateral forces throughout the hull length and the yaw moments under a oblique motion of the two ship models are shown in Fig.1 and

Fig. 2. The comparison of the longitudinal distribution of the lateral forces are shown in Fig. 3 and Fig. 4.

When the drift angle is larger than 10 degrees, there is observed a considerable difference between the calculated value and the measured value of the hydrodynamic force on the full length of the hull of the container ship. The cause of such difference is believed to lie in the fact that wave induced force at the bow is not considered in the calculation. The localized wave making at the bow under oblique towing is larger for the fine ship form such as a container ship while it is less for the full ship form such as a tanker. So this effect is shown more prominently at the container ship. This is confirmed by comparing the distribution of lateral force at low speed and that at high speed as shown in Fig. 3.

Excluding the effect of wave making at the bow, the calculated results agree fairly well with the measured results at the tests.

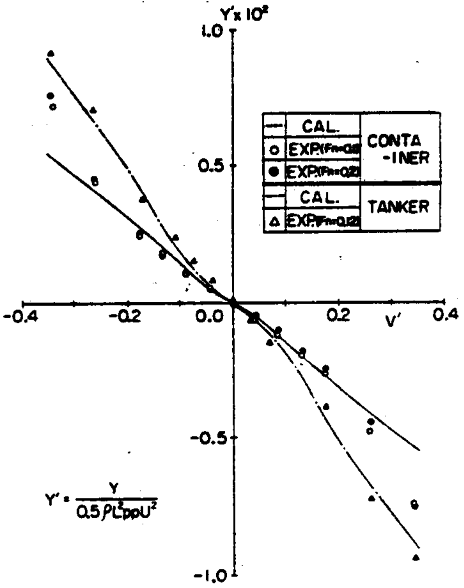


Fig. 1 Lateral force

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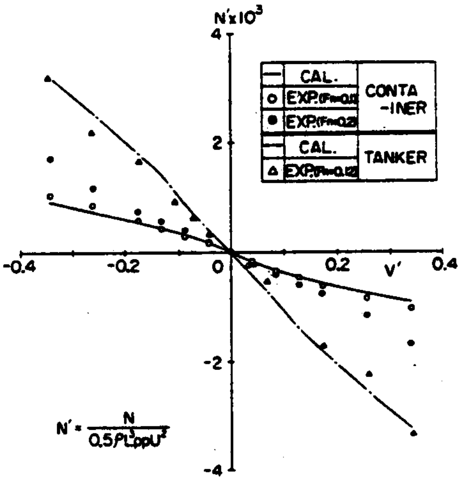
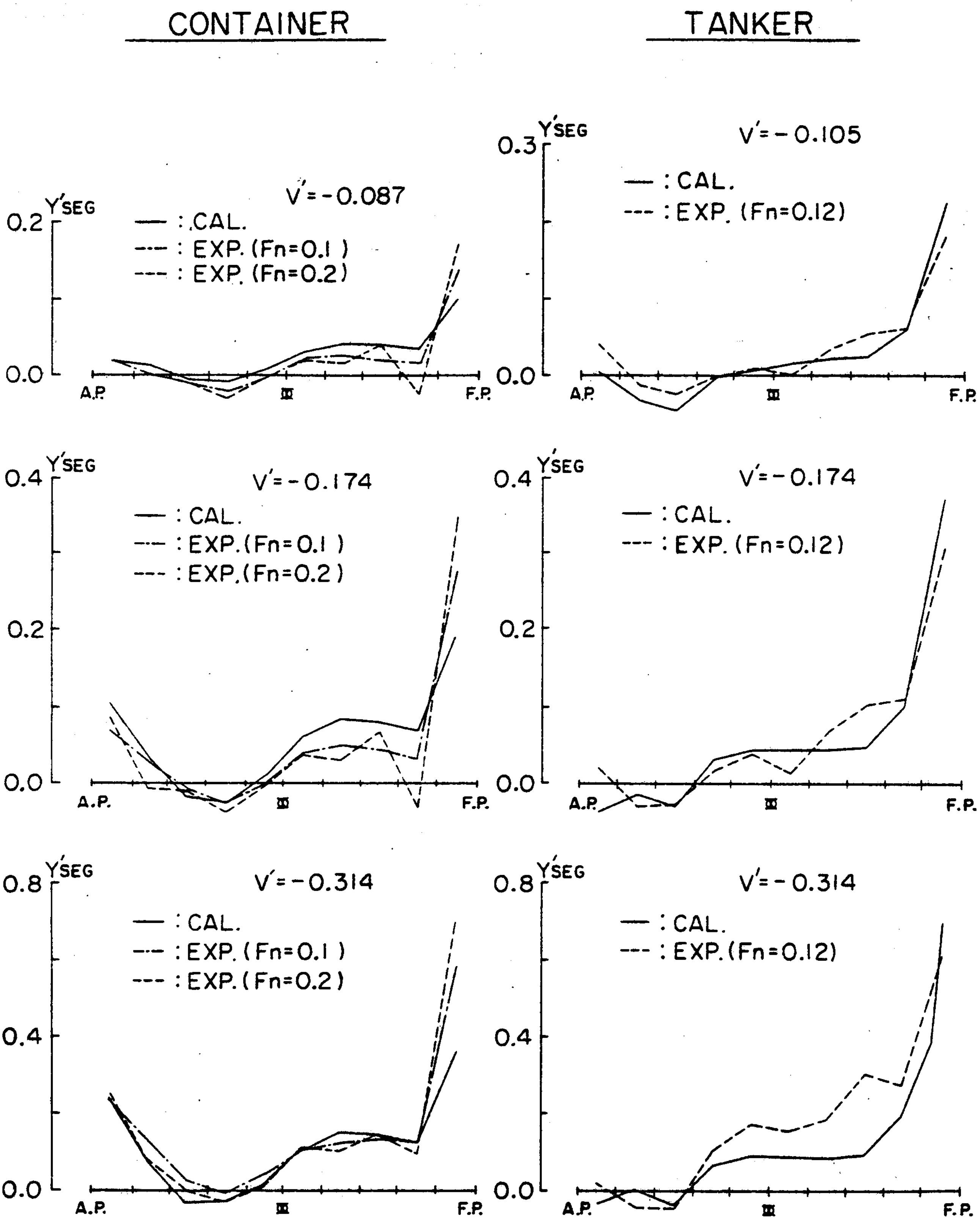
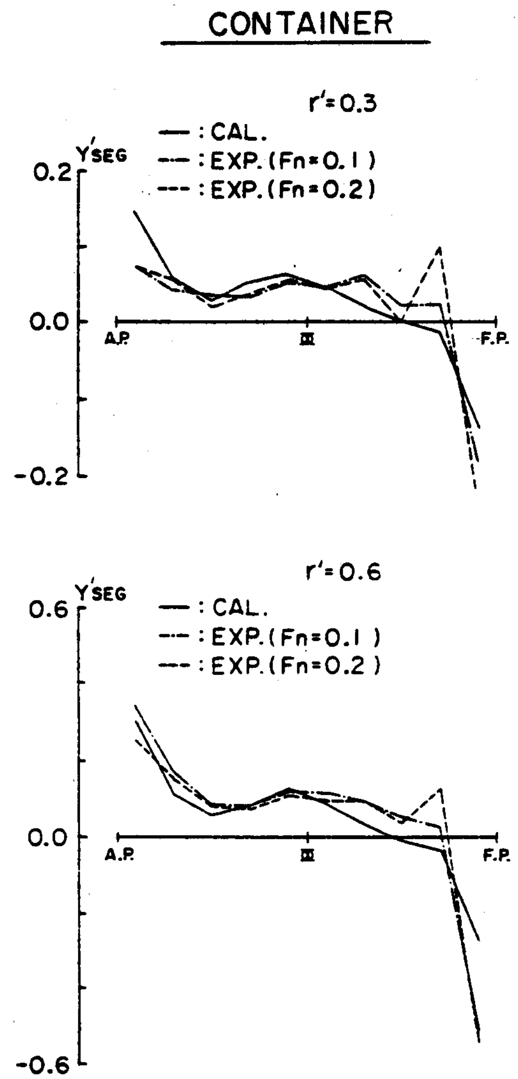


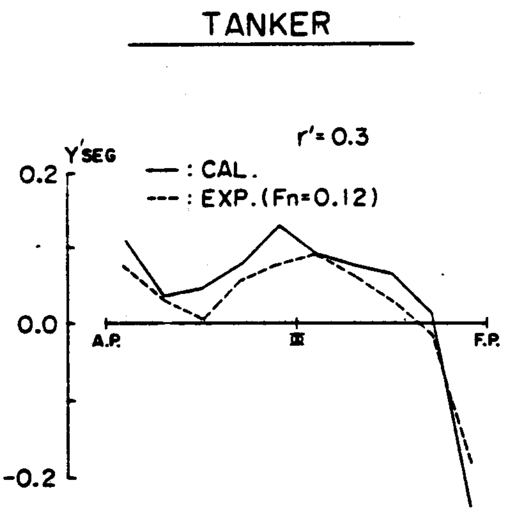
Fig. 2 Yaw moment



$$Y'_{SEG} = \frac{(\text{ Lateral force acting on segment })}{0.5 \times \rho \times (\text{ Projected area of segment }) \times U^2}$$

