SESSION ON SEAKEEPING

Chairman: Mr. J.C. Dern

Seakeeping Committee memberships: M. Ohkusu (Chairman) - A.R.J.M. Lloyd (Secretary) - K.J. Bai - J.C. Dern (to September 1988) - T.O. Karppinen - T.A. Loukakis - J.F. O'Dea - D. Puls - S.G. Tan.

Discussion of the Report and the Draft Recommendations of the Seakeeping Committee (Cf. Proceedings, Volume 1, pp. 429-477).

I. DISCUSSIONS

SK-1

I. WATANABE
Ship Research Institute, Tokyo, Japan

REMARKS ON INFLUENCE OF BOW FLARE FORM ON DECK WETNESS

1. INTRODUCTION

In the Section 12 titled INFLUENCE OF ABOVE WATER HULL FORM ON SEAKEEPING, page 453 of the vol.1, 19th ITTC report, Our experiment[1] has been referred with the commitees's remark which expresses difficulty to interpret our conclusion that "in spite of larger rms of relative bow motion for the original hull form, the deck wetness is more frequent on the increased bow flare form." The discusser as one of the authors feels necessary to elaborate our points a little more to get the committee better view of our conclusions.

There have been discussions on how the bow flare form influences seakeeping characteristics of ships. It is generally accepted that the influence on deck wetness and vertical bending moment is most important. Studies done by O'dea[2] and Lloyd et al.[3] have presented us with opposite conclusions on the effects of the bow flare on the deck wetness of destroyer type ships. We are not given with clear conclusion whether a ship with incrased bow flare is more frequent or less frequent in deck wetness. Nor is it clear how the effect works for merchant ships form their experiment since their destroyer have considerably finer hull form than conventional high speed merchant ships.

These were our backgrounds when we started model experiments using an elastic model of a container ship both with original and with increased bow flares. The model ship has S–175 hull form. The body plans are shown in Fig.1 with solid lines for the original model (O–model) and with dashed lines for the increased bow model(M–model). The flare angle (δ), a parameters which characterizes flare part[3] is δ=45*deg* for the O–model and 50*deg* for the M–model. The experiment was done as part of the ITTC comparative experiment on deck wetness. The test conditions were in conformity with the specification by the committee except for running speeds. Only lower speed cases were tested because of the restriction of our wave basin. Only free running model test was done. Tested waves were irregular waves with the ITTC spectrum as specified by the committee. The deck wetness and the vertical wave bending moments were the main measuring items of the experiment. Followings are some of tested features on relative bow motion, deck wetness and vertical wave bending moments seen in our experiment.

2. DISTRIBUTION OF RELATIVE MOTION AMPLITUDES

Relative bow motions were measured using capacitance–type wire gauges placed at several locations in the bow region. The gauges had been made sure to have enough sensor length even in cases of bottom emergence and deck submergence. Fig.2 shows histograms of peak amplitudes of the relative motion at FP for several Froude numbers in head sea condition. The amplitudes were measured from the LWL not from the mean line of the time history. From these results, it is clear that the amplitudes of the M–model are distributed dense in region around 0,06L, which is approximately freeboard height at the bow (0.054L). They are distributed not like the Rayleigh distribution which has been shown in shaded columns in the figure. On the other hand, those of the O–model

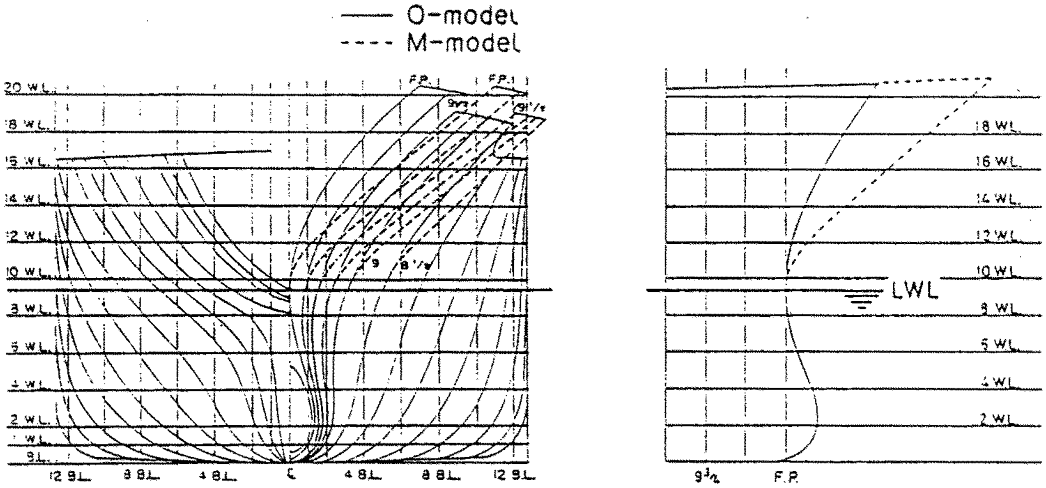

Fig.1 Body Plan of Models

are closer to the Rayleigh distribution. Detailed examination of the distributions revealed that the M-model has larger portion of peak amplitudes exceeding the freeboard than the O-model in spite of the smaller variance for the M-model. This explains why the smaller rms of the M-model leads to more frequent deck wetness.

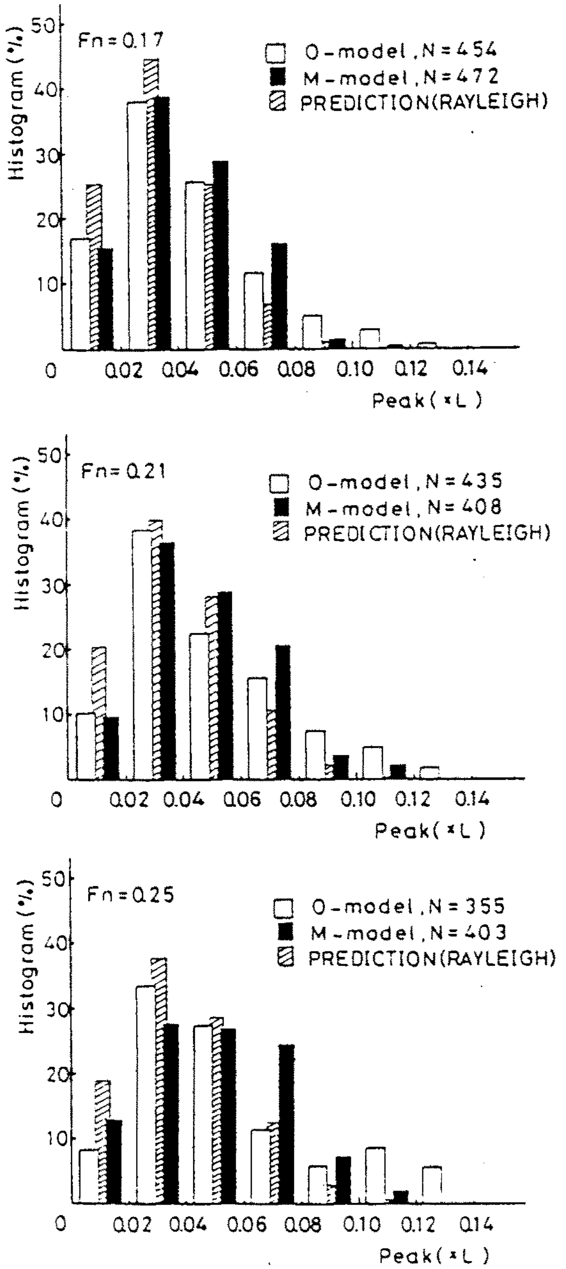

Fig.2 Histogram of Peak Amplituide of Relative Motion at FP

The distribution of the relative motion of the M-model is deviated from the Rayleigh distribution especially in higher speed regime while that of the O-model follows the theoretical distribution rather well. Since there is no significant difference in ship motions as far as pitching and vertical bow acceleration of both models are concerned, the deviation has to come from disturbed wave form in nonlinear manner, it may be said that the deviation is caused by presence of larger flare form of the M-model. The bow flare seems to act as to flatten higher amplitudes and heighten lower amplitudes according to these figures.

