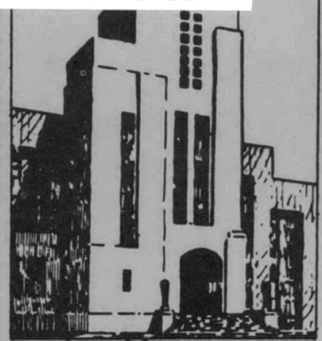
#1



DEPARTMENT OF THE NAVY
DAVID TAYLOR MODEL BASIN

HYDROMECHANICS

○

AERODYNAMICS

○

STRUCTURAL MECHANICS

○

APPLIED MATHEMATICS

EXPERIMENTS ON THE EFFECT OF BOW FORM ON SHIP SLAMMING

by

Kazuo M. Ochi, Dr. Eng.

[redacted]

[redacted]

HYDROMECHANICS LABORATORY

RESEARCH AND DEVELOPMENT REPORT

January 1962 Report 1400

RNC-TMB-648 (Rev. 3-58)

EXPERIMENTS ON THE EFFECT OF BOW FORM ON SHIP SLAMMING

by

Kazuo M. Ochi, Dr. Eng.

January 1962

Report 1400

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

This report presents the results of an experimental study of the effect of ship bow form upon ship motion and upon hydrodynamic loads due to slamming. A 5.5-ft model of MARINER, regarded as representative of the U-form type, and of a V-form modification were tested in head seas in regular waves. Pitching, heaving, bow acceleration, and hydrodynamic impact pressure due to slamming were measured and a comparative evaluation of the two types is made.

It was found from the tests that the V-form experiences lower slamming pressure than MARINER (U-form) between 0.10 L and 0.15 L aft of the forward perpendicular, however MARINER (U-form) experiences lower pressure than the V-form modification between 0.20 L and 0.30 L aft of the forward perpendicular. This was found to be true irrespective of ship speed. Since structural damage due to slamming usually occurs within the domain between 0.15 L and 0.20 L aft of the forward perpendicular, the test results may serve to provide information in the design of the forward hull form with respect to slamming.

INTRODUCTION

The object of this report is to study the effect of ship form, especially the form of the ship's forward section, upon the hydrodynamic loads due to slamming.

Many papers have been published to date concerning the effect of ship form upon the behavior of ships in waves,[1–8] yet few papers[9–12] have referred to the effect of bow form upon slamming.

A few years ago, the author carried out slamming tests in regular waves on two merchant ships forms, representative of U- and V-sections forward, and concluded in his paper that the V-form ship seemed to be superior to the U-form ship as far as slamming is concerned.[10] However, the lines of the U-form ship employed in that experiment might not be considered as a typical representative of the U-form type, for the model employed does not have plumb lines in its forward sections as do MARINER and Series 60. Partly for this reason and partly to obtain the effect of ship form upon slamming for a different block coefficient, experiments on two new models were made in regular waves. One was a MARINER model which is regarded as a representative of the U-form type, the other was a V-form modification which had principal dimensions identical with MARINER but with V-sections forward.

---

[1]References are listed on page 19.

Pitching, heaving, bow acceleration, and hydrodynamic impact pressure due to slamming were measured in regular waves. A greater part of the experiments were made at a light draft condition to induce slamming, however tests at the maximum draft condition were also carried out in a wave whose length was equal to the model length.

DESCRIPTION OF EXPERIMENT

MODEL PARTICULARS

Two 5.5-ft models were employed in the experiments. One model had the original lines of MARINER, the other had principal dimensions identical with those of MARINER, but with V-sections forward as shown in Figure 1. The modification of the lines was made between the forward perpendicular and Station 7 with changes in the sectional area below the design draft held to a minimum. However, the V-form hull had no bulb, so the sectional areas of V-form MARINER for those lines between the forward perpendicular and Station 3 show some difference from those of MARINER. Such differences may be considered to cause a minor alteration of hull-form coefficients. The characteristics of the models and the ship are given in Table 1.

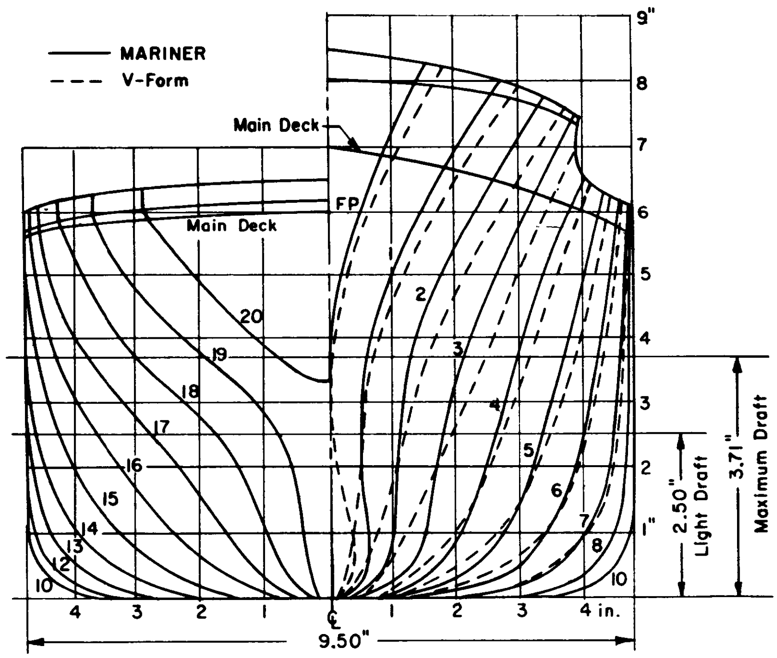


Figure 1 – Lines of MARINER and V-Form Modification

TABLE 1

Characteristics of MARINER

Item	Prototype	Model	
		MARINER	V-Form
Length, *LOA*, ft	563.64	5.86	5.86
Length, *LBP*, ft	528.00	5.50	5.50
Breadth, *B*, ft	76.00	0.79	0.79
Depth, *D*, ft	35.50	0.37	0.37
Draft, max, H_{max}, ft	29.75	0.31	0.31
Block coefficient, C_f	0.624	0.624	0.624
Prismatic coefficient, C_p	0.635	0.635	0.635
Midship coefficient, C	0.983	0.983	0.983
Waterplane coefficient, C_w	0.745	0.745	0.745
Displacement, max (mould)	20,954 (ton)	53.1 (lb)	53.1 (lb)
Displacement, light draft (mould)		33.1 (lb)	33.1 (lb)
Radius of gyration	0.24 L aft of F.P.	0.24 L aft of F.P.	0.24 L aft of F.P.
Natural pitching period, at light draft, sec		0.75	0.69
Natural heaving period, at light draft, sec		0.78	0.71
Scale ratio	1	1:96	1:96

TEST PROCEDURE

The experiments were carried out in the 140-ft tank of the David Taylor Model Basin. All runs were made in head seas in regular waves of various lengths. As is shown in Table 2, the majority of the tests were made at a light draft condition of $H/L = 0.038$ to induce slamming. However, tests were also carried out at the maximum draft in waves of length equal to the model length. The wave height-wave length ratio was taken as 1/20 for all wave lengths in the experiment.

Resistance, pitching and heaving motion, bow acceleration and pressure were measured. The measurement apparatus was the same as that used in the slamming study of the effect of the bulbous bow of MARINER.[13] The locations of the pressure gages for both models are listed in Table 3.

TABLE 2

Outline of Experiment

Item	Wave Length λ (ft)	λ/L	Wave Height h (in.)	h/λ	Draft H (in.)	Trim by Stern in.	Model Speed knots
Influence of wave length	9.64	1.75	5.80	1/20	2.50	0.90	from 0 to about 2.8
	6.88	1.25	4.13	1/20	2.50	0.90	from 0 to about 2.3
	5.50	1.00	3.30	1/20	2.50	0.90	from 0 to 2.5
	4.13	0.75	2.48	1/20	2.50	0.90	from 0 to 1.7
Influence of draft	5.50	1.00	3.30	1/20	3.72	0	from 0 to 2.2

TABLE 3

Location of Pressure Gages

Pressure Gage No.	Location		
	Longitudinal	Transverse	Vertical
1	0.100 L aft of F.P. (MARINER only)	Centerline	Bottom
2	0.125 L	Centerline	Bottom
3	0.150 L	Centerline	Bottom
4	0.175 L	1 1/8 in. outboard (MARINER) 13/16 in. outboard (V-form)	1/4 in. above B.L.
5	0.175 L	1 5/8 in. outboard (MARINER) 1 5/16 in. outboard (V-form)	3/4 in. above B.L.
6	0.200 L	Centerline	Bottom
7	0.225 L	1 1/2 in. outboard (MARINER) 1 5/16 in. outboard (V-form)	1/4 in. above B.L.
8	0.250 L	Centerline	Bottom
9	0.300 L	Centerline	Bottom

EXPERIMENTAL RESULTS

RESISTANCE AND SPEED LOSS

Resistances obtained from tow forces are plotted versus model speed for various wave lengths at light draft condition and are shown in Figure 2. Resistance for the maximum (design) draft condition in waves of length equal to the model length and resistances in still water are also shown in Figure 2.

