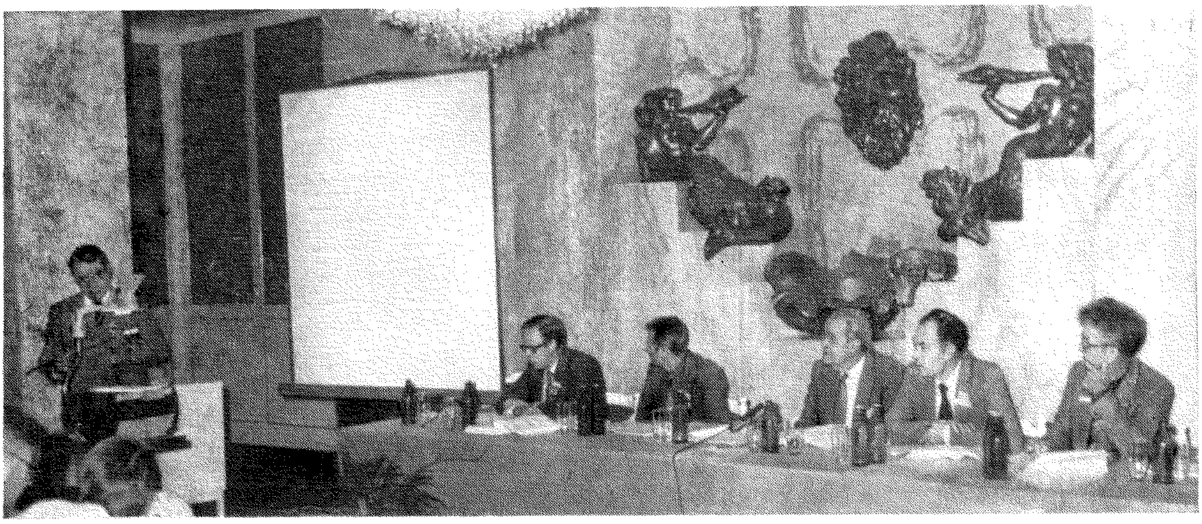
SESSION ON PROPULSION, PROPELLERS

Chairman: Prof.,Dr. J.D.van Manen



Presidium of the Session

Discussion of the Report and the Draft Recommendations of the Propeller Committee

I. DISCUSSIONS

CHAI YANG-YI, CHEN TA-CHUAN - Shanghai Ship and Shipping Research Institute, China.

COMPARISON AND ANALYSIS OF THE WAKE DISTRIBUTION OF THE PASSENGER SHIP "HONG XING 514" AND ITS MODEL

I. Wake measurements on full scale ship "Hong Xing 514" and its model. The body lines, stem and stern shape of "Hong Xing 514" are shown in Fig.1. The stern shape is of extra-V form according to its body form coefficient $\tau = 0.83$.

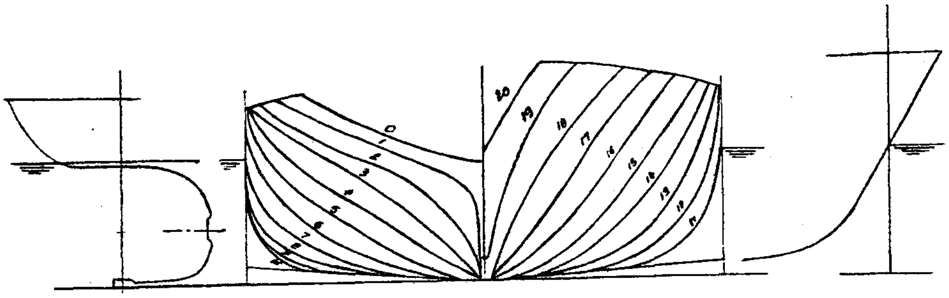


Fig.1. Body Plan and Shape of Stem and Stern

The principal particulars of "Hong Xing 514" are as follows:

Loa	(m)	39.50
Lwl	(m)	37.58
Lbp	(m)	36.60
B	(m)	7.60
H	(m)	2.70
T	(m)	2.00
Cb		0.48
∇		267.00
Cp		0.353
β		0.873
α		0.706
Lcb (m) (After Midship)		0.606
Designed Speed		11.0

Machinery 6300 , MCR 400Hp,rpm 400

The measurement of the nominal wake on "Hong Xing 514" was carried out in the plane of propeller and was done on 4m long model by employing a rake of pressure probes rotating around the propeller shaft as is shown in Fig. 2.

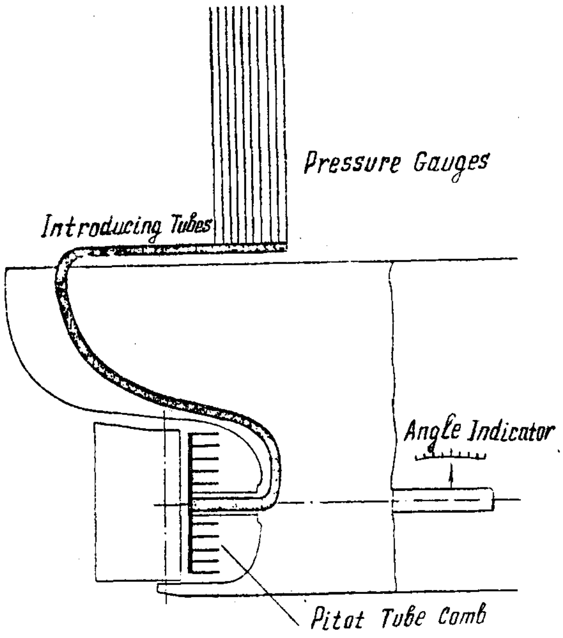


Fig.2. Arrangement of Full Scale Wake Measurement Installation

The ship was towed by a 500Hp tug with 120m hawsers. The depth of trial area was over 10 m and the weather condition was good (Beaufort scale I and sea state 1). The measuring angle interval of both full scale and model was 10 degrees and 5 degrees at high wake region near central plane. The ship speed was measured by two blade wheel current meters (which were checked in advance), located on port and starboard side respectively.

The model wake measurements were made at towing tank at our institute. The measured results of full scale ship and its model are shown in Fig. 3 and 4.