The relative bow motion shows significant wave height dependence in relative bow motion vary in regular waves with different wave heights. By symbols experimented results are shown and by a curve estimation by linear strip theory is drawn. On top the lowest wave height case is shown and higher wave height cases are arranged in sequal. It is clear that the amplitudes in larger wave heights deviate from the linear estimation and those of the M-model deviates more than the others. The discrepancy may be attributed to the bow and wave interaction since vertical motions like pitching and heaving were found to be insensitive to the variation of bow flare forms treated here.

These results imply that we have to put more efforts to studies on the bow and incoming wave interaction in order to make more accurate estimation of relative bow motion and related phenomena in bow region.

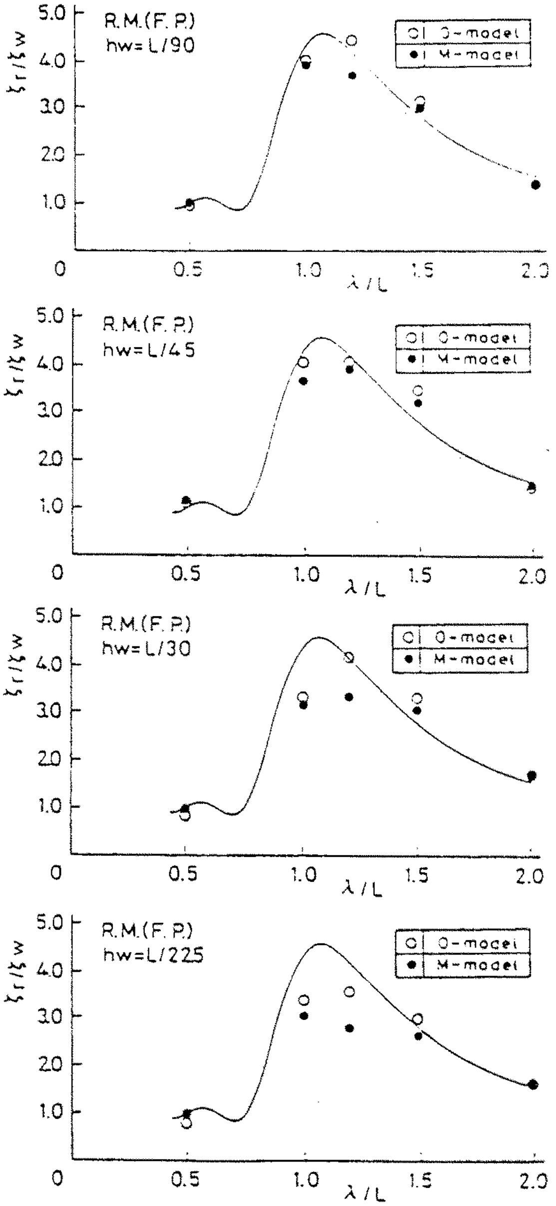

Fig.3 Amplitude of relative bow motion with diferrent wave heights

3. DECK WETNESS

We had used three different kinds of measurements to know deck wetness.

- Instances when relative motion exceeds the bow deck side have been counted as an index of deck wetness.
- A pressure gauge was placed upward at the FP center on the deck so as to sense impact or variation of water pressure due to flooding water on the deck.
- We have also observed deck wetness by a video camera onboard.

Through these three means we could define frequency and intensity of deck wetness. Fig.4 shows deck wetness frequencies derived through these three means. It is clear that the M-model experiences more frequent deck wetness than the O-model as far as the relative motion analysis and video observation are concerned. But from deck pressure records it is apparent that the M-model is less frequent in deck wetness. According to the distribution of relative bow motion, the frequency of the peak amplitudes exceeding the freeboard (0,054L) is larger for the M-model than for the O-model. But the amplitudes of the M-model are distributed around the amplitude of just above the freeboard height and they are seldom to have enough energy to run through the pressure gauge. This tendency had been confirmed by observations by the video camera.

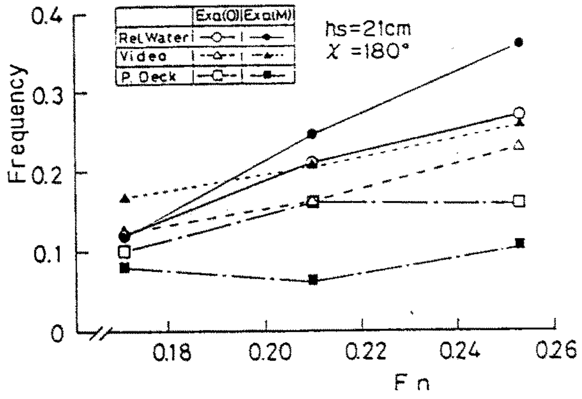

Fig.4 Frequency of Deck Wetness vs. Forward Speed

4. ASYMMETRY OF VERTICAL WAVE BENDING MOMENT

Another interesting problem related to the bow flare form is effect on asymmetric components of vertical wave bending moment provoked by it. Fig.5 shows typical example of the vertical bending moment time histories taken from the present elastic model. The M-model experiences larger offset and higher order component of the bending moment in addition to whipping moment. They amount to such extent as to be equal to 30 or 40 percent of the amplitudes. The authors have developed a theoretical method to estimate these nonlinear components excluding whipping component, based upon strip theory[4]. Fig.6 shows how well the present method can estimate experimented linear and nonlinear components excluding whipping component of the vertical bending moments in regular wave. The calculation shows a good agreement with the experimented results. Further studies would increase accuracy of the prediction of this important information on wave loads.