Fig. 3 Longitudinal distribution of lateral force under oblique motion





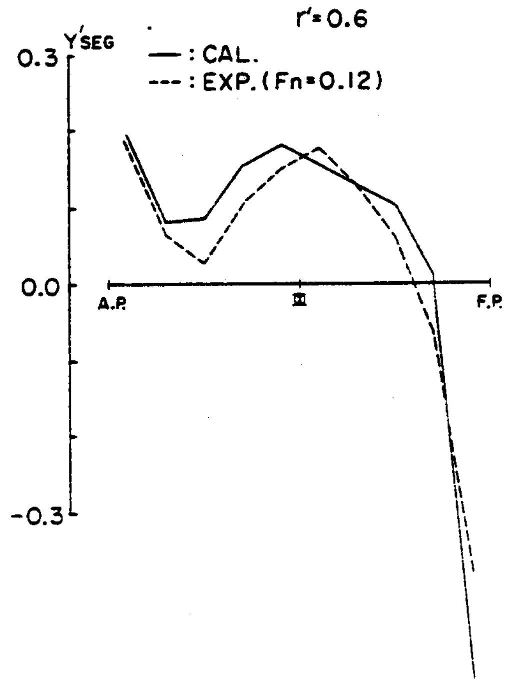


Fig. 4 Longitudinal distribution of lateral force under circular motion (V' = 0)

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The committee has collected a comprehensive review of theoretical and empirical methods for the estimation of hydrodynamic forces. The writer would like to present a set of expressions for ship hull derivatives which can be used for rough estimation of shallow water effect on ship manoeuvring.

According to the strip theory the lateral force, per unit length, acting on the cross section of ship body is:

$$\frac{dY}{dx} = -V\frac{d}{dx}\left[\lambda_y(x)\, v(x)\right] \qquad (1)$$

where $v(x) = V(\beta - \frac{rx}{V})$ - side-slip velocity of cross section,

$\lambda_y(x)$ - two-dimensional added mass of cross section,
V - ship forward velocity,
r - yaw rate.

With the simplifying assumption that ship hull sections were all elliptical with same width and draught, Fedyaevsky and Sobolev (1) derived the well-known expressions for ship hull derivatives in deep water.

$$\left.\begin{aligned}(Y'_\beta)_\infty &= \frac{\pi\lambda}{2}, & (N'_\beta)_\infty &= \frac{\pi\lambda}{2},\\ (Y'_r)_\infty &= \frac{\pi\lambda}{4}, & (N'_r)_\infty &= -\frac{\pi\lambda}{8},\end{aligned}\right\} \quad (2)$$

where subscript ∞ denotes deep water and $\lambda = 2T/L$ (T-ship draught, L-ship length).

Fedyaevsky-Sobolev's results can be extended to shallow-water case, if shallow water effect on added mass λ_y (x) is taken into account.

Based on experimental results the added mass of elliptical sections in shallow water can be written as:

$$\lambda_y = \rho\pi t^2\left[K_0 + K_1\frac{b}{t} + K_2\left(\frac{b}{t}\right)^2\right] \quad (3)$$

$$\left.\begin{aligned}K_0 &= 1 + \frac{0,0775}{\left(\frac{H}{t}-1\right)^2} - \frac{0,0110}{\left(\frac{H}{t}-1\right)^3}\\ K_1 &= -\frac{0,0643}{\left(\frac{H}{t}-1\right)} + \frac{0,072}{\left(\frac{H}{t}-1\right)^2} - \frac{0,043}{\left(\frac{H}{t}-1\right)^3}\\ K_2 &= \frac{0,0342}{\left(\frac{H}{t}-1\right)}\end{aligned}\right\} \quad (4)$$

where b, t are the width and draught of the section respectively and H water depth.

As an approximation, the lengthwise distribution of b is supposed to be parabolic in form. Thus, substituting equation (3) into equation (1) we obtain for the static and rotary derivatives $Y_\beta, N_\beta, Y_r, N_r$

$$\left.\begin{aligned}\frac{Y_\beta}{(Y_\beta)_\infty} &= K_0 + K_1\frac{B}{T} + K_2\left(\frac{B}{T}\right)^2\\ \frac{N_\beta}{(N_\beta)_\infty} &= K_0 + \frac{2}{3}K_1\frac{B}{T} + \frac{8}{15}K_2\left(\frac{B}{T}\right)^2\\ \frac{Y_r}{(Y_r)_\infty} &= K_0 + \frac{2}{3}K_1\frac{B}{T} + \frac{8}{15}K_2\left(\frac{B}{T}\right)^2\\ \frac{N_r}{(N_r)_\infty} &= K_0 + \frac{1}{2}K_1\frac{B}{T} + \frac{1}{3}K_2\left(\frac{B}{T}\right)^2\end{aligned}\right\} \quad (5)$$

where B is the ship width.

By using of equation (3) we can also derive expressions for ship's added mass m_y and added moment of inertia J_z:

$$\left.\begin{aligned}\frac{m_y}{(m_y)_\infty} &= K_0 + \frac{2}{3}K_1\frac{B}{T} + \frac{8}{15}K_2\left(\frac{B}{T}\right)^2\\ \frac{J_z}{(J_z)_\infty} &= K_0 + \frac{2}{5}K_1\frac{B}{T} + \frac{24}{105}K_2\left(\frac{B}{T}\right)^2\end{aligned}\right\} \quad (6)$$

In Fig.1 through 14 are shown calculated results from equation (5) and (6) for a Mariner type ship and Tokyo Maru. (l'_β and l'_r in Fig. 15 and 16 are dimensionless abscissa of points of application of sway damping force and yaw damping force respectively). For comparison, Fujino's forced yaw test results on the models of the same ships (2), as well as calculated results by Newman (3), Kan-Hanaoka (4), Inoue (5), Kogan (6) and Hess (7) are also shown in those figures.

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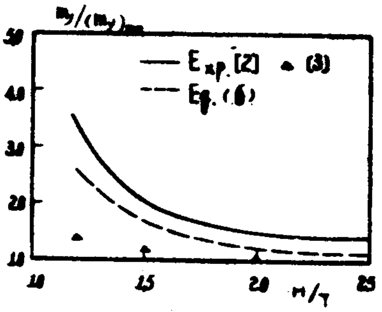