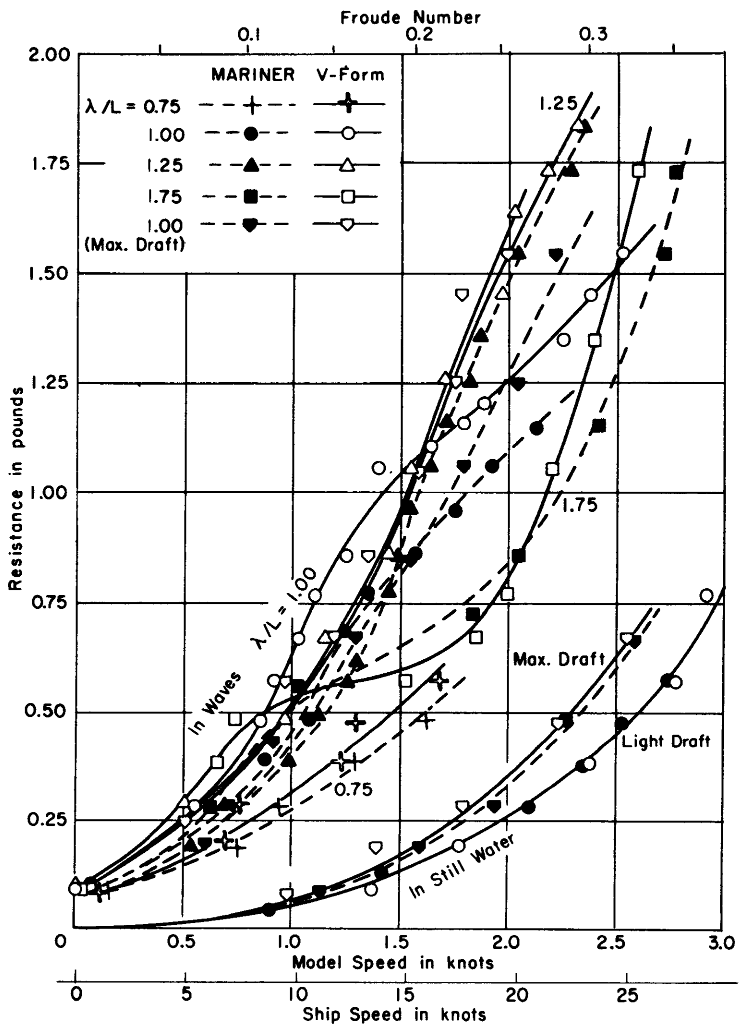


Figure 2 – Comparison of Resistance between MARINER and V-Form Modification

Note that MARINER has generally less resistance than the V-form model in waves. The resistances in still water at light draft condition are almost the same for both models. However, the resistances in waves for the V-form model are higher than those for MARINER. This may be explained by the effect of ship motion upon resistance. As will be mentioned later, the study of ship motion shows clearly that the motions of the V-form model in waves at light draft condition are generally more severe than those of MARINER except in very long waves ($\lambda/L > 1.75$).

A considerable speed loss for both models is indicated in Figure 2. A comparison of speed loss between MARINER and the V-form model at light draft condition in waves of various lengths for a constant thrust is shown in Figure 3. The thrust of 0.35 lb for MARINER and 0.38 lb for the V-form model correspond to the thrusts which are necessary to achieve the design speed in still water at maximum draft. The thrust of 0.67 lb, Figure 3, corresponds to that necessary for 2.58 knots and 2.55 knots (25.3 and 25.0 knots in full scale) at the maximum draft condition in still water for MARINER and the V-form model, respectively. Figure 3 shows that the speed loss for the V-form model is greater than that for MARINER. For example, for wave length equal to ship length, the V-form model loses 73 percent of its speed in still water for a constant thrust, whereas the MARINER loses 63 percent.

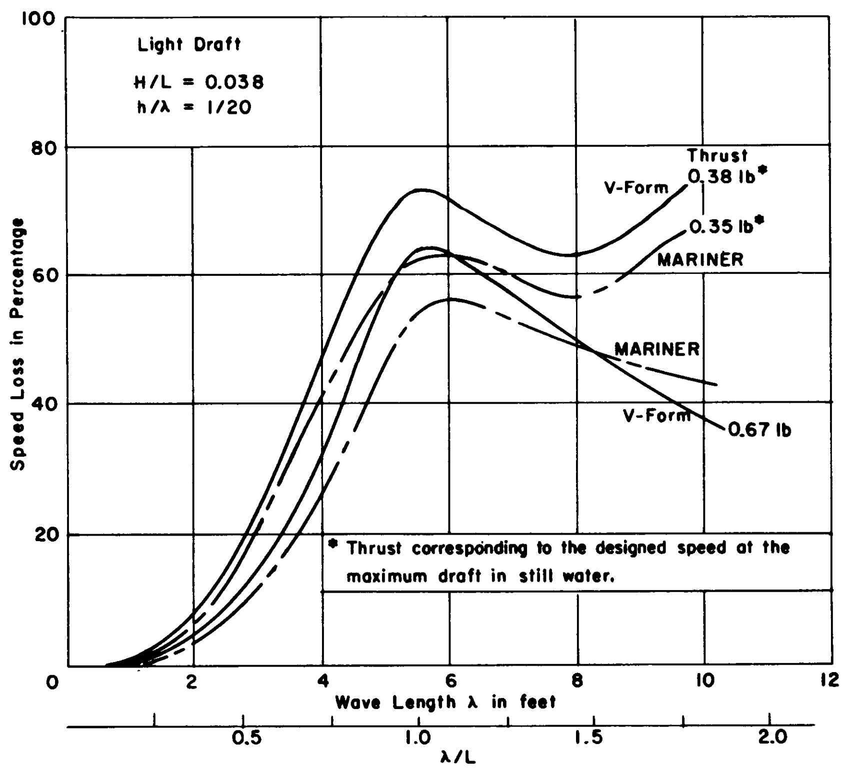


Figure 3 – Speed Loss versus Wave Length for MARINER and V-Form Modification

Figure 3 also shows that the waves whose length is equal to ship length would be the most severe for loss in speed. However, both ships show a large magnitude of speed loss even in waves as long as 1.75 L for a thrust corresponding to design speed. This can be seen in Figure 2, where a considerable speed loss is indicated near $F = \frac{V}{\sqrt{gL}} = 0.1$ in waves of great length. The reason for such large speed loss at these particular speeds in waves of great length cannot be explained clearly at the present stage; however, a similar trend can be seen in the test results obtained by Sibul.[14, 15] He mentioned that at the critical value of $\omega_e \frac{V}{g} = 0.25$, a sudden change in pitch and heave motion occurs which in turn increases the resistance. He also pointed out that this phenomenon was particularly significant in waves of great height. Now, the computed value of $\omega_e \frac{V}{g}$ in the present case ($\lambda/L = 1.75$, $h/\lambda = 1/20$, $F = 0.1$) was 0.23, and this value is close to the critical value given by Sibul. The pitching and heaving motion are indeed off the faired curve at this particular speed (see Figures 4 and 5). It may, therefore, be said that the large speed loss at the particular speed observed in the tests can be attributed to a sudden change in ship behavior in waves of great height.

MOTION IN WAVES

The measured pitch, heave, and bow acceleration formed the basis of the motion analysis. The dimensionless pitching and heaving amplitudes were computed and are shown in Figures 4 and 5. It appears that the pitching and heaving motions of the V-form model are generally larger than those of the MARINER at both light and maximum draft conditions except in waves of great length such as $\lambda/L = 1.75$.

A more interesting plot is obtained if the dimensionless pitching and heaving amplitudes are expressed as a function of tuning factor T_p/T_e or T_h/T_e, where T_p and T_h are the measured natural pitching and heaving periods of a model afloat in still water, and T_e is the encounter period of the model with wave. Figure 6 shows an example obtained at light draft condition in waves of ship length. Some important conclusions may be derived from the figure: (1) Since the natural pitch period is close to the natural heave period for both models (see Table 1), the synchronous speed for heaving is higher than that of pitching for both MARINER and the V-form modification, (2) the synchronous speed of pitching and/or heaving for MARINER is higher than that for the V-form modification, and (3) amplitudes of both pitching and heaving of the V-form hull are greater than those of MARINER at light draft condition. These conclusions are in agreement with the conclusions that were obtained in the comparison tests made on U- and V-form models of block coefficient 0.74.[9] The identical tendency in the two series of tests with different block coefficients suggests that the preceding three conclusions would be generally applicable to ships of any block coefficients at light draft.

