EFFECT OF BULBOUS BOW ON MOTION OF SHIP

The thesis is submitted to the Department of Naval Architecture and Marine Engineering, BUET, Dhaka, in partial fulfilment of the requirements for the degree of Bachelor of Science in Naval Architecture and Marine Engineering.

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CERTIFICATE OF RESEARCH

This is to certify this research work has been done by the candidate and it was not submitted elsewhere for the award of degree of Bachelor of Science in Engineering or for any diploma.

Signature of the supervisor

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CONTENTS

Chapter Four: Conclusions and Recommendations

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Above all, we are thankful to the almighty, for His blessings accompanied by which we have come so far.

Dedicated

To our

Parents

ABSTRACT

Motion response prediction is a very effective tool in this era of high tech computers. As motion response give researchers a comprehensive idea about any model performance at any given condition and constraints. Hence this research is performed having a keen interest in Motion response prediction of ship for stability and safety at sea.

It is quite a common phenomenon that ships have bulbous bows these days. The reason is mainly savings in fuel consumption and occasionally added buoyancy. Fuller vessels are quite efficiently using this technology. But it's effect on finer vessels particularly faster vessels are not much known and understood. The numbers of published research works in this field are also very limited. Therefore, this project puts light upon finding motion response of a finer vessel (Series 60, C_b = 0.6) incorporating different types of bulbous bows.

Different types of bulbous bows have been designed in three-dimensional (3D) computer aided design (CAD) software. The vessels with their new bows were panelled. A C++ computer program is developed for this panelling purpose. With these new designed bulbous bows the motion characteristics are studied using 3-D source distribution technique in regular wave.

Since the research project is in the early stage, no conclusion can be easily drawn. But based on the available research findings, it is evident that bulbous bows influence the amplitude of motions, particularly in the region of natural frequency. It is quite an important fact that resonance occurs in this region. Therefore, minimising the amplitude of motion in this region would be quite an achievement.

Chapter 1

INTRODUCTION

1.1 General

The ocean is a nibbling ground where conventional marine vehicles, high-speed merchant ships, yachts / passenger ships, naval vessels etc are moving from one place to another. These vehicles are the cheapest mode of transportation for goods, equipment and passengers. Ships also serve a large variety of other purposes like naval operations, drilling, marine operations, fishing, sports and leisure activities. They are equipped with sophisticated sensors and equipment. Wave is an important phenomenon which developed in the sea and having a considerable effect on the floating structures at sea. Wave induced motions like heaving, rolling, pitching etc can hamper the movement of ship, create severe stress on the structure and problem from an operational point of view of fishing vessels, crane vessels, passenger ships and naval vessels. Relative vertical motions between the ship and the waves are important responses. Excessive motion of ship is an important reason for seasickness. So the knowledge about wave induced motions are important both in design of ships and its operational studies.

The physical phenomenon of ship motion is not yet fully understood due to its complexity. The ship itself is a complex geometry, elastic body and from the environment around the ship i.e. sea, wind etc. which is a complete stochastic process of yet no clear statistical estimates and probability functions. However, this research involves the investigation of motion of ship with forward speed and effect of bulbous bow. As a mater of fact, bulbous bows are getting quite a common part of ship these days. Therefore, the variations in amplitude of motion are studied which were due to various bulbous bow formations.

1.2 Literature Review

Today the bulbous bow is a normal part of the modern sea going vessel. As model experiments show, a ship fitted with bulbous bow can require far less propulsive power because of reduction in resistance and have increased cruise speed; which gives an overall reduction in fuel consumption [1].

The bulbous bow was discovered rather than invented [2]. Before the turn of the century, towing experiments performed in the US with warships established that the ram stem projecting below the water had a resistance decreasing effect. A torpedo boat model showed that an under water torpedo discharge pipe ending in the forward stem also reduced resistance.

A flat board, intended to suppress the bow wave, was fitted by W. Froude [3] to a model of H.M.S. Fury in 1873, "with benefit to the performance". Many clipper ships of the 1850's sailed at speeds where Froude number (Fn) exceeded 0.33. The designers learned that fining the bow at the surface waterline and hollowing it further aft was one method of reducing pressure resistance.

Some interesting tests were conducted by J.G. Thewsin [3] between 1930 and 1932 on a small 2.5ft model in the 30ft model basin at Washington. At first a model without bulb was towed, then a submerged bulb was towed by itself without the model, and finally a model was towed with the bulb attached. By superposing graphically the wave profiles created by the model and bulb alone, a wave profile was obtained which closely resembled that on the model when towed with the bulb attached. The model tests showed a reduction in resistance in certain high ranges of torque, just as had all the previous tests on models of large ships.

A few years later W.C.S. Wigley [3], at the William Froude Laboratory at Teddington, derived mathematical expressions for the pressure resistance due to wave making and the vertical amplitudes in the wave trains. Wigley's analytic work was supplemented and confirmed by model experiments, embodying certain combinations of bulb volume, bulb position with reference to the hull and ship speed.

In 1962, Dr. Takao Inui [4] of the University of Tokyo presented a paper at the annual meeting of the Society of Naval Architects and Marine Engineers in New York City in which the author advanced some remarkable theories and test results of the studies of wave-making resistance. These theories were the result of a number of years of research in the model basin at the University of Tokyo where Inui had developed new and ingenious techniques of analysis. These studies have led through various configurations of bulb forms not only at the bow but at the stern, where the extensions concentrated on wave cancellation and speed augmentation in the moderate to low Froude Number values.

However, in spite of all these efforts the effect of bulbous bow on motion has been ignored and the number of research is also limited. This particular research involves the effect of shape, size, and position of bulbous bow on the motion characteristics due to various bulbous formations. Consequently this research work puts light upon some traditional and also some innovative bulb formation. In this regard, the program developed by Islam [5,6] is extended and modified for computation of the motion in six degrees of freedom.

Generally wave responses of floating body are often calculated by 2-D strip theory [7,8] and slender body theory [9,10], which are inadequate because of the over all dimensions and arbitrary shape of the body. Strip theory is also a low Froude number theory [11] doesn’t properly account for the interaction between the steady wave system and the oscillatory effects of ship motions. However, to avoid the above limitations 3-D source distribution technique [12,13,14,15] is adopted for this particular research. The 3-D source method is a versatile technique for calculating the potential flow field in harmonic oscillation.

Panel methods are very efficient for sea-keeping calculations. But the problem lies with the forward speed at which a lot of numerical and theoretical difficulties appear. Recently, using either Steepest Decent Method [16], Super Green Function Method [17] or Simpson Adaptive Method [18,19] progresses in calculations of Green function have been performed. Chapman [20], Yeung and Kim [21], Yamasaki and Fujino [22] have performed considerable work on solving the problems in this field. Therefore, 3-D source distribution technique has become the most accurate method for finding motion responses.

No research has been done on motion response prediction considering the effect of bulbous bow. Hence this research is subjected to find out the motion responses with forward speed effect and the effect of bulbous bow by 3-D source distribution technique.

1.3 Development of the research work

This study focuses on some traditional as well as on some innovative bulb formations. For simplicity and easy understanding, five different types of bulbous bows, as shown in Figure 1.1, have been designed:

Shape - 1: Circular Cross-section Dome Nose (CCDN) Type

Shape - 2: Eye Cross-section & Sharp Nose (ECSN) Type

Shape - 3: Triangular Cross-section (TC) Type

Shape - 4: Inverse Triangular Cross-section (ITC) Type

Shape - 5: Sonar Dome (SND) Type

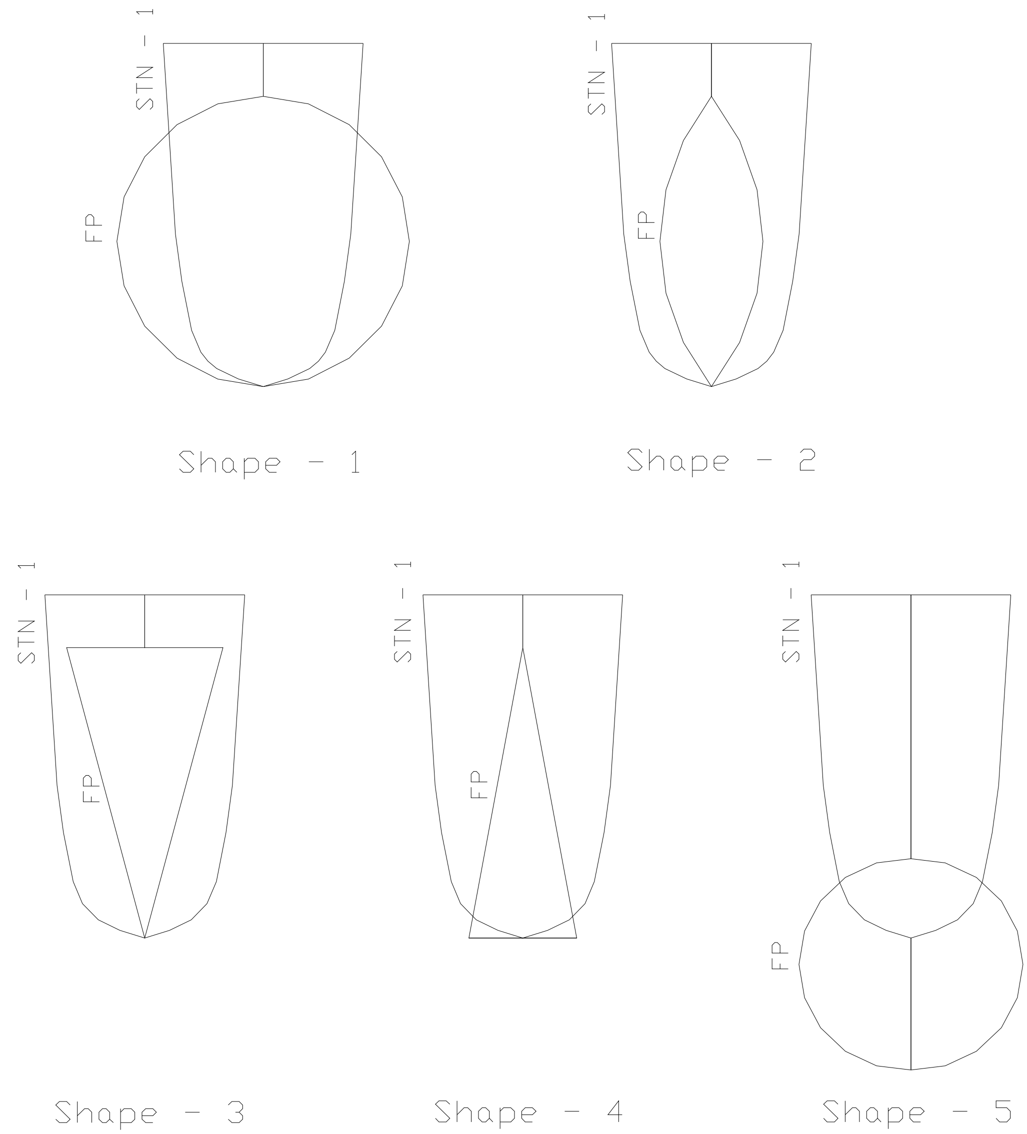


Figure 1.1: Front view of five different shapes of bulb cross-section

The first two shapes (Shape-1 and Shape-2) are quite common in fuller vessels. Shape-3 and Shape-4 are new concepts and not much seen in the waterways. Shape-5 is more commonly used in Naval Vessels/Warships, which requires sonar dome for the placement of sonar devices.

However, variants of these bows are designed by altering the bulb cross section, position of bulb below load water line (LWL) and length of projection forward of forward perpendicular (FP). Figure 1.2 shows these the parameters in detail. One of the prime objectives of this research is to find out how the parameters influence the motion of ship. With this view in mind some 27 bulbous bows are designed from which 5 different shapes of bulbous bow are computed in this research considering time limitations. Their particulars are shown in Table 1.1.

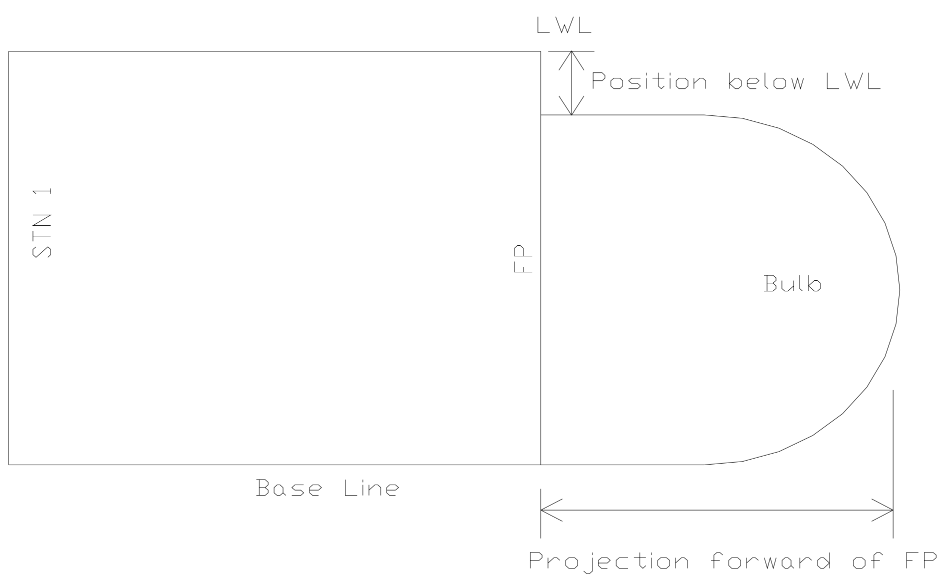


Figure 1.2: Definition Sketch of bow

Table 1.1: Particulars of Different Bow Shapes

Bulb Type Group	Code Name	Particulars	
		Position below LWL (m)	Projection forward of FP (m)
Shape – 1 Circular Cross-section Dome Nose (CCDN)	CCDN_D1 CCDN_D2 CCDN_D3 CCDN_p3m_D1 CCDN_p3m_D2 CCDN_p3m_D3 CCDN_p5m_D1 CCDN_p5m_D2 CCDN_p5m_D3	1.0 2.0 3.0 1.0 2.0 3.0 1.0 2.0 3.0	2.75 2.25 1.75 5.75 5.25 4.75 7.75 7.25 6.75
Shape – 2 Eye Cross-section & Sharp Nose (ECSN)	ECSN_D1 ECSN_D2 ECSN_D3 ECSN_p3m_D1 ECSN_p3m_D2 ECSN_p3m_D3 ECSN_p5m_D1 ECSN_p5m_D2 ECSN_p5m_D3	1.0 2.0 3.0 1.0 2.0 3.0 1.0 2.0 3.0	2.0 2.0 2.0 5.0 5.0 5.0 7.0 7.0 7.0
Shape – 3 Triangular Cross-section (TC)	TC_1 TC_2 TC_3	1.0 2.0 3.0	4.0 4.0 4.0
Shape – 4 Inverse Triangular Cross-section (ITC)	ITC_1 ITC_2 ITC_3	1.0 2.0 3.0	5.0 5.0 5.0
Shape – 5 Sonar Dome (SND)	SND_CC_1 SND_CC_2 SND_CC_3	6.0 5.5 5.0	1.0 1.5 2.0

Chapter 2

Numerical Model Development

2.1 General

This chapter addresses to the development of numerical model of the vessel. Reliable prediction and clear understanding of the dynamic characteristic of a floating body is significant from the view point of reality, safety and operation of the structure. These factors are mainly governed by the accuracy of the mathematical models used to describe motion behavior of the floating body. The present research work has interest in fine vessels with various bulbous bows. The motion responses have been determined by 3-D source technique by using panel method that is also called Boundary Element method.

2.2 Co-ordinate system

Two right-handed Cartesian co-ordinate systems are used in the present study. One fixed with respect to the mean position to the body (X, Y, Z) and another fixed to the space (x_o, y_o, z_o) have been used. The positive Z-axis is the vertically upward. For the fixed co-ordinate system, the positive Z-axis (OZ) passes through the centre of gravity of the body in still water condition; the origin O in the plane of the undisturbed free surface i.e. in the calm water surface and oxy represents the calm water plane. If the body moves with a mean forward speed ($\bar{U}$), this coordinate system moves with the same speed. The body is normally assumed to have the X-Z plane as a plane of symmetry. The translatory displacements in the X, Y and Z directions with respect to the origin be X_1, X_2 and X_3 respectively so that X_1 is the surge, X_2 is the sway and X_3 is the heave displacement. Furthermore, the angular displacement of the rotational motion about the X, Y and Z axis be X_4, X_5 and X_6 respectively so that X_4 is the roll, X_5 is the pitch and X_6 is the yaw angle. The coordinate system and the translatory and angular displacement conventions are shown in Figure 2.1.

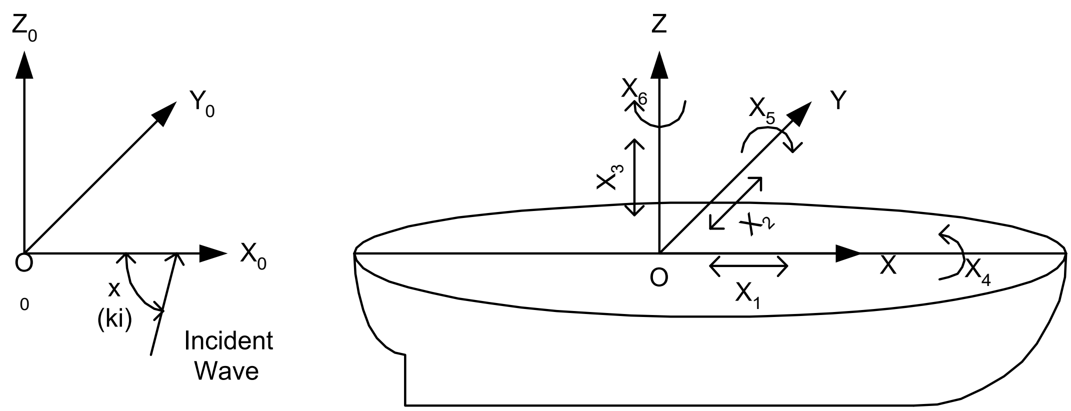


Figure 2.1: Convention for co-ordinate system.

