Effect of Hull Form Parameters On Ship Motion

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Acceptance Certificate

This is to certify that the project titled “Effect of Hull Form Parameters on Ship Motion” submitted by Akhil Gupta, Roll No. 14NA10005, to the Department of Ocean Engineering and Naval Architecture, Indian Institute of Technology Kharagpur, Kharagpur under the supervision of Prof. Debabrata Sen is a satisfactory fulfillment of Bachelor of Technology Thesis Project, during the 4th year of his undergraduate course in academic session 2017-18 in the Department of Ocean Engineering and Naval Architecture, Indian Institute of Technology Kharagpur

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Table of Contents

1. Objective **4**

2. Introduction **4**

3. Factors Affecting Heave and Pitch **5**

3.1 Overall Length of the ship 5

3.2 Overall Breadth and Depth of the ship 5

3.3 Design speed of the ship 5

3.4 Heading Angle 5

3.5 Ship Proportions 6

3.6 Ship Coefficients 6

3.7 Other Design Considerations 7

4. Calculation of Heave and Pitch RAOs **7**

5. Hull form design and modifications **7**

6. Effect of various ship parameters on ship motion **8**

6.1 Effect of Length overall on heave and pitch 8

6.2 Effect of Breadth overall on heave and pitch 8

6.3 Effect of Depth on heave and pitch 9

6.4 Effect of ship velocity 9

6.4 Effect of Heading Angle 9

7. Future Works **10**

8. Conclusion **10**

9. References **10**

1. Objective

This study aims to identify the effect of hull form parameters on seakeeping performance. Hull form parameters are believed to have massive impact on seakeeping performance and are taken into consideration during design stage. However, their effect is mostly quantified by model testing or using prior data. This study focuses on implementing a systematic approach to studying seakeeping performance. Effects of longitudinal motions (pitch, heave and surge) and transverse motions (roll, yaw and sway) are considered separately because in theory, design features to reduce ship motions are generally different for the two cases.

The longitudinal motions are considered first, since they are affected more by choice of ship dimensions. Have a greater effect on attainable speeds in rough seas, and are less amenable to artificial control followed by the study of effect on transverse motions. Basic hull form parameters include, overall length of the ship (L_{OA}), Breadth overall (B_{OA}), Depth (D), Speed of the ship (V), heading angle (β), etc. will be studied first. More complex parameters such as block coefficient (C_B), Prismatic Coefficient (C_P), Longitudinal center of buoyancy (L_{CB}), etc. will be taken into account later. Finally, effect of several design considerations such as shape of bulbous bow, shape of stern and transom will also be incorporated into the study.

2. Introduction

Ship parameters have huge impact on the seakeeping performance. In general, they are measured by model testing or using data basic hull form design. Good seakeeping performance refers to a specific aspect of ship response to a seaway (amplitude of motion, individual event or frequency of occurrence of events), each of which-if severe enough-can degrade the performance of one or more of the elements of a total ship system to an unacceptable level. Some of the seakeeping criteria are: -

1. Absolute motion amplitudes (Roll angle, Pitch angle, etc.)
2. Absolute velocities and accelerations (vertical and lateral acceleration, motion sickness)
3. Motions relative to sea (slamming, deck wetness, propeller emergence, etc.)

Ship performance can be obtained by making systematic calculations of the various responses at different speeds and headings in specific sea conditions, as defined by their directional sea spectra. These results can then be plotted on the basis of different hull form parameters as well as compared to see the effect of various parameters taken into account. Ship response spectra is calculated by using frequency domain analysis which will be discussed in later sections. Longitudinal motions (pitch, heave and surge) and of transverse motions (roll, yaw and sway) can, for practical purposes, are considered separately. This is because, design parameters affecting both are different. For example, longitudinal motions depends more on basic design parameters than than transverse motions. On the other hand, transverse motions are subject to artificial controls more than basic design parameters.