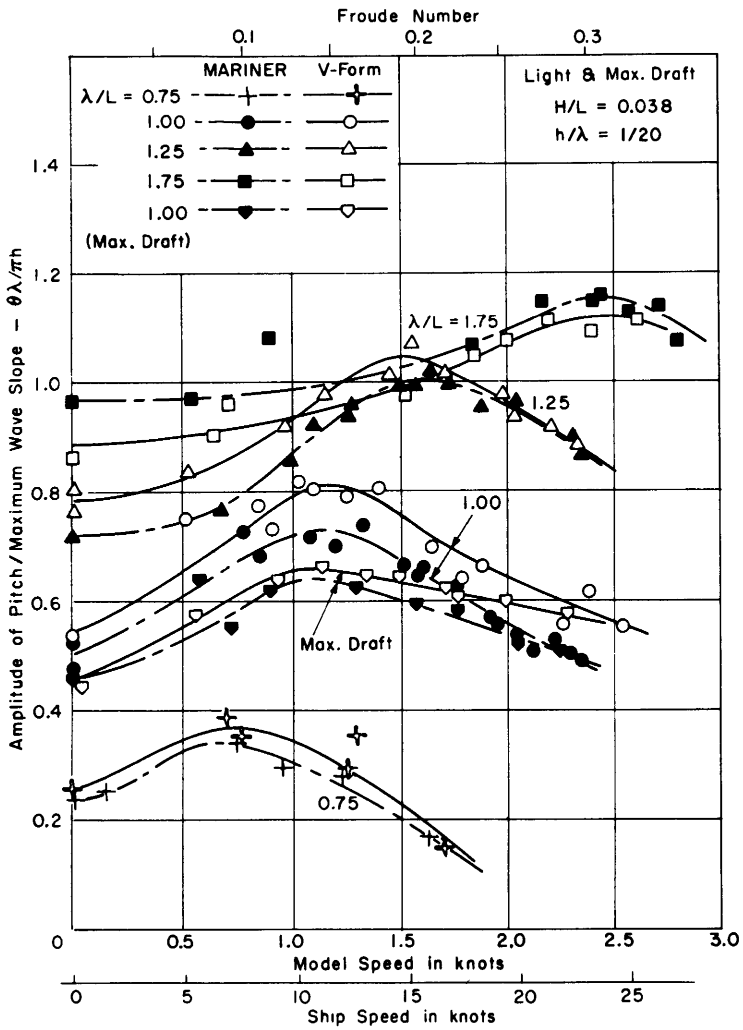


Figure 4 – Dimensionless Pitch Amplitude of MARINER and V-Form Modification versus Ship Speed

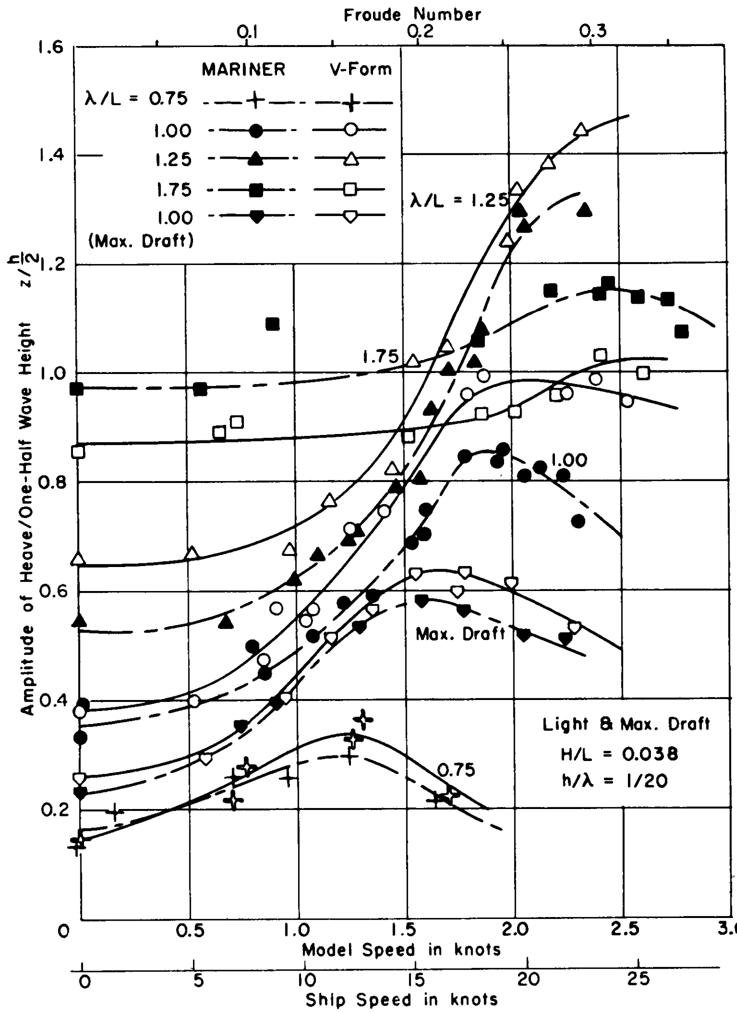


Figure 5 – Dimensionless Heave Amplitude of MARINER and V-Form Modification versus Ship Speed

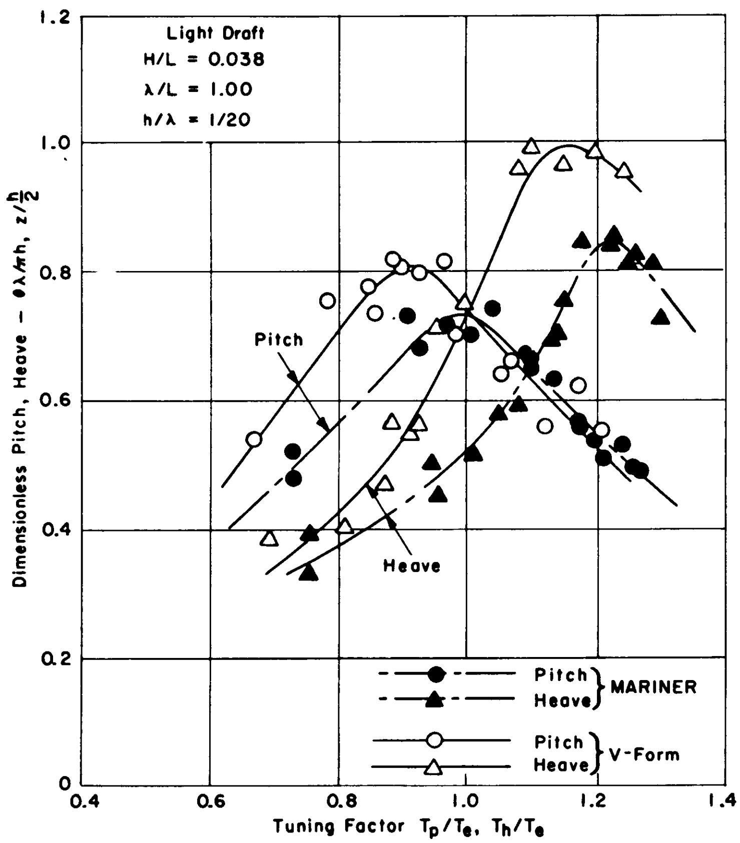


Figure 6 – Dimensionless Pitch and Heave Amplitudes of MARINER and V-Form Modification versus Tuning Factor

Figure 7 shows the relation between dimensionless pitching and heaving amplitudes and wave length for a thrust of 0.35 lb for MARINER and 0.38 lb for the V-form model. These are the thrusts for design speed in still water as was mentioned previously. It appears that both pitching and heaving amplitudes increase with increasing wave length and that the pitching amplitude flattens out for waves of $\lambda/L \geqq 1.5$. Also it is of interest to note that both pitching and heaving amplitudes of MARINER are less than those of the V-form hull for $\lambda/L \leqq 1.5$, and vice versa for $\lambda/L > 1.5$.