2.3 Selection of ship

In the past, a lot of numerical models analysis has been carried out on fuller vessels. Significant works have also been performed in floating bodies with zero forward speed. But analyses on finer vessels are very limited. In fact analysis with forward speed effect is very complex and time consuming. This caused very little work on vessels of fine form. Therefore, as a new thought, a fine ship of block coefficient 0.6 is chosen from Series-60 vessels with different bulbous bow formations. The reason that influenced in choosing the Series-60 vessel is the availability of experimental results. The principle particulars of the vessel are given in the following table.

Table 2.1: Principle Particulars of the Series-60 Vessel

Model Number	4210W
Length (Water Line)	124.0 m
Length (Between Perpendicular)	122.0 m
Breadth	16.26 m
Draft	6.50 m
Block coefficient	0.60
Displacement	7807 tons
Water- plane coefficient	0.706

2.4 Paneling of the ship

The three dimensional surface of the ship is generated in Auto CAD, a common 3-D drawing tool, applying the offset table provided by Todd [23]. Using the AutoCAD surface modeler, which defines faceted surfaces using a polygonal mesh, the ship is paneled over 300 to little over 400 pieces depending on the bulb formation.

The ship is paneled in such a way that each panel consists of four nodes and no two nodes in the same panel have the same coordinate value (i.e. X,Y,Z).The coordinates of all the nodes are obtained in an 'unformatted' form from Auto CAD.

2.5 Development of computer programs

Several computer programs are developed for preparing input files. One called 'PanGen' or Panel Generator is for generating the panel number with their corresponding nodes. It generates rectangular panels and gives output in the text form. Another computer program is developed to format the bulk amount of data obtained form Auto CAD. The purpose of this program is to prepare the files consist of all the information about the coordinates (i.e. nodes) and panels (i.e. elements). The developed programs are given in the Appendix A, Appendix B and Appendix C.

To study the motion characteristics of ship at sea waves with forward speed, a computer program is being developed [5,6]. This program is based on 3-D source distribution technique and uses panel method, which is also called Boundary Element Method.

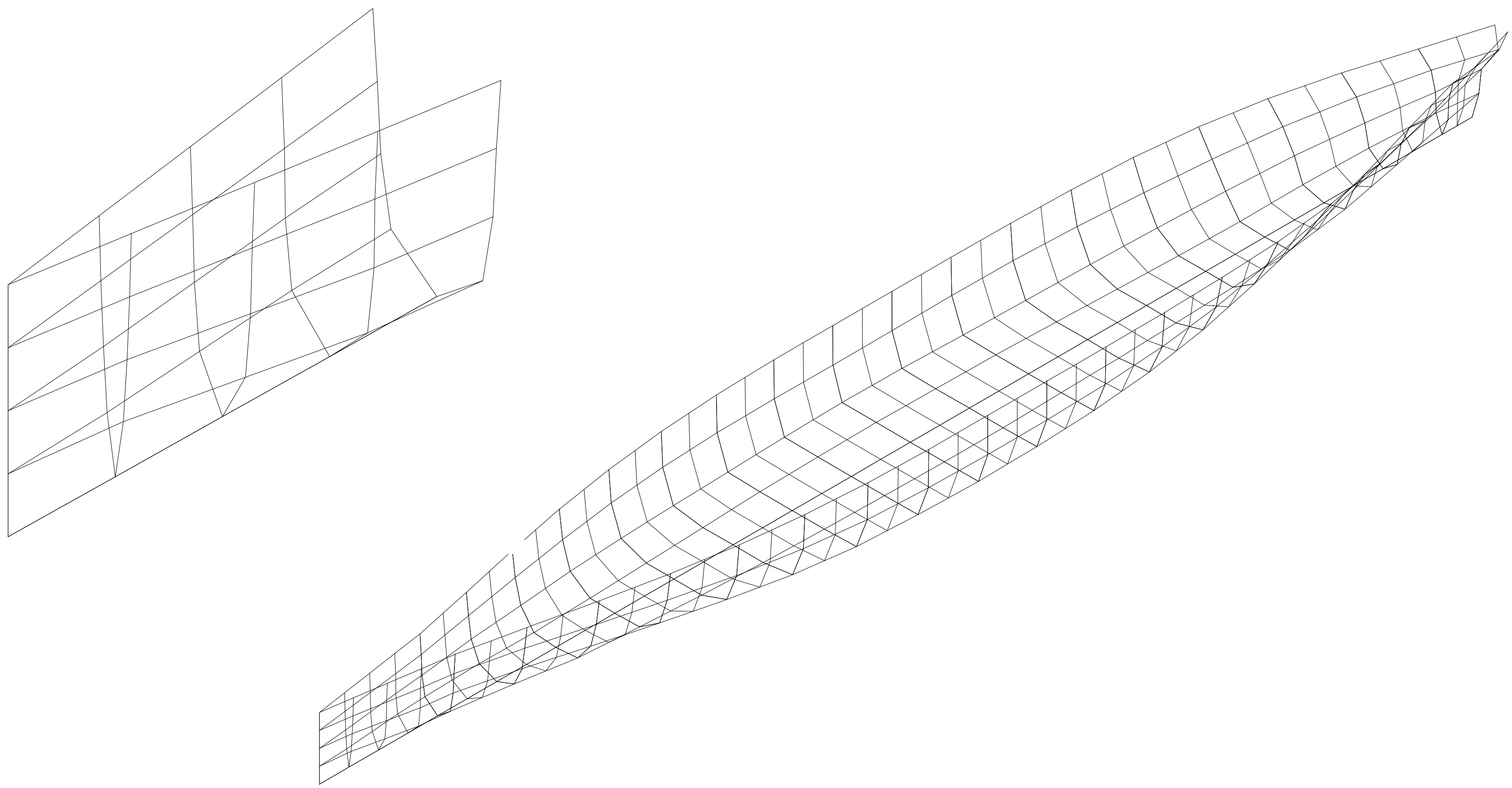


Figure 2.2: Mesh drawing of Series-60 ($C_B = 0.6$) vessel (Code Named 'Base').

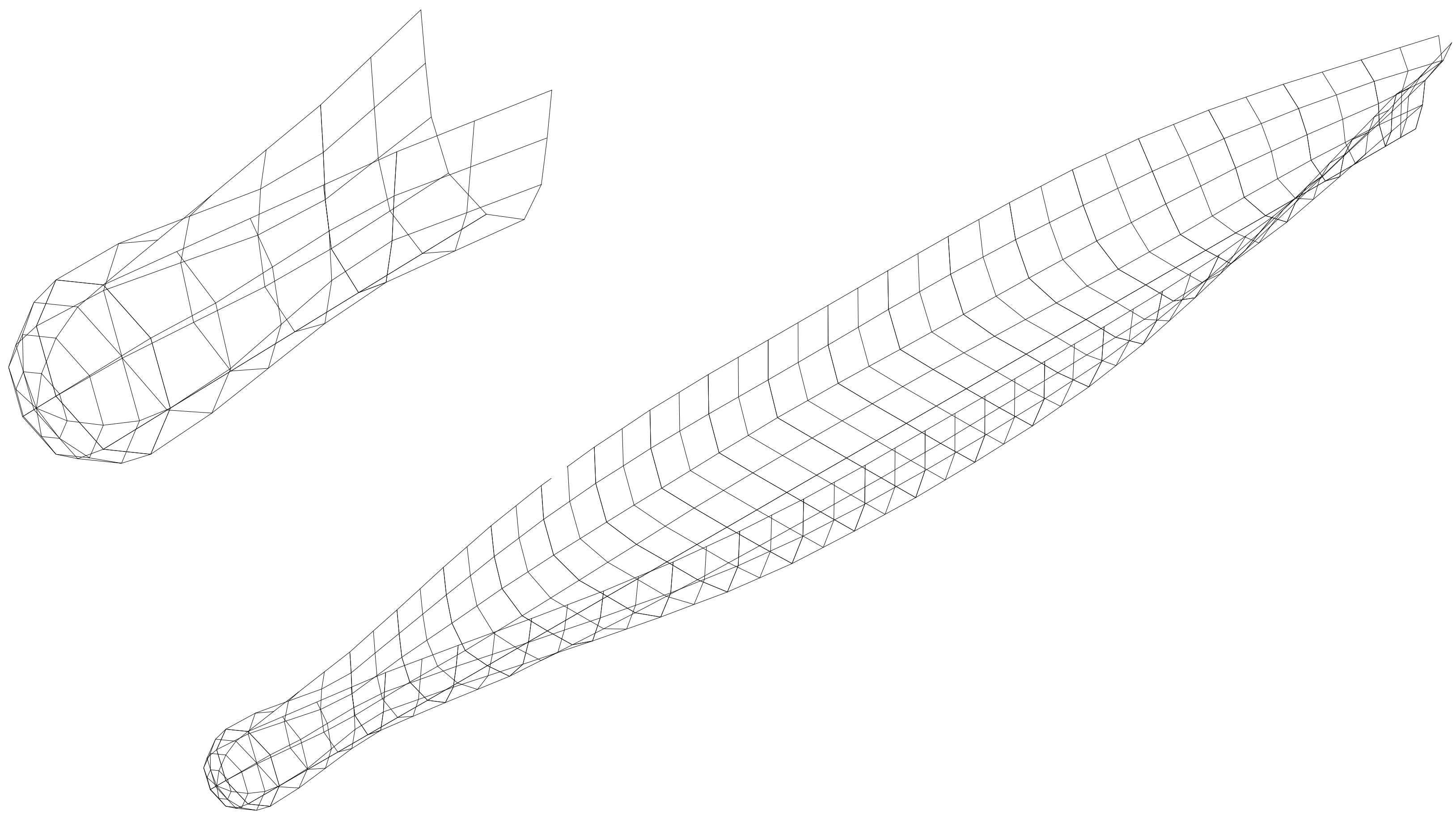


Figure 2.3: Mesh drawing of Series-60 ($C_B = 0.6$) vessel with CCDN_D1 bow.