First part of the study involves studying effect of basic hull form parameters such as (Design speed V, Length overall L_{OA}, Breadth overall B_{OA}, Depth overall D and heading angle β, on heave and pitch responses. Analyses is done by plotting heave and pitch Response Amplitude Operator (RAO) curve with respect to change in sea condition and compared with the results derived from theoretical concepts as well as results obtained from model testing and full scale observation of ship motions. Change in sea condition is measured by the ration λ/L_{OA}.

Further study will be done by taking more complex hull form parameters into account. Next part will be focused studying the effect of hull form parameters on transverse motions by calculating roll and yaw RAOs in various sea conditions as well.

3. Factors Affecting Heave and Pitch

3.1 Overall Length of the ship

Theory, supported by model tests and full-scale observations, provides some good general guidance for the general analysis of pitch and heave. Both pitch and heave are affected by dimensional effect of length in relation to sea conditions encountered. Theoretically, for conventional monohulls in head seas, the longer the ship the less the average wave excitation. This is mainly because the probability of encountering waves of near ship length decreases with increasing length, but also because the average height of long waves, and hence wave slope, is less than short waves. The advantage of greater length applies whether overall size, as indicated by displacement, remains the same or increases with length.

3.2 Overall Breadth and Depth of the ship

Theoretically, Increasing overall breadth of the ship should have similar effect as to increasing the overall length (see Fig. 1) as discussed in the section 3.1. However, unlike increasing length it has somewhat smaller impact on the ship motions. This is because, there is no effect on how ship encounters sea condition but only the effect of decrease in ship motion due to increasing overall size of the ship, i.e., favorable effect of increasing all dimensions.

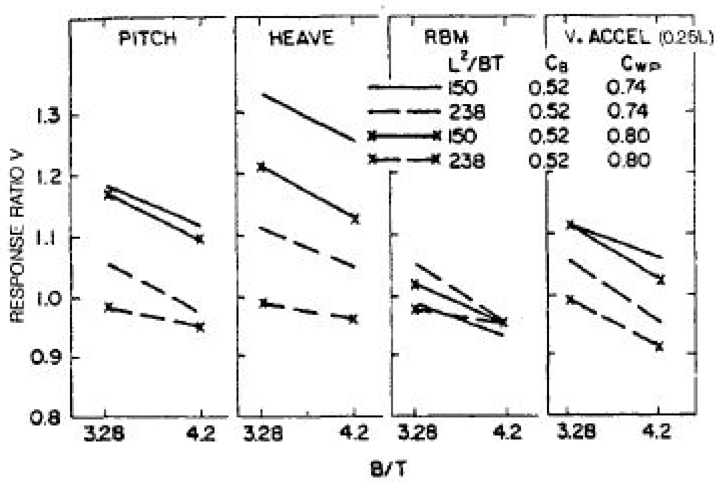

Fig 1. Effect of Change in B/T on Pitch and Heave Responses

Increasing overall Depth of the ship should have no impact on heave and pitch responses if model tests and full scale observations are to be followed. This is mostly because increase can only be marginal and hence it will have no effect on ship response

3.3 Design speed of the ship

Ship of different design speed behaves differently in various sea conditions. Attaining sub-critical pitching and heaving behavior of normal ships over as wide a range of speed as possible requires consideration at early stages of design of the relationship of length-the most important dimension-and other hull characteristics to the natural periods of oscillation. In order to develop hul with desired design speeds it is thus necessary to analyze effect of increase in speed on heave and pitch response.

3.4 Heading Angle

The angle at which ship encounters the wave can have huge impact on heave and pitch response as well. This is because at different heading angles the effective wavelength, i.e., encounter wavelength changes, which in turn affects longitudinal responses. It is important to take into account all heave and pitch responses in different heading angles during design stage. Theoretically, decreasing heading should result in decrease in both heave and pitch responses because of impact of wave is distributed among all the degrees of freedom.

3.5 Ship Proportions

B/T ratio:- increasing B/T results in Increase in damping thus reducing heave and pitch responses. Although it may not always be favorable for reduced natural periods. But since the effect of beam increase is felt mostly near midship.

