The Influence of a Proboscidean Bow on Ship Motions

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ABSTRACT

An efficient and practical computer-based ship-hull generation technique has been developed in the current research. A library of practical hull forms is first created. The computer program then "merges" or "blends" these hulls from the data base.

The hull is next analyzed by a ship-motions program HYDROS, described by Doctors (1993). This program has the ability to automatically generate the required computer panelling and mesh needed for the hydrodynamic analysis. Examples of the heave and pitch response of the different hull forms are presented in the paper.

INTRODUCTION

Background

One of the early attempts to apply computers to the fairing of ships lines was described by Theilheimer and Starkweather (1961). The purpose of the work was to fair existing lines and not to create new ones.

Another approach to fitting a mathematical surface to the hull is to use splines. There is a vast array of different splines suitable for this purpose. An early example is the work of Berger, Webster, Tapia, and Atkins (1966), in which two-dimensional splines were used to *smooth* a given hull surface. In the spline approach, mathematical patches are used to cover the surface. A well-known spline is that of Bézier (1972).

A radically different idea was proposed by Letcher (1984). His so-called Fairline hull-definition method comprises a family of mathematical schemes, simple enough to implement on small computers.

Current Work

The method described in this paper is based on a very simple idea. It requires the user to establish a small data bank of hull forms which are known to be practical from the point of view of, for example, resistance, motions, and stability. The computer program simply interpolates between selected members of the parent hulls. Naturally, it is then necessary to analyze the new hull form in order to determine its usefulness.

METHODOLOGY

Hull Definition

The primary input information consists of the hull definition. The surface of the hull is defined by a surface mesh which consists of a set of longitudinal lines and a set of girthwise lines.

Method of Hull Generation

We assume that there is a set of N parent hulls, whose surface coordinates are given by $X_i(x_i, y_i, z_i)$. The coordinates x, y, and z are respectively longitudinal to bow, transverse to port, and vertically upward. The index i refers to the particular parent hull and, for the sake of brevity, we omit the index for the individual points on any one hull.

The simplest way of blending the hulls is the combination:

$$x = \sum_{i=1}^{N} \alpha_{x,i} x_i \,, \tag{1}$$

$$y = \sum_{i=1}^{N} \alpha_{y,i} y_i \,, \tag{2}$$

$$z = \sum_{i=1}^{N} \alpha_{z,i} z_i \,. \tag{3}$$

Here, $\alpha_{x,i}$, $\alpha_{y,i}$, and $\alpha_{z,i}$, are the scaling factors which will, in principle, be different for each parent hull.

Hydrodynamic Analysis of the Hull

We will now show computed results for heave and pitch, based on the method of Salvesen, Tuck, and Faltinsen (1970). They demonstrated that the heave (index 3) and pitch (index 5) equations of motion could be written as:

$$(A_{33}+M)\ddot{\eta}_3+B_{33}\dot{\eta}_3+C_{33}\eta_3+A_{35}\ddot{\eta}_5+ \\ +B_{35}\dot{\eta}_5+C_{35}\eta_5=\widehat{F}_3\exp(j\omega t)\,, \quad (4)$$

$$A_{53}\ddot{\eta}_3+B_{53}\dot{\eta}_3+C_{53}\eta_3+(A_{55}+I_5)\ddot{\eta}_5+ \\ +B_{55}\dot{\eta}_5+C_{55}\eta_5=\widehat{F}_5\exp(j\omega t)\,, \quad (5)$$

where M is the vessel mass and I_5 is the moment of inertia about the transverse axis (which is located at the longitudinal centre of gravity LCG). The coefficients A_{ij}, B_{ij}, and C_{ij} are the hydrodynamic added mass, damping, and stiffness, respectively. The complex heave and pitch are denoted by η_3 and η_5. The *generalized* forces, that is, the complex heave force and pitch moment, are denoted by F_3 and F_5. The hat $\widehat{}$ is used to indicate the relevant quantity without the phaser $\exp(j\omega t)$.

Next, t is the time and ω is the *encounter* angular frequency given by

$$\omega \;=\; \omega_0 - Uk_0\cos\gamma\,, \quad (6)$$

where ω_0 is the angular frequency of the sea wave, U is the speed of the vessel and γ is the direction of the sea (0° being stern seas). The sea wavenumber is given by

$$k_0 \;=\; \omega_0^2/g\,, \quad (7)$$

in which g is the acceleration due to gravity.

Finally, the formula for the local elevation of the sea wave itself is

$$\zeta \;=\; A_0\exp[j(-k_0x\cos\gamma+k_0y\sin\gamma+\omega_0t)]\,, \quad (8)$$

where it is understood that the real part is desired. Additionally, A_0 is the sea wave amplitude.

RESULTS AND DISCUSSION

Examples of Generated Hulls

Figures 1(a) and (b) show the body view and a pictorial view, respectively, for the three parent hulls used in the current investigations.

Parent 1 is a 20 m demihull suitable for a catamaran, which was drawn by Soars (1987). The design waterline length is 18.5 m. This corresponds to a nominal draft T_N of 1.500 m (relative to the baseline) and a draft of 0.658 m. Parent 2 is identical to Parent 1, except that the longitudinal fairing line in the planing part of the hull surface below the chine has been shifted outward and forward to create a bulbous bow. Finally, Parent 3 is identical to Parent 2, *with the single exception* of the forward-most point on the abovementioned shifted longitudinal fairing line, which is now somewhat lower, creating a deeper bulb.