Fig 1 Mariner: m_y

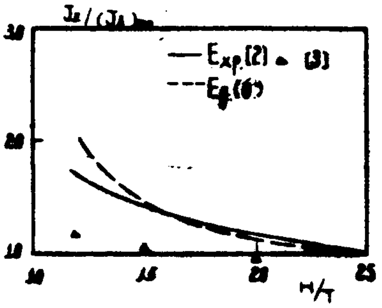

Fig 2 Mariner: J_z

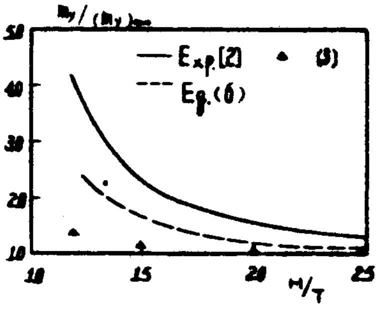

Fig 3 Tokyo Maru: m_y

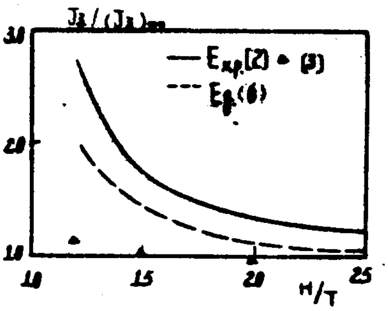

Fig 4 Tokyo Maru: J_z

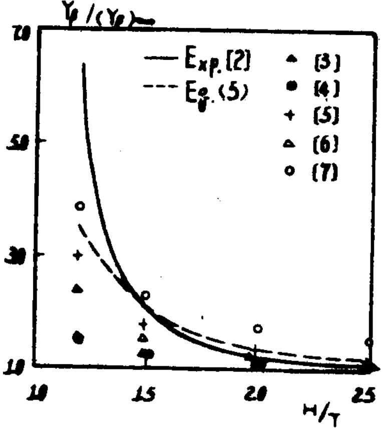

Fig 5 Mariner: Y_β

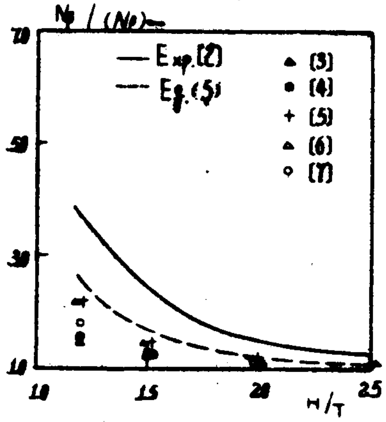

Fig 6 Mariner: N_β

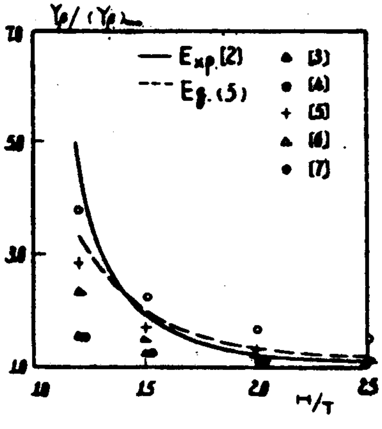

Fig 7 Tokyo Maru: Y_β

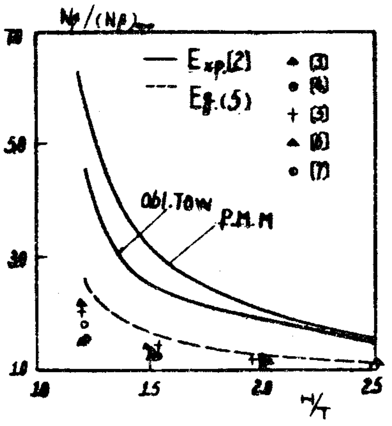

Fig 8 Tokyo Maru: N_β

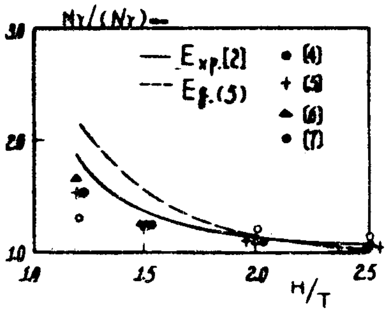

Fig 12 Tokyo Maru: N_r

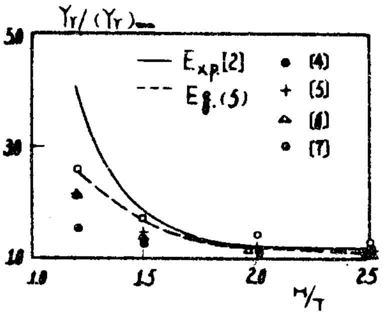

Fig 9 Mariner: Y_r

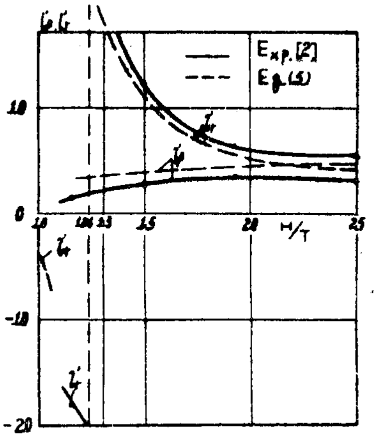

Fig 13 Mariner: l_β', l_r'

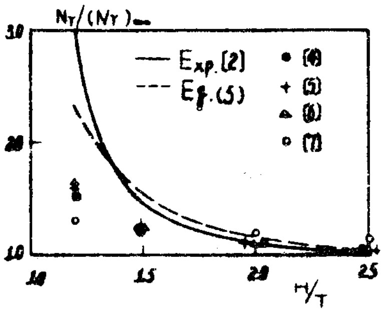

Fig 10 Mariner: N_r

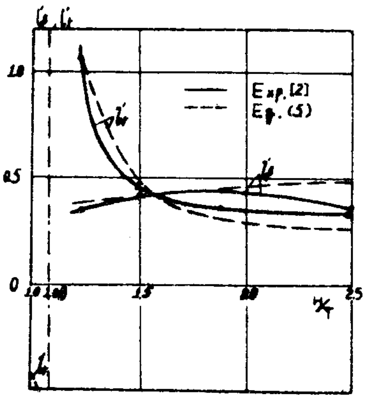

Fig 14 Tokyo Maru: l_β', l_r'

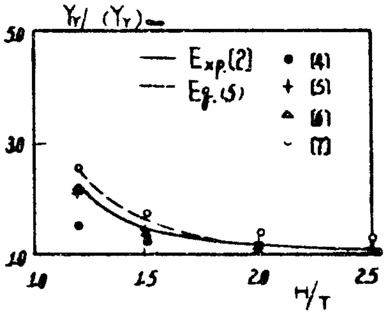

Fig 11 Tokyo Maru: Y_r

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In heavy weather, because of slamming, racing, shipping of water and accelerations, captain reduces speed. Another resource is changing the course. In high seas, changing course to ease motions may be difficult for a light-loaded containership. The ship, facing the waves obliquely, pays off to leeward. To be able to keep course without submitting the ship to excessive whipping stresses a minimum draught forward is required, this draught increasing with wave height. A number of observations are considered on eight merchant ships, weather, speed, number of slams, whipping stresses and frequency of racing. Slamming is directly related to draught forward. The number of slams increases with speed, but the highest whipping stresses are observed in the highest waves. All the observations relate to the light-loaded condition, and for each observation the ship comes up into the wind, strongly for the orecarrier and the tanker, weakly for the cargoships and the containership. Only in three cases is the ship paying off to leeward, these observations allowing to establish the draught required to keep course facing the waves.

Preventing the ship to glide in the trough of the wave is associated with very high whipping stresses. The highest whipping bending moment at probability 10^{-8} being $M = 0.00075 \rho g L^3 B$, dividing M by the bending modulus I/V gives the whipping stress 10^{-8}. On the other hand, when gliding in the trough of the wave, the roll angle attained 20° on the containership, the lateral acceleration at the top of the deck containers 0.5 g, the vertical bow acceleration 0.7 g all significant double amplitude.

The whipping stresses, roll angles and lateral acceleration are thresholds in the ship behaviour, and they allow to ascertain the minimum draught required in waves. There was a difference however between the behaviour of the cargo-liner of 146 m and the containership of 218 m.

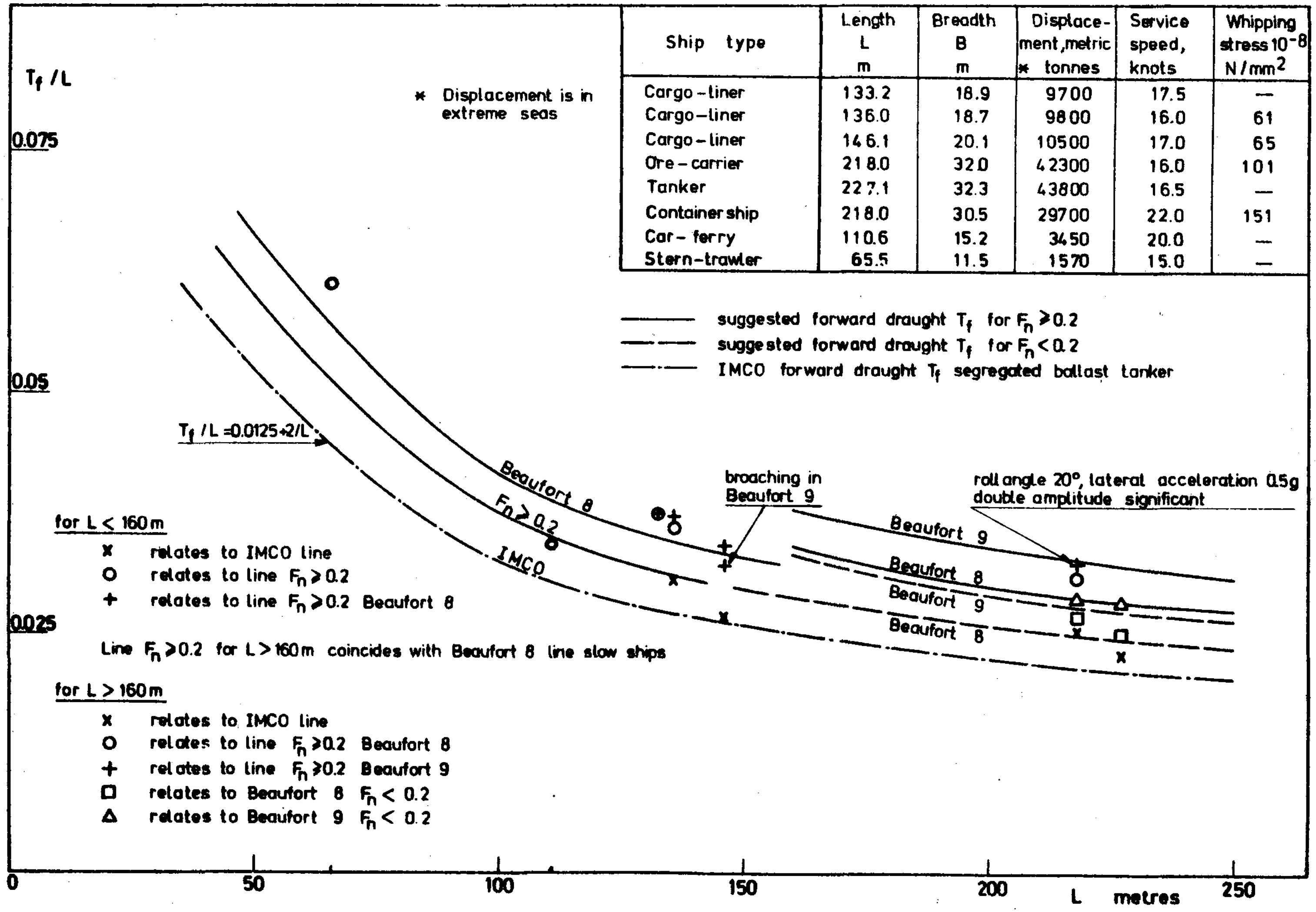
The cargo-liner, when facing obliquely a sea state Beaufort 9 to 10, frankly broached to, gliding in the trough of the wave. To resume his course master had to come up into the wind, the revolutions were increased and the ship forced at 45° into the waves, slamming and racing heavily. Captain of the containership, to ease motions in a head sea nearly Beaufort 9, changed course to take the waves at 30° at the highest attainable speed. The maximum roll angle double amplitude being 36°, the captain seeing his deck-cargo endangered, came back head to the waves.