L/T ratio:- Studies have shown that larger L/T ratio has shown in general, smaller relative bow motion. This is especially in the case of moderate to high speed ships. Furthermore, if bow freeboard is proportional to length, the shipping of water should decrease with increasing L/T.

L/B ratio:- It is assumed to be constant while taking other ratios into consideration. However, pitch and heave responses will benefit from the larger L/B ratio.

3.6 Ship Coefficients

Coefficient of Midship Section (C_M):- Reduced coefficient of midship section C_M, results in reduction of natural periods of pitch and heave which in turn results in increased damping.

Coefficient of Waterplane Area (C_{WP}):- Increased coefficient of waterplane area C_{WP}, results in reduction of natural periods of pitch and heave which in turn results in increased damping (See Fig. 2). Increase in C_{WP} can be obtained from more V-form and reduced coefficient of vertical plane C_{VP}. Studies have shown that the increase of C, or decrease in C,, using V-sections was more effective in the forebody than in the aft body. However, V-form forward may exact a penalty in added resistance in calm water and/or waves.

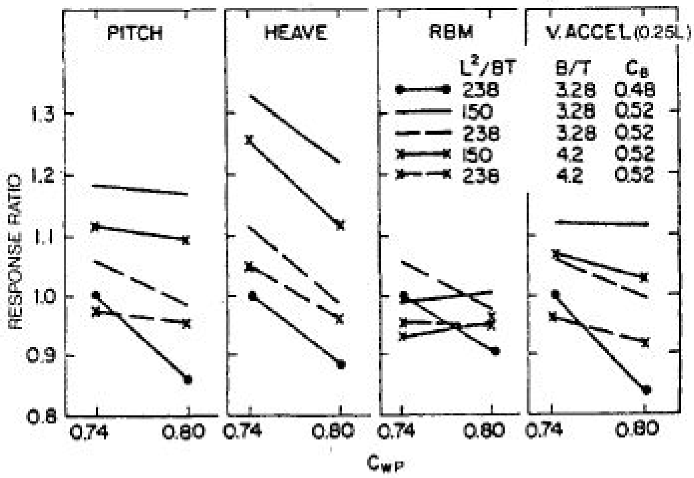

Fig 2. Effect of Change in C_{WP} on Heave and Pitch Responses

Block Coefficient (C_B):- Reduced block coefficient of the ship C_B, have a favourable effect on pitch and heave responses (see Fig.) especially in the case of high-speed ships. Also, for low-speed ships these advantages may not be there.

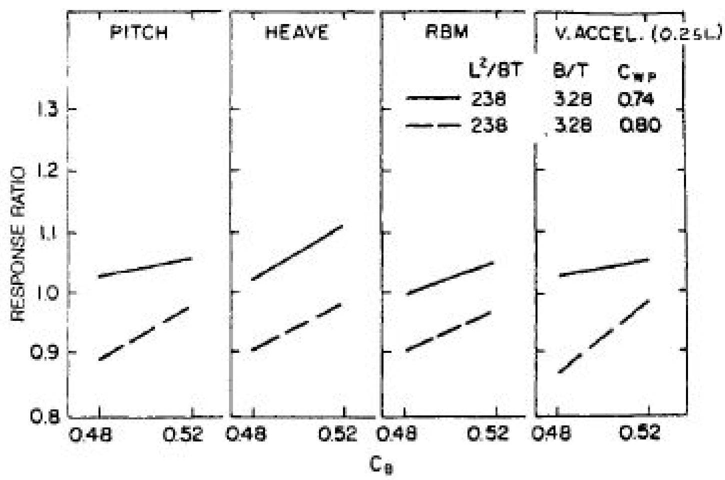

Fig 3. Effect of Change in C_B on Heave and Pitch Responses

3.7 Other Design Considerations

<u>Slenderness Ratio</u> L^2/BT:- With displacement constant there is in all cases a distinct reduction in pitch and heave amplitudes, and in vertical acceleration from the bow, as L^2/BT increases