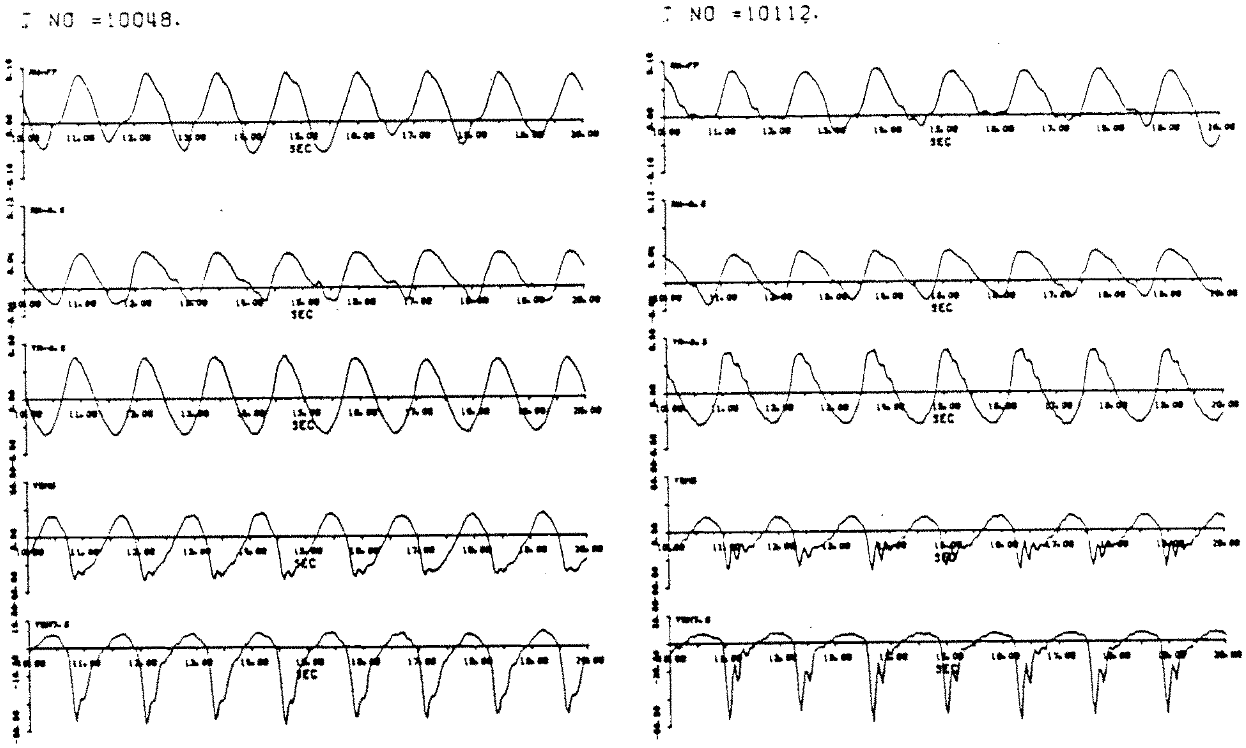

Fig.5 Time Histories of Vertical Wave Bending Moment

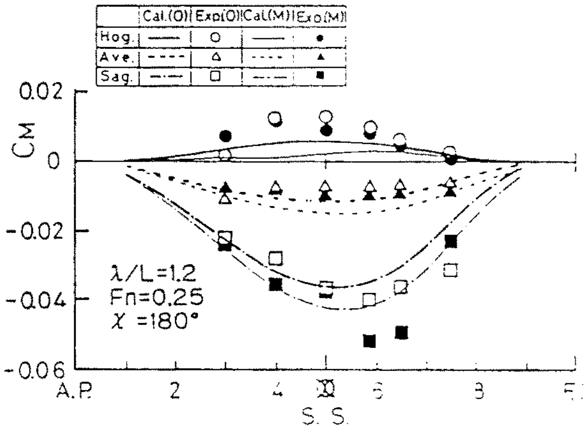

Fig.6 Distribution of Amplitude of VWBM in Regular Wave.

5. CONCLUSION

According to our experiment, the increased bow flare form reduces relative bow motion and serious deck wetness. It was also found that the increased bow may deform incoming wave profile considerably. The increased bow also increases vertical bending moment.

It is nor our intention that the flare effects seen in this experiment are universal. Rather the discusser wishes to stress importance of examining individual bow forms both experimentally and theoretically before any conclusive formula could be drawn on the relation between bow form and deck wetness or wave loads. For that end, it is urgent to develop theoretical studies on nonlinear wave and ship hull interaction in the bow region. The discusser feels these point should be added to the committee's comment that "careful and systematic investigations on the effect of above water hull form must be continued".

References

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SK-2

S.W. HONG and S.Y. HONG
Korea Research Institute of Ships and Ocean Engineering, Daejeon, Korea

ON THE CORRELATION BETWEEN THE MEASURED DECK WETNESS AND THE MEASURED RELATIVE MOTION

We have participated in the collaborative experiments on rarely occuring events.

We would like to discuss the conclusion drawn in pp438 just below Fig.3.5 about the correlation between the measured wetness and the measured relative motions.

We have investigated the correlation between the measured deck wetness and the measured relative motion, from the results of our experiment with a 1/43.75 S-175 model. Deck wettings were measured by two capacitance type depth probes installed on the centerline of the deck at F.P. and 0.1 L_{pp} abaft F.P., respectively. The signals which exceed the 10% of the sensing area were counted as deckwettings. Six sets of wave signals with same statistics were used to present the repeating of the waves during the measurements. Measured wave statistics are shown in Table 1. All the waves satisfied the given wave condition[1] within 5 percent relative errors. For each set of wave signals four or five runs were executed for F_n=0.275, and two runs for F_n=0.15. Table 2 shows the record length corresponding to each set of waves. The measured relative motion at the stemhead, the absolute vertical

Table 1 Measured Wave Statistics

Wave	SP1	SP2	SP3	SP4	SP5	SP6	Average	Nominal
$rms^{\bullet}$	1.99	2.01	1.88	2.05	2.00	2.01	1.99	1.97
$H^{\bullet}_{1/3}$	7.81	7.57	7.35	7.75	7.67	7.67	7.64	-
$T^{\bullet}_z$	11.52	11.52	11.20	11.56	10.88	11.48	11.36	-
N_z	142	141	147	141	181	169	-	
$H^{*}_{1/3}$	7.94	7.88	7.52	8.04	8.01	7.85	7.87	7.88
T^{*}_z	11.20	11.08	10.74	10.81	10.63	10.73	10.87	10.50

$\bullet$: Superscript $^{\bullet}$ denotes the zero-upcrossing method.
$*$: Superscript * denotes the FFT method.
$H_{1/3}$: Significant wave height in meter
T_z : Mean zero-upcrossing period in second
N_z : Number of upcrossings

Table 2 Record Length Accoring to Wave Spectrum

	No. of RUNs	
Wave	F_n=0.275	F_n=0.15
SP1	4	1.5
SP2	5	2
SP3	4	2
SP4	4	2
SP5	4	2
SP6	4	2
Time / RUN (Ship Scale)	5.65 min.	11.29 min.
Total Record Length	141 min.	107.3 min.

motion at F.P. and the measured number of deck wetness at F.P. are presented in Table 3.

Table 3 Measured Motions and Deck Wetness

F_n	Items	SP1	SP2	SP3	SP4	SP5	SP6	Average
0.275	ζ_r	6.14	6.09	5.67	5.79	5.53	5.77	5.83
	Z_a	4.53	4.52	4.17	4.28	4.11	4.24	4.32
	N_W	111.6	110.6	82.4	98.3	79.7	90.4	95.5
0.15	ζ_r	5.15	5.15	5.12	5.33	5.08	-	5.17
	Z_a	4.01	4.01	3.90	4.02	3.91	-	3.96
	N_W	29.2	31.9	34.5	26.6	39.9	-	32.42

ζ_r : rms value of relative motion at stemhead in meter
Z_a : rms value of vertical motion at F.P. in meter
N_W : number of deck wetness per hour at F.P.

Two methods were adopted to analyze the correlation between the measured relative motion and the measured deck wetness.

The first one estimates the correlation coefficient by the following formula:

$$\rho_{xy}=\frac{C_{xy}}{\sigma_x\sigma_y}$$

ρ_{xy} : correlation coefficients between x and y
C_{xy} : covariance of x and y
σ_x : standard deviation of x
σ_y : standard deviation of y
x, y: random variables such as relative motion and deck wetness.

The estimated correlation coefficients are 0.964 for F_n=0.275 and −0.78 for F_n=0.15. The results for F_n=0.275 shows that there is a good correlation between the measured deck wetness and the measured relative motion. While the results for F_n=0.15 shows somewhat negative correlation.

The second one analyzes the correlation by comparing the measured deck wetness with the calculated one using the measured relative motion at stemhead by Ochi's formula.

$$N_w=\frac{3600}{2\pi}\sqrt{\frac{m_2}{m_0}}\exp\left(-\frac{F^2}{2m_0}\right)$$

N_w : number of deck wetness per hour
m_n : n–th moment of the measured relative motion spectrum (n=0,2)
F : effective free board

The results of comparison of the measured deck wetness and the estimated deck wetness are shown in Table 4 and in Figure 1. The measured and estimated deck wetnesses show good agreement within 5 percent relative error for F_n=0.275, which confirms the results of the first method. However, for F_n=0.15, the estimated deck wetness is higher than the measured value by roughly twice.