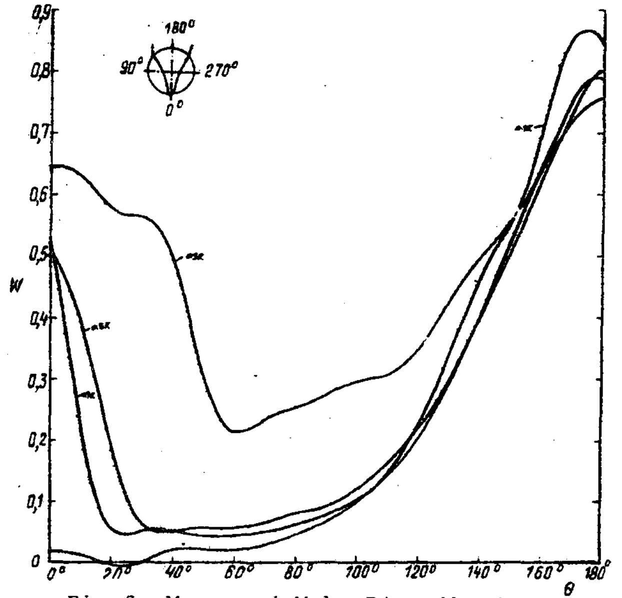


Fig.3. Measured Wake Distribution of Model

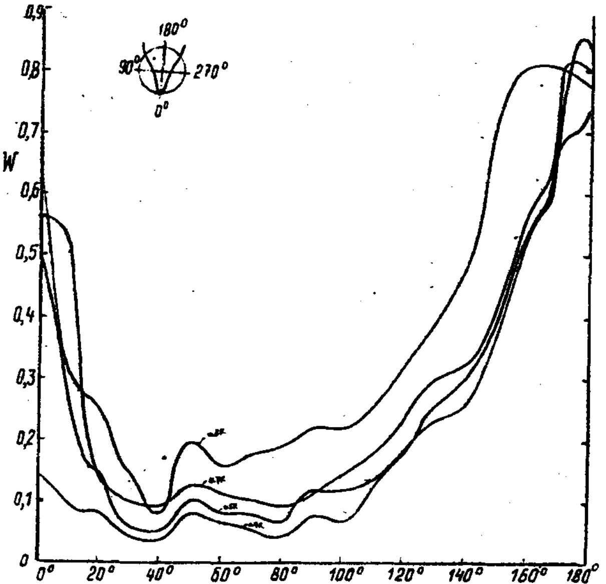


Fig.4. Measured Wake Distribution of Full Scale Ship.

2. Comparison and analysis of ship's measured wake field with measured one of model and predicted results from model wake distribution by Sasajima's method. It will be seen in Fig. 4 and Fig.6 that the difference in wake distribution between full scale and model is distinct, especially in the high wake region near center plane. The model wake is somewhat higher than that of full scale because of difference of Reynolds number. It can also be seen in Fig. 3 and Fig.4 that the pattern of the wake distributions are similar and the difference in peak wake values is not very large.

Comparing the measured results it is obvious that the scale effect in low wake region (about 40 to 100 angle position of propeller) is smaller than in high wake region. The main reason for this is that the block coefficient of "Hong Xing 514" is small and ship itself is short, so the scale effect on wake distribution should not be large. The absence of the rudder has some influence on wake measurements when measuring model's wake without it. The dummy boss which was installed on the propeller shaft increased the flow instability around it, so the full scale wake of radius 0.3R was higher than that of model.

The measurement results are shown in Fig.

3 and Fig. 6, which shows that the full scale ship's wake is shrunk in general in comparison with the model's.

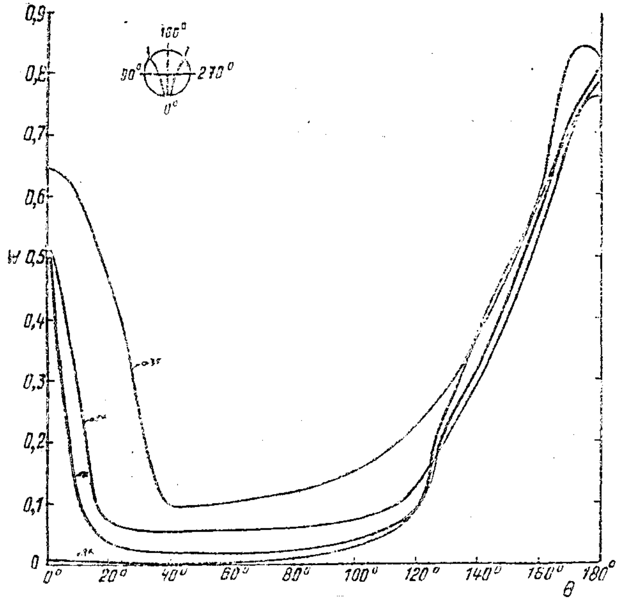


Fig.5. Predicted Full Scale Wake Distribution from Model Results by Sasajima's Method

The full scale ship wake distribution predicted from its model results by approximate Sasajima method (see Fig. 5) are compared with the measurement results of the full scale ship in Fig. 7. It can be seen that the predicted and full scale results coincide well with each other. The difference in the high wake region is about 0.02, the predicted results are slightly higher in general.