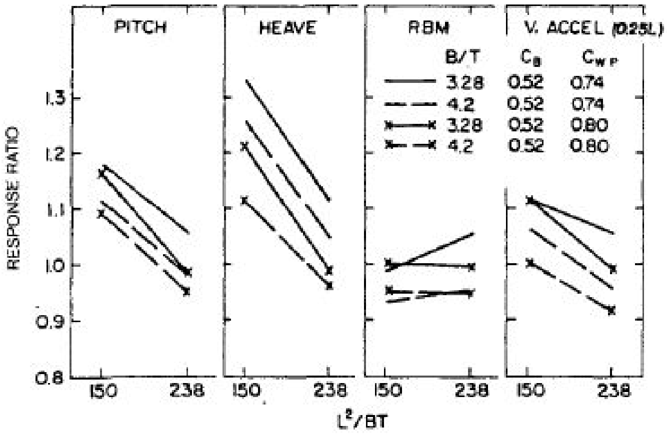

Fig 4. Effect of Change in L^2/BT on Heave and Pitch Responses

<u>Length to Displacement Ratio</u> L/∇^{3}:- It shows the similar trend as the slenderness ratio discussed in the section above if block coefficient of the ship remains the same.

Apart from these there are several other factors which also affect heave and pitch responses such as completeness of waterline, area BT of the midship, etc. and can be taken into account as well.

4. Hull form design and modifications

Initial Hull form design is a basic ship with no complexities introduced in the form of bulbous bow, stern shape, ship decks, etc. as depicted by the Fig 5.

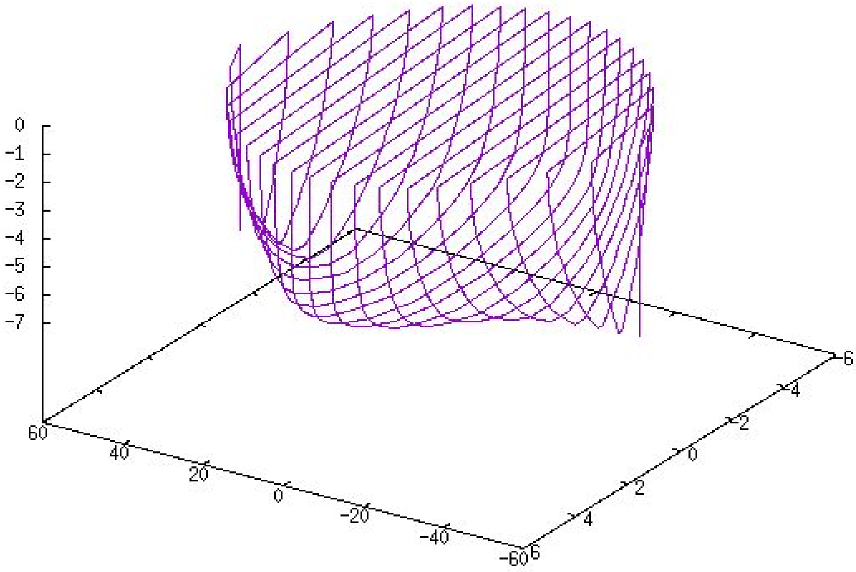

Fig. 5 Hull from generated from offset table using splot

Number of stations in the hull form can be increased as per requirements. Spacing between the station can be unequal to take into account more complex shapes like bulbous bow, stern shapes, etc. These areas will require to introduce more stations to improve accuracy in calculations. In later part of the study, more complex hull forms will be used to analyze the effect of hull form parameters on ship motions. Bulbous bow, stern shape will also be included to analyze slamming as well as other seakeeping criteria such as deck wetness, relative bow motion, etc. Basic Geometry of the ship has:-

L_{OA} = 100m, B_{OA} = 10m and D_{OA} = 6.25m. C_M = .907 and C_B = .5584. While Longitudinal Center of Gravity (LCG) is taken in the form of Input interactively on the screen.