Weather worsening until Beaufort 10, the ship was kept 10 to 15° into the waves at a speed of 8 knots, low enough to prevent slams and green seas to exceed 5 per 100 *pitch oscillations, taking care however* incidentally to increase the revolutions when nearly broaching, such in spite of some minor deck damage. A whipping stress as high as 140 N/mm^2 was attained. Bending modulus being 16.4, the estimate at probability 10^{-8} is 150 N/mm^2.

It is suggested the IMCO regulations for segregated ballast tankers be a basis of minimum draught for all ships. Concentrating on the requirements for mean draught T_m and trim, the IMCO minimum draught forward T_f works out as given by formula

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

To obtain agreement between the forward draught as given by formula (1) and the actual draught, allowances are needed, according to the behaviour in waves. On fast ships (F_n above 0.2), as soon as



Ship type	Length L m	Breadth B m	Displacement, metric * tonnes	Service speed, knots	Whipping stress 10^{-8} N/mm^2
Cargo-liner	133.2	18.9	9700	17.5	—
Cargo-liner	136.0	18.7	9800	16.0	61
Cargo-liner	146.1	20.1	10500	17.0	65
Ore-carrier	218.0	32.0	42300	16.0	101
Tanker	227.1	32.3	43800	16.5	—
Containership	218.0	30.5	29700	22.0	151
Car-ferry	110.6	15.2	3450	20.0	—
Stern-trawler	65.5	11.5	1570	15.0	—

* Displacement is in extreme seas

Fig. 1. Suggested minimum draught in waves

pitching is important enough to induce slams, an allowance of 15% is suggested (Fig.1) Moreover, on ships ranging from 50 to 160 m, an extra allowance 10% is suggested in Beaufort 8, the extra allowance for ship ranging from 160 to 250 m being 15% in Beaufort 8 and 30% beyond Beaufort 9.

D.PULS - Wilhelm-Pieck-University of Rostock, Department of Naval Architecture, Rostock, GDR.

In the report of the manoeuvrability committee it is suggested, that further studies on the ESSO OSAKA - ship form may form the subject of a new ITTC cooperative programme.

In connection with the problem of ship-model-correlation I think that it will be very useful, too, in comparing the various captive model techniques. In the GDR we would provide rotating-arm-tests and experiments with free running models of the ESSO OSAKA in deep and shallow water.

We propose the committee to gather information as soon as possible from all members if they are interested in this programme.

Perhaps member organisations could too balance some details of the experimental studies.

In connection with the 3rd recommendation of the report about forces and moments at steered ships it should be clearly stated, that we are not only needing more theoretical knowledge about transverse force and yawing moment, but also about the alterations of resistance and propeller-thrust due to yawing angle, curvature of path and rudder angle. This arises from the very growing importance of such subjects as collision avoidance or to avoid energy losses in manoeuvering.

A written contribution in this area is given to the committee and I think, if it can be agreed, that it will be more useful to publish it in the 2-nd Volume of the proceedings because of the restricted time for discussion here.

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SOME RESULTS OF THE SHIP HYDRODYNAMICS FOR THE PREDICTION OF COLLISION MANOEUVRES WITH SHIPS

(Written contribution)

As a cause, an additional pressure resistance due to boundary layer separation and the formation of single eddies in the stern region have been determined (3).

As a kind of approximation for the calculation of collision manoeuvres was introduced, that the resultant is directed perpendicularly to the ship's longitudinal axis.

From this the resistance results as a component in the path direction. It has been shown, that this approximation occurs for the case of motion with an angle of attack on a curved path as well (4).

For runs on curved paths with angle of attack, an inertia resistance results from the rotation of the hydrodynamical impulse vector. This resistance shouldn't be neglected in the motion calculations.

Further investigations showed, that during runs out of straight trajectory into turning circles after a solitary putting of the rudder the rudder resistance can be neglected in the motion calculations compared to the other parts of resistance (4).

In order to illustrate the reliability of motion calculations, the following has been calculated: the decrease of speed and the advance and transverse offset for a cargo ship without propeller with the approximation for the resistance. The results are dropped in Fig.2.

They do correspond to the calculated results that have been obtained using forces measured in the rotating arm facility. The results of a free-running model are only little differing.

A precise calculation of the influence of the propeller on the forces and moments regarding yawing angle and curvature of path fails because of lacking knowledge about the wake field. Concerning this, at present extensive investigations are carried out.

As a kind of provisional approximation for the motion calculations concerning collision manoeuvres, it has been supposed that the change of the thrust could be determined from the rate of advance due to varying speed of ship.

Determining the change of the effective dynamic pressure as a function of the thrust coefficient, the influence of the propeller on the rudder can be regarded.

In Fig.3, some results of motion calculations are shown. The equations of motion have been solved, on the one hand, applying forces and moments measured in the rotating arm facility and, on the other hand, using the approximations for the resistance alteration and the change of the thrust.

There could hardly be stated any difference between the path lengths covered on several trajectories after constant time intervals.

Small differences are to be stated if for the calculation of the ship's positions during collision manoeuvres the resistance alteration due to the real inclination of the resultant hydrodynamic force is introduced according to Fig.1.

Then the resistance is higher.

Applying the maximum inclinations of the resultant, shown in Fig.1, the results plotted in Fig.4 can be obtained. The points reached by bow and stern are connected by lines of equal time. A collision may safely be avoided if other ships go around the areas that are limited by these curves.

The results showed that those areas can be predicted with a fairly good reliability using the above mentioned methods.

A more comprehensive description of methods and results concerning the calculation of collision manoeuvres will appear in (5).

Out of the present conditions in international maritime traffic often arise situations where many ships have to manoeuvre at close quarters.

In order to avoid collisions, the ship's commands must know the course of path as a function of time, the position and the speed of their ships during various steering manoeuvres as precise as possible.

Path and position of a ship may be determined from the solution of linearized equations of motion.

The coefficients of transverse force and yawing moment that are necessary for the solution and the hydrodynamical added masses and the hydrodynamical moments of inertia may approximately be determined by theory (1).

In order to calculate the speed for steered ship motions, too, using the equations of motion, in addition to this, information on resistance alterations and changes of the thrust due to yawing angle, curvature of path and rudder angle is necessary.

According to the lifting-foil theory, the ship must be considered as a very thick foil with a low aspect ratio.

The calculation of the resistance due to angle of attack fails because of insurmountable mathematical difficulties and because of the conditions concerning the stern flow that can't exactly be determined, whereas for foils the Kutta-Joukovski rule is valid. For thin foils with low aspect ratio, an elliptical distribution of circulation arises over the span of the hydrofoil (2).

The effective angle of attack equals half the geometrical angle of attack.

Apart from the lifting force, an induced resistance can be stated.

In Fig.1, the angle of inclination of the resultant hydrodynamic force towards the perpendicular of the ship's longitudinal axis is plotted for various ship models.

The inclination of the resultant is more directed to the stern than it could be supposed according to the thin-foil lifting theory. With this, the resistance, too, is increasing compared to the induced resistance.

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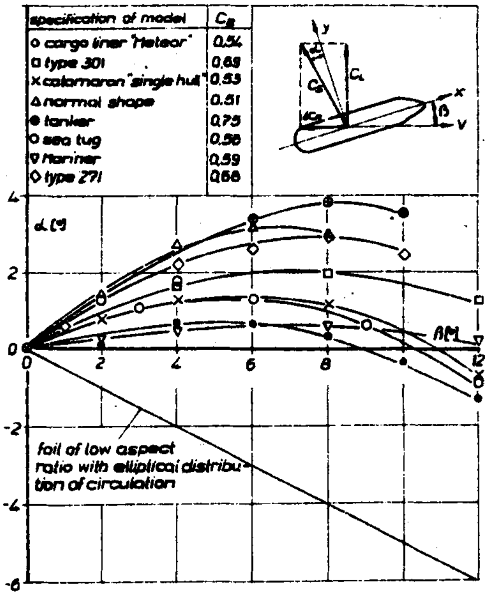

Fig. 1:
Angle of inclination α between the direction of the resultant hydrodynamic force due to drift angle and the direction of the y-axis from force measurements on models of different types of ships

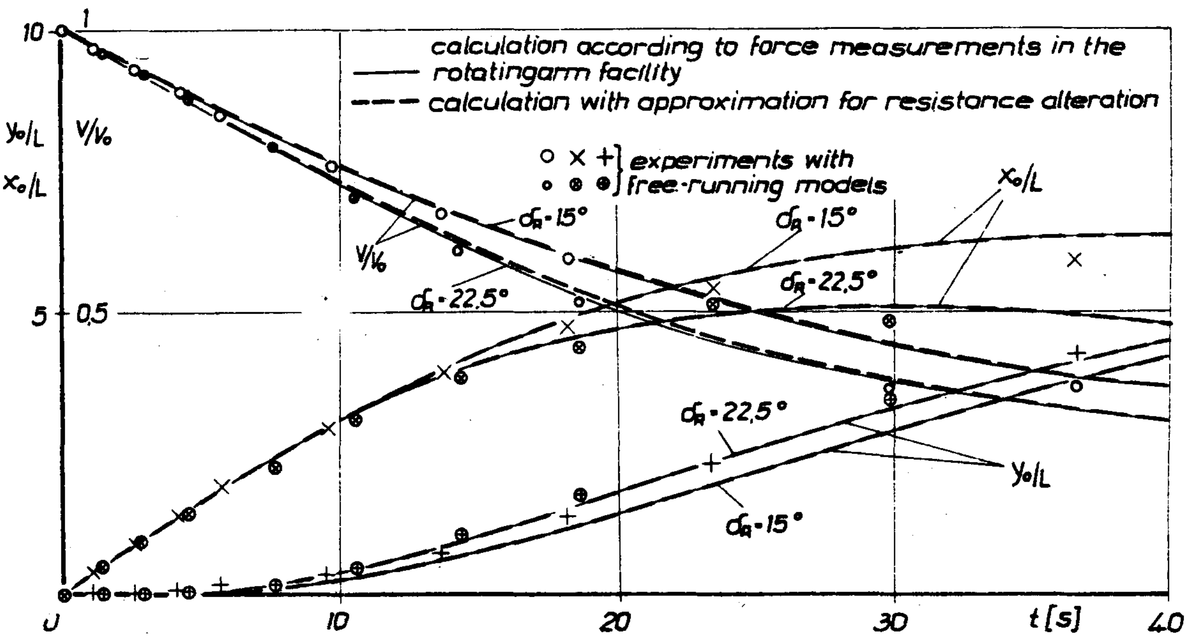

Fig. 2

Time histories of advance x_0/L, transfer y_0/L and speed alteration V/V_0 for entrance in turning circles of a type 301 ship model without propeller