Table 4 Comparison of Measured Deck Wetness and the Estimated Deck Wetnesses

F_n	Items	SP1	SP2	SP3	SP4	SP5	SP6	Average
0.275	N_W	111.6	110.6	82.4	98.3	79.7	90.4	95.5
	N_W^*	112.0	105.8	90.8	97.8	78.7	96.7	97.0
0.15	N_W	29.2	31.9	34.5	26.6	39.9	-	32.4
	N_W^*	67.7	70.55	66.08	70.03	61.53	-	67.2

N_W : measured number of deck wetness per hour at F.P.
N_W^* : calculated number of deck wetness per hour at F.P.

Our results implies that there is a good correlation for F_n=0,275, but, the correlation is not clear for F_n=0.15. This can be explained by the correlation between the freeboard exceedance and the deck wetting. For F_n=0.275, most of the freeboard exceedance resulted in deck wettings, while for F_n=0.15, the freeboard exceedance did not always result in the deck wettings. The correlation between the deck wetness and the measured relative motion varies with the factors such as, bow shape, ship speed, and sea state.

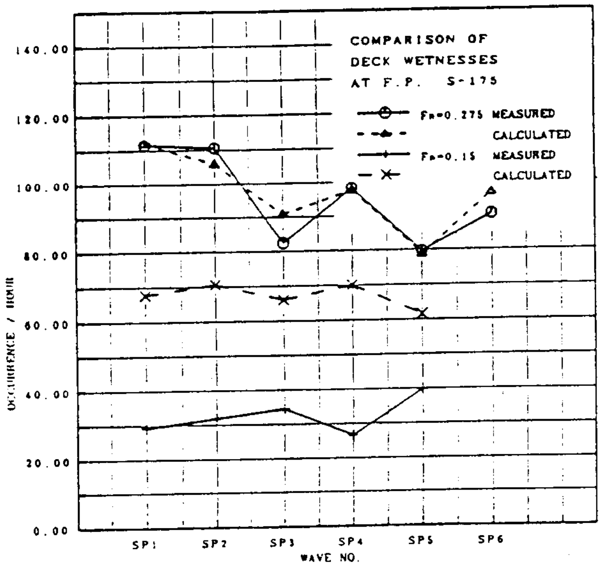

Figure 1 Comparison of the measured deck wetness and the estimated deck wetness at F.P.

The bow shape of the ship has been known as the most important factor that affects the deck wetness by many researchers. However, there is no clear tendancy between the results as pointed by Lloyd[2]. The efficiency of bow shape varies with sea state and ship speed.For a given bow shape, as the sea condition becomes more severe the relative motion and the correlation increase. In other words, freeboard exceedance results in the deck wettings as the sea condition becomes worse. The efficiency of the bow shape is degraded in very rough sea conditions and there may be a threshold sea condition for a given bow shape and ship speed.

For the same reason, given a bow shape and a sea condition, we can deduce that there exists a threshold ship speed.

We can not conclude hastily whether there is a good correlation between the relative motion and the deck wetness or not. The correlation depends on the bow shape, sea condition and ship speed.

To understand the deck wetness phenomena thoroughly, the systematic experimental study is needed for various bow shapes, sea conditions and ship speeds.

References

[1] "Report of the Seakeeping Committee", Proceedings of the 19th ITTC, Vol.1, 1990.

[2] Lloyd, A.R.J.M., Salsich, J.O. and Zseleczky, J.J., "The effect of Bow Shape on Deck Wetness in Head Sea", Transaction of RINA, Vol.128, 1986.

[3] "Report of the Seakeeping Committee", Proceedings of the 16th ITTC, Vol.1, 1981.

[4] Hong, S.Y., et al.: "Experimental Study on the Deck Wettings of a Container Ship in Irregular Head Waves", Journal of the Society of Naval Architects of Korea, Vol.27, No. 2, June 1990. (In Korean).

SK-3

D.J. YUM and Y.R. CHOI

Hyundai Maritime Research Institute, Ulsan, Korea

ON THE ESTIMATION OF DECKWETNESS FREQUENCIES FROM EXPERIMENT

With regard to the Ch. 3 of the Seakeeping Committee Report which describes the ITTC comparative experiment on rarely occurring events, the following discussion describes briefly the theoretical approach for the estimation of deckwetness frequency from experimental data using the Poisson random process.

Let N(t) denote the number of events occurring in a time interval 0 to t. The counting process N(t) is called Poisson process when it satisfies following conditions[1]:

1. For t > 0, the simultaneous occurrence of events is not possible.
2. The occurrence of event in the future is unaffected by past occurrence (Independent Increments).
3. The distribution of the number of occurrences of the events depends only on the length of the time (Stationary Increments).

The Poisson probability density function has the following form.

$$P(N(t)=k)=e^{-\nu T}\frac{(\nu T)^k}{k!}=e^{-\lambda}\frac{\lambda^k}{k!} \qquad (1)$$

where k is integer, ν is the mean rate of occurrence of the events per unit time and λ is the expected number of occurrences of the events in time T.

In the field of naval hydrodynamics, the slamming and deckwetness phenomena are known to be the typical examples of the Poisson process even though there exist some degrees of grouping effects in the frequencies of occurrings depending on the narrow bandedness and the severity of the excitations and the responses[2]. In order to confirm this aspect, comparison was made between the measurement results of participant No. 3 of the ITTC comparative experiment and those of theory in Figure 1. The expected(mean) value of deckwetness, λ, used for the Poisson distribution curve was 8.88.

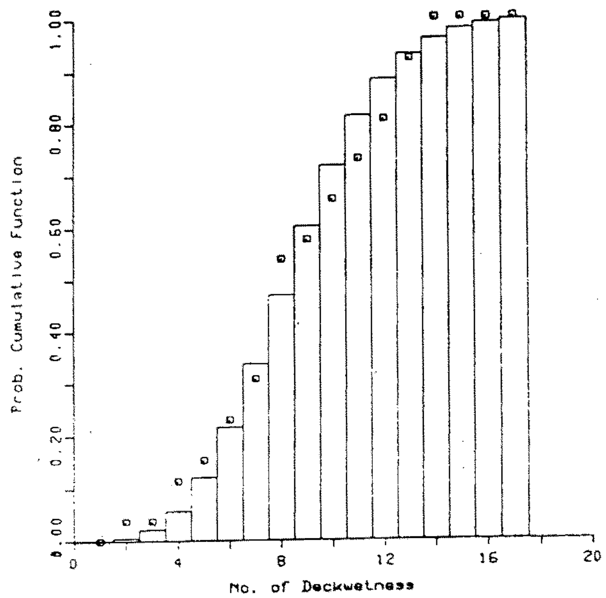

Fig. 1. Prob. Cumulative Fn. for No. of Deckwetness in 40 Sec. (Participant No. 3)

This value was obtained from the mean value of number of wettings shown in Table 3.6 in the Committee's report[3]. Good agreement can be seen between the theoretical and experimental results. Ochi[4] also showed that the Poisson process could be used for the deckwetness phenomenon.