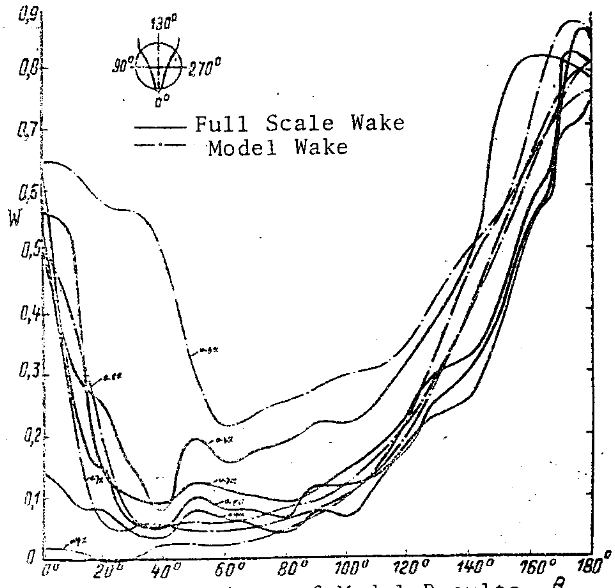


Fig.6. A Comparison of Model Results with Full Scale Wake Measurements

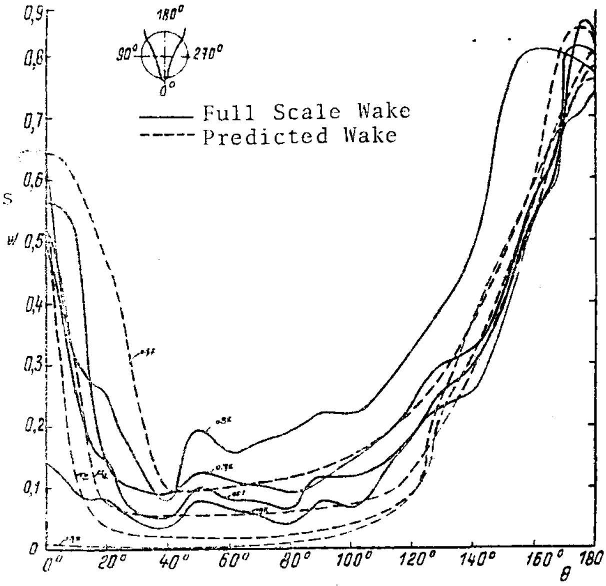
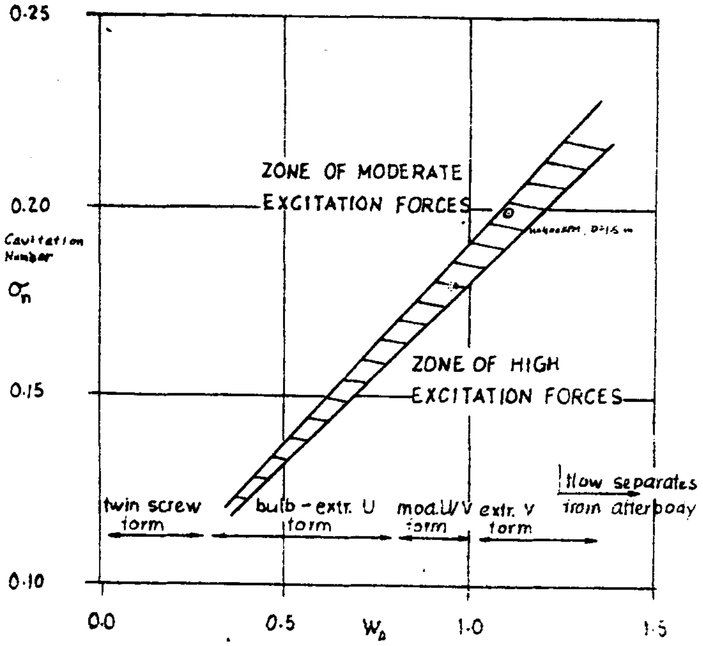


Fig.7. A Comparison of Predicted Wake Distribution from Model Results with Full Scale Wake Measurements

3. The estimation of the possibility of the occurrence of large excitation forces.

The criteria for acceptable levels of propeller induced vibration is based on full scale ship vibration data and analysis of their model wake distribution. The cavitation number σ_n as defined in Fig. 8 is a measure of the maximum susceptibility of the outer sections of a propeller blade to form back, sheet cavitation, while the quantity W_Δ , taken at a representative propeller radius, is a measure of the non-uniformity of the velocity field in which the propeller operates and hence is an indication of the severity of cavity pulsations. Above the shaded band it means that unacceptable vibration, caused by large excitation forces set up by the propeller, can be avoided.



$$\sigma_n = \frac{p_a - p_v + \rho g H_1}{\frac{1}{2}\rho(\pi n D)^2} = \frac{9.903 + H_1}{0.51(nD)^2}$$

$$W_\Delta = \left\{ \frac{W_{MAX} - W_{MIN}}{1 - \overline{W}} \right\}_{1.0R} \qquad H_1 = T_A - (Z_p + D/2)$$

where p_a is the atmospheric pressure, p_v is the saturated vapour pressure, ρ is the water density, g is the gravitational constant, H_1 is the tip immersion depth, W_{MAX} and W_{MIN} are the maximum wake fraction and minimum wake fraction (within 160° of the vertical upright position) and $\overline{W}$ is the circumferential average wake fraction.

Fig. 8. A Cavitation Criterion for the Assessment of Wake.

For"Hong Xing 514" σ_n =0.199, W_Δ =1.08 are just located in the shaded band which means that the potential vibration problem would arise. The local vibration measurement results has confined that severe vibration happened on the stern deck. The calculated acceleration of vertical vibration is 0.245 g when rpm=403 and 0.342g when rpm=412. The periodical resonant vibration was found in the stern deck zone which indicated that the three-bladed propeller with no skew would enter the high wake region behind the stern frame with greater shock and hence produce larger vibration forces because the leading edges of blades passed this region instantaneously. The local vibration measurement results of "Hong Xing 514" are as follows:

Table 1

Local Vibration Measurement Results

Position of Measurements	Revolutions of Propeller rpm	Frequency	Full Amplitude mm	Calculation Acceleration $a=0.0403F\frac{A}{20}(g)$
Stern Deck	192	576	0.02	0.004
	249	747	0.03	0.009
	330	990	0.05	0.027
	403	1209	0.30	0.245
	412	1236	0.40	0.342
Steering Gear Room	397	1191	0.20	0.159

A— Full Amplitude

a — Calculation Acceleration $F=\frac{f}{60}$ (HZ)

4. Concluding remarks

Making all comparison and analysis of measurement and prediction results above, we deduced the following conclusions ;

(1) It is clear that the non-uniformity of wake distribution is remarkable for the extra-V form stern, although the block coefficient of the ship is small and its length is very short.

(2) The scale effect on wake distribution between full scale ship and model is obvious in the high wake region near the central plane.

(3) Predicting the full scale wake from model measured results Sasajima's method is available. The difference in the high wake region is only about 0.02 and the predicted results are slightly higher in general.

(4) The posibility of the occurrency of of large exciting forces was estimated. The estimation is in good agreement with the full scale ship's vibration measurements.

E.A. WEITENDORF - Hamburg Ship Model Basin, Federal Republic of Germany

The Propeller Committee mentioned a poor correlation between full-scale and model pressures presented by Koestermann (67).

In the large HSVA cavitation tunnel (circular test section with D = 750 mm) we investigated the same case (Fig.1).According to the Propeller Committee the model basins A and B obviously do not belong to " the larger and more experienced facilities"; on the other hand the following question emerges, do we belong to those facilities, if we use the model revolutions n=15, 20 or 25Hz? The blade frequency $f_0 = Z. n = 4 . 25 = 100$ Hz shows the highest null pressure amplitude K_{P4} in Fig. 1. The hull pressure amplitude K_{P5} also from the large tunnel for $f = 5 \cdot 20 = 100$ Hz of the " Sydney Express" comparison , displays again the highest value (Fig.2).