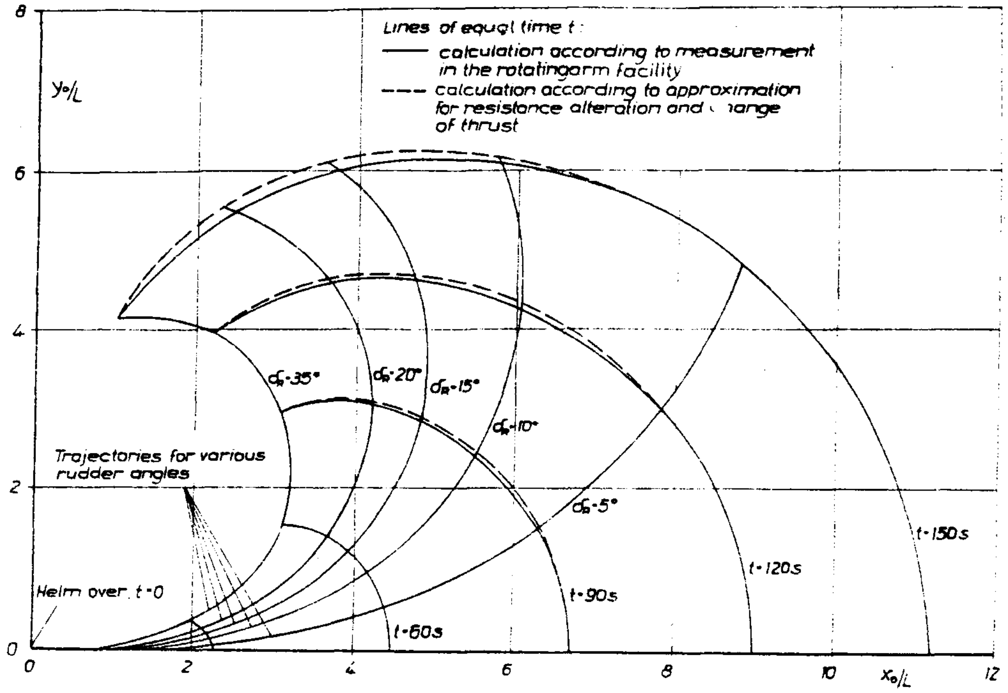

Fig. 3. Trajectories and lines of equal time for a cargo ship of the type 301 for different times with initially straight trajectory of the ship

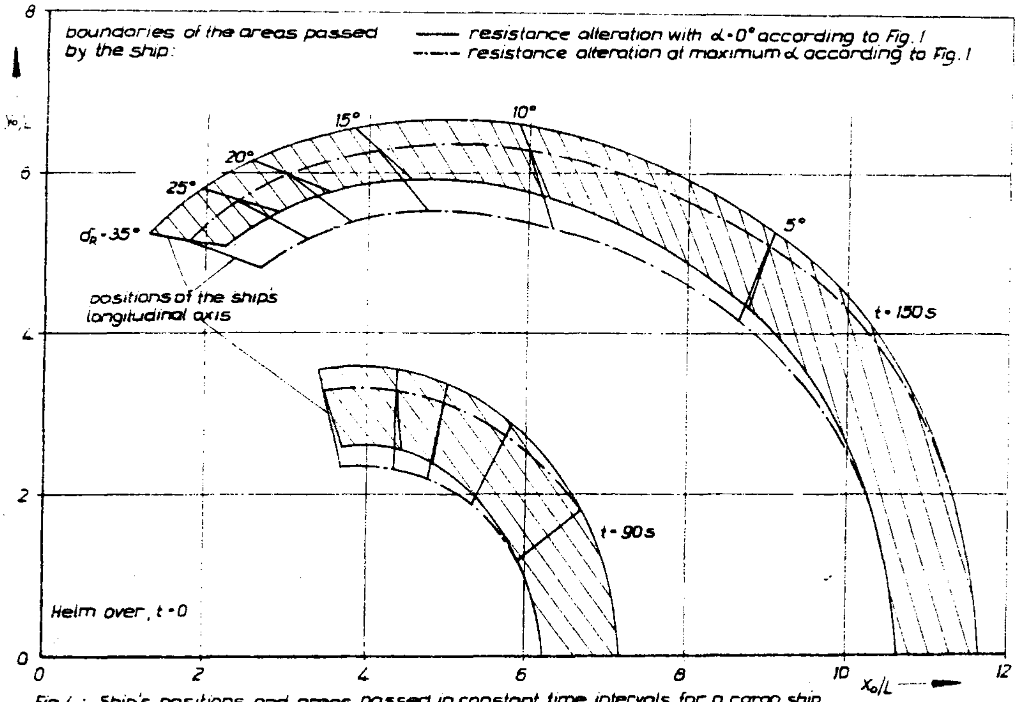

Fig. 4: Ship's positions and areas passed in constant time intervals for a cargo ship of the type 301 according to motion calculations

4. Göhler, U.: Determination of domains of risk with regard to resistance alteration due to yawing angle and curvature of path according to model tests. Research report of the research group "Manoeuvrability of ships" at the Wilhelm-Pieck-University of Rostock, Rostock 1980, unpublished.
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N.H.NORRBIN - Swedish Maritime Research Center, Göteborg, Sweden.

I have read this report with much interest, and with much of recognition, too. I will comment on the requirements of statutory bodies on manoeuvring standards, on traffic regulations that discard of ship dynamics, and on the related questions of bridge displays of ship manoeuvring capabilities.

The input by expert professionals to the Maritime Safety Committee of IMCO is largely canalized by national government authorities, and a specific problem may easily be overlooked. It has also happened that ITTC member individuals have furnished contradictory recommendations this way. Some eight or ten years ago the Manoeuvrability Committee realized a need for monitoring, and if possible for guiding the IMCO activities in the areas pertinent to our competence. We were informed by the Secretary General of IMCO, however, that the organization could offer a consultative status on certain conditions only. Since then, again, IMCO has appointed a special group of nautical experts to handle problems of ship manoeuvrability, and I would recommend that ITTC take action to have an observer within that group.

As illustrated in the Committee Report several other statutory bodies require manoeuvring data to be displayed for easy access of the ship officers, and many of the ITTC member organizations are involved in the preparation of these data sheets for use as wall decorations on the bridge. Whereas this type of diagrams may be consulted by the officer or pilot planning an approach they may also make him confused when load conditions and wind and tide disturbances do not conform to the standard format.

It is easy now to see the advantages of fitting a data-logging and computer-based predictor on board. By use of a trial knob the officer-on-watch may first choose the future track of his ship onto the screen of the radar PPI, and the same predictor is then used to facilitate ship control during the actual approach. The Committee Report mentions two papers on this subject presented at the International Conference on Marine Simulation in 1978, i.e. references /22/ and /23/. Earlier work at SSPA was documented by Willem van Berlekom in papers before the Conference of the Safety of Nuclear Ships in Hamburg 1970, and at the RINA Spring Meeting in 1978.

The SSPA proposal for a predictor device was first demonstrated in a Swedish tanker in 1968, but the first true implementation was made on board a medium-sized Exxon tanker some five or six years ago.

Coming back to the standards and rules now being introduced it is also worth of observation, that local authorities may impose speed restrictions to the traffic in a certain fairway, which, albeit all good intention, are in clear conflict with the safe handling of many of the ships using that fairway. I had the opportunity to illustrate that in case of a modern passenger ferry with a large windage area failing to turn the proper way, all in a paper to the 4th International Symposium on Vessel Traffic Systems in Bremen in April 1981. Incidentally, this Symposium is not listed in the table on page 252 of the Report.

P.BOGDANOV, P.VASSILEV, D.RADEV,
V.TCHOTOUKOV - Bulgarian Ship Hydrodynamics Centre, Varna, Bulgaria

SYSTEM FOR REGISTRATION OF FREE-RUNNING SHIP MODEL MOTION

1. INTRODUCTION

The recommendations on ship manoeuvrability of the 15th ITTC [1] and the report of the Manoeuvrability Committee of the 16th ITTC [2] devote important attention to the experimental methods and instrumentation. As is well known, a great diversity of methods and systems for registration of free-running ship model trajectory exists, as each of them possesses certain advantages. Nevertheless, the common tendency of these systems is, on the one hand, to avoid the undesired influence on the natural motions of the model under test and, on the other hand, the preference for minimum size and weight of the instrumentation on board the model.