Once the deckwetness phenomenon is considered to have Poisson process, the following important property can be used for further analysis. The length of time, t_k, from the start of observations to the occurrence of the k–th deckwetness is a random process obeying gamma distribution[4],

$$P(t_k)=\frac{\nu^k}{\Gamma(k)}t_k^{k-1}e^{-\nu t_k},\quad 0\le t_k<\infty \qquad (2)$$

Figure 2 shows the typical example of probability distribution function $P(t_k)$ when ν and k are 0.222 and 200 respectively. The 95% confidence interval of the time duration is designated as $t:_{0,025}$ and $t:_{0,975}$ in this figures. If we nondimensionalize the results using the notation used in the Committee's report, the curve of 95% confidence interval of mean deckwetness frequency can be obtained varying nondimensionalized test duration ($N_R L_T/L_{BP}$). In Figure 3, the 95% confidence intervals are given for three values of estimated mean deckwetness frequencies, that is, Nw=0.2413, 0.482 and 0.9652. This Figure also shows the running mean nondimensional deckwetness frequency of participant No. 3. The measurement results show good agreement to the theoretically obtained 95% confidence intervals until the value of 300 in nondimensional test duration. The discrepancies after this value mainly come from the limitation of test run number. Two broken lines representing 1.1 and 0.9 time of the estimated mean are well within both bound even when the nondimensional test duration is 500 or more. This result means that the nondimensional test duration required to obtain reasonably reliable estimate of deckwetness frequency is much larger than the value recommended by the Committee.

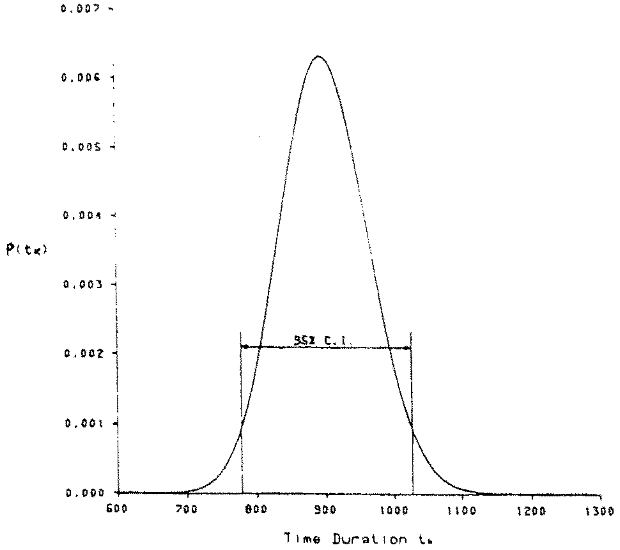

Fig. 2. Gamma Distribution Fn. $P(t_k)$ and 95% Confidence Interval

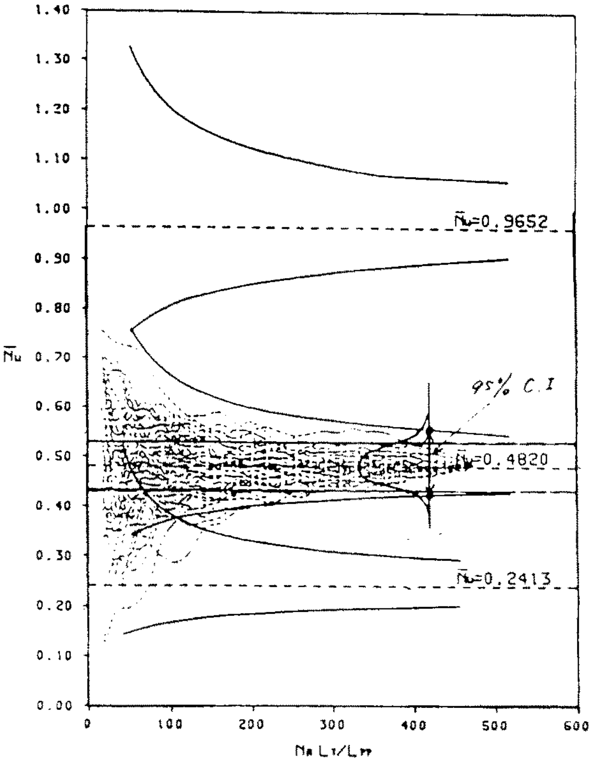

Fig. 3. Mean Nondimensional Deckwetness Frequencies and 95% Confidence Intervals

From the above considerations, the following conclusions can be obtained. Firstly, the deckwetness phenomenon can be theoretically investigated using the Poisson process. Secondly, the Committee's recommendation for the test duration of rarely occurring event need to be reconsidered until further research results are manifested for this topic.

References

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[3] Seakeeping Committee Report of 19th ITTC, 1990.

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SK-4

J. LUNDGREN
SSPA, Gothembourg, Sweden

DISCUSSION OF REPORT OF THE SEAKEEPING COMMITTEE

Chapter 3, dealing with rarely occurring events such as deck wetness and slamming, is very interesting. The members of the ITTC were asked to carry out experiments to measure deck wetness in irregular head waves on a model of the S–175 container ship.

The results of the test showed that the measured deck wetness frequency varied very much between the different organizations.

The results also showed that it is necessary to run the tests for at least one hour in full scale time for conventional ships at conventional speeds to obtain reliable results.

At the tests the absolute motions and the relative motions at the bow were also measured, and the results of the measured rms–values were very consistent.

My question is: Would it not be better to calculate the frequency of deck wetness based on measured rms relative motions than direct measurement of deck wetness, having in mind that only about 15 minutes testing in full scale time gives reliable estimates of the rms–values?

SK–5

S. NAITO and K. TAKAGI
Osaka University, Osaka, Japan

INFLUENCE OF ABOVE WATER HULL FORM ON DECK WETNESS

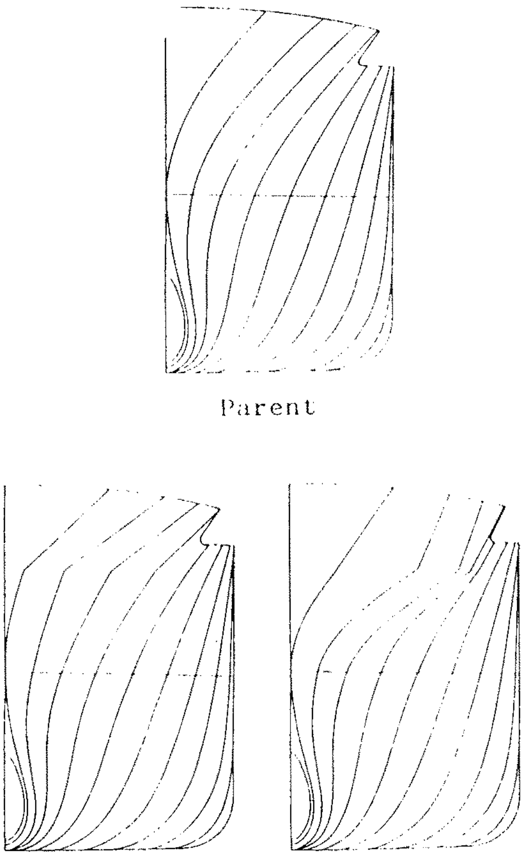
1. INTRODUCTION

The reduction of deck wetness is a one of important requirement for the seakeeping performance and it should be achieved without any loss of the propulsive performance. Thus the solution of the reduction of deck wetness is improvement of the above water hull form. For this purpose, the mutual relation between the above water hull form and deck wetness should be investigated.

Variations of the above hull form may be divided into three groups, the flare with knuckle, the straight flare and the increased flare. Characters of these hull forms are investigated experimentallly and theoretically. The more detailed investigation is necessary for the final conclusions on the problem, however this is a preliminary solution of the mechanism of deck wetness.

2. EXPERIMENTAL APPROACH

Experiments are carried out with three models of which the above water hull form is different as shown in Fig. 1 (Parent is S–175 model.) Measurements of heave motion, pitch motion and the vertical acceleration at FP are performed in regular head waves at $\lambda/L=1.0\sim1.4$, Fn=0.275. The wave steepness H/λ is varied from 0.01 to 0.05. The behaviour of the free water on the deck is recorded with a video camera.