The double amplitude of bow acceleration produced by ship motion in waves is shown in Figure 8. The definition of bow acceleration should be mentioned. The vertical acceleration of the ship's bow is generally divided into two parts; one is produced by the combined pitching and heaving of the ship and the other is the slamming acceleration related to the hull shudder which is produced by the slamming impact. The former has usually a sinusoidal form and its period is identical with the encounter period of ship with wave, while the latter appears only at the time of ship slamming and has a high frequency corresponding to the natural frequency of the ship's hull and damps out quickly. In Figure 8 the first of these is shown. It can be seen that the bow acceleration for MARINER is generally less than that for the V-form hull

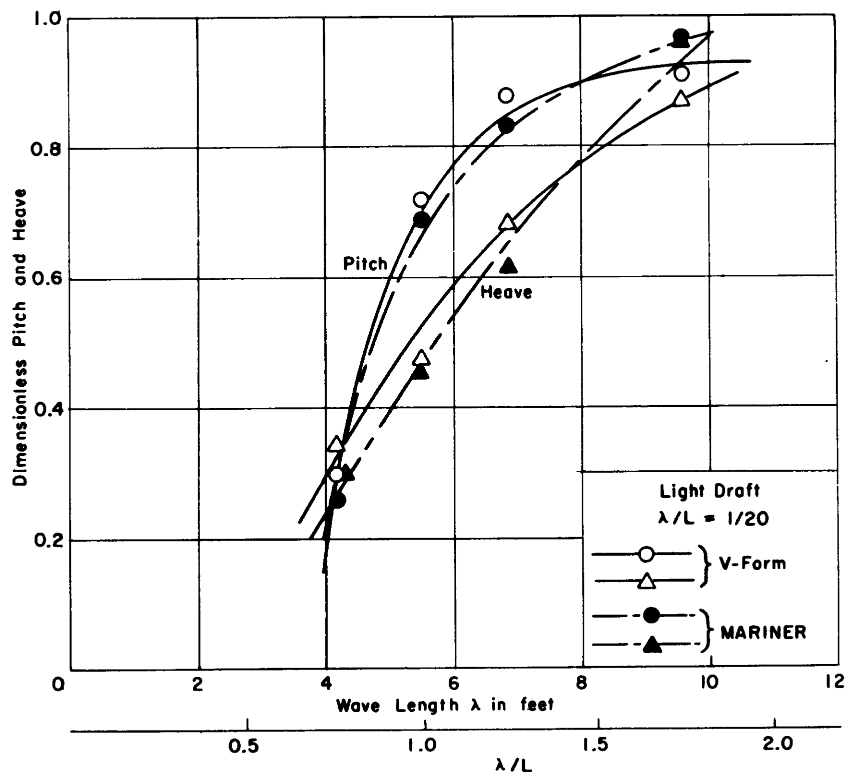


Figure 7 – Dimensionless Pitch and Heave Amplitudes of MARINER and V-Form Modification versus Wave Length

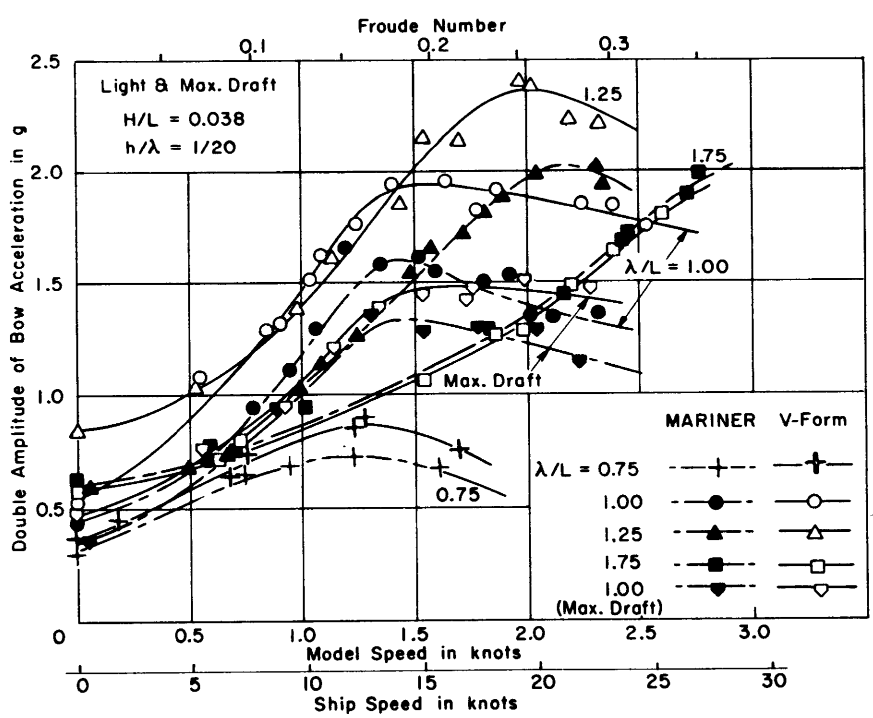


Figure 8 – Comparison of Double Amplitudes of Bow Acceleration between MARINER and V-Form Modification

except in waves of great length. The difference of the acceleration between MARINER and the V-form hull in waves of $\lambda/L < 1.5$ appears large.

It appears from the discussion so far that with respect to ship resistance, speed loss, and ship motion such as pitching, heaving, and bow acceleration, MARINER is superior to the V-form modification. However, it is of considerable importance to note that less motion of MARINER does not always result in less slamming than the V-form model. Slamming depends not only on the magnitude of ship motion but also on the phase between wave and bow motion, and on the flatness of the bottom, and/or form of the ship bow. The magnitude of slamming acceleration, i.e., the maximum sudden change in bow acceleration at the instant of slamming impact, shows the significance of the foregoing statement. That is, the magnitudes of slamming acceleration for MARINER are generally larger than those for the V-form modification except in short waves, as can be seen in Figure 9. Inasmuch as the slamming acceleration has a close relation with the impact pressure due to slamming since it shows the response to the impact pressure, it has to be borne in mind that ship slamming cannot be discussed merely from the ship motion point of view.

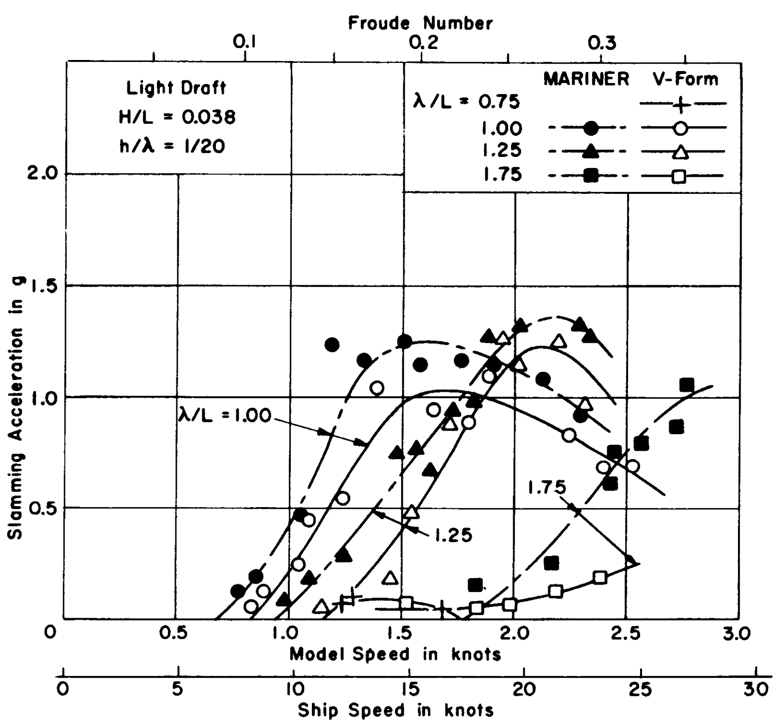


Figure 9 – Comparison of Slamming Acceleration between MARINER and V-Form Modification

In Figure 9, no slamming acceleration is recognized for MARINER at any speeds in short waves ($\lambda/L = 0.75$), although the ship's forward bottom suffers a slight impact pressure from the waves as is seen in Figures 10 and 11. This may be explained by considering the

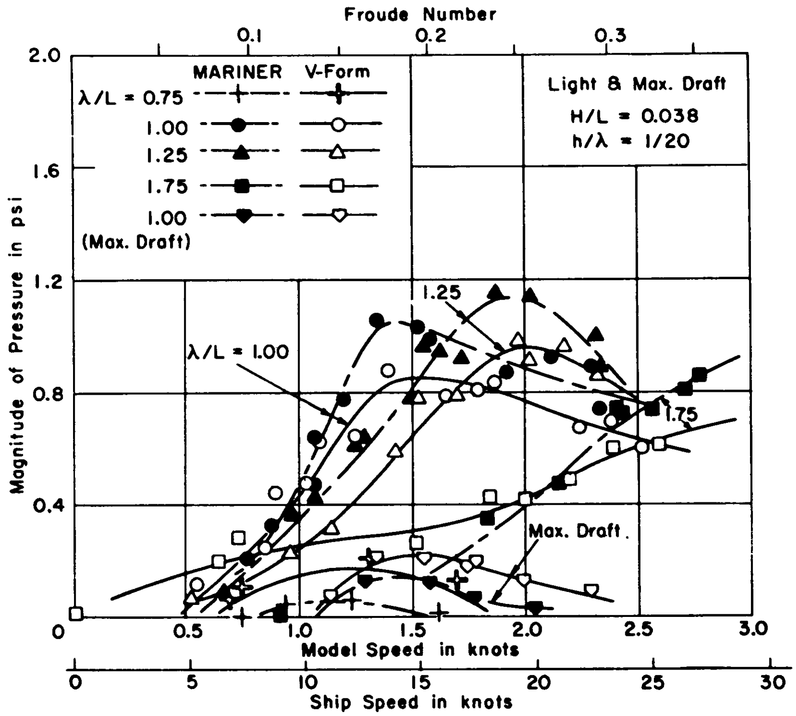


Figure 10 – Comparison of Slamming Pressure between MARINER and V-Form Modification at Location 0.125 L aft of F.P.