It is difficult to show, however, method and system which are to solve all above mentioned problems and to meet the majority of the requirements of the free-running ship model experiments. On the other hand, two obligatory requirements must be fulfilled: 1) registration of the ship model trajectory with high accuracy, and 2) automation of the entire measuring process.

Even at the preliminary detailed investigations accomplished at BSHC it was found, that a number of solutions made on the basis of optical systems, television systems and optoelectronic systems, despite their disadvantages in respect of the size and weight of the instrumentation on board the model, have some important drawbacks. It turned out that complex optomechanic tracking systems, complicated optics and lens systems will be necessary including "facet eye" cameras. The systems for control of the cameras are also sophisticated and expensive, and the process of measuring the data obtained becomes additionally complicated. The substantial disadvantage of these systems is that the error in determination of the co-ordinates is depending on the distance to the model as well as on the nonlinearity of the detector-lens systems. The accumulation of these errors with errors introduced by other sources of inaccuracies leads to relatively lower accuracy, despite the current achievements reached at increasing the resolution of the cameras. In addition, the algorythms are complicated due to the necessity of application of trigonometric functions related to the measured angles. On the other hand, the nonlinearity of the lens systems must be compensated as well.

The experience, gained in the ultrasonic system developed by BSHC and utilized in the manoeuvring-seakeeping basin, confirmed the advantages of the underwater ultrasonic method in comparison with the systems mentioned briefly above [3], [4], [5]. Therefore, brief characteristics of the BSHC ultrasonic system is given in the present paper.

2. DESCRIPTION OF THE HARDWARE AND PRINCIPLE OF OPERATION OF BSHC US SYSTEM

The ultrasonic (US) system "Trajectory" was put into operation in the BSHC manoeuvring-seakeeping basin in December 1979 and since then it had been in continuous successful exploitation. Fig. 1 shows a simplified block diagram of the ultrasonic system, which is a component of the measuring-computing complex of the manoeuvring-seakeeping basin. An onboard transceiver (BT), containing hydroacoustic transmitter synchronized by radiochannel, is installed on the model under test. The control unit of the ultrasonic system generates syncpulses with frequencies 1.25, 2.5 and 5 Hz, which are chosen by the operator in conformity with the type of tests. The syncpulses are transmitted to the BT via radiotransmitter RT. Simultaneously the control unit triggers the systems of counters for measuring time intervals, which are housed in the receivers r_1 to r_4. Upon receipt of syncpulses the hydroacoustic transmitter (component of BT) sends powerful ultrasonic pulse with 100 mS duration. The ultrasonic pulse is received by 4 appropriate hydrophones (H_1 to H_4) situated at a 0.5 m height from the bottom of the basin, in the corners of 40m X 40m square. The hydrophones receive the radiated pulse with delays determined by the distances to the transmitter, accordingly. With the receiving of the pulse each receiver stops counting clock frequency in the corners.

In this way the measurement of 4 time intervals T_1 to T_4 is realized, the latter being proportional to their coordinates versus BT. The clock frequency 1.5 MHz for transforming the delay into a number ensures resolution in distance 1 mm. The ultrasonic velocitymeter, incorporating transmitter H_6 and receiver H_5, gives the necessary correction resulting from the changes of the velocity of the ultrasound in water. The measurement data obtained is entered in the measuring-computing complex of the manoeuvring-seakeeping basin (Fig.1). The computing complex consists of:

- minicomputer PDP11/34 with 24 K words users available memory, with KD11E processor;
- disk drive RK05J with 1228 K words capacity of one disk cartridge;
- fixed head disk drive RK05F with 2500 K words capacity of one disk cartridge;
- display VT55 with screen dimensions 207 X 122 mm;
- plotter DP10 with format 420 x 270 mm;
- console LA36.

The connection between the PDP11/34 computer and the ultrasonic system is effected by DR11C interface.

3. DESCRIPTION OF THE SOFTWARE SYSTEM

The application software developed at BSHC, is a part of the AMEX (automated system for acquisition, registration and processing of data obtained during manoeuvring tests carried out in the manoeuvring-seakeeping basin). All program modules are written in FORTRAN IV and are working under RSX11M, V03 - operation system for minicomputer family PDP11. Module SORTU sorts the registrated data. File T.DAT is developed, containing the time intervals collected for the entire period of registration. The program module COORD operates in the presence of file T.DAT. The module calculates the velocity of the ultrasound for the period of registration and transforms the time intervals into distances. The data for the distances R_1, R_2, R_3 and R_4 between the transmitter and the corresponding receiver are building file R.DAT. The sphere equations are used for all hydrophones:

$$(X-X_i)^2 + (Y-Y_i)^2 + Z^2 = R_i^2 \quad , \quad i = 1,2,3,4$$

where X_i, Y_i are the corresponding coordinates of the hydrophones H_1 to H_4. The solution of the equations gives the coordinates of the model centre of gravity. A criterion for rejection of false measurements is foreseen. In addition, the coordinates calculated from the experimental data can be approximated according to user's preference. In order to ensure suitable output, a plotting program is developed for visualisation of the ship model trajectory on VT55 and plotting on DP-10 plotter-Fig.2.

For better evaluation of the manoeuvring qualities of the ship model, the trajectory can be plotted with respect to the relative coordinate system which presents identical conditions for the different model manoeuvres (Fig. 3). The program module VARB calculates the model speed, acceleration, and the radius of turn of model's trajectory, on the basis of the known X - Y coordinates of the model center of gravity. Modified standard software is used for numerical smoothing and differentiating of tabulated functions. The data obtained for model speed, acceleration and radius of turn are some of the most important values for further processing and analysis of the manoeuvring qualities of model under test. DP10 plots are shown in Figures 2, 3, 4, and 5.

4. CONCLUSIONS

A great number of tests were carried out in BSHC using the ultrasonic system "Trajectory" and as a result valuable data for evaluation of ship model manoeuvrability were obtained. The experience confirmed the anticipated advantages of the hardware as well as of the algorythms and software. The possibility of plotting of different analytical and graphic data for the purposes of investigations is a significant advantage of the system (Figures 2 to 5). The ultrasonic system was not originally designed for underwater investigation. After modifications, however, of the synchrochannel the system should be espesially helpful for investigations of submerged bodies. All these aspects give grounds to consider the ultrasonic system as a recommendable technical solution for successful manoeuvring tests with free-running ship models.

5. ACKNOWLEDGEMENTS

The authors of the present paper avail themselves of the opportunity to express their gratitude to Prof. Dr. T.Penkov, Dr. H.Dimitrov and the staff of thr Naval Academy, Varna who assisted the collaborators of BSHC Departments "Measuring Equipment" and "Manoeuvring and Seakeeping" in the design and utilization of the ultrasonic system "Trajectory", which proved to be an efficient experimental facility. We have the great pleasure to notice the cooperation with the Norwegian Hydrodynamic Laboratories and especially the collaboration of Mr. Tore Flobakk during the development of the preliminary version of the programme modules for data acquisition.

6. REFERENCES

1. 15th International Towing Tank Conference, Proceedings, Volume 1, The Hague, The Netherlands, September 1978.
2. 16th International Towing Tank Conference, Proceedings, Volume 1, Leningrad, the USSR, September 1981.