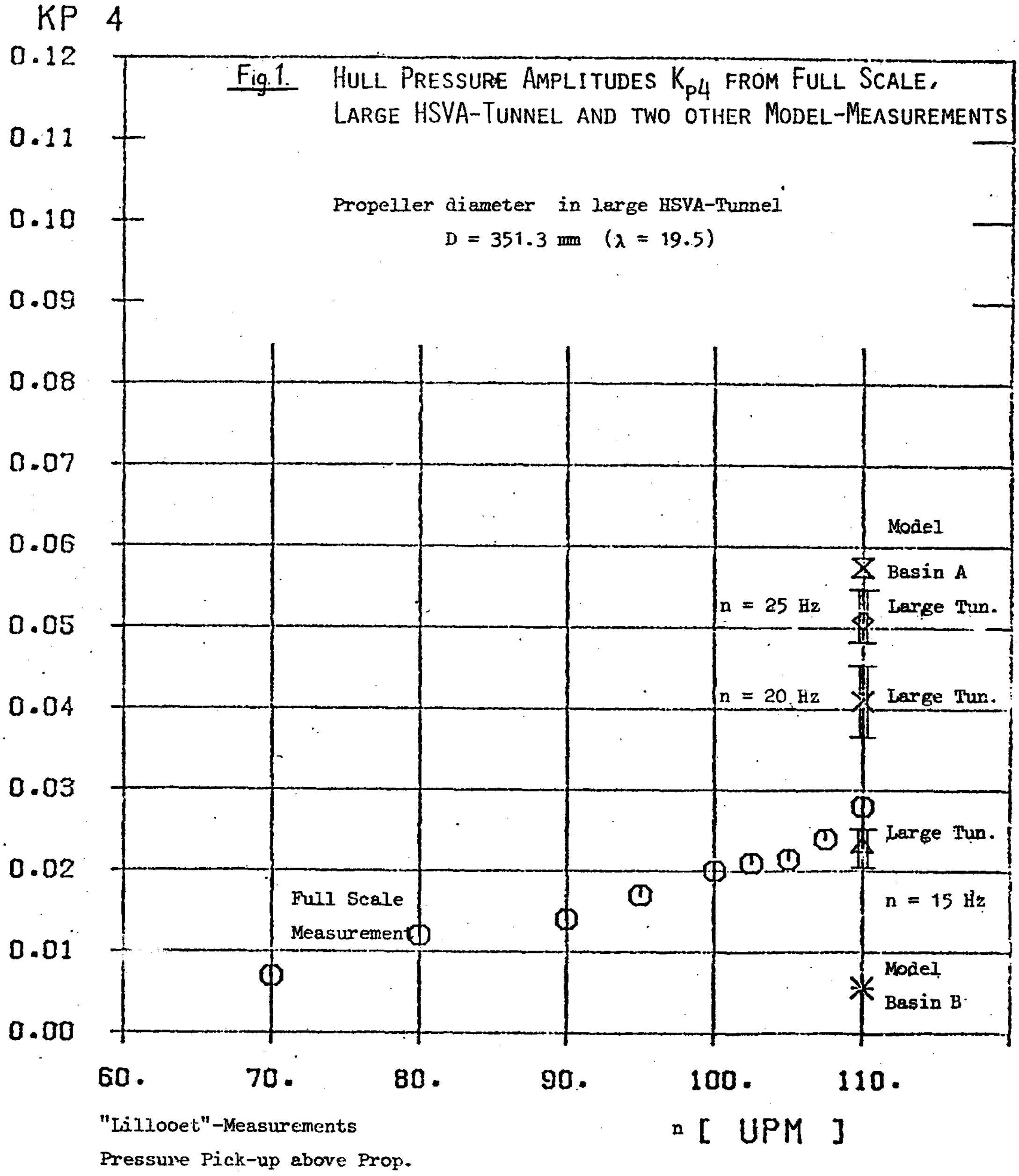
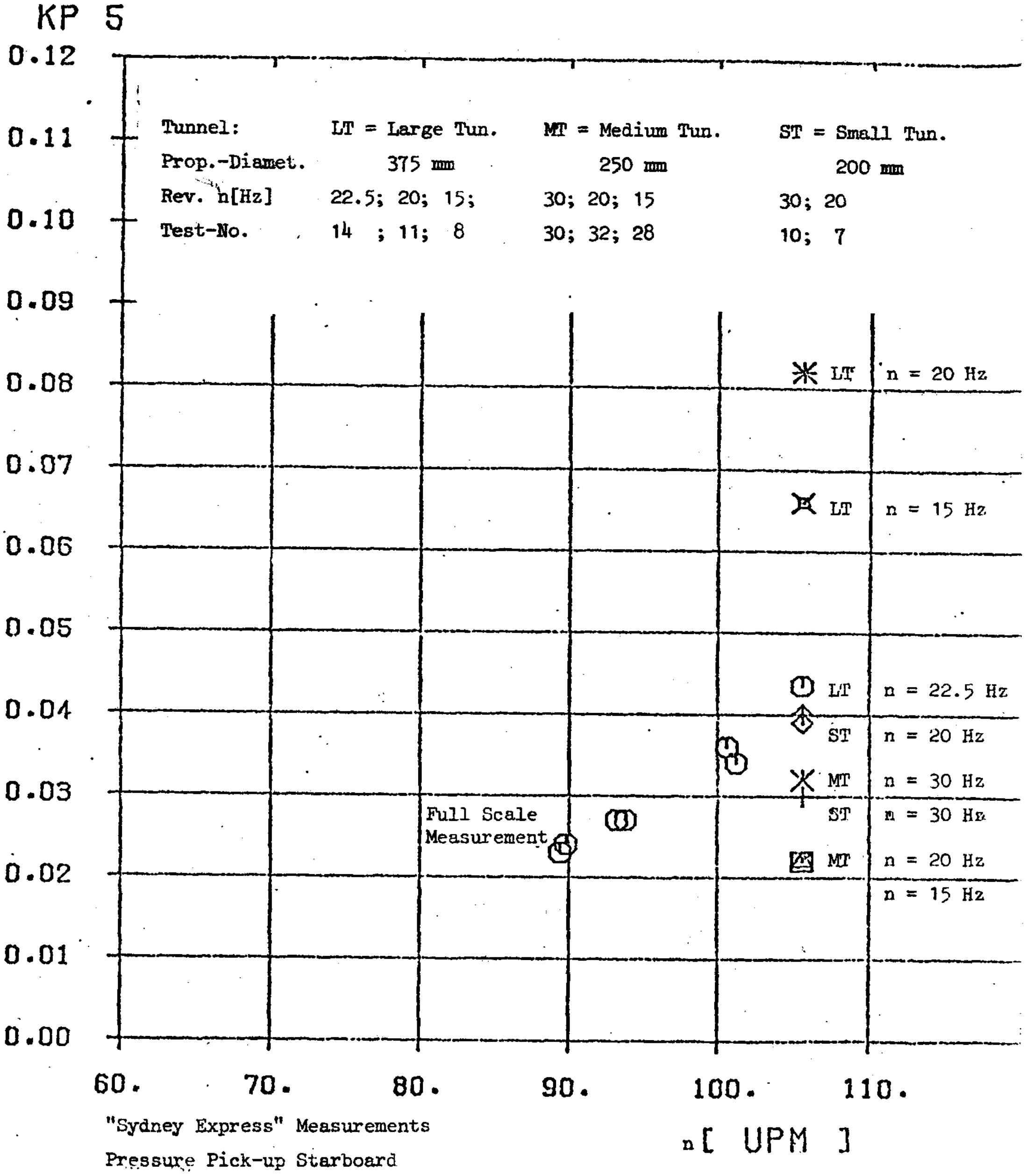


Fig.1. Hull Pressure Amplitudes K_{p4} from Full Scale, Large HSVA-Tunnel and two other Model-Measurements



"Sydney Express" Measurements

Pressure Pick-up Starboard

Fig. 2: HULL PRESSURE AMPLITUDES K_{p5} FROM FULL SCALE AND THREE HSVA-TUNNELS

The reason for this striking coincidence is a maximum value of standing pressure waves in the tube, which is formed by our large cavitation tunnel. This was found by theoretical investigations by Krohn. In Table 1 results of calculated values are given, which include a maximum value for $f_0 = 100$ Hz. Extreme values can be found if the relation between the length L of the tunnel and the wavelength λ amounts to