Modifying Hull forms to analyze Pitch and Heave Responses

Hull form is modified as per the requirement of the study. To study the effect of increase in overall length of the ship (L_{OA}), whole ship was stretched along the longitudinal direction proportionally such that the ratio of distance between the stations remain same. To study the effect of change in both depth and breadth, again, the hull form was stretched with a stretching factor of (B_F/B_I) for breadth and (D_F/D_I) for depth was multiplied with each point of the hull form table. And as a result, final geometry was obtained as can be seen in the Fig. 6. First figure below (Fig. 6 (a)) represents the initial hull section. While second and third figure represents new hull sections developed after modification in breadth and depth of the hull form.

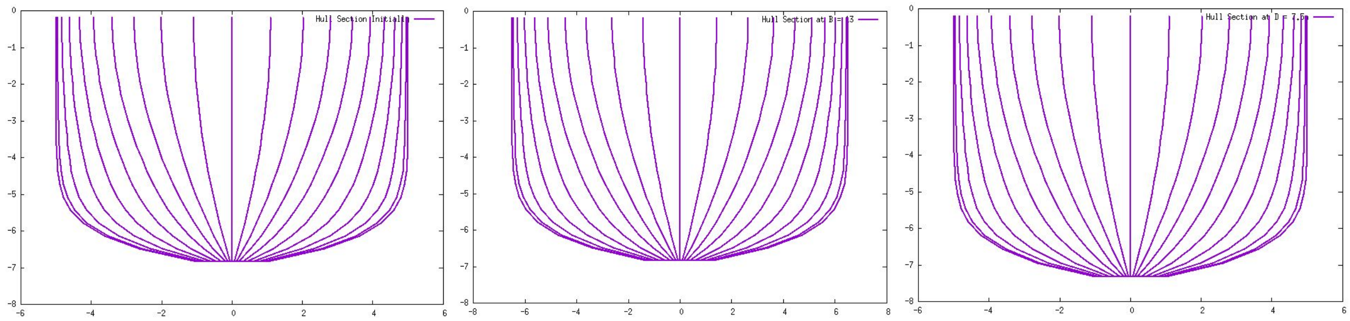

Fig. 6 a) Hull Sections at B = 10m & D = 7m b) Hull Sections at B = 13m & D = 7m c) Hull Sections at B = 10m & D = 7.5m

5. Effect of various ship parameters on ship motion

5.1 Effect of Length overall on heave and pitch

For the analysis heave and pitch responses were calculated for two different L_{OA}, i.e., first at initial L_{OA} = 100m and second at L_{OA} = 110m and found drastic decrease in response amplitudes as can be seen from the Fig. 7 a and b. Which coincides with the speculated results from theoretical and experimental analysis.