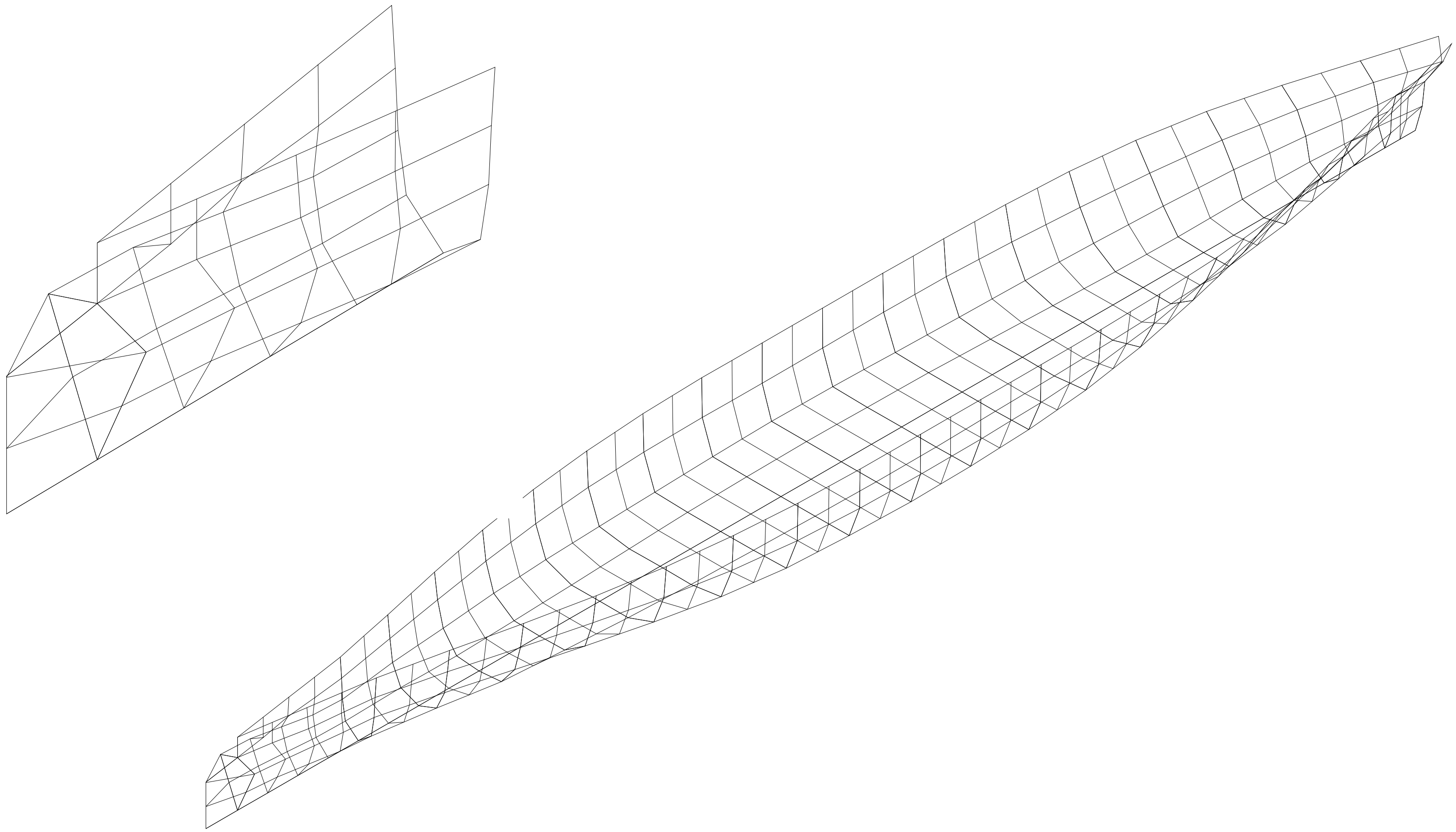


Figure 2.4: Mesh drawing of Series-60 ($C_B = 0.6$) vessel with TC_1 bow.

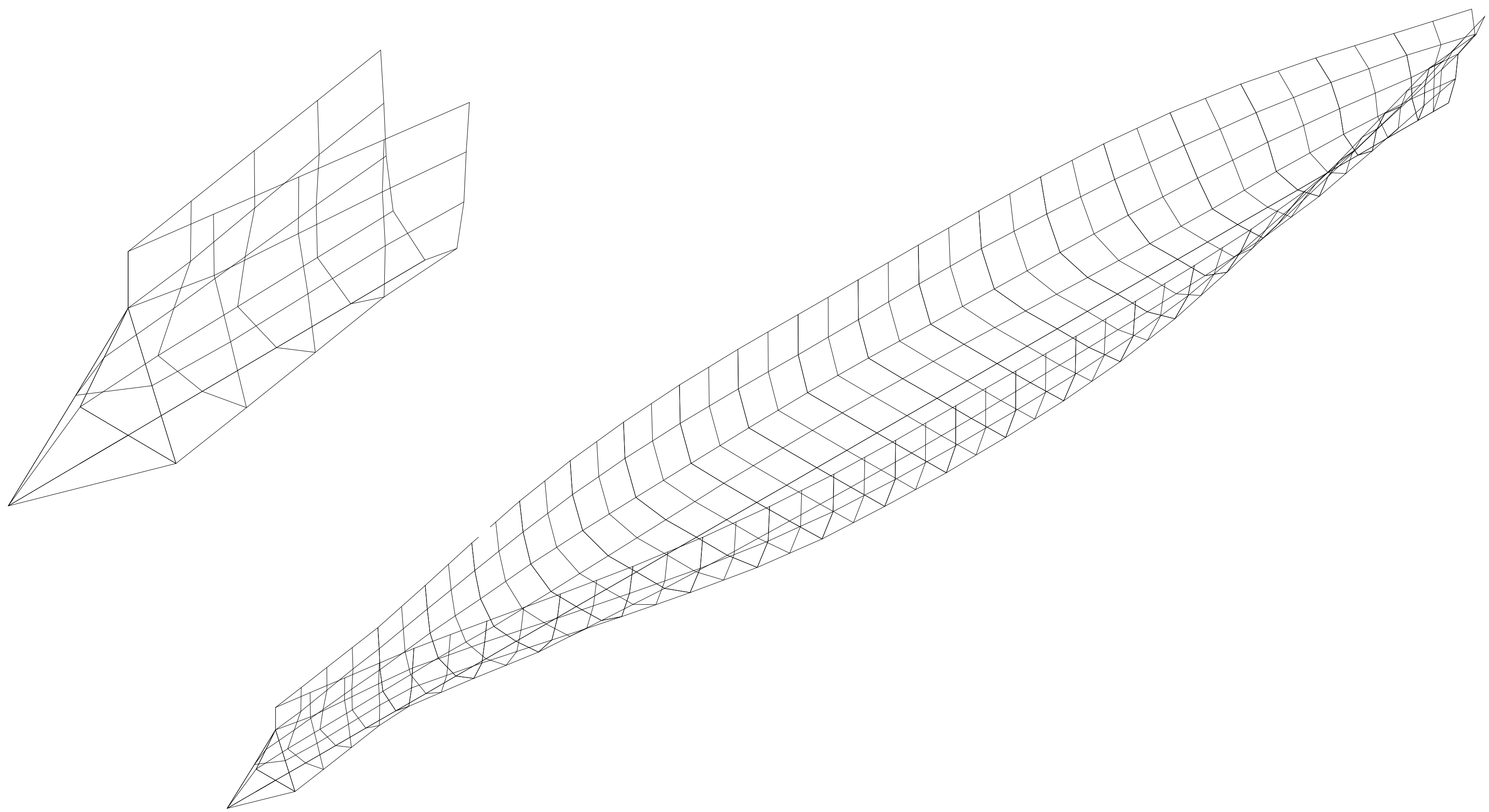


Figure 2.5: Mesh drawing of Series-60 ($C_B = 0.6$) vessel with ITC_1 bow.