$\frac{L}{\lambda}=\frac{2n+1}{4}$ (Maximum) and $\frac{L}{\lambda}=\frac{n}{2}$ (Minimum)

$L=55.5m$; $n= 0, 1,2,3$

Maximum		Minimum	
f [Hz]	λ [m]	f [Hz]	λ [m]
		53,3	27,9
60,0	24,7		
		66,7	22,2
73,3	20,2		
		80,0	18,5
86,7	17,1		
		93,3	15,9
100,0	14,8		
		106,7	13,9
113,3	13,1		
		120,0	12,3
126,7	11,7		
		133,3	11,1
140,0	10,6		
		146,7	10,1
153,3	9,7		
		160,0	9,3
166,7	8,9		
		173,3	8,5
180,0	8,2		
		186,7	7,9
193,3	7,7		
		200,0	7,4

TABLE 1 Calculated extreme frequency for standing pressure waves in the large HSVA tunnel

The theoretical results of Tab.1 coincide with experimental ones obtained with an electrodynamic exciter (Chasapeak J-9). The experimental results were shown in the discussion to the paper of Chiba, Sasajima and Hoshino at the Symposium on Naval Hydrodynamics in Tokyo 1980.

It should be emphasized here that this new type of tunnel effect which can occur by standing pressure waves is additional to that tunnel effect which Huse described in a NSFI report from 1974.

A remedy inside the large HSVA tunnel regarding the standing pressure waves has to be pursued. The medium HSVA tunnel exhibits a different behaviour.

Concluding and looking at Fig.1 again it has to be said that the correlation problem of the hull pressure fluctuations due to unsteady cavitation forms a challenging problem for most facilities. This cannot be covered by a statement like the larger and more experienced facilities can enable predictions of pressure amplitudes with a deviation of 20 percent.

I agree with the Propeller Committee that there is a need for a better understanding of possible scale effects.

The dynamic behaviour and development of the unsteady cavitation with its cavitation scale effect due to different absolute pressures on the model and full scale propeller and further the scale effect of the ship's wakefield with its local loading influence on the cavitation inception and duration. Those topics are treated in the paper by Weitendorf (ASME, Cavitation Inception Symposium, New York 1979).

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

Propeller Induced Vibration

The discussors have the following two comments to the Report of the Propeller Committee.

1) According to the observation of cavitation patterns of a propeller operating in non-uniform flow, the cavitation geometry differs frequently from the ones used in theoretical calculations, as illustrated in Fig.1. In order to improve the accuracy of the theoretical prediction method of time-dependent cavitation patterns, the discussors think it necessary for the Committee to review the propeller cavitation patterns and geometry in non-uniform flow to understand the physical phenomena for making reasonable cavitation models.

2) Response to the questionnaire on criteria for acceptable levels of propeller induced vibration is summarised in the report of the Propeller Committee. However, as shown in Fig.2, pressure fluctuation is not always correlated with the vibration level. Thus the discussors consider it misleading if the critreria of pressure fluctuation are discussed without referring to the structural response of the ship hull, even though the lower pressure fluctuation is always preferable.

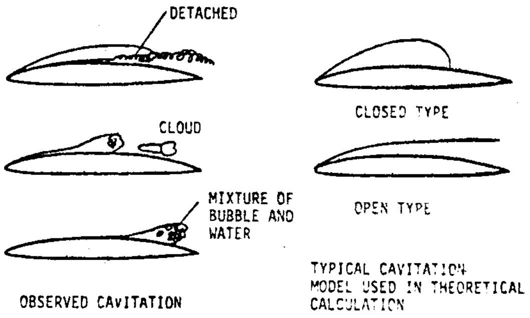


Fig. 1 Cavitation geometry

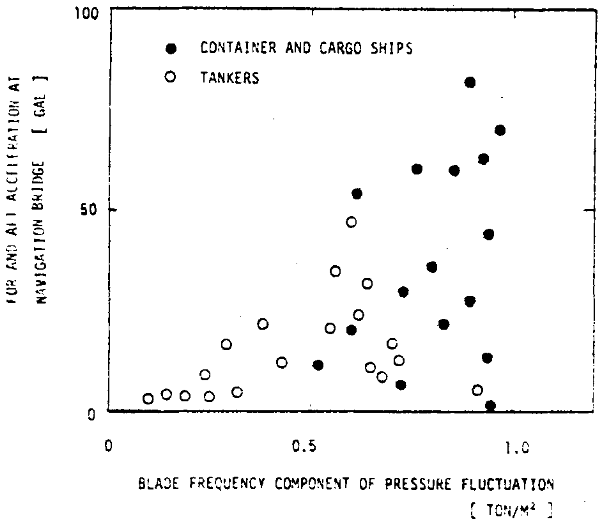


Fig.2 Relation between vibration level and pressure fluctuation

W.-H. ISAY - Institut für Schiffbau,
Hamburg, Federal Repablic of Germany

I would like to call your attention to an important problem which, in my opinion, has not been adequately considered in the Report of the Propeller Committee. I am referring to the attempts and efforts directed at the measurement of pressure distributions on propeller blades, especially in a wake, that is under unsteady blade loading.

The mathematical formulation of the lifting-surface propeller theory was essentially completed over ten years ago yet the numerical evaluation of the theory has yielded very different results for the pressure distribution depending upon the approximations and corresponding simplification used (1).Only comparisons with reliable experiments can decide upon the usefulness of all these computational procedures, see for instance (2) for an overview. Unfortunately, such experimental results are not yet available in a sufficient amount, so that further activity in this field appears to be urgently needed. For a definite knowledge of the pressure distribution on the propeller blade, first of all in the cavitation-free condition, is an indispensable prerequisite for all cavitation studies and calculations.

At least a few encouraging results of pressure distribution measurements are already available. Thus in 1976 such a measurement was conducted in air in the Aerodynamische Versuchsanstalt Göttingen, and that in a shiplike wake simulated by the use of flaps (3,4). Experiments in water in a cavitation tunnel, in uniform inflow as well as in a simulated wake, were done by Takahashi and Oku (5) and by Takei, Koyama and Kurobe (6). Yamasaki (7) measured the pressure distribution on a specially large propeller model in a towing tank. The results of all these experiments, which cannot be discussed in detail here, are quite encouraging and offer a valuable foothold for the assessment of theoretical computational procedures.

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K. VARSAMOV, V. HADJIMIKHALEV - Bulgarian Ship Hydrodynamics Centre, Varna, Bulgaria

SOME CONSIDERATIONS CONCERNING OPTIMUM LOAD DISTRIBUTION FOR WAKE ADAPTED PROPELLERS

1. INTRODUCTION

The choice of optimum radial load distribution for wake adapted propellers, as it is well known, is possible only on the basis of a compromise between effectiveness and vibroactivity. In most cases, the optimum circulation distribution with consideration of efficiency is determined using the criteria of Lerbs [1], van Manen [2] and Ivchenko - Stojanov [3], which lead practically to the same results.