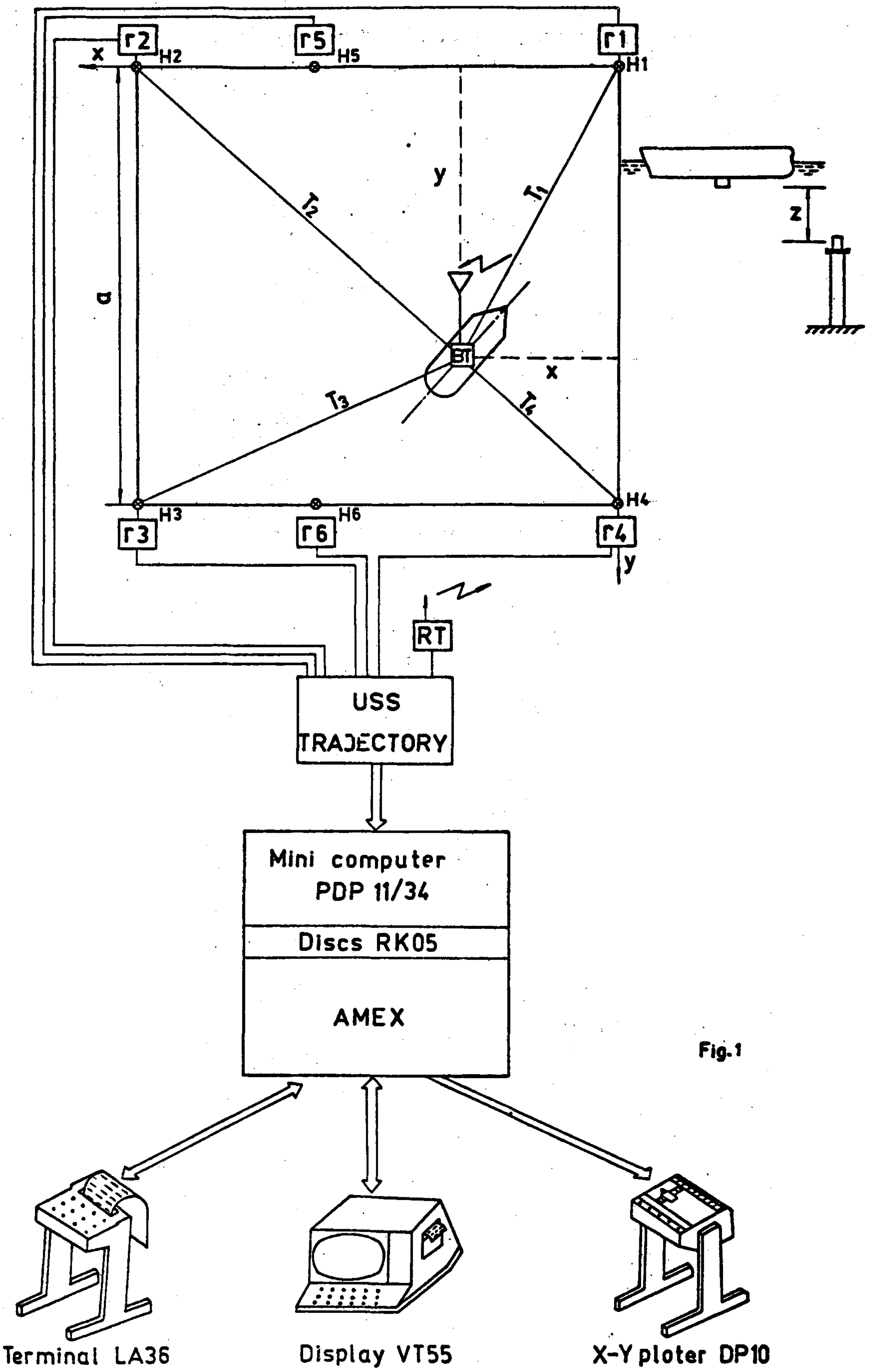
r2
r5
r1
x
H2
H5
H1
y
a
T2
T1
BT
x
T3
T4
z
H3
H6
H4
r3
r6
r4
y
RT
USS
TRAJECTORY
Mini computer
PDP 11/34
Discs RK05
AMEX
Terminal LA36
Display VT55
X-Y ploter DP10

Fig.1

3. Penkov T., Tchotoukov V., Dobrev D., "Ship Model Trajectory Registration by means of Supersound Method at BSHC", Shipbuilding & Shipping, Vol. 4, April 1980, Varna.
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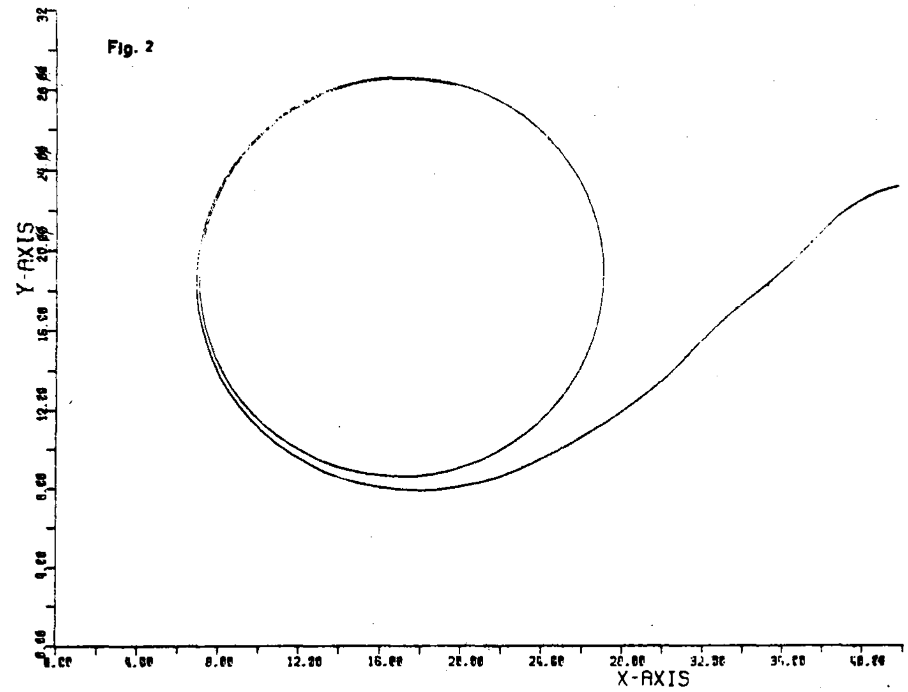


Fig. 2

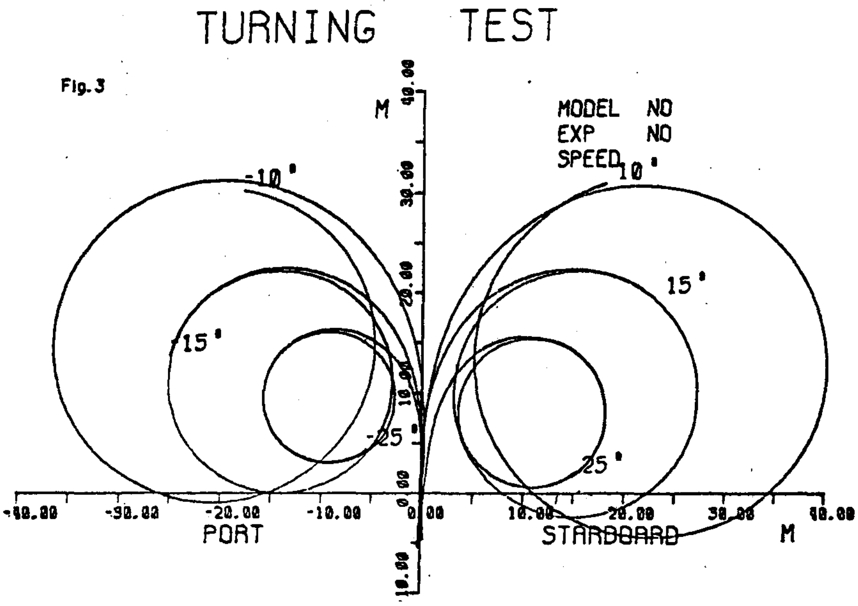


Fig. 3

TURNING TEST

Fig. 4

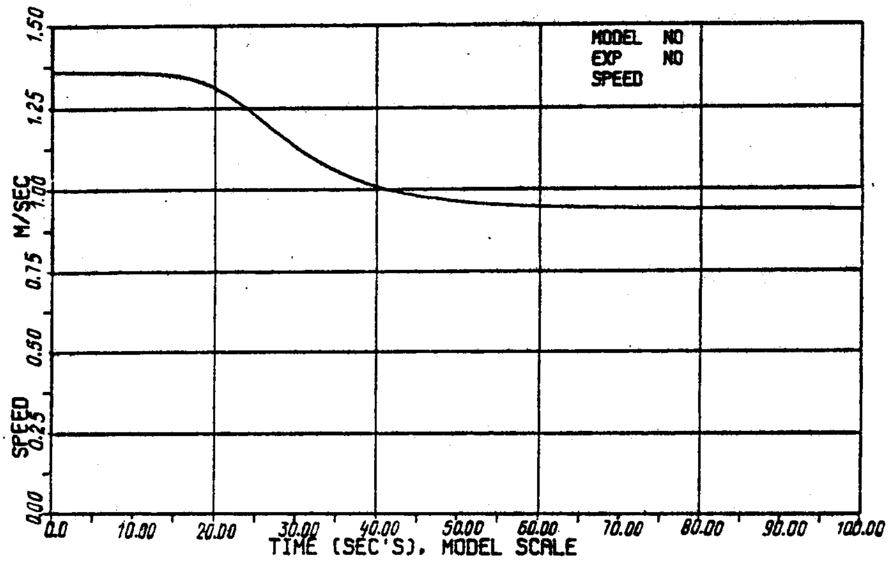
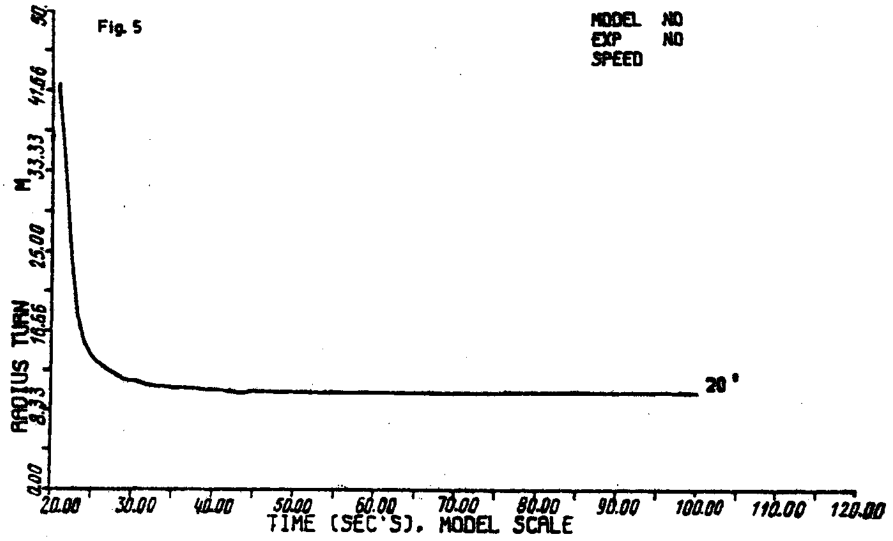


Fig. 5



W.C.WEBSTER, J.V.WEHAUSEN - University of California, Berkeley, USA

We would like to point out that the Committee's report appears to dismiss the use of impulse methods. At the University of California, Berkeley we have done considerable research in this area and we feel that the Committee's summary underestimates the usefulness and efficiency of this approach. The research was just reported in a paper by ourselves and thus presented at the 1976 Symposium on Naval Hydrodynamics in London, and later formed the foundation for U.C. Berkeley doctoral theses by C.Scragg and D.Loeser. Summaries of this work have appeared or will appear in the JSR. This research included successful application of the impulse method in both deep and shallow water. The results of small-scale experiments agree rather well with those obtained by Fujino.