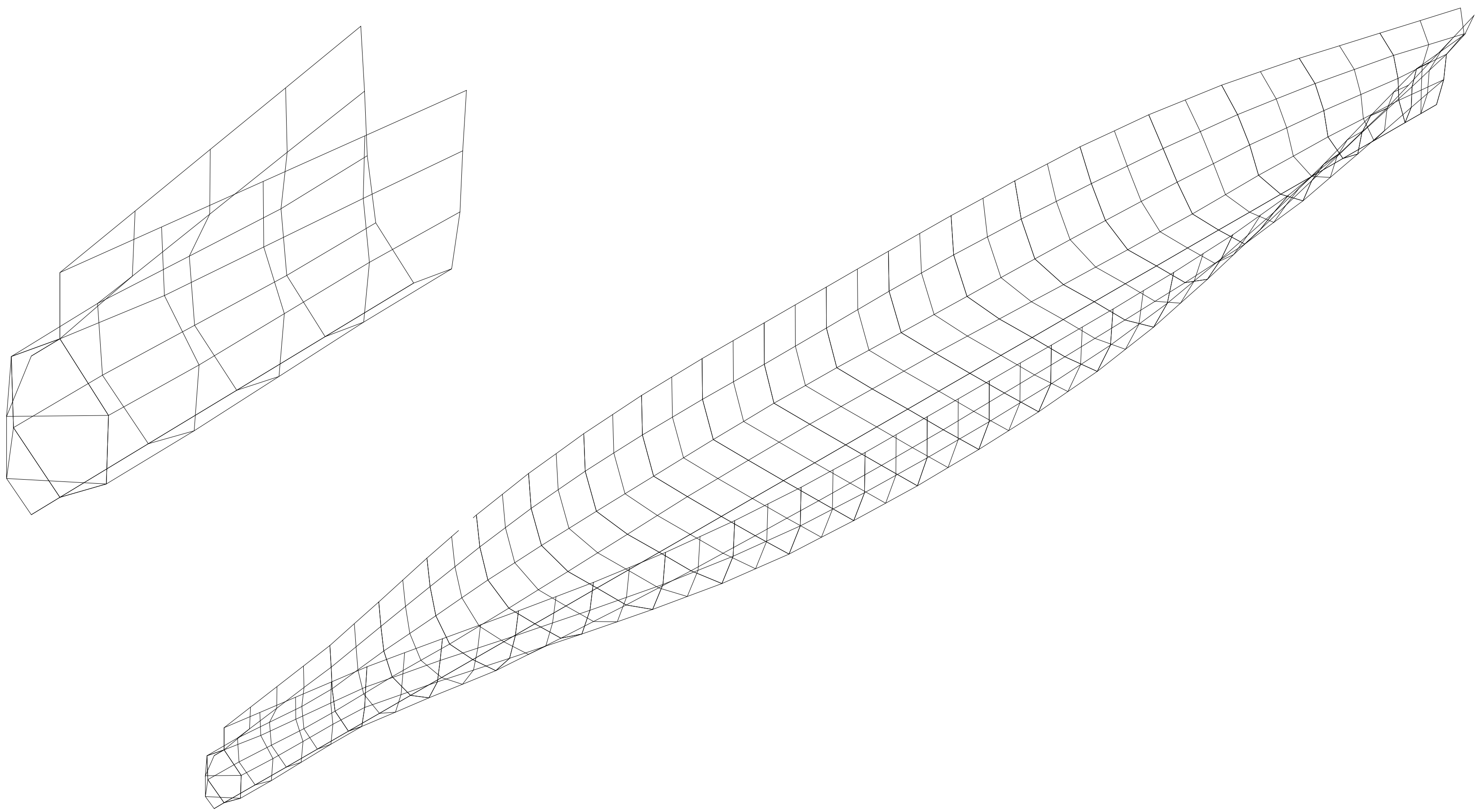


Figure 2.6: Mesh drawing of Series-60 ($C_B = 0.6$) vessel with ECSN_D1 bow.

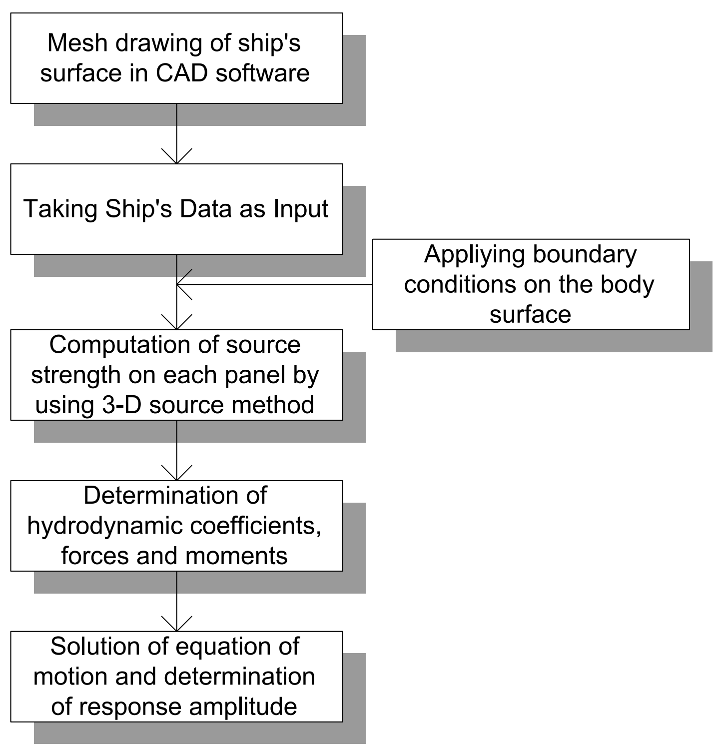
Chapter 3

Motion Response Analysis

3.1 General

This chapter discusses the procedure of motion response analysis as well as the results obtained from the analysis. Obtaining motion responses of the models were quite time consuming. The principal interest of the current research is to investigate the motion responses with forward speed; therefore, the amplitudes of surge, heave and pitch were of main concern. The motion amplitudes (surge, heave and pitch) were determined at 50 different encountering frequencies, which covered the region of natural frequency. Froude-number (Fn) 0.3 was taken through out the study.

3.2 Flowchart for motion responses



3.3 Validation of the results

To validate the current study some experimental data of series 60 vessel, as obtained by Gerritsma [24], are plotted in Figure 3.1 and Figure 3.2. The comparison between the theoretical model and experimental data are quite satisfactory except for a little discrepancy in the region of natural frequency (ω_e = 1.0). This might be due to very old experimental data and unavailability of sufficient results in that region of frequency.

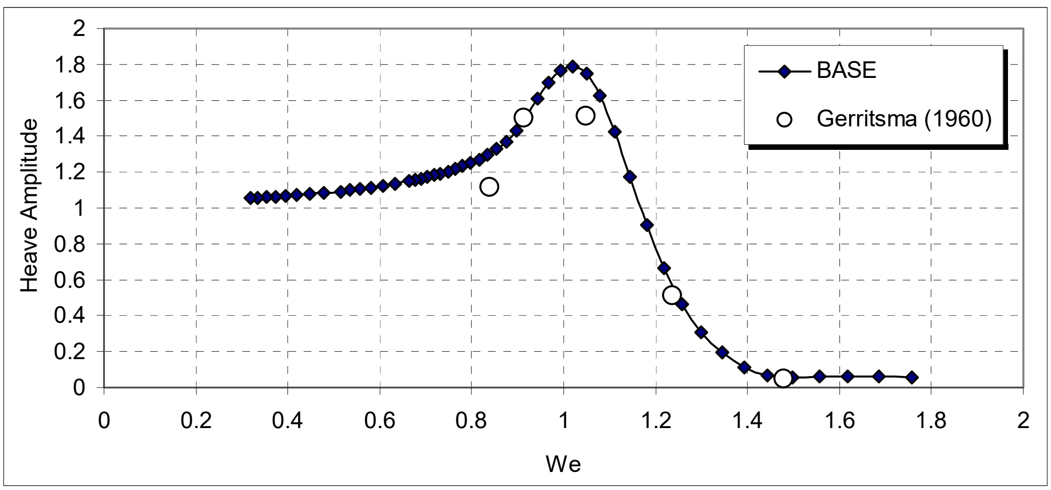


Figure 3.1 Validation of results of heave amplitude.

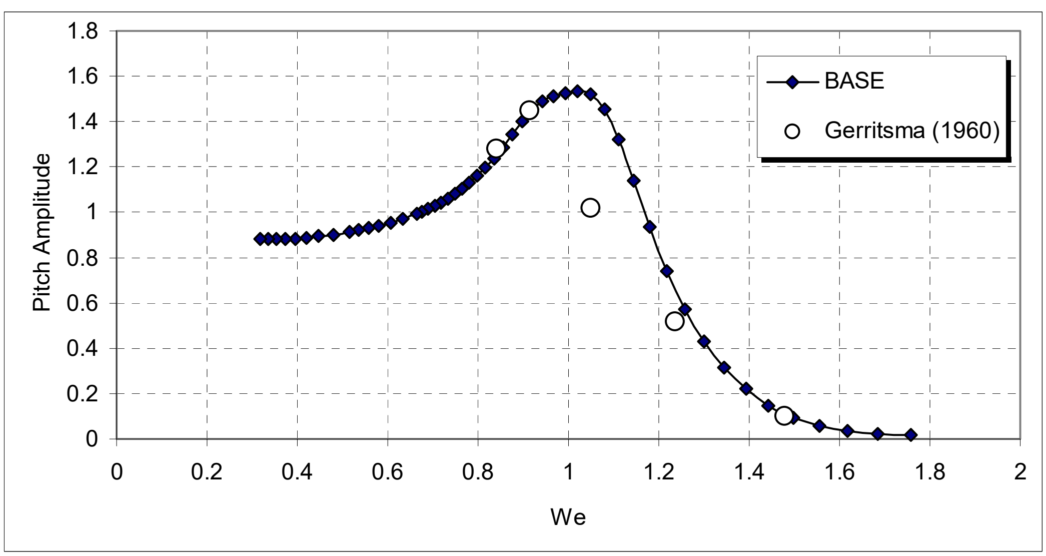


Figure 3.2 Validation of results of pitch amplitude.