The problems related to the optimization are subject of serious attention in the paper of the Propeller Committee [4] as well. The purpose of the present contribution is to give information about some of the numerical optimization procedures developed in BSHC.

2. BRIEF OUTLINE OF THE PROCEDURE DEVELOPED AT BSHC

The numerical procedure for optimization of radial load distribution [5], developed in BSHC with consideration of strength and lack of cavitation, permits reaching propulsive efficiency of 3-4% higher than that obtained with use of criteria mentioned above. This increase is achieved with additional loading of the propeller tip sections. It is evident that this way for increasing the propulsive efficiency is contrary to the requirement of vibroactivity, as on loading tip sections the unsteady forces and pressures induced by the propeller increase as well. The combining of this approach for increasing the propulsive efficiency with use of highly skewed propeller blade shape, the latter leading to significant decrease of unstationary loading induced by the propeller, makes possible the design of screw propellers with higher propulsive efficiency and acceptable vibration characteristics. An additional effect of the loaded tip highly skewed propeller appears to decrease radial pitch distribution gradient, which generally reaches 100%, as a result of which it is possible to improve the strength characteristics of the tip sections.

Along with that, however, the realization of this approach for improving the propulsive and vibration characteristics of screw propellers is connected with the solution of the following problems:

a/. When determining the effective wake in propeller disk necessary for its design by the experimental procedure in [6], it is extremely important to exclude properly the induced velocities. The use of stock propellers for carrying out such experiments, which generally may have entirely different load distribution, and therefore different induced velocities distribution in comparison with loaded tip highly skewed propellers, for which the induced velocities in the tip region reach extremal values $U_a/V_s = 0{,}7 \div 1{,}0$, may lead to significant structural changes in effective velocity field. This requires profound investigations for evaluation of the influence of radial load distribution over the flow formation in propeller disk.

b/. Profound researches of elastic

deformations of loaded tip highly skewed propeller blades are necessary with a view of undertaking measures for evaluation of their influence over ship performance prediction.

c/. For loaded tip highly skewed controllable pitch propellers, measures are necessary for "balancing" of propeller blades towards their axis with the purpose of decreasing the spindle torque.

For illustration of the effectiveness of the proposed method, numerical results of characteristics estimation for 3 versions of 5 blade propeller for San Clemente class OBO ship with skew of 72°are presented, the input data for which are taken from [7]. The radial circulation and pitch distribution are presented on Figs. 1 and 2 respectively. The values of propulsive coefficients are given in Table 1. It can be seen that in this case the propulsive coefficient increases by ~ 4% when the tip sections are loaded.

3.CONCLUSION

The developed in BSHC numerical procedure for radial load distribution optimization permits reaching a higher propulsive efficiency in comparison with the results obtained with the use of some of the known criteria in this field.

The problems related to the vibration characteristics are subject of additional investigations in BSHC, the results of which are to be published in near future.

Table 1

Symbols	Load distribution	Propulsive efficiensy
① ———	Lerbs optimum	0,761
② – – – – –	Tip and root unloaded	0,741
③ —·—·—	Tip loaded (optimum)	0,799

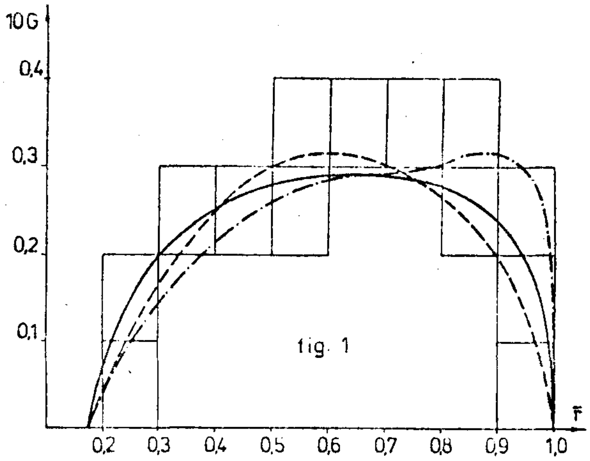

fig. 1

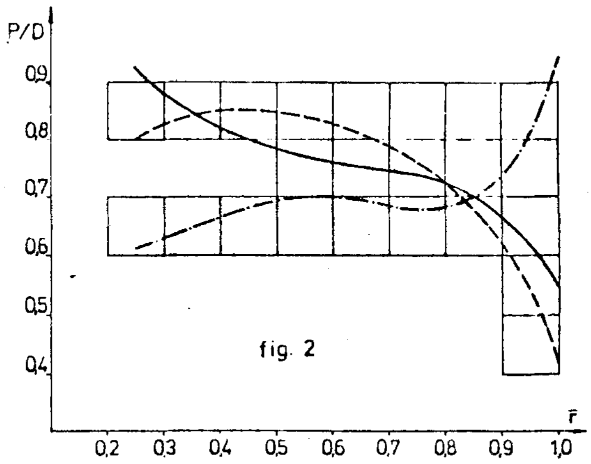

fig. 2

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SUN QIN, GU YUN-DE - Shanghai Ship and Shipping Research Institute, China.

ON THE TANDEM PROPELLER

In the 70's in order to improve the efficiency of certain heavier load propellers and to reduce the stern vibration, the tandem propeller was investigated in our Institute. A practical design method was put forward and six sets of open water series test with tandem propellers and the computer program on the theoretical basis completed for practical use. Some conclusions were obtained, of which a few are as follows :

(1) The gain in efficiency is shown as Fig.1. The tandem propeller's efficiency is slightly higher for $\sqrt{Bp} \geq 5$ and the opt. diam. is smaller when comparing under the condition of no restriction on diameter and the same total blade disc area with conventional propeller.

In the case of the restricted diameter, the tandem propeller's efficiency is higher than conventional propeller, and the greater the power coefficient Bp and the more the restriction on diameter, the more the gain in efficiency.

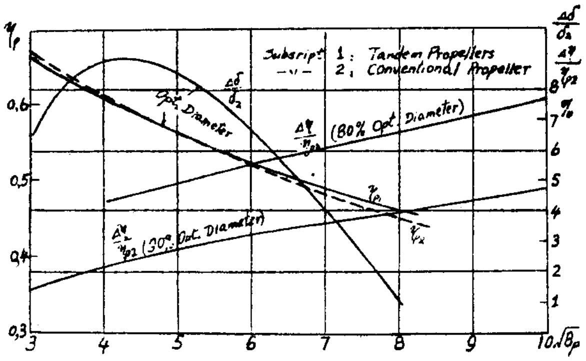

Fig. 1

(2) A formula for optimum phase angle between rear and forward propellers is derived from the point of view of efficiency:

$$\theta = \frac{L/D}{P_1/D} \times 360^\circ - \frac{180^\circ}{Z}$$

where L/D= axial spacing ratio, (L the distance between rear and forward propellers)

P_1/D = pitch ratio of the forward propeller

Z = number of blades (Forward and rear propellers have the same Z)

A typical test result of the influence of phase angle on the performance of tandem propeller as shown in Fig. 2, in which $\theta = 22.6$ is the optimum phase angle calculated from above formula.