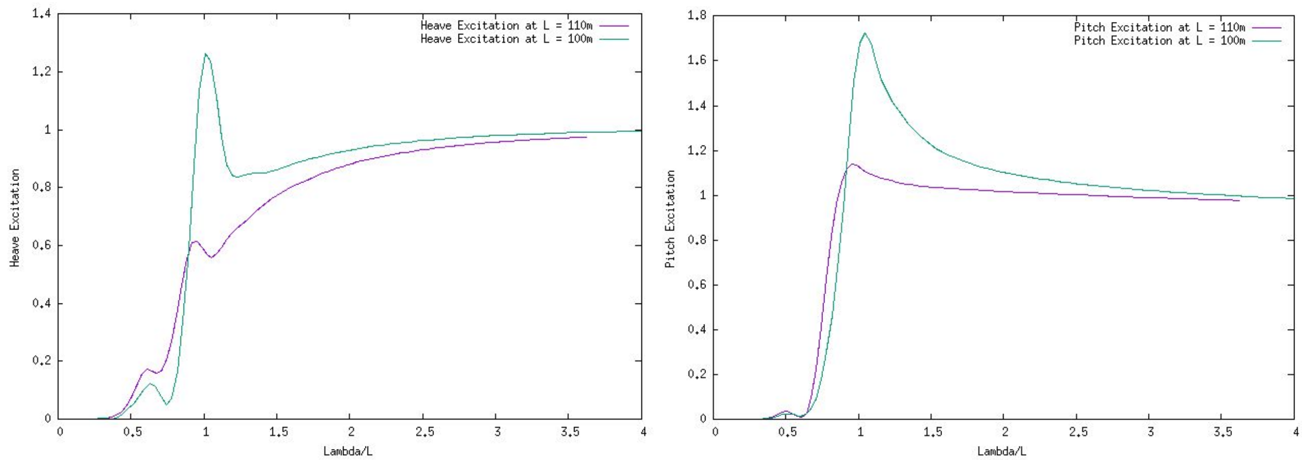

Fig. 7 a) Heave RAO at L = 100m & 110m b) Pitch RAO at L = 100m & 110m

5.2 Effect of Breadth overall on heave and pitch

Pitch and Heave RAOs were calculated at two different overall breadth (see Fig.). First response is at initial B_{OA} = 10m and second is at B_{OA} = 13m. No significant change in response was observed. However, slight decrease in the response is because of the overall increase in ship size.

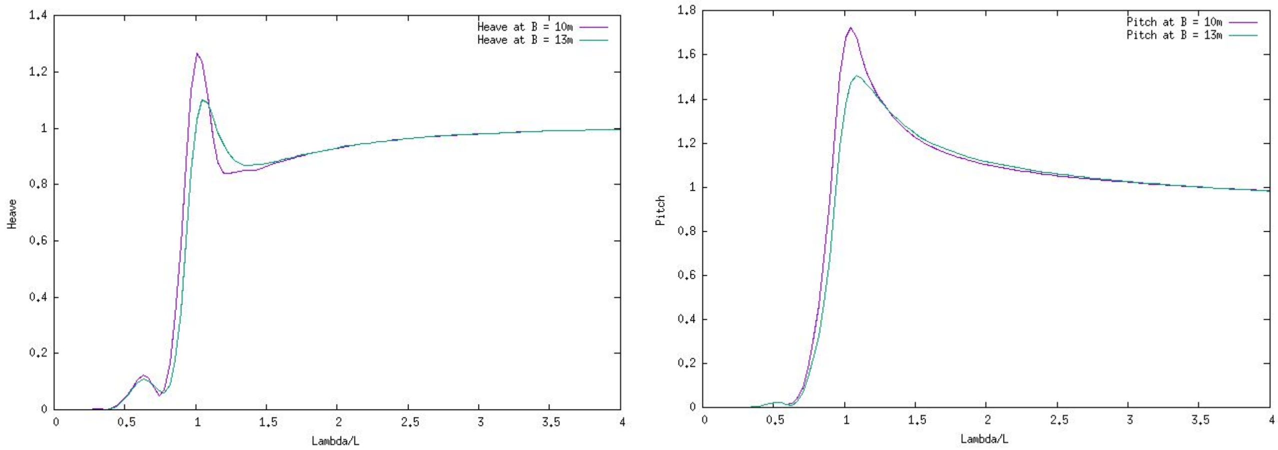

Fig. 7 a) Heave RAO at B = 10m & 13m b) Pitch RAO at B = 10m & 13m

5.3 Effect of Depth on heave and pitch

Again, no significant change in heave and pitch RAO curves (see Fig.). Responses were calculated at D_{OA} = 7m (initial) and 7.5m (modified). Slight decrease in RAO is observed due to increase in overall size of the ship.