Parent

Type A

Type B

Fig. 1. Body plans

Results are shown in Figures 2 and 3 and show that the effect of the above water hull form on the motion and the acceleration is small. The observed free surface are shown in Fig. 4. The lines in these figures show the front line of the free water. Time interval is 1/30 second. In case of λ/L=1.0, model B experiences much shipping water rising from deck side than that of model A and Parent. After falling down on the deck, the free water flows backward and the longitudinal velocity of it varies with the above water hull form. The order of the longitudinal velocity is: model A~Parent>model B. In cases of λ/L=1.2 and 1.4, phenomenon are almost same as in case of λ/L=1.0. These results show that the difference on deck wetness performance is not obvious. However the behaviour of free water varies with the above water hull form and it can be considered that variation of the form causes the variation of the behaviour of the free water on the deck.

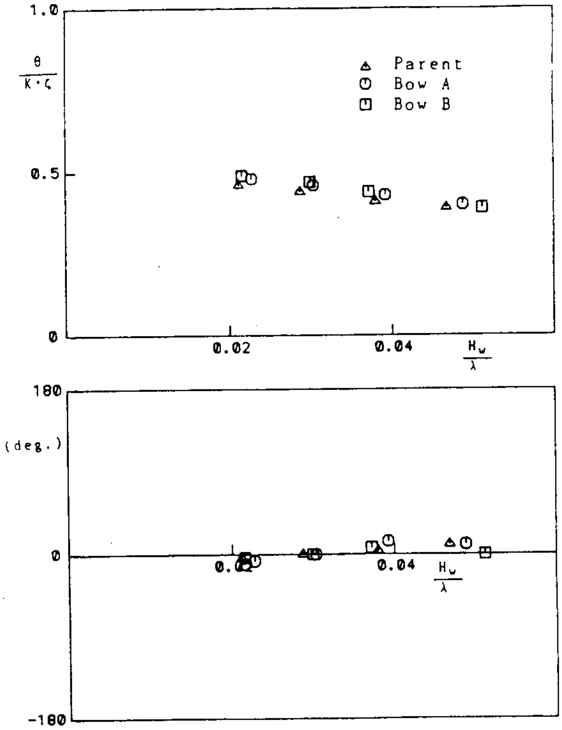


Fig. 2. Pitch amplitude ratio and phase. (Fn=0.275, λ/L=1.0)

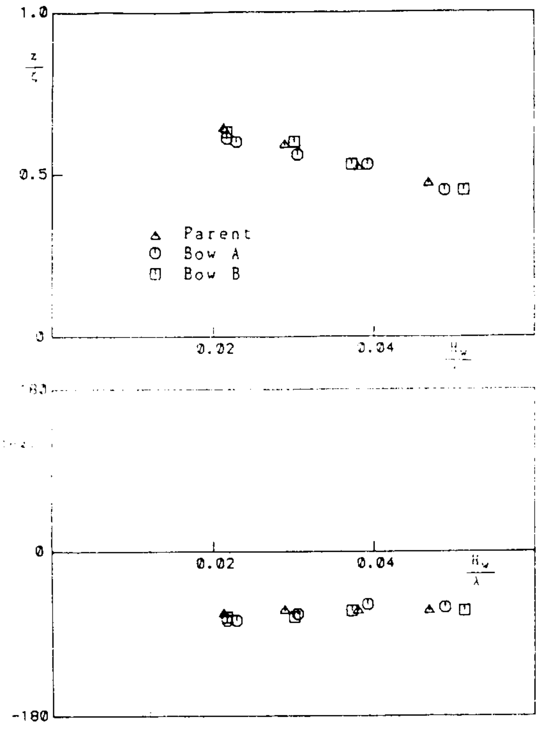
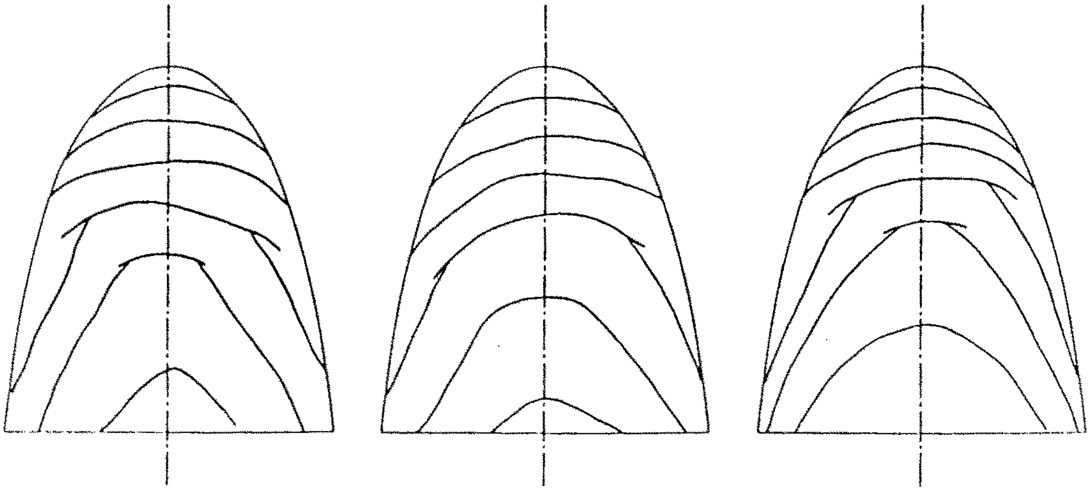


Fig. 3. Heave amplitude ratio and phase. (Fn=0.275, λ/L=1.0)

3. THEORETICAL APPROACH

One of the authors discussed the effect of the above water hull form on deck wetness in a recent paper [1]. The two dimensional self similar flow is applied to the analysis of deck wetness on the assumption of the long wave lenght and high Froude number. Calculated results of the free surface are shown in Fig. 5. It shows that the increased flare type has a better performance that that of the flare with knuckle. This result is similar to the experimental results and the findings of O'Dea and Walden [2].



Type A $\lambda/L=1.0$, $H_w/\lambda=0.049$ Parent $\lambda/L=1.0$, $H_w/\lambda=0.048$ Type B $\lambda/L=1.0$, $H_w/\lambda=0.049$

Fig. 4. Behaviour of the water on the deck. (λ/L=1.0). Time interval is 1/30 sec.)

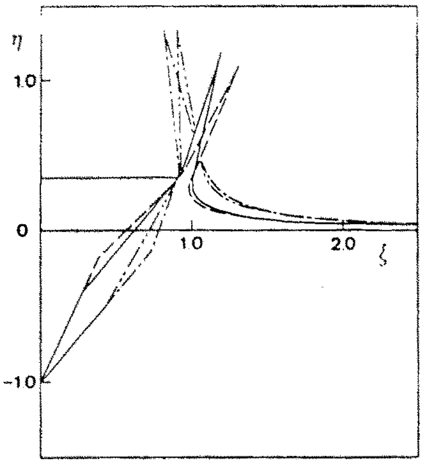


Fig. 5. Free–surface profiles for different body shapes

Reference

[1] Tagaki, K. and Niimi, A.: "A Theoretical Approach to Bow Deck Wetness of a High–Speed Ship", JSR, Vol. 34, No. 3, Sept. 1990.

[2] O'Dea, J.F. and Walden, D.A.: "The Effect of Bow Shape and Nonlinearities on the Deck Wetness ". 15th Symposium on Naval Hydrodynamics, 1984.