3.4 Surge amplitude vs. encountering frequency

The results obtained in this study show that there are some noticeable changes in the amplitudes of motion, particularly in the region of resonance (i.e. around ω_e = 1). Figure 3.3 shows the non-dimensional surge amplitude (X_1/ς_a ; ς_a = wave amplitude) against encountering frequency (ω_e). It is seen from the figure that there are no noticeable changes in amplitude until ω_e = 0.9. After that CCDN_D1 and TC_1 gets quite separate from each other as well as from the Base. They are quite separable up to ω_e = 1.3. The fact to understand from this result is that adding bulb to a vessel might just increase surge amplitude. But this amplitude is very small (below 0.1).

3.5 Heave amplitude vs. encountering frequency

The non-dimensional heave amplitudes (X_3/ς_a) are plotted in Figure 3.4 against the encountering frequency. The results are somewhat interesting. Around the region of resonance (say ω_e = 0.9 to 1.1), CCDN_D1 produces less heave amplitude than the others do. But in lower frequency region it is slightly higher. For the others (TC_1 and Base), there is not much of change in amplitude all throughout the frequency range.

3.6 Pitch amplitude vs. encountering frequency

Figure 3.5 shows the non-dimensional pitch amplitude ($\theta_a/k\varsigma_a$; k =wave number) against the encountering frequency. The results are also interesting as like as the heave. At the lower frequencies, CCDN_D1 produces less pitch than the others do. But as the encountering frequency increases, pitch for CCDN_D1 increases than others noticeably. Certainly this is quite opposite to the case of heave. It seems, for a particular encountering frequency (especially ω_e < 1), heave and pitch are inversely related.