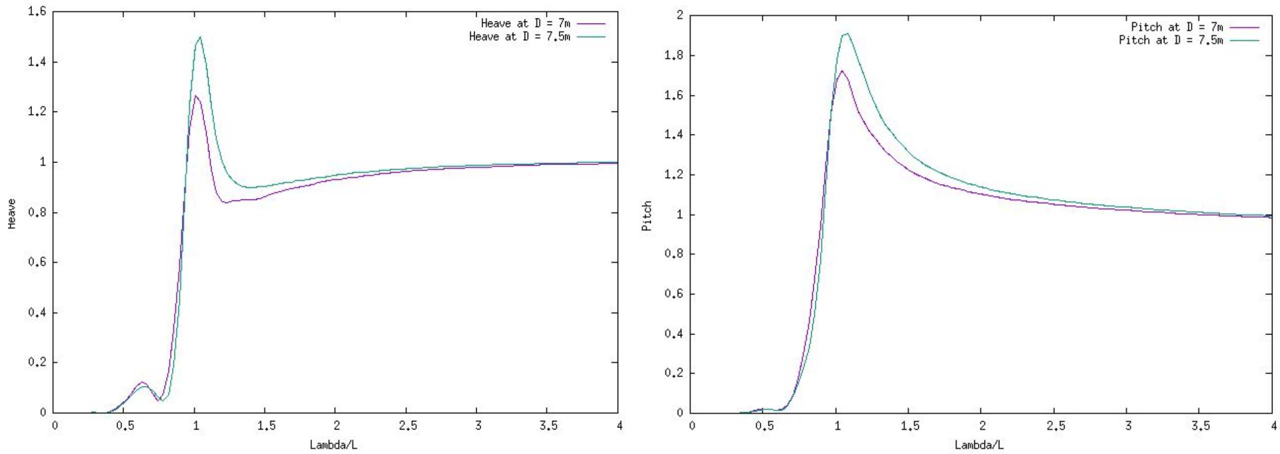

Fig. 7 a) Heave RAO at D = 7m & 7.5m b) Pitch RAO at D = 7m & 7.5m

5.4 Effect of ship velocity

To analyze the effect of ship velocity on heave and pitch RAOs, heave and pitch responses were plotted for three separate values of design speed (v = 10 knots, 14 knots and 18 knots) and comparisons were drawn from the obtained results. It was found that their was a drastic change in response amplitudes as can be seen from the Fig. , which is in accordance with the theoretical analysis.

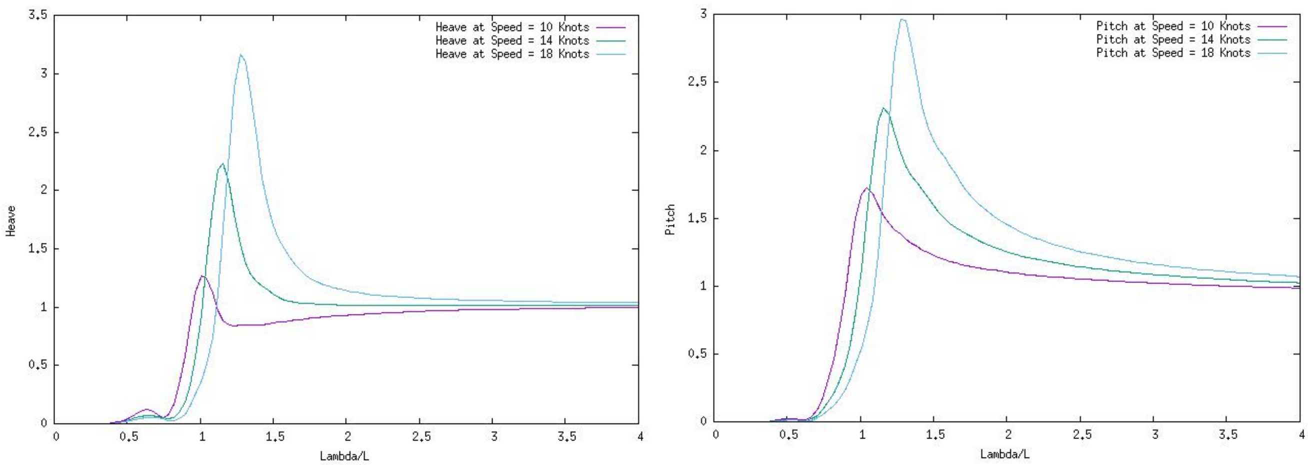

Fig. 7 a) Heave RAO at V = 10 knots, 14 knots & 18 knots b) Pitch RAO at V = 10 knots, 14 knots & 18 knots

5.5 Effect of Heading Angle

In the case of heading angle, pitch and heave response shows contrasting results (see Fig.). Heave response amplitude shows increase in amplitude. On the other hand, pitch response shows decrease in amplitude. The results were plotted for head sea condition as well as for β = 135.