SK–6

J.P. HOOFT
Maritime Research Institute Netherlands, The Netherlands

COMMENTS ON THE REPORT OF THE SEAKEEPING COMMITTEE

Assessment of the ship's behaviour in waves

As is indicated in the Report of the Seakeeping Committee two separate items are involved in the judgement of the ship's seakeeping, i.e.:

1. Determination of the ship's behaviour by model tests or full scale trials of calculations.
2. Judgement of the observed ship's behaviour in waves based on available criteria.

In the Report examples of criteria are:

- deck wetness in head seas determined by pitch and heave motions;
- slamming in head seas determined by pitch and heave motions;
- human performance affected for instance by roll motions in mainly beam waves.

In the above shown procedure it is most essential that it will be possible first of all to determine the ship motions in a well defined way.

However, most test results are largely influenced by the method of testing as shown by the following example:
The behaviour of a ship in stern quartering seas is largely influenced by the rudder control for course-keeping. As a result of this aspect it will be quite difficult to compare the test results from various model tanks with each other or to extrapolate them to full scale conditions.

The Seakeeping Committee has paid some attention to this aspect in section 16.2, entitled: "Experimental Uncertainty". However, it would strongly recommend that the next seakeeping committee will devote much more attention to model testing techniques and its influence on the measured ship's behaviour in waves. Therefore I would like to change recommendation 7.4 into:

7.4 Surveys of tests techniques, beach characteristics and methods of uncertainty analysis should be extended. Also the consequences of the experimental techniques on the test results should be considered.

SK-7

G.E. HEARN
Newcastle University, Newcastle-upon-Tyne, U.K.

TANK WALL INFLUENCES, HIGHER ORDER BOUNDARY ELEMENTS, IRREGULAR FREQUENCIES AND SEAKEEPING FOR DESIGN

My comments relate to Sections 2.4 and 11/12 of the report and are presented in that order.

The influence of tanks walls upon radiation heave damping is clearly presented in Fig. 2.1. I would like to report that similar 3D eigenfunction based calculations, undertaken at Newcastle University, confirm the predictions related to the geometries investigated by Kashiwagi et al which were first presented at the Water Waves and Floating Structures Workshop held in Norway in 1989. Furthermore, I can report that second order forces [1] and low frequency damping [2] are equally sensitive to the influence of tank walls. Our studies show that tank wall influence is more significant than the effect of water depth. Whereas motion responses in some degrees of freedom can became independent of other degrees of freedom, because of geometric planes of symmetry in the floating structure, tank induced resonances in one mode may strongly influence the second order forces in directions coincident with the independent motions. For ships this recoupling of influences may be attributed to the dominant relative motions contributions, whereas for offshore barges the dominant influence is the pressure head corrections of the Bernoulli pressure contributions. Following extension of the analysis method the case of a tank with a deep pit may also be investigated. This indicates where first order forces, motion responses and second order forces may or may not be considered consistent with deep water conditions.

Higher order boundary element based 2D fluid–structure interaction analysis, which may be used in strip–theory analysis (section 4.1 of report), indicate that 2 or 3 elements are sufficient to represent any ship section, but greater care is required concerning the "solid angle" weighting used in the integral equation formulation at the free–surface [3]. There is no CPU cost benefit, but continuous pressure distributions for use with structural analysis are readily generated. Higher order boundary element analysis for 3D analysis, with and without forward speed, can also be used in a new procedure we have designated the green function matching technique [4]. A combined first kind and second kind Fredholm integral equation formulation for 3D zero speed problems has also been formulated [5]. The first kind integral equation contribution arises from distribution of fluid singularities within the floating body. Proof of uniqueness and the non–existence of irregular frequencies (section 4.5 of report) has been provided with calculations undertaken with and without the proposed modification. We would be glad to communicate our findings on these subjects to the committee.

Optimization of hull forms for seakeeping (section 11 of report) must be undertaken with great care, otherwise the associated mathematical analysis (which knows no better) can produce very impractical hull forms [6]. Our studies show that seakeeping is readily improved by increasing waterplane coefficient, but for hull forms of small block coefficient the optimization can produce sections with near zero tangency to the undisturbed water plane if the block coefficient is fixed. We have also built in such constraints as automatic satisfaction of IMO stability requirements with no increase in either added resistance or calm water resistance. If particular sections still look impractical we blend them with the above water hull form and reanalyse to see how "optimized" hull performances have been modified. However, the influence of the changes in hull form upon the wake and the implications upon propeller design should also be considered. Once again we would be most happy to communicate our findings to the Committee. Perhaps the ITTC Committee might consider the organization of a workshop on seakeeping for design.

References

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(b) Hearn and Liou: OMAE 1990.

[2] Hearn and Liou: OTC 1990.

[3] Hearn and Donati: Int. J. Num. Methods in Fluids, 1988.

[4] Hearn and Lau: SERC MTD Final Contract Report on Floating Production Systems, Dec. 1989.

[5] Lau and Hearn: Int. J. Num. Methods in Fluids 1989.

[6] (a) Hearn, Hills and Sarioz: SMSSH 90, Varna, Bulgaria.
(b) Hearn, Hills and Sarioz: RINA Spring Meeting. Submission for 1991.

SK-8

Y. TAKAISHI
Ship Research Institute, Japan

ON THE NECESSITY OF WAVE DATA FOR SEAKEEPING EVALUATION OF SHIPS

It is needless to say that the evaluation of seakeeping qualities of a ship always relates closely to the wave conditions to be encountered in the world oceans. The information of waves in both senses of short-term and long-term predictions, as accurate as possible, is required for applying the seakeeping qualities not only to ship design but also ship operation such as weather routing.

One example is the model testing in irregular waves. The ITTC already has recommended the use of a standard wave spectrum together with the wave energy spreading function, i.e. $\cos^2$ distribution, which has been used for long time. Today, the effects of directionality on the seakeeping attracts more attention and many model basins or towing tanks have been developing the various sophisticated wave makers which are capable to generate arbitrary short-crested waves, as reviewed in the report. Then, in such situation, which kind of the short-crested waves should be selected for the general seakeeping testings of the basins?

On the other hand, many projects of directional waves measurements have been carried out in various aspects. The results of these measurements may give a better understandings on the directional spreading functions of wave energy in the oceans. Therefore, the seakeeping committee should pay attention on these results and review the wave data in order to establish a more realistic spreading function than the conventional $\cos^2$ function, if necessary, which will be used for the model testing in the basin.

The next point is the interpretation and usage of the long-term wave statistics such as the joint probability distribution of wave heights and periods. Dr. Hogben et al. recently revised the long-term statistics diagrams for world oceans.

This is considered to represent more rational features of the wave statistics because the wave data based on the visual observations of voluntary ships have been corrected. In Japan, the similar but more detailed statistics of wind and waves of the North Pacific Ocean are being performed. Such improved long-term statistics of waves will be used for the seakeeping criteria as described in the chapter 14 of the report.

My opinion is as follows:

1. The Seakeeping Committee should review the directional wave recently obtained data, also

attention should be paid to the state of the art of wave forecasting technologies which could be useful for understanding the feature of ocean waves, and recommend the revision of the conventional spreading function of ITTC for use of the model testing in the basin.

2. The Seakeeping Committee should review the application method of the long-term statistics of wave heights and period based on the newly generated data base.

At the 18th ITTC, it was decided that the waves as the environmental condition of ships should be treated exclusively by the Ocean Engineering Committee. But it seems that the Ocean Engineering Committee has interest on the wave characteristics from the viewpoint of only offshore structures which are operating normally at the specified sea area not in Open Ocean but near coastal zone.

Therefore, the waves in the world-wide oceans should be again treated mainly by the Seakeeping Committee of 20th ITTC.