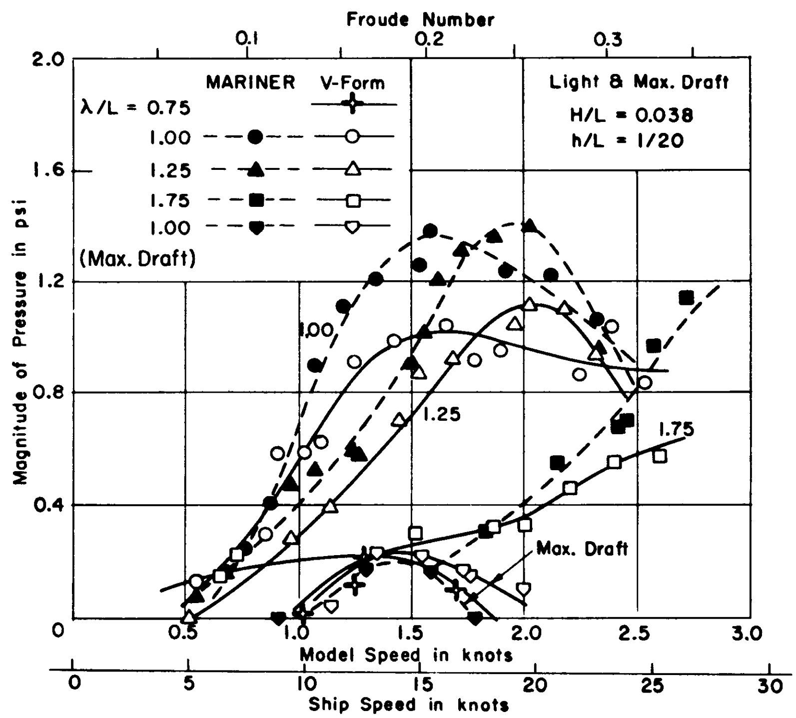


Figure 11 – Comparison of Slamming Pressure between MARINER and V-Form Modification at Location 0.15 L aft of F.P.

total impact force at the instant of slamming. Since the integrated impact pressure over the whole impact area is not large enough for a hull to respond significantly to the impact, the slamming acceleration does not appear in waves of short length.

Another interesting trend in Figure 9 is that the slamming acceleration for the V-form model is much less than that for MARINER at high speeds over 2.0 knots (19.6 knots, full scale) in long waves (λ/L = 1.75), even though there is no particular difference between their motions at these speeds. Also, the slamming acceleration for the V-form model in long waves is still observed at speeds under 1.8 knots (17.6 knots, full scale), but no slamming acceleration is observed for MARINER. As the same tendency can also be seen in slamming impact pressure, which will be discussed later, it may be concluded that the slamming acceleration has a very close relation with the impact pressure due to slamming.

SLAMMING PRESSURE

The magnitudes of maximum impact pressure measured at several forward sections are plotted versus ship speed for various wave lengths and are shown in Figures 10 through 14. The pressures shown in these figures were all obtained along the keel-line within the range from 0.125 L to 0.30 L aft of the forward perpendicular.

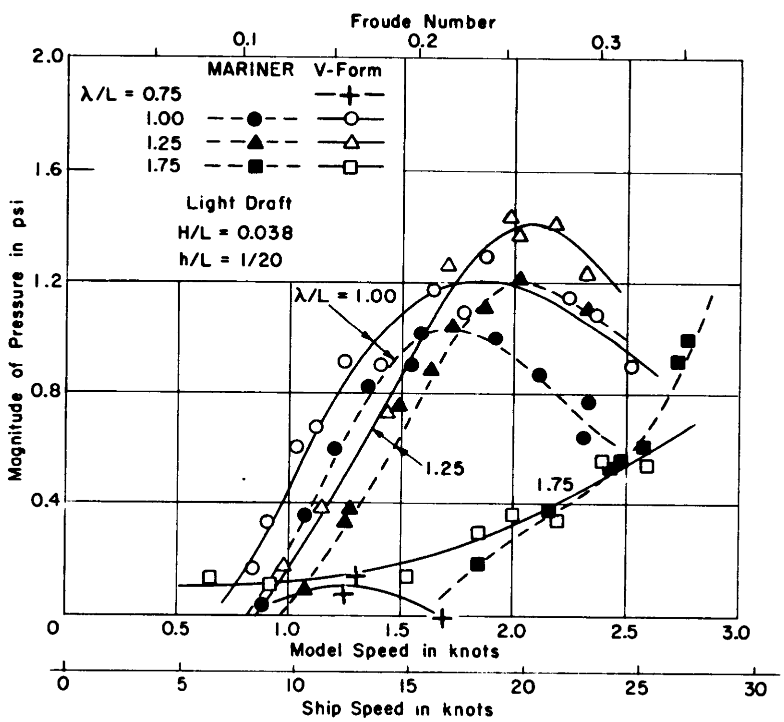


Figure 12 – Comparison of Slamming Pressure between MARINER and V-Form Modification at Location 0.20 L aft of F.P.

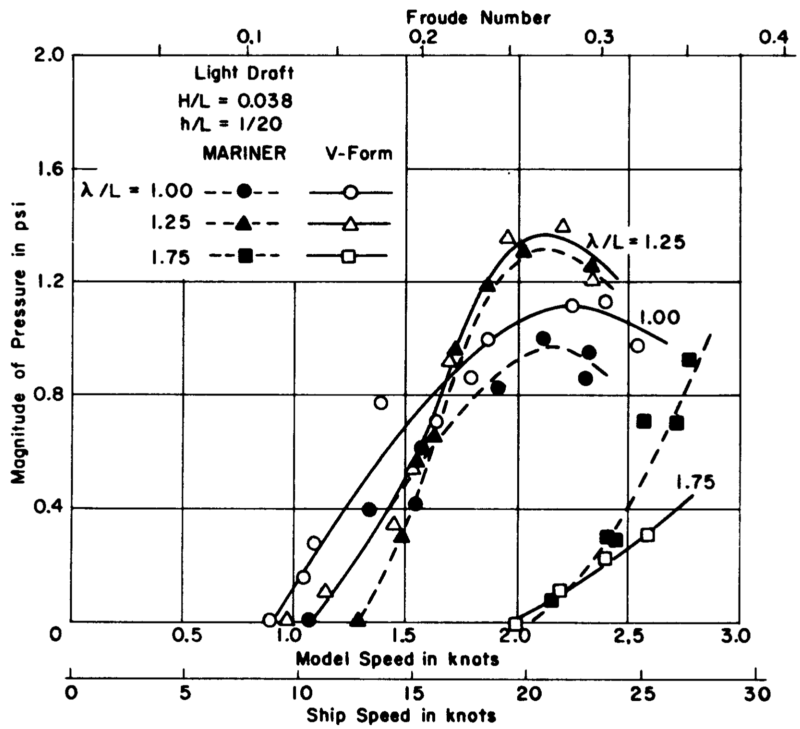


Figure 13 – Comparison of Slamming Pressure between MARINER and V-Form Modification at Location 0.25 L aft of F.P.

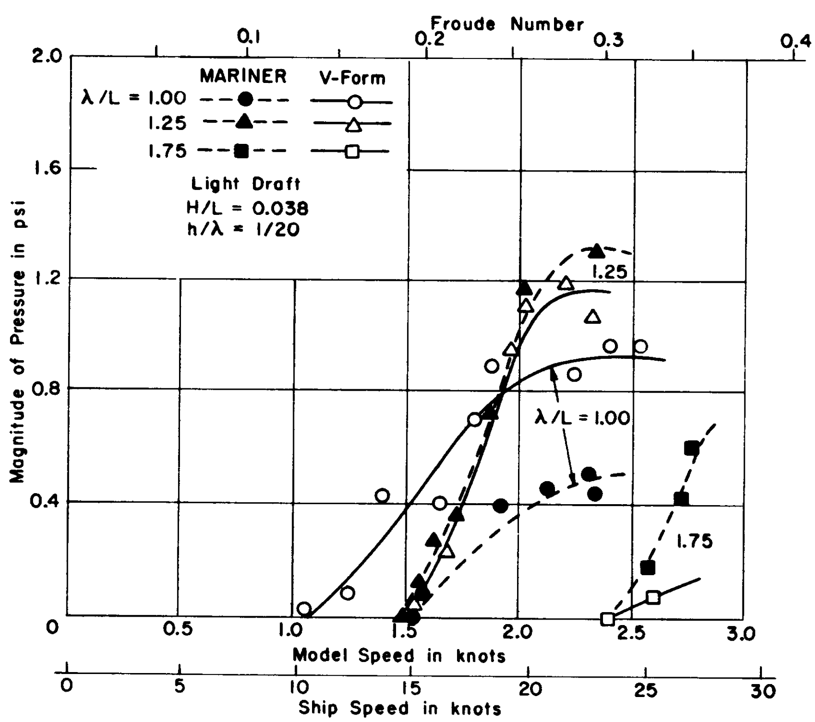


Figure 14 – Comparison of Slamming Pressure between MARINER and V-Form Modification at Location 0.30 L aft of F.P.