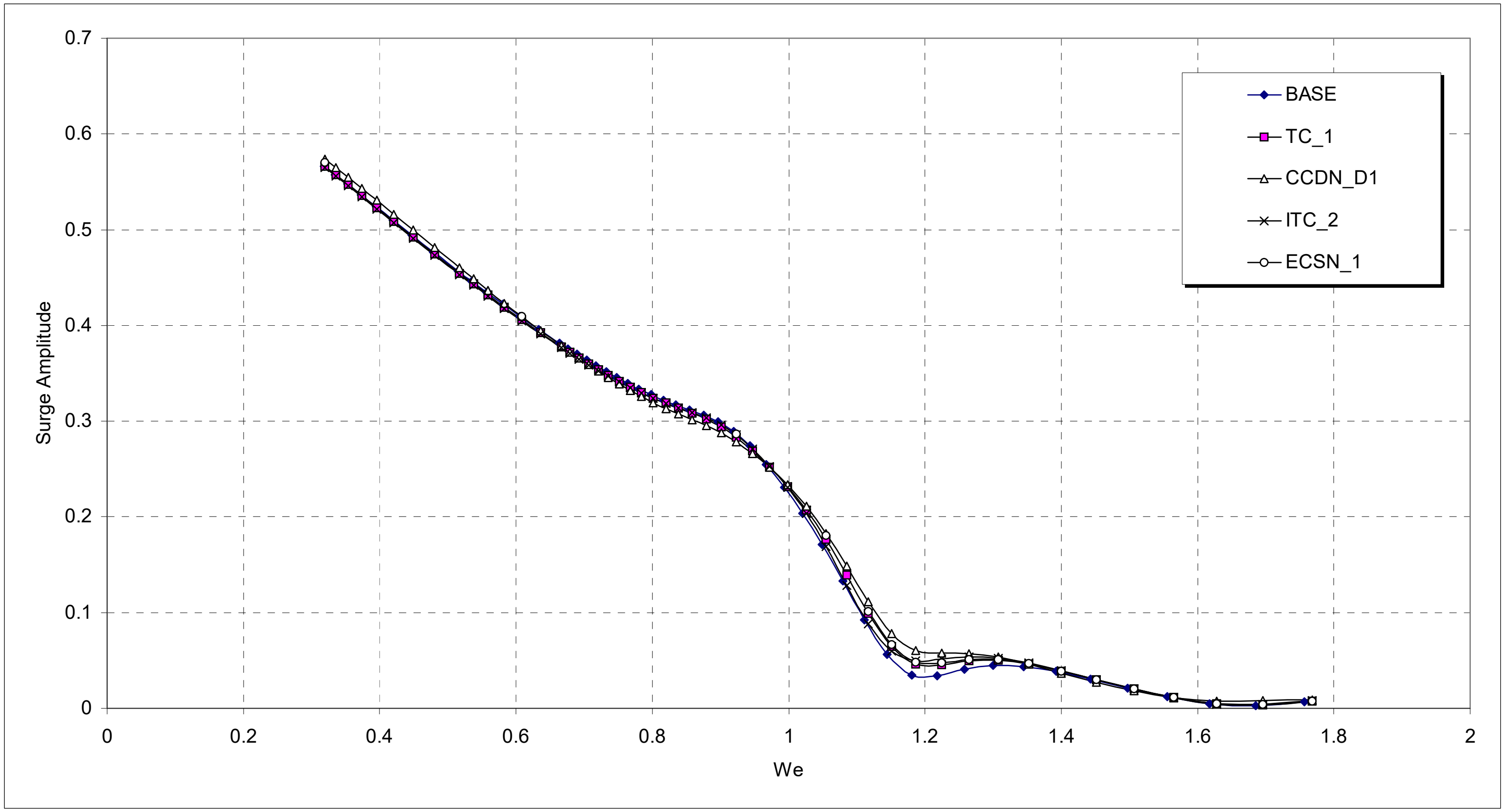


Figure 3.3 Surge amplitude vs. encountering frequency

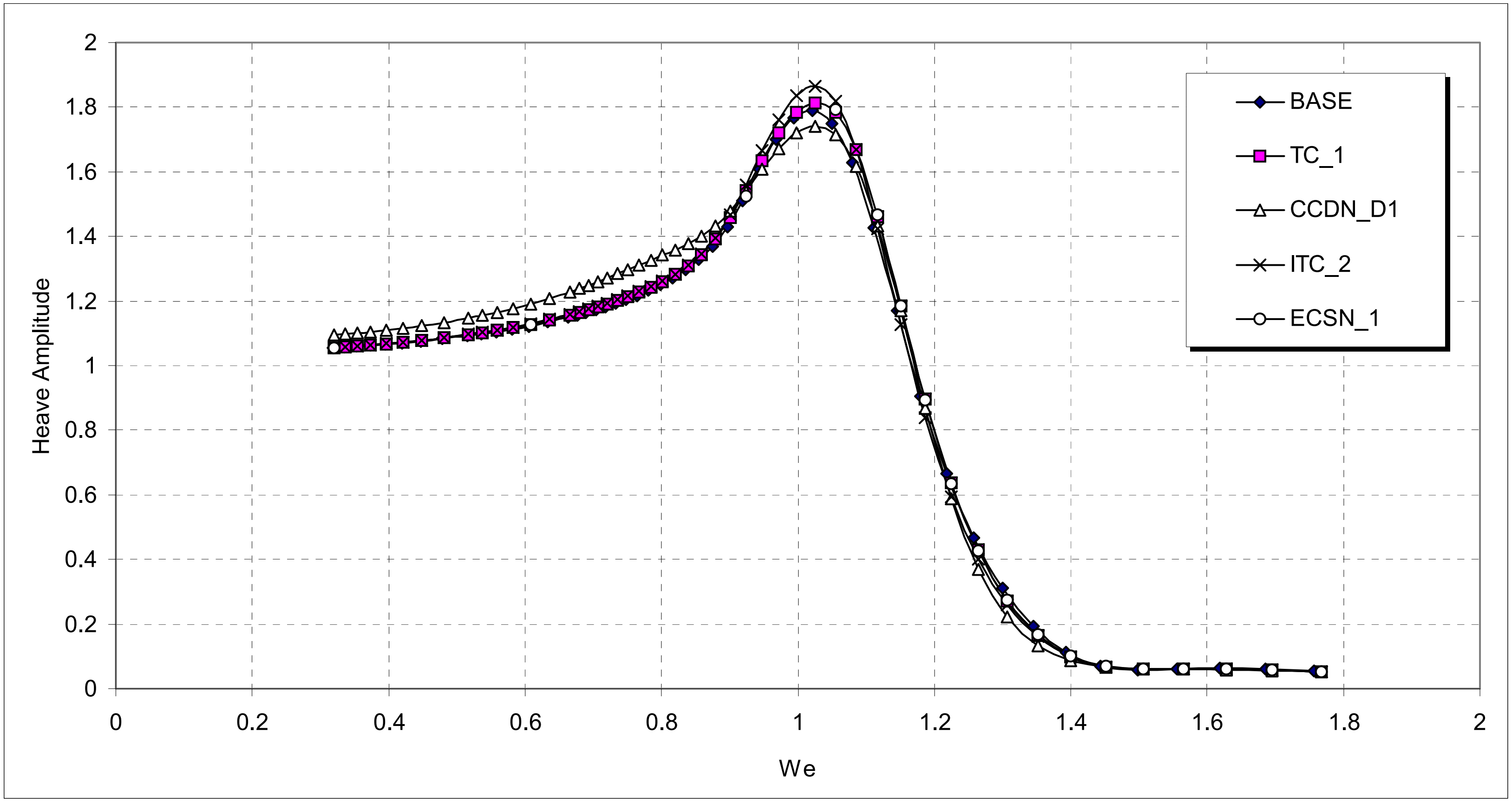


Figure 3.4 Heave amplitude vs. encountering frequency

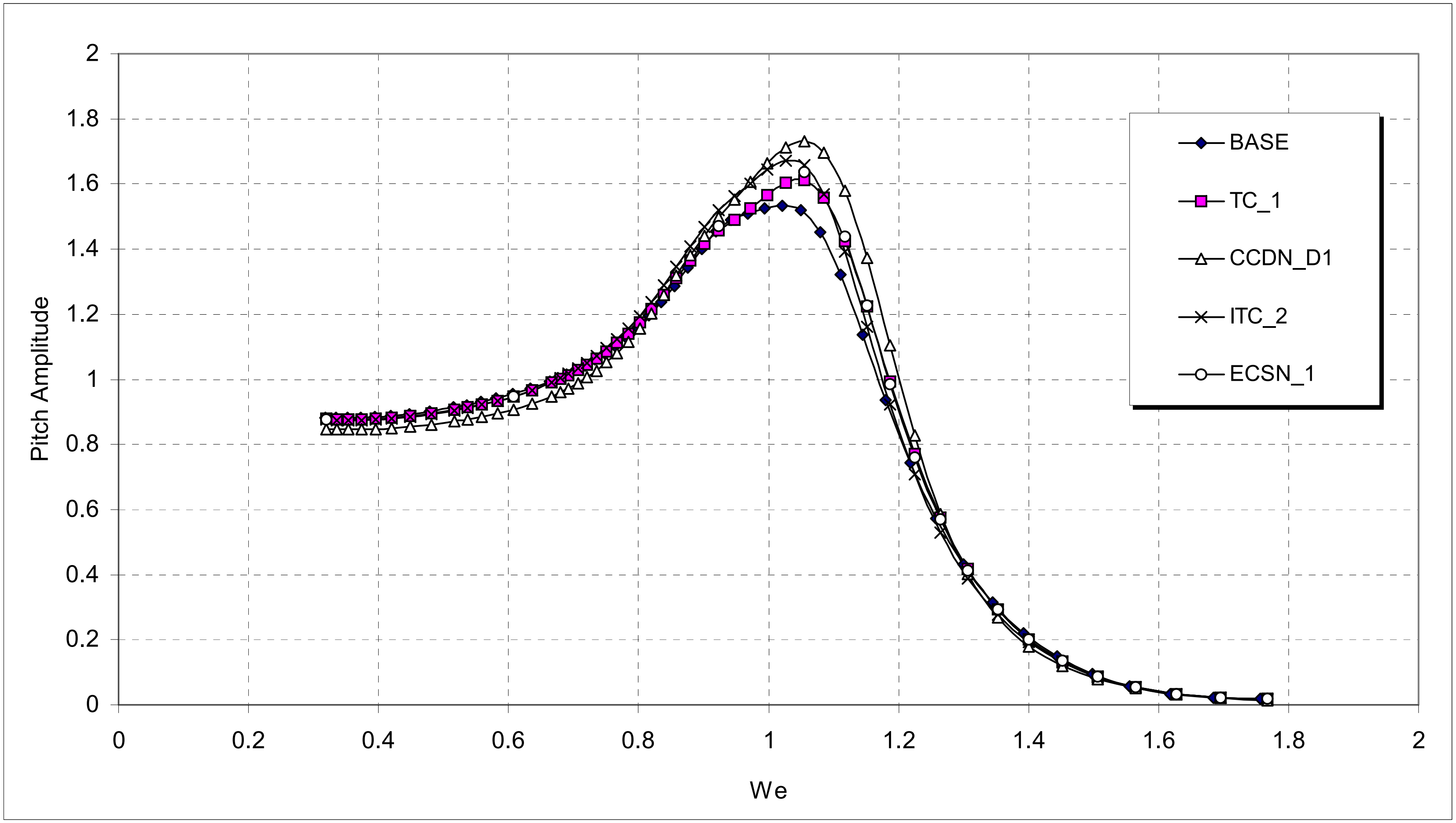


Figure 3.5 Pitch amplitude vs. encountering frequency

Chapter 4

Conclusions and Recommendations

4.1 Concluding remarks

This particular research is very much in the early stage and specified as Phase I. Phase I is mainly focusing on the behavior study of different amplitudes of motion (i.e. surge, heave and pitch) due to various bulb formations. Therefore, the prime objective is to obtain as much results as possible. However, based on the available results the following concluding remarks may be drawn:

- Addition of bulbous bow does not have significant influence in the surge amplitude of motion.

- CCDN_D1 produces smaller heave amplitude in the region of natural frequency and produces higher amplitude in the region beyond natural frequency as compared to the BASE.

- ITC_1 produces larger heave amplitude in the region of natural frequency and remains unchanged in other regions as compared to the BASE.

- CCDN_D1 produces greater heave amplitude in the region of natural frequency and produces lesser amplitude in the region beyond natural frequency as compared to the BASE.

In a nutshell, bulbous bow seems to reduce pitch amplitude and increase heave amplitude of motion, particularly beyond in the region of natural frequency. But in the region of natural frequency the opposite phenomena occurs, i.e. heave amplitude reduces and pitch amplitude increases.

4.2 Recommendation for future research

The results obtained in this study are not fully conclusive. As stated earlier that the research is in Phase I, a number of initiatives are required to be taken for future research. The following recommendations, therefore, may be stated:

- In this study Froude number, encountering angle, and wave amplitudes were kept constant. But in the reality these factors vary quite often during a sea voyage. For future investigations, variations of these factors may be considered.

- A program can be developed which will automatically produce an input file from CAD software. This will reduce the required amount of time spent in preparing input files.

- Increasing the number of panels and reducing the panel size will always lead to more accurate results. Therefore, for future research, it is recommended to increase the number of panels and reduce the size of panels.

- This particular research was a frequency domain analysis. For future works time domain analysis is recommended.

- Through out the research the steady potential (Φ_S) has been ignored. For future study it is recommended to include steady potential.

References

[1.] Dominic S. Cusanelli, 'Development of a Bow for a Naval Surface Combatant which Combines a Hydrodynamic Bulb and a Sonar Dome', Technical Report Presented at the American Society of Naval Engineers Technical Innovation Symposium, September 1994.

[2.] H. Schneekluth, 'Ship Design for Efficiency and Economy', p. 49-60, Germany, 1987.

[3.] Harolds E. Saunders, 'Hydrodynamics in ship design', Volume I, Chapter 25, p. 366-374

[4.] Modern Ship Design, T.C. Gillmer, 1970, p. 102-106

[5.] Islam, M.R., Baree, M.S. and Islam, M.N., 'Motion Simulation of a Surveillance Vessel in an Irregular Sea', Proceedings of the Marine Technology Conference, UTM, Malaysia, 2004.

[6.] M.N. Islam, M.R. Islam, and M.S. Baree, Computation of Ship Responses in Waves Using Panel Method, Journal of Naval Architecture and Marine Engineering, December 2004.

[7.] Salvesen, N. Tuck, E.O. and Faltinsen,O., Ship Motions and Sea Loads, SNAME 78, 1970, pp 250-287.

[8.] Vugts, J.H., The hydrodynamic forces and Ship Motions in Oblique Waves, Research Centre TNO for Shipbuildig, Delft Report No 150S, 1971.

[9.] Newman, J.N., Marine Hydrodynamics, Cambridge (Mass), MIT Press, 1977.

[10.] Newman, J.N., The Theory of Ship Motion, Advances in Applied Mechanics 18, 1978, pp 221-283.

[11.] Faltinsen, O.M., Sea loads on ships and offshore structures, Cambridge Ocean Technology Series, 1993

[12.] Faltinsen, O.M., & Michelsen, F.C., ‘Motions of large structures in waves at zero Froude number., International Symposium on the Dynamics of Marine Vehicles and Structures in Waves, Mechanical Engineering, London, 1975, pp 99-114.