SK-9

Y. DUDZIAK
Ship Design and Research Centre, Gdansk, Poland

RECOMMENDATION CONCERNING MODEL TESTS OF RARELY OCCURRING EVENTS

Taking into account the results of the common model tests of deck wetness, the Seakeeping Committee has come to the conclusion, that experiments to determine the statistics of rarely occurring events such as slamming or deck wetness in irregular waves should last for a minimum of one hour (full scale equivalent).

This recommendation seems to me a little to rough. In my opinion the total exposing time in model tests of rarely occurring events should depend on such parameters as: ship speed, ship type and sea state. Assuming that the minimum number of the rarely occurring events, when they affect significantly the ships behaviours, should be at least 50, which is in line with the earlier ITTC recommendation concerning the minimum length of a sample in the seakeeping model tests, I prefer the following recommendation.

The minimum total time of the experiments to determine the statistics of rarely occurring events in irregular waves should be such that -at the higher sea state- the total number of deck wetnesses or slammings is at least [50] (the figure in square brackets is for the discussion) assuming that the total number of encountered waves is not more than $\mathrm{Int}([50]/p_L)$ or it should be such -at lower sea state- that the total number of encountered waves is at least $\mathrm{Int}([50]/p_L)$ assuming that the total number of deck wetness or slammings is less than [50], where p_L is the limiting average frequency of deck wetness or slammings, depending of the ship type.

In comparative tests the number of encountered waves should be kept constant and the wave condition should be chosen so that a substantial number of events occur.

Bearing in mind that -as far as the matter concerns the deck wetness- the p_L values belong approximately to the range <0.05; 0.12> (e.g. p_L=0.05 for container vessels and p_L=0.12 for tankers) one can come to the conclusion that the maximum number of encountered waves in model tests of deck wetness never will be higher than about 400÷1000, depending of the ship type.

II. REPLIES BY THE SEAKEEPING COMMITTEE

Before replying to the Discussion the Committee would like to draw attention to an error in the report: On the third line of Chapter 2 on page 432 "10th ITTC" should read "12th ITTC".

Many of the contributions relate to the comparative experiments on deck wetness. Before dealing with these the Committee would like to record its appreciation of the very considerable efforts of the 12 members organisations who took part in the project. Without their enthusiastic cooperation it would not have been possible to complete this project and to present the results given in the report. Each participant will, in the near future, receive a detailed report on the entire project, giving more detailed information than it has been possible to present in the Committee report. This will include data obtained from a follow-up questionnaire and results from a thirteenth participant, received too late for inclusion here.

Dr. WATANABE's detailed explanation of his results is most welcome and throws further light on the complex deck wetness process. It shows that many of the usual assumptions made need to be questioned and it is clear that the routine application of the Rayleigh formula in cases of this sort may not be justified.

In reply to **Messrs HONG and HONG** we would point out that our statement that there was "... no evident correlation between the measured deck wetness and the measured motions..." was intended to mean that a participant who recorded a higher than average motion did not generally also record a more frequent deck wetness. In other words the scatter in the results appears to be the result of random variations in the experiments resulting from lack of control over some of the variables rather than any consistent bias in the motions. The approach used by the contributors is interesting but we do not understand how an rms wetness is defined when the wetness (however measured) is a discontinuous process. Is it legitimate to define a correlation coefficient between a continuous and a discontinuous signal?

We welcome the contribution by **Dr. YUM and Dr. CHOI**. The expert application of the appropriate probability formula puts the whole rare events study on a much sounder basis and it would have been valuable to have had access to this expertise when the results were being analysed. Their recommendation of a run length as long as 500 model lengths would be, we feel, too much for most institutions to accept. We were very much aware of the practical implications of any recommendation on run length we might make and this was in our minds when we arrived at our conclusion. We should point out that we observed that scatter might be as high as 10% even for run lengths of 300 model lengths.

We cannot agree with **Dr. LUNDGREN**'s suggestion and the reasons for this view have already been discussed. Relying on the relative motion as an indicator of deck wetness is obviously very risky. Our studies and the discussion we have already heard have amply demonstrated that

a) the Rayleigh formula may be inappropriate
b) many freeboard exceedances do not result in deck wetness.

In any case we would dispute that 15 minutes exposure is generally adequate for a good estimate of the rms motion. The ITTC good practice recommendation is for 100 wave encounters and this will generally require at least 20 minutes exposure, depending on the speed and heading to the waves.

The discussion by **Messrs NAITO and TAKAGI** provides further evidence of the sensitivity of deck wetness to details of the above water hull form. It is clear from this, the discussion already considered and work reported by the 18th and 19th Seakeeping Committees that further work is needed before the effect of above water bow shape is well understood. Of equal importance is the fact that the discussion provides evidence of the insensitivity of the rigid body motions (heave and pitch) to changes in above water hull form although it is clear that the heave and pitch responses are non linear with respect to wave steepness. As further evidence of non linearity Figures 1-4 show the results of experiments conducted at the US Naval Academy compared with the present data from the discussers and data published previously (Takagi, 1987). The heave data are remarkably consistent while for pitch there is clearly a shift between the two sets of data. Nevertheless, similar trends with respect to wave steepness are shown. Data for the zero steepness limit extrapolated from experiments conducted by Townsend (1990) at the Australian Maritime College (not shown in the Figures) are also generally consistent. All these data point to the possibility that non linearities in the rigid body motions may play a role in relative motion and deck wetness so that the difficulties seen in the various attempts to predict these phenomena using linear methods and associated statistical assumptions are not so surprising. These data also support the need for more rigorous standards for reporting experiment data. In regular waves the wave steepness must be recognised as an important parameter which should be reported.

Dr. HOOFT raises an important point and quotes the example of the effect of rudder activity on the motions measured in quartering waves. Another good example is shown in Figures 3.7 for Participant No 4 in the comparative experiments. Results are shown for deck wetness at the Forward Perpendicular using two different methods: a contact electrode on the forecastle (CE) and a video camera. Even here with the same experiment team and the same model experiment runs there is a marked difference between the two sets of data both in terms of scatter and mean values. Clearly the method of measurement is having a significant effect on the results. The influence of the method of testing is one part of experimental uncertainty which is considered in Chapter 1.2 of our report. Four of our recommendations for the future work of the Committee deal with experimental methods and their accuracy and these include the effects of experimental methods.

Dr. HEARN provides some additional information supporting our report and this is very welcome. We cannot, however, accept that tank wall interference is generally more significant than the effect of water depth. The relative importance must surely depend on the proximity of the walls and the actual depth of the water together with other test paramenters. We would support Dr. Hearn's suggestion for a workshop on seakeeping for design but we are not in a position to organise it.

As **Dr. TAKAISHI** points out, the 18th ITTC Advisory Council proposed that advances in the understanding of ocean waves should be monitored and reported by the Ocean Engineering Committee. This was accepted by that Committee and they were reminded that this responsibility should include an interest in deep water waves applicable to ship design in an exchange of letters between the two Committees in November 1988.

Dr. DUDZIAK's proposal to take account of the limiting frequency or criterion for the rare event in question is interesting and has intuitive appeal. We should point out that our recommendation applies only to ships of the type tested. It is also interesting to note that Dr. Dudziak's suggestion yields equivalent full scale test times of about 40 minutes for p_L=0.12 and about 100 minutes for p_L=0.05. Our recommendation for 60 minutes lies between these estimates so we are in broad general agreement.

In conclusion the Seakeeping Committee would like to thank all the contributors for a lively and useful discussion.

References

[1] Townsend M: S175 Seakeeping Experiments Part 1: Regular Waves. Australian Maritime College Ship Hydrodynamics Centre. February 1990.