From a survey of these figures, the following conclusions may be drawn:

1. The waves whose length is equal to or a little longer than ship length seem to be most severe for ship slamming at speeds under the design speed.
2. The magnitudes of slamming pressure for short waves such as $\lambda/L = 0.75$ are so small that they cannot properly be called slamming pressures, as they do not produce measurable responses.
3. The speed at which the slamming pressure becomes highest tends to shift towards higher speed with increase of wave length.
4. The magnitude of the slamming pressure and also the speed range within which the pressure is recognizable are very small at the maximum draft; see Figures 10 and 11.

A comparison of the magnitude of slamming pressure obtained from these figures is of considerable interest. Inasmuch as the slamming pressure is a function of wave length, ship speed, and location of the pressure gage, Figures 15 and 16 are prepared for convenience to show this dependence. Figure 15 shows the slamming pressure versus wave length for the two models for various speeds at the station 0.15 L aft of the forward perpendicular, and Figure 16 shows the comparison at the station 0.20 L aft of the forward perpendicular. An interesting and important result is that the magnitude of slamming pressure of MARINER is larger than that of the V-form model at all speeds and wave lengths at the station 0.15 L aft of the forward perpendicular, while the reverse is true at the station 0.20 L aft of the forward perpendicular.

By preparing similar figures for other stations, the following results can be derived.

1. In short waves ($\lambda/L = 0.75$), MARINER is superior to the V-form hull with respect to slamming. However, the slamming pressures are generally very small for these waves.
2. In wave lengths causing severe slamming such as $\lambda/L = 1.00$ to 1.50, the V-form model experiences lower pressures between stations 0.10 L and 0.15 L, whereas MARINER pressures are lower between 0.20 L and 0.30 L aft of the forward perpendicular. This was found to be true irrespective of ship speed.
3. In long waves ($\lambda/L = 1.75$), MARINER is superior to the V-form hull at speeds under the design speed, while the V-form ship is superior at very high speeds.

In the preceding conclusions, the second item is, of course, the most important for ship slamming, since the pressure magnitudes are much higher than those in the other cases. Although the conclusion is for a portion of the hull bottom, a comparison of magnitude of severe slamming pressure between two forms at the portion (from Station 2 to 6) may still be meaningful, since the structural damage due to slamming usually occurs within this domain of hull bottom. However, in order to discuss the pressure distribution along the ship length, Figures 17 and 18 were prepared.

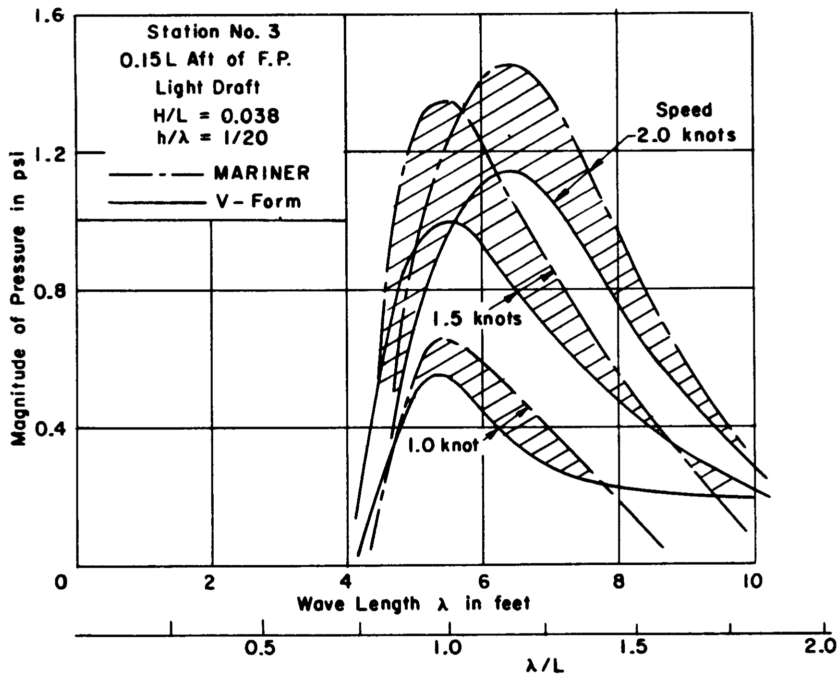


Figure 15 – Comparison of Slamming Pressure between MARINER and V-Form Modification at Location 0.15 L aft of F.P.

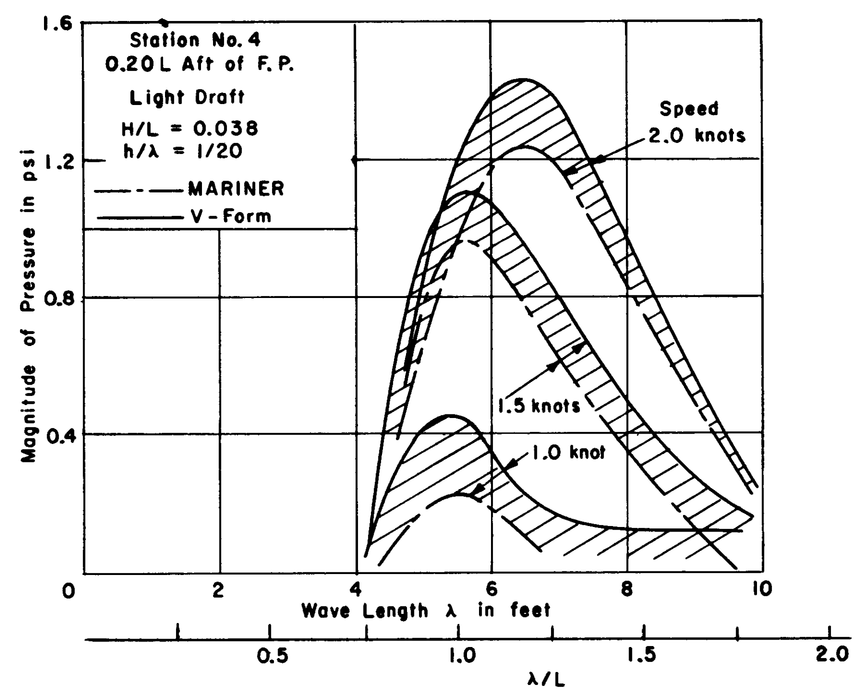


Figure 16 – Comparison of Slamming Pressure between MARINER and V-Form Modification at Location 0.20 L aft of F.P.