We now turn to Figures 2(a) and (b), which show three out of the five linear combinations of Parents 1 and 2. For this purpose, the parameters in Equations (1) to (3) have been selected as follows:

$$\alpha_{x,i} \;=\; \alpha_{y,i} \;=\; \alpha_{z,i} \;=\; (1/18.5)\alpha_i\,, \quad (9)$$

in which the overall scaling factor has been chosen to make the waterline length of Parent 1 equal to unity. This is the nominal length L_N, which, in addition to g and the density of the water ρ, is used for nondimensionalizing the results.

The two parts of Figure 3 may be compared to the corresponding two parts of Figure 2. In this case, however, Parents 1 and 3 have been combined — rather than Parents 1 and 2.

Lastly, we examine Figure 4, in which all three parents have been combined in the proportions noted by the values of the scaling factors α_i.

Systematic Investigation of Hull Variation

The first set of results for heave and pitch is shown in Figures 5(a) and (b), respectively. The heave amplitude A_3 and the pitch amplitude A_5 have been made dimensionless in the usual way, as has the angular frequency of the sea wave ω_0. Other parameters on the graph include the nominal-draft-to-length ratio T_N/L_N, the ratio of the longitudinal radius of gyration to the nominal length k_5/L_N and the nominal Froude number $F_N = U/\sqrt{gL_N}$.

Regarding heave, in Figure 5(a), the effect of adding the bulbous bow by means of merging Parents 1 and 2 — corresponding to the geometries shown in Figure 2 — is seen to decrease the peak acceleration response and to lower the frequency at which this occurs. On the other hand, the pitch response in Figure 5(b) is seen to drop substantially, on a percentage basis, in the neighborhood of a dimensionless frequency of 1.75.

Similarly, we see the heave and pitch response in Figure 6 for merging Parents 1 and 3 — corresponding to the geometries shown in Figure 3. While the gross variations in heave in Figure 6(a) are greater, we observe some really substantial reduction of pitch in Figure 6(b), of the order of 85% at a dimensionless frequency of around 1.6.

Next, in Figure 7, are shown the responses for merging *all three parents*, corresponding to the geometries seen in Figure 4 — and maintaining a fixed beam and draft. We note an even greater improvement in the pitch response, in that there is a marked increased range of frequencies over which the pitch is reduced. The greatest pitch reduction is now up to about 90%.

CONCLUSIONS

The research in this paper has shown the great ease with which practical hull forms can be generated by the extremely simple approach of adding linear combinations of parent hulls. Clearly, it is possible to extend the method even further by using scaling factors that vary in a prescribed spatial manner over the individual hulls.

ACKNOWLEDGMENTS

The author would like to express his appreciation to Mr N.A. Armstrong of InCat Pty Ltd, Lane Cove, New South Wales, for providing him with the lines plans of a suitable catamaran demihull.

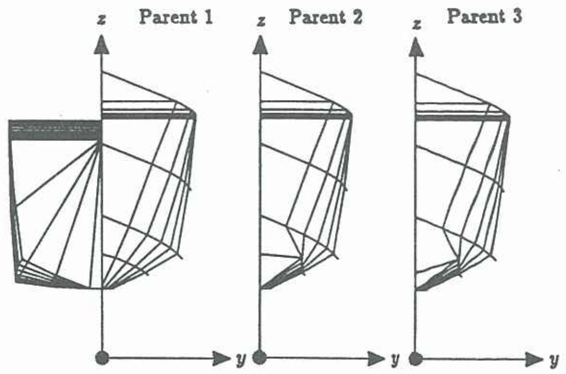


Figure 1: Input Mesh for the Parent Hulls
(a) Front Elevation

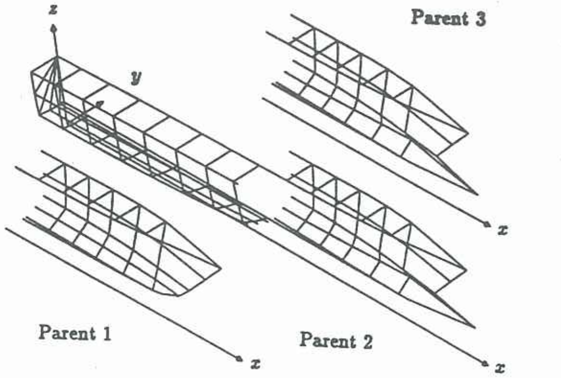


Figure 1: Input Mesh for the Parent Hulls
(b) Pictorial View

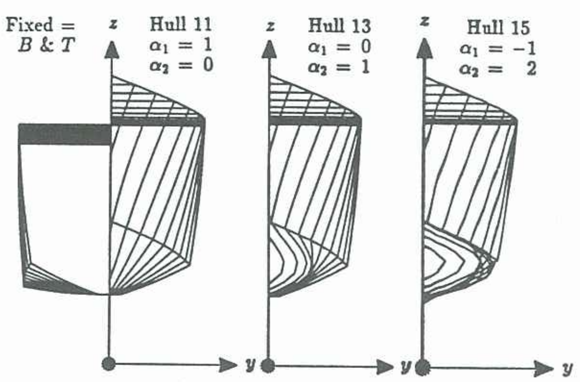


Figure 2: Sections for First Set of Mergers
(a) Front Elevation