Finally, we note that use of the impulse theory does not require generation of Dirac delta functions or even approximations thereof. A complete theory for an arbitrary motions history extending over a finite time has been developed. Our experience shows that just a few tests (3 or 4) are sufficient to obtain the complete frequency dependence of the stability derivatives, including the values at zero frequency. This latter result requires a somewhat more involved analysis of the data.

A.BAQUERO - EL PARDO TANK, Madrid, Spain

I want only to point out one fact that is related to the recommendation number 1 of the Committee. Recent maritime disasters involving manoeuvring qualities of large tankers have encouraged the need for a closer survey of inherent manoeuvrability of ships, mainly of tankers. At the Inter-Governmental Maritime Consultative Organization (IMCO) one of the tasks of the Sub-Committee of Ship Design is to study the possibility of establishing rules concerning minimum standards for manoeuvrability properties. As far as I know IMCO has not yet arrived at an agreement but if the discussions come to an end and regulations are proposed, the consequences will be of a major importance to ship designers. Meanwhile, it appears, in my opinion, to be convenient that ITTC, through the Manoeuvrability Committee, suggests that the Member Organizations work in this field and submit data or proposals about the minimum acceptable values of parameters recognized as representative of manoeuvring qualities, such as turning diameter, advance, width of hysteresis loop, Norrbin P number, etc. in order to elaborate a rough recommendation from this organization to help the compliance with future governmental manoeuvrability requirements.

II. REPLY OF THE MANOEUVRABILITY COMMITTEE

The Manoeuvrability Committee would like to express their thanks to all the delegates who took part in the discussion of the Committee Report.

Dr. Yamanouchi presented two papers on behalf of *Drs. Hirano* and *Takashima.* The first paper described a very interesting method for calculating the manoeuvring motion of a ship. In the second paper the proposed method is considered to be very useful for analysing the turning trajectory of a ship in regular waves. It is pointed out that the manoeuvrability of a ship in waves should be studied as an important subject in ship handling. It has been recognised by the Manoeuvrability Committee that a prediction method for manoeuvring motion in waves should be established, not only including the deformation of manoeuvring trajectory during a harbour transit but also the coupling motion with roll in a severe seaway. However, the estimation of the wave drifting force acting on a ship or a floating body in oblique waves is difficult to calculate theoretically, and is also difficult to measure experimentally with sufficient accuracy. The problem of predicting the wave drifting force is also concerned with both the Seakeeping and Ocean Engineering Committees. Future co-operative work on this problem is necessary and efforts to accumulate data relevant to the drifting force of a ship in oblique waves should be encouraged.

In reply to *Dr. Tamura,* the Committee has been aware that there is a close relationship between the "unusual phenomena" occurring in manoeuvring model tests and the "unstable flow phenomena" occurring in self-propulsion tests. Certainly, the fact has been reported that the unusual phenomena mainly occur in the full load condition and on the contrary, that the unstable flow occurs in the ballast condition. Therefore, there may be some differences between them, though the cause of both phenomena are supposed to be due to an asymmetrical separation of flow at the stern. As shown in Fig. 18 of the Committee Report, the unusual hydrodynamic turning moments show some complicated changes which depend on a slight change in fullness of the afterbody, loading condition, position of propeller and rudder angle. Accordingly, it may be seen that the change of the flow around stern, due to rudder action, appears in the characteristics of manoeuvring motion, such as the spiral curve. A joint study of these phenomena by both Performance and Manoeuvrability Committee should be continued.

The collection of model and full-scale data and the establishment of a ship-model correlation technique is a most important subject in the prediction of manoeuvrability of a full-scale ship from model tests. *Dr. Nikolaev* presented some valuable results from his studies of the nature of scale effect in manoeuvring tests. He emphasized the importance of comparative tests of scale effects using the data of Esso Osaka full-scale measurements, which is recommended by the Manoeuvrability Committee.

Prof. Nakato introduced a contribution from *Dr. Kijima,* who has shown some interesting analytical results concerning the hydrodynamic interactions between two ships during meeting and passing situations. He employed the method af matched asymptotic expansions originally proposed by Yeung, Reference [94] of the Committee Report. The results shown in that paper provide a useful basis for further computer simulation studies, under meeting and passing conditions. By utilising hydrodynamic interaction data obtained experimentally at DTNSRDC, a series of computer simulation runs were made to examine ship dynamic behaviour under meeting and passing conditions in a channel. This study was covered in the Committee Report. Dr.Kijima has stated in his contribution that he carries out both calculations and experiments to determine hydrodynamic interactions. The Committee look forward to see his comparisons between computations and test results in the near future.

Dr. Matsumoto and *Dr Suemitsu* have shown some very interesting results of theoretical calculations on hydrodynamic forces, together with experimental data. In their calculations, they employed the slender body theory originally proposed by Fuwa and later simplified by Inoue and Kijima. In their experiments, they utilised segmented ship models to determine longitudinal distributions of hydrodynamic side-force. Results indicate encouraging correlations between calculations and experimental results. The Committee feel that this work is certainly an important contribution to the current state of the art in this area.

Another contribution concerned with the calculation of hydrodynamic forces was presented by *Dr. Wang* on behalf of the author *Dr. Sheng*. Based on a strip theory, the author has shown some interesting results of hydrodynamic derivative calculations, which indicate significant changes in the magnitude of those derivatives, with change in water depth. The changes with water depth show similar tendencies to those of experimental results in the published literature using tanker and cargo- ship configurations. It is noticed in the figures that the differences between the calculations and the experimental results are more pronounced in extremely shallow water depths than at the medium water depths. This is thought to be due to more pronounced tree-dimensional effects in very shallow water, which are not considered in the simplified strip theory. These effects are usually more pronounced at the stern end of the ship.

The contribution by *Prof. Aertssen* can be related to ship manoeuvring problems in the broadest sense, since the author includes a minimum draught forward,as one of the ship characteristics being controlled. The minimum forward draught influences the ship's ability to keep course in a seaway, but at the same time, a decrease in ship speed or a change in the desired course may be required, because these conditions determine the level of ship motions, slamming and propeller racing. On the basis of full-scale trials, the author proposes the IMCO regulations for segregated ballast tankers to be a basis of minimum draught for all ships. The discussion by Prof. Aertssen is extremely interesting and is welcomed by the Committee. It is noted that the author's conclusions are in good agreement with the Committee's recommendations.

The contribution by *Dr. Puls* presents information regarding investigations into the calculation of ship trajectories in collision situations. The author supposes that the path and position of a manoeuvring ship can be determined from the solution of the linearised equations of ship motion. In order to calculate the steered motion of a ship, information on resistance and thrust variations is also necessary. For this purpose the author uses an estimation of the resistance due to boundary-layer separation in the stern region of a ship. The method has been used to calculate values which determine the possibility of ship collision; as well as the decrease of speed, advance and transverse offset. The Committee members agree with Dr.Puls' idea, relevent to the very complicated problem of developing methods for the determination of forces acting on manoeuvring ships, which is in accordance with the Committee Recomendations.

The Committee was very glad to have the comments of *Dr. Norrbin.* His suggestions regarding an ITTC observer being present in the IMCO group dealing with ship manoeuvring is endorsed by the Committee. Although this may be a matter for delegates to take up with their respective national government agencies represented at IMCO. The introduction of speed limits can certainly be dangerous in some circumstances, if no regard is paid to ship type or conditions of wind and current. Dr. Norrbin implies that a predictor fitted onboard, which includes the effects of the actual wind and tide disturbances would certainly be superior to a standard manoeuvring diagram. However, such a predictor also represents a considerably higher level of cost and technical complexity than used in current navigational instrumentation.

The details of the ultra-sonic tracking system described by *Dr. Bogdanov* are noted with interest and should certainly be included in the list of new facilities and instrumentation. The question of the relative accuracies of optical and ultrasonic systems mentioned, is no doubt a subject open to debate.

Dr. Webster and *Prof. Wehausen* questioned the attitude of the Committee towards the use of the pulse response method, covered in the section on System Identification. This section of the report was intended as an overview of the whole topic of system identification, bringing together all the different techniques in an introductory manner. The Committee regrets the omission of the work of Scragg, concerning the use of impulse response techniques for the determination of manoeuvring derivatives. However they would point out that this work was covered in the Report of the 15th ITTC Manoeuvrability Committee in 1978 in The Hague (page 143).

Dr. Baquero also pointed out the need for the Manoeuvrability Committee to attempt to influence the thoughts of the legislative bodies such as IMCO. The Committee agree wholeheartedly that they may be able to contribute significantly to the establishment of tentative manoeuvring criteria, which may in turn influence future legislation.