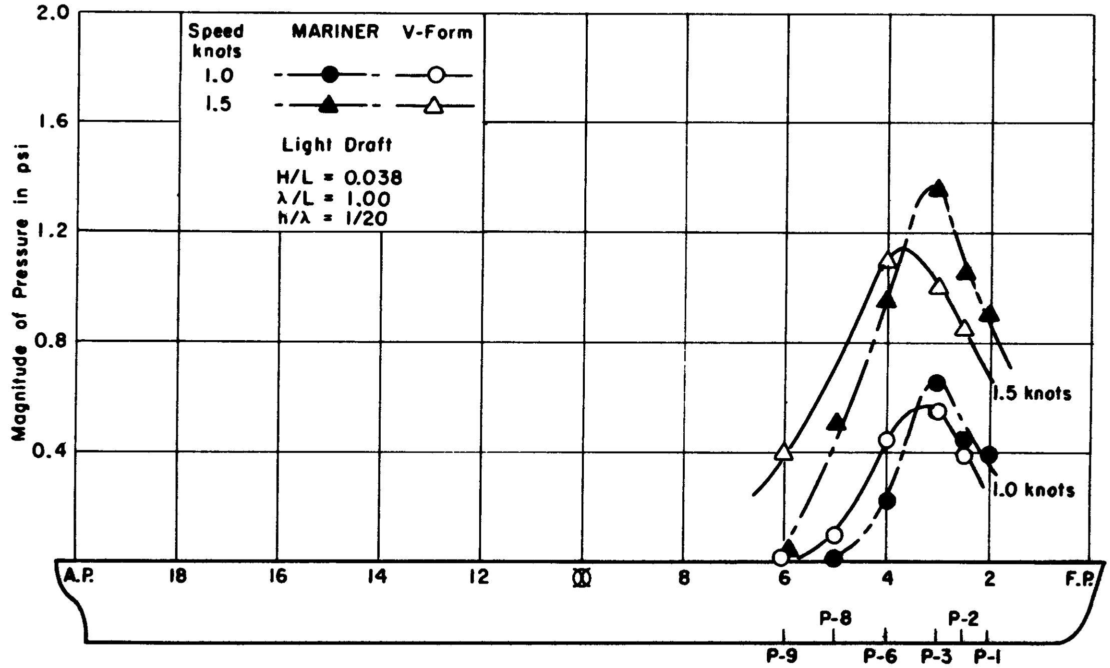


Figure 17 – Distribution of Slamming Pressure in Waves of $\lambda/L = 1.00$

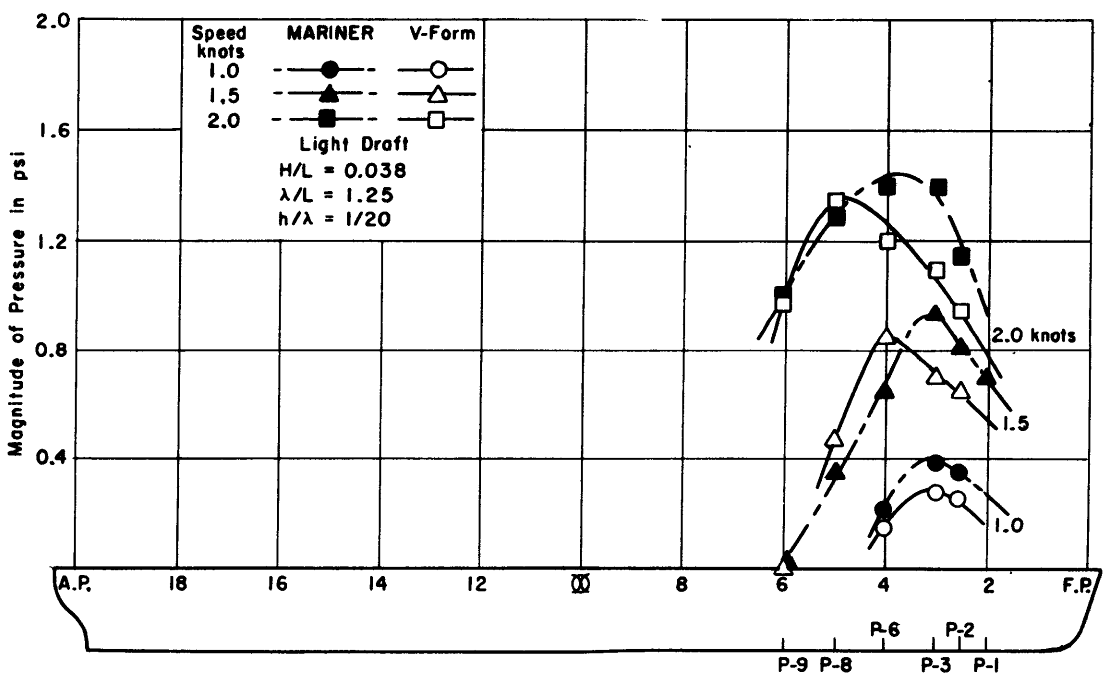


Figure 18 – Distribution of Slamming Pressure in Waves of $\lambda/L = 1.25$

Figure 17 shows the distribution of the slamming pressure along the keel-line obtained in waves of $\lambda/L = 1.00$, and Figure 18 is for waves of $\lambda/L = 1.25$. It is clear from these figures that the longitudinal position of maximum slamming pressure shifts aft with increase of ship speed, and the longitudinal position of maximum slamming pressure for the V-form hull aft of the longitudinal position for MARINER. These results are in agreement with the conclusions obtained in the experiments on brass models with block coefficients 0.74.[10]

Figure 19 shows an example of the distribution of slamming pressure along the ship's girth at the station 0.175 L aft of the forward perpendicular. In the figure, the magnitudes of pressure were plotted normal to the surface of model bottom at the points where the pressure was measured. The figure is for the wave whose length is equal to ship length, and at moderate and severe speeds for slamming. The distribution curve presents the envelope of peak pressure at each point during one slam. It is seen from the figure that the maximum pressure occurs around the flat bottom of both models.

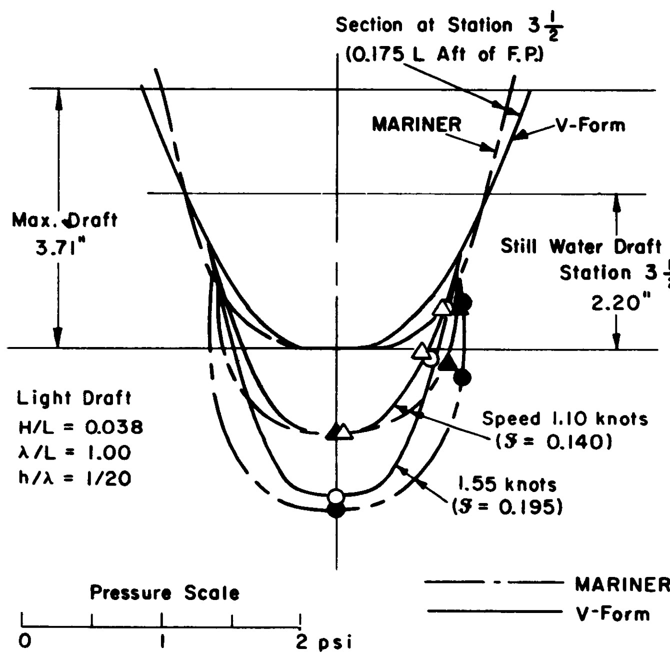


Figure 19 – Distribution of Slamming Pressure along Ship Girth at Location 0.175 L aft of F.P.

CONCLUSIONS

The experimental work on the effect of ship's bow form was made on two models, a normal MARINER with U-sections forward and a modified form with V-sections forward, to determine comparative qualities with respect to slamming.

On the basis of the experimental results, the following conclusions can be drawn:

1. The conventional MARINER has generally less resistance and less speed loss than the V-form modification in waves.

2. The amplitudes of pitching and heaving of MARINER are generally less than those of the V-form modification at both light and maximum draft conditions, except in waves of great length such as $\lambda/L = 1.75$. The synchronous speed of heaving is generally higher than that of pitching on both models.

3. The amplitudes of vertical acceleration at the ship bow due to rigid body response are generally less for the MARINER than for the V-form hull except in waves of great length.

4. The amplitude of slamming acceleration for the MARINER is generally larger than that for the V-form hull.

5. The magnitudes of impact pressure at the instant of ship slam in waves of length causing severe slamming ($\lambda/L = 1.00$ to 1.25) are much higher than those in waves of shorter or longer lengths.

6. With respect to slamming pressures, the V-form hull is superior to the MARINER between stations 0.10 L and 0.15 L aft of the forward perpendicular in waves of which produce severe slamming ($\lambda/L = 1.00$ to 1.25), while the MARINER is superior to the V-form hull between the stations 0.20 L and 0.30 L aft of the forward perpendicular at any ship speed.

7. The longitudinal position of maximum slamming pressure for the V-form hull is aft of the position for the MARINER.

8. The pressure distribution curve along the ship's girth shows the maximum value around the flat part of the bottom.

ACKNOWLEDGMENTS

The author wishes to express his appreciation to Miss M. Watts for her help in the experiments and to Messrs. M.K. Bennett and J.L. Leahy of the Instrumentation Division for their cooperation in the measurement. Valuable technical advice was received from Dr. W.E. Cummins for which the author is deeply appreciative.

REFERENCES

1. Lewis, E.V. and Numata, E., "Ship Model Tests in Regular and Irregular Seas," ETT Note 567, Stevens Institute of Technology (1956).

2. Numata, E. and Lewis, E.V., "An Experimental Study of the Effect of Extreme Variations in Proportions and Form on Ship Model Behavior in Waves," ETT Note 643, Stevens Institute of Technology (1957).

3. Stefun, G.P., "The Influence of Ship Form on Pitch and Heave Amplitudes," David Taylor Model Basin Report 1235 (1958).

4. Todd, E.H., "Resistance Tests and Motion Observations on Models in A Seaway," David Taylor Model Basin Report 931 (1954).

5. Kreitner, H., "Heave, Pitch, and Resistance of Ships in a Seaway," Institute of Naval Architecture, Transactions Vol. 81 (1939).

6. St. Denis, M., "On Sustained Sea Speed," Transactions, Society of Naval Architects and Marine Engineers Vol. 59 (1951).

7. Korvin-Kroukovsky, B.V., and Jacobs, W.R., "Pitching and Heaving Motions of a Ship in Regular Waves," Transactions, Society of Naval Architects and Marine Engineers, Vol. 65 (1957).

8. Bledsoe, M.D., "A Study of the Seaworthiness of the CA-68, CB-1, and DLG-9 Classes of Ships," David Taylor Model Basin Report 1163 (in preparation).

9. Ochi, K. and Akita, Y., "Ship Behavior and Slamming in Regular Waves," Proceedings, Symposium on the Behavior of Ships in a Seaway (1957).

10. Ochi, K., "Model Experiments on Ship Strength and Slamming in Regular Waves," Transactions, Society of Naval Architects and Marine Engineers, Vol. 66 (1958).

11. Bledsoe, M.D., "Series Investigation of Slamming Pressures on TMB Series 60 Models," David Taylor Model Basin Report 1043 (1956).