(3) Though no model test of the influence on unsteady exciting force with tandem propellers has been carried out in our Institute, vibration measurements for several actual ships equipped with tandem propellers show that the stern vibration level has been significantly reduced in comparison with those using conventional propellers.

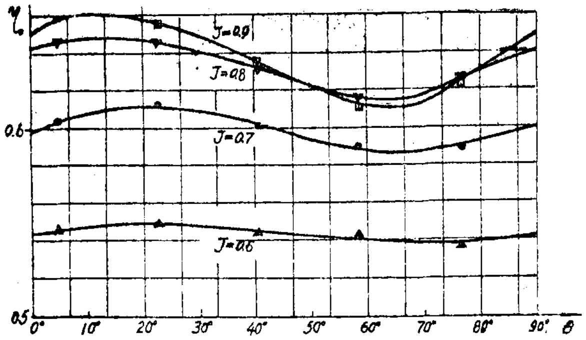

Fig. 2

E.-A. WEITENDORF - Hamburg Ship Model Basin, Federal Republic of Germany

In relation to this section it is considered worthwhile to draw the attention of the Committee to a device which was not mentioned in the report, that is the propeller and vane system (Fig.1) invented by Prof. Grim.
Full scale measurements with and without the system were performed last year on the Baltic.

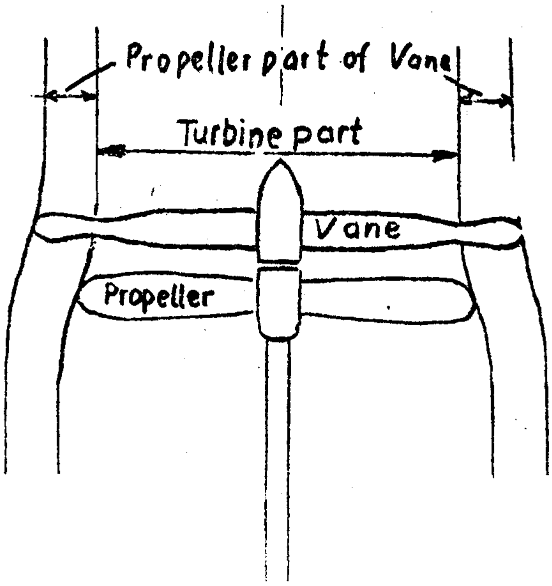

Fig.1. Propeller and Vane

The results of the power-measurements are given in Fig. 2. The power increase for the propeller alone is about 9.5%. The other qualities of the ship remained unchanged. The pressure impulses were also unchanged due to the low amount of cavitation at around 13 kn. All these results were published in the " Hansa " at the end of 1980. The research vessel has been sailing with the propeller and vane system since May 1980 without any trouble. Although the idea of the vane-system is a power reduction by a kind of hydrodynamic reduction gear at a given relatively high Diesel motor revolution, another investigation in the large HSVA tunnel for a vessel of about 16 knots with more cavitation showed that the pressure impulses can also be reduced significantly by the vane. Results are presented in Fig. 3.

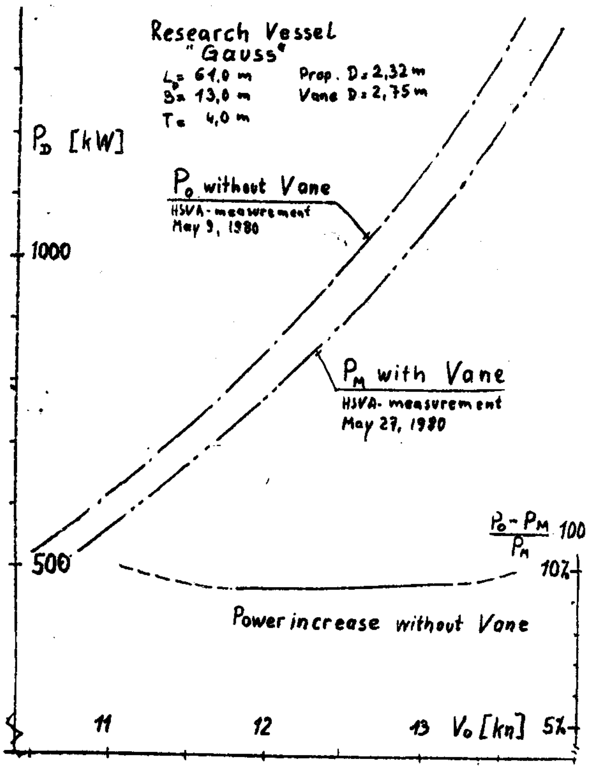

Fig.2. Power of the Vessel with and without Vane

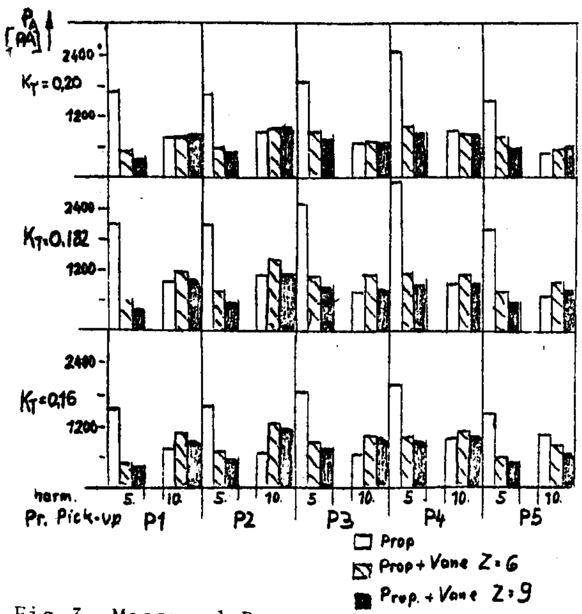

Fig.3. Measured Pressure Anplitudes
Prop.2005 0.24
Large HSVA - Tunnel

These were published in the Institut für Schiff, Hamburg, Rep. No 388 and in the Journal of Ship Research , January 1981.

Furthermore it should be mentioned that the propeller-hull vortex, observed for the propeller alone in the large HSVA tunnel, was avoided by applying the vane. This is obviously due to an acceleration of the flow in the high wake peak above the propeller.

Concluding a possible explanation for the reduction of the pressure impulses may be that the vane takes about 15-20% of the total thrust. A reduction of the thrust of the propeller at the outer radii leads to a smaller cavity volume and the pressure impulses reach very sensitively to the cavity volume.