[13.] Hogben, N. Standing R.G., Wave loads on large bodies, International Symposium on the Dynamics of Marine Vehicles and Structures in Waves, Mechanical Engineering, London, 1975, pp 273-292.

[14.] Garrison, C.J., Hydrodynamic loading of large offshore structures, Three Dimensional Source Distribution Methods, Numerical Methods in Offshore Engineering, 1978, pp 87-140.

[15.] Inoue, Y., Saeed, M.S., Asada, H., and Yamashita S., Motion Analysis of Parallely Connected FPSO unit and LNG Carrier, 1996 OMAE, Volume-I, Part-A, pp 415-421.

[16.] Iwashita, H. and Okhusu, M., Hydrodynamic forces on a ship moving at forward speed in waves, JSNA, Japan, 166, 1989, pp 87-109.

[17.] ChenX.B., Noblesse, F., Super Green Function, Proceedings, 22nd Symposium on Naval Hydrodynamics, Washington, 1998, pp 860-874.

[18.] Ba, M., and Guilbaud, M., A fast method of evaluation for the translation and pulsating Green's function, Ship Technology Research, 42.2, 1995, pp 68-80.

[19.] Nontakaew, U., et al, Solving a radiation problem with forward speed using a lifting surface method with a Green's Function, Aerospace Science and Technology,8, 1997, pp 533-543.

[20.] Chapman, K.B., Numerical Solutions for Hydrodynamic Forces on a Surface Piercing Plate Oscillating in Yaw and Sway, 1st International Conference on Numerical Ship Hydrodynamics, Maryland, USA, 1975, pp 333-350.

[21.] Yeung, R.W., Kim, S.H., Radiation Forces on Ship with Forward Speed, Proceedings of the 3rd International Conference on Numerical Ship Hydrodynamics, Paris, France, 1981, pp 499-515.

[22.] Yamasaki, K. and Fujino, M., Linear Hydrodynamic Coefficients of Ships with Forward Speed During Harmonic Sway, Yaw, and Roll Oscillations, 4th International Conference on Numerical Ship Hydrodynamics, USA, 1985, pp 56-70.

[23.] Todd F. H.,'Some further Experiments on Single Screw Merchant Ship Forms-Series 60', paper presented at the annual meeting of the SNAME, Neyork,November,1953.

[24.] R. Bhattacharia, Dynamics of Marine Vehicles.

Appendix A

Program 1

```
C
C     Panel Generator
C

      integer total_panel, wl, st, total_node, panel
      integer a,b,c,d
      integer fwp, fwn

      open(1, file='out.txt')
      open(2, file='outx.txt')

10    format('ELEM', I8,I8,I5,I5,I5)

100   print*,      ' '
      print*, 'Enter (1) for normal (2) for stepped (3) exit'; read*,
cc
      if(cc.eq.1) goto 110
      if(cc.eq.2) goto 111
      if(cc.eq.3) goto 112
      goto 100


110   print*, 'Enter no. of horizontal lines : ';     read*, wl
      print*, 'Enter no. of vertical lines   : ';     read*, st

      total_panel = (wl-1) * (st-1)
      total_node  = wl * st

      print*, 'Total Panel :', total_panel
      print*, 'Total Node  :', total_node

      do i = 1, (st-1)
      do j = 1, (wl-1)
      panel = panel + 1
      a = wl*(i-1) + j
      b = a + 1
      c = a + wl + 1
      d = c - 1
      write(1,10) panel,a,b,c,d
      end do
      end do
      goto 100

111   print*, 'Enter forward stepping (panel): ';     read*, fwp
      print*, 'Enter forward stepping (node) : ';     read*, fwn
      print*, 'Enter no. of horizontal lines : ';     read*, wl
      print*, 'Enter no. of vertical lines   : ';     read*, st

      total_panel = (wl-1) * (st-1)
      total_node  = wl * st

      print*, 'Total Panel :', total_panel
      print*, 'Total Node  :', total_node

      panel = fwp
```

```
      do i = 1, (st-1)
      do j = 1, (wl-1)
      panel = panel + 1
      a = wl*(i-1) + j
      b = a + 1
      c = a + wl + 1
      d = c - 1
      write(2,10) panel,a+fwn,b+fwn,c+fwn,d+fwn
      end do
      end do

      goto 100
112   stop
      end
```

Appendix B

Program 2

```
C
C     This program modifies the data from Auto CAD and prepares
C     the input file for the main program
C

      dimension x(10000), y(10000), z(10000)

      open (1, file = 'in.txt')
      open (2, file = 'out.txt')

10    format (2x, F9.3, 4x, F9.3, 4x, f9.3)
20    format ('NODE', I8, F12.3, F12.3, F12.3)

      do 100 i = 1, 50, 1
      read(1,10) x(i), y(i), z(i)
100   continue

      j =   1

      do 200 i = 1, 25, 5
      write(2,20) j,   x(i+4), y(i+4), z(i+4)
      write(2,20) j+1, x(i+3), y(i+3), z(i+3)
      write(2,20) j+2, x(i+2), y(i+2), z(i+2)
      write(2,20) j+3, x(i+1), y(i+1), z(i+1)
      write(2,20) j+4  , x(i),   y(i),   z(i)
      write(2,20) j+5, x(i+1),-y(i+1), z(i+1)
      write(2,20) j+6, x(i+2),-y(i+2), z(i+2)
      write(2,20) j+7, x(i+3),-y(i+3), z(i+3)
      write(2,20) j+8, x(i+4),-y(i+4), z(i+4)
      j = j + 9
200   continue

      stop
      end
```

Appendix C

Program 3

```
C
C     This program reads the output files and sorts the results
C

      dimension surge(50), sway(50), heave(50), pitch(50)

      open(1,  file= 'C:\main\Results\070.txt')
      open(2,  file= 'C:\main\Results\072.txt')
      open(3,  file= 'C:\main\Results\074.txt')
      open(4,  file= 'C:\main\Results\076.txt')
      open(5,  file= 'C:\main\Results\078.txt')
      open(6,  file= 'C:\main\Results\080.txt')
      open(7,  file= 'C:\main\Results\082.txt')
      open(8,  file= 'C:\main\Results\084.txt')
      open(9,  file= 'C:\main\Results\086.txt')
      open(10, file= 'C:\main\Results\088.txt')
      open(11, file= 'C:\main\Results\090.txt')
      open(12, file= 'C:\main\Results\092.txt')
      open(13, file= 'C:\main\Results\094.txt')
      open(14, file= 'C:\main\Results\096.txt')
      open(15, file= 'C:\main\Results\098.txt')
      open(16, file= 'C:\main\Results\100.txt')
      open(17, file= 'C:\main\Results\102.txt')
      open(18, file= 'C:\main\Results\104.txt')
      open(19, file= 'C:\main\Results\106.txt')
      open(20, file= 'C:\main\Results\108.txt')
      open(21, file= 'C:\main\Results\110.txt')
      open(22, file= 'C:\main\Results\112.txt')
      open(23, file= 'C:\main\Results\114.txt')
      open(24, file= 'C:\main\Results\116.txt')
      open(25, file= 'C:\main\Results\118.txt')
      open(26, file= 'C:\main\Results\120.txt')
      open(27, file= 'C:\main\Results\122.txt')
      open(28, file= 'C:\main\Results\124.txt')
      open(29, file= 'C:\main\Results\126.txt')
      open(30, file= 'C:\main\Results\128.txt')
      open(31, file= 'C:\main\Results\130.txt')
      open(32, file= 'C:\main\Results\132.txt')
      open(33, file= 'C:\main\Results\134.txt')
      open(34, file= 'C:\main\Results\136.txt')
      open(35, file= 'C:\main\Results\138.txt')
      open(36, file= 'C:\main\Results\140.txt')
      open(37, file= 'C:\main\Results\145.txt')
      open(38, file= 'C:\main\Results\150.txt')
      open(39, file= 'C:\main\Results\155.txt')
      open(40, file= 'C:\main\Results\160.txt')
      open(41, file= 'C:\main\Results\165.txt')
      open(42, file= 'C:\main\Results\170.txt')
      open(43, file= 'C:\main\Results\180.txt')
      open(44, file= 'C:\main\Results\190.txt')
      open(45, file= 'C:\main\Results\200.txt')
      open(46, file= 'C:\main\Results\210.txt')
      open(47, file= 'C:\main\Results\220.txt')
      open(48, file= 'C:\main\Results\230.txt')
```

```
      open(49, file= 'C:\main\Results\240.txt')
      open(50, file= 'C:\main\Results\250.txt')

100   format(/////////////////////////////////////////////////////
     +20x,f8.5,11x,f8.5,11x,f8.5,31x,f8.5)
200   format(f10.6,f10.6,f10.6,f10.6,f10.6,f10.6)
300   format(f9.3,5x,f9.3,5x,f9.3,5x,f9.3)
400   format(/////////////////////////////////////////////////////
     +76x,f11.5)

      open(100, file = 'out.txt')

      do 1 i = 1, 50, 1
      read(i,100) surge(i), sway(i), heave(i), pitch(i)
      print*,     surge(i), sway(i), heave(i), pitch(i)
      write(100,300) surge(i), sway(i), heave(i), pitch(i)
1     continue

      stop
      end
```