12. Szebehely, V.G., "Ship Slamming in Head Seas," David Taylor Model Basin Report 913 (1955).

13. Ochi, K., "Model Experiments on the Effect of a Bulbous Bow on Ship Slamming," David Taylor Model Basin Report 1360.

14. Sibul, O.J., "Ship Resistance in Uniform Waves as a Function of Wave Steepness and Beam of the Ship," Institute of Engineering Research, University of California (1959).

15. Sibul, O.J., "Ship Resistance and Motion in Uniform Waves as a Function of Block Coefficient," Institute of Engineering Research, University of California (1961).

'NITIAL DISTRIBUTION

Copies	
5	CHBUSHIPS 3 Tech Info (Code 335) 1 Prelim Des Br (Code 420) 1 Lab Mgt (Code 320)
2	CHONR 1 Fluid Dyn (Code 438) 1 Undersea Programs (Code 466)
1	ONR, New York
1	ONR, Pasadena
1	ONR, Chicago
1	ONR, Boston
1	ONR, London
1	NAVSHIPYD, NORVA
1	NAVSHIPYD, BSN
1	NAVSHIPYD, PTSMH
1	NAVSHIPYD, PUG
1	COMSURASDEVDET
1	CO, USNMDL, Panama City
1	CO, USNUOS
1	CDR, USNOL
1	CDR, USNOTS, China Lake
1	CDR, USNOTS, Pasadena Annex
10	CDR, ASTIA
1	DIR, USNRL
3	Dir, DL, SIT, Hoboken 1 E.V. Lewis 1 Dr. B.V. Korvin-Kroukovsky
1	Dir of Def R & E
1	Dir, Exptl Nav Tank, Univ of Mich, Ann Arbor
1	Dir, Inst for Fluid Dyn & Appl Math, Univ of Md
1	Dir, Scripps Inst of Ocean, Univ of Calif

Copies	
1	Dir, WHOI
1	Dir, ORL, Penn State
1	O in C, PGSCOL, Webb
1	CO, USNROTC & NAVADMINU, MIT
1	James Forrestal Res Ctr, Princeton Univ, Princeton Attn: Mr. Maurice H. Smith, Asst to Dir
1	SUPSHIP, Camden
1	NYSB Corp Attn: Mr. J.N. Thompson, NA(DES)
1	SUPSHIP, Quincy, Mass
2	NNSSB & DD Co 1 Asst Nav Arch 1 Dir, Hydra Lab
1	NRC
1	Mgr, Structure & Dynamics Operation, Space Sciences Lab, General Electric Co, Philadelphia
1	Dr. Aldo Andreoni, Instituto de Pesquisas Techncolocgicas, Sao Paulo, Brazil
1	Chief Supt Naval Res Establishment c/o Fleet Mail Office, Halifax Nova Scotia, Canada
1	Hydro-Og Aerodynamisk Laboratorium Hjortekaersvej 99, Lyngby, Denmark Attn: Prof. C.W. Prohaska
1	Prof. L. Howarth, Dept of Math, Univ of Bristol, Bristol, England
2	Dir, Admiralty Experiment Works, HASLAR, Gosport, Hants, England 1 Mr. E.C. Tupper
1	Dir of Research, British Shipbldg Res Assoc, London
1	Dir, Ship Div, Hydro Lab, National Phy Lab, Feltham, Middlesex, England
8	ALUSNA, London

Copies

1	RADM R. Brard, Dir, Bassin d'Essais des Carenes, 6 Blvd Victor, Paris (15e), France
1	Dr. J. Dieudonne, Dir, Institut de Recherches de la Construction Navale, 1 Blvd Haussman, Paris (9e), France
1	Prof.Dr.-Ing Georg P. Weinblum, Dir Institut fur Schiffbau der Universitat Hamburg Hamburg 33, Germany
1	Dr. Siegfried Schuster, Head, Berlin Model Basin, Versuchsanstalt fur Wasserbau und Schiffbau, Schleuseninsel im Tiergarten, Berlin 87, Germany
1	Dr. H.W. Lerbs, Dir, Hamburg Model Basin Hamburgische Schiffbau-Versuchsanstalt, Bramfelder Str. 164, Hamburg 33, Germany
1	Gen. Ing. U. Pugliese, Dir, Istituto Nazionale per Studi ed Esperienze di Architettura Navale, Via della Vasca Navale 89, Roma-Sede, Italy
2	Dir, Nederlandsh Scheepsbouwkundig Proefstation, Haagsteeg 2 Wageningen, The Netherlands 1 Ir. G. Vossers
1	Ir. J. Gerritsma, Delft Shipbldg Lab, Prof. Mekelweg 2, Delft, The Netherlands
1	Prof. J.K. Lunde, Skipsmodeltanken, Trondheim, Norway
1	Senor Manuel Lopez-Acevedo, Director, Canal de Esperiencias Hidrodinamicas, El Pardo, (Madrid) Carretera de la Sierra, Spain
1	Dr. Hans Edstrand, Dir, Statens Skeppsprovningsanstalt, Goteborg C 14 Stet Gibraltargatan, Sweden

David Taylor Model Basin. Report 1400.
EXPERIMENTS ON THE EFFECT OF BOW FORM ON SHIP SLAMMING, by Kazuo M. Ochi. Jan 1962. iv, 21p. illus., graphs, tables, refs. UNCLASSIFIED

This report presents the results of an experimental study of the effect of ship bow form upon ship motion and upon hydrodynamic loads due to slamming. A 5.5-ft model of MARINER, regarded as representative of the U-form type, and of a V-form modification were tested in head seas in regular waves. Pitching, heaving, bow acceleration, and hydrodynamic impact pressure due to slamming were measured and a comparative evaluation of the two types is made.

It was found from the tests that the V-form experiences lower slamming pressure than MARINER (U-form) between 0.10 L and 0.15 L aft of the forward perpendicular, however MARINER

1. Cargo ships--Slamming--Model tests
2. Ship hulls--Slamming--Hydrodynamic characteristics
3. MARINER C-4 class (U.S. merchant cargo ships)
I. Ochi, Kazuo M.

David Taylor Model Basin. Report 1400.
EXPERIMENTS ON THE EFFECT OF BOW FORM ON SHIP SLAMMING, by Kazuo M. Ochi. Jan 1962. iv, 21p. illus., graphs, tables, refs. UNCLASSIFIED

This report presents the results of an experimental study of the effect of ship bow form upon ship motion and upon hydrodynamic loads due to slamming. A 5.5-ft model of MARINER, regarded as representative of the U-form type, and of a V-form modification were tested in head seas in regular waves. Pitching, heaving, bow acceleration, and hydrodynamic impact pressure due to slamming were measured and a comparative evaluation of the two types is made.

It was found from the tests that the V-form experiences lower slamming pressure than MARINER (U-form) between 0.10 L and 0.15 L aft of the forward perpendicular, however MARINER

1. Cargo ships--Slamming--Model tests
2. Ship hulls--Slamming--Hydrodynamic characteristics
3. MARINER C-4 class (U.S. merchant cargo ships)
I. Ochi, Kazuo M.

David Taylor Model Basin. Report 1400.
EXPERIMENTS ON THE EFFECT OF BOW FORM ON SHIP SLAMMING, by Kazuo M. Ochi. Jan 1962. iv, 21p. illus., graphs, tables, refs. UNCLASSIFIED

This report presents the results of an experimental study of the effect of ship bow form upon ship motion and upon hydrodynamic loads due to slamming. A 5.5-ft model of MARINER, regarded as representative of the U-form type, and of a V-form modification were tested in head seas in regular waves. Pitching, heaving, bow acceleration, and hydrodynamic impact pressure due to slamming were measured and a comparative evaluation of the two types is made.

It was found from the tests that the V-form experiences lower slamming pressure than MARINER (U-form) between 0.10 L and 0.15 L aft of the forward perpendicular, however MARINER

1. Cargo ships--Slamming--Model tests
2. Ship hulls--Slamming--Hydrodynamic characteristics
3. MARINER C-4 class (U.S. merchant cargo ships)
I. Ochi, Kazuo M.

(U-form) experiences lower pressure than the V-form modification between 0.20 L and 0.30 L aft of the forward perpendicular. This was found to be true irrespective of ship speed. Since structural damage due to slamming usually occurs within the domain between 0.15 L and 0.20 L aft of the forward perpendicular, the test results may serve to provide information in the design of the forward hull form with respect to slamming.

U-form) experiences lower pressure than the V-form modification between 0.20 L and 0.30 L ft of the forward perpendicular. This was found to be true irrespective of ship speed. Since tructural damage due to slamming usually occurs within the domain between 0.15 L and .20 L aft of the forward perpendicular, the test results may serve to provide information in the esign of the forward hull form with respect to slamming.

(U-form) experiences lower pressure than the V-form modification between 0.20 L and 0.30 L aft of the forward perpendicular. This was found to be true irrespective of ship speed. Since structural damage due to slamming usually occurs within the domain between 0.15 L and 0.20 L aft of the forward perpendicular, the test results may serve to provide information in the design of the forward hull form with respect to slamming.