H. LINDGREN - Swedish Maritime Research Centre SSPA, Göteborg, Sweden

1. Is it really the task of the propeller committee or ITTC to develop methods for the design and criteria for the optimization of hull shape and propulsion device as indicated in recommendations 5 and 6? We are not in the neighbourhood of that kind of ambition in any of the other ITTC committees. Compare for instance with the discussion of the resistance committee report.

2. I would also like to put forward a very general question dealing with the choice of the technical committees. If we go on forming new committees every time ITTC has its meetings we will soon need a month for the general session. We have always to be open for the possibilities to combine the work of different committees. My question to-day is whether the propeller committee regards that the future work of for instance the propeller and cavitation committees might preferably be handled by one committee. We have

seen many signs of interference between the committees and confusion as to which committee should deal with what.

II. REPLY OF THE PROPELLER COMMITTEE

The first item of the contribution of *Chai Yang-Yi and Chen Ta-Chuan* dealing with measurements of nominal wake at full scale and at model scale is very useful, full scale measurements of nominal wake are scarce.

It is satisfying to learn that the Sasajima method for scale effect connection and the estimate of the possibility of the occurence of large excitation forces by means of the criteria for wake non-uniformity, as mentioned in the Report, were indicated.

There is, however , one important aspect to this contribution: the data available and the methods used do not include any effect of the propeller, although the propeller generates the excitation forces. When it is attempted to reduce the excitation forces by a modification to the propeller design, one needs methods which take into account the propeller action. The Propeller Committee considers that accurate methods for such calculations are not available and therefore it is necessary to stimulate research in this direction.

We appreciate very much the comment and additional information given by *Dr. Weitendorf*. The Committee agrees that there are many possible error sources and pitfalls when doing model measurements of propeller-induced hull pressures.Scale effect on the dynamic behaviour and development of unsteady cavities at different pressure in model and full scale is indeed one possibility . Wake distribution scale effect is another.

We are a little surprised that one can calculate standing waves at a few specific frequencies. Considering the complex geometry of the tunnel and taking into account pressure wave reflections at oblique incidence to the tunnel walls, one would expect an infinite number of frequencies, i.e. a continuous spectrum. In any case, our advice is to check it experimentally as has been done earlier at NHL and now at HSVA.

Regarding Ref.(67) our comments are as follows: first of all our statement in the Report that " tests can enable predictions to be made to an accuracy of the order of 20%" does not exclude the possibility of cases beyond this limit. Reference (67) was mentioned in our Report to illustrate this fact. Furthermore, one should be careful not to over-dramatize the case of Ref.(67). According to Dr. Weitendorf's data we are here talking of relatively low pressure amplitudes. For very low amplitudes the 20% limit will of course not apply. We may have been careless not making that reservation in our Report. When the amplitudes are very low , however, a high relative accuracy is not important, at least not from a practical ship design point of view.

The Committee fully agrees with *Drs. Tamura and Sasajima* in their comment about the inability of present day theories to describe accurately the cavity geometry. We have already included this item in our proposed recommendations for the next Committee.

We also agree fully with the statements of Tamura and Sasajima concerning criteria for assessing the acceptable levels of propeller-induced vibration. In fact we say in our Report, " These simple criteria are used in the early stages of design before the structural characteristics of the ship are known , with full realisation that vibration depends upon both excitation and structural response." As long as such criteria are being developed and used , we feel that we should evaluate them and let the profession know what are the pitfalls.

Prof. Isay is correct in concluding that experimental results concerning pressure distribution on the propeller blade are not yet available in a sufficient quantity, even in the cavitation-free conditions. Further activity in this field appears to be urgently needed, as noted in the Introduction to Part II of the Report. Therefore this topic is recommended for continuation by the next Propeller Committee, and references supplied will be useful in the context.

Drs. Varsamov and Hadjimikhalev gave in their discussion information on a numerical procedure for optimum load distribution for wake adapted propellers in use in Bulgaria. One of their findings was that it was possible to reach a propulsive efficiency of 3 to 4 percent higher than that indicated by the conventional criteria for optimum circulation, by increasing the load at the propeller tip.

One of the reasons for this result might be that these criteria are formed without considering the fact that the propeller is changing the vorticity of the wake. In the future, when this effect has been taken into account, we might very well get quite different criteria for optimum load distribution from those we have today. Following one of the proposed recommendations, the Committee will within the next period study these problems more closely and the work done by Drs. Varsamov and Hadjimikhalev will then be of great value. We therefore ask them to send further information on this work to the members of the next Propeller Committee.

Mr. Sun Qin and Gu Yun-de studied tandem propeller sets and presented conclusions concerning the gain in efficiency, the optimum phase angle between forward and aft propellers and some remarks connected with vibration measurements for several actual ships equipped with tandem propellers.

The problem of dividing the total power into the forward and aft propeller of the tandem set is one of the principle problems in tandem propeller design. The efficiency gain is largely dependent on the correct solving of this problem. The criterion of power division can be the cavitation criterion based on the requirement that the cavitation should initiate simultaneously on both propellers. Such a criterion is used by T.Tuszkowska (173)

The optimum phase angle between the forward and aft propellers is determined by the criterion that the aft propeller blades should lie midway between the tip vortices of the forward propeller. It depends therefore upon the axial distance between the two propellers and upon the pitch of the tip vortices of the forward propeller. This was also shown by Tuszkowska [173] among others.

With regard to unsteady exciting forces from tandem propellers, Miller [121] and Titov and Biskup [122] have shown that by phasing between the propellers of a tandem set the unsteady exciting forces can be reduced.

The Committee expresses its gratitude to *Dr. Weitendorf* for the information he gave on full scale and model results with the propeller and vane invented by Prof. Grim. The reason why we did not mention this propulsion system in the Report is that it primarily is used to increase the propulsion efficiency of existing ships with small, fast rotating propellers. It is,however, interesting to hear that it also has a beneficial effect on the pressure fluctuations on the hull especially when cavitation occurs. The combination of propeller and free rotating vane is a kind of hydrodynamically geared slow rotating propeller. Probably the gain in efficiency and reduction in vibratory pressures would have been less if the comparison was made, not with the existing conventional propeller, but with a conventional slow rotating propeller with the same diameter as the vane.

In reply to *Dr. Lindgren's* first questions concerning Recommendations 5 and 6 on methods for the design and criteria for optimising the hull shape and the propulsion device , it is not intended that the Committee should concern itself with optimisation and design but with assessing the criteria and evaluating methods of design used. The Committee is concerned with extravagant claims being made for some propulsion devices and hulls where the assessment of comparative performance has not been done correctly. Dr. Lindgren's concern over the overlap between the work of the Propeller and Cavitation Committees is also a concern to many of us but it is really a question for the Advisory Council. Judging from the work load of most towing tanks,there is enough work for the two Committees. The Conference must, however , assure that the work of the Committees is properly coordinated.