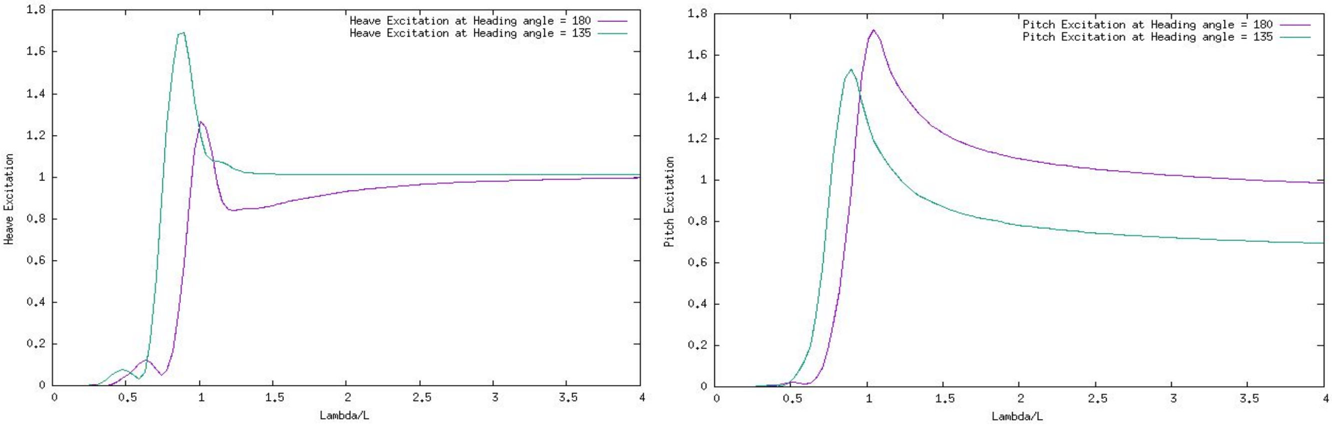

Fig. 7 a) Heave RAO at Beta = 180 & 135 degrees b) Pitch RAO at Beta = 180 & 135 degrees

6. Future Works

The first part of the study involved studying the effect of the basic hull form design parameters. More complexities can be introduced in the hull form by introducing bulbous bow, stern, transom, etc. to achieve results driven towards real life situations. New hull forms can also be tested against the same set of design parameters. Effect of hull form parameters can also be analyzed on transverse motions (mostly rolling). Similar procedure can be implemented for the analysis of the rolling responses. Finally, several seakeeping criteria can be taken into account to develop good seakeeping attributes for a given hull form requirements. These Seakeeping criteria includes Relative Bow Motion, Bow Slamming, Deck Wetness, Sea Sickness, etc. After doing these analysis, a systematic approach can be developed to predict seakeeping performances in different sea conditions.

7. Conclusion

In this study of effect of hull form parameters, we first built the expected results based on theoretical analysis as well as on the observations from model testing as well as full scale experiences. We first studied the effect of change Length overall on the ship's transverse motion by plotting both heave and pitch responses with varying Lambda/L ratio and found that results were in abidance with those speculated from the theoretical as well as experimental results and finally came to conclusion that as the length of the ship increases both heave and pitch responses decreases. Then, we studied the effect of breadth and depth on the ship motion and found that these two parameters have marginal effect on ship response. This was mostly because of overall increase in ship size rather than explicit effect. Finally we analyzed the effect of design speed as well as heading angle and found it to follow the same pattern as the theoretical and experimental studies have suggested. It was found that with increase in design speed, heave and pitch responses increase drastically. However, in case of heading angle the result in pitch and heave responses were contrasting. Heave decreased with decrease in heading angle, on the other hand pitch increased with decrease in heading angle.

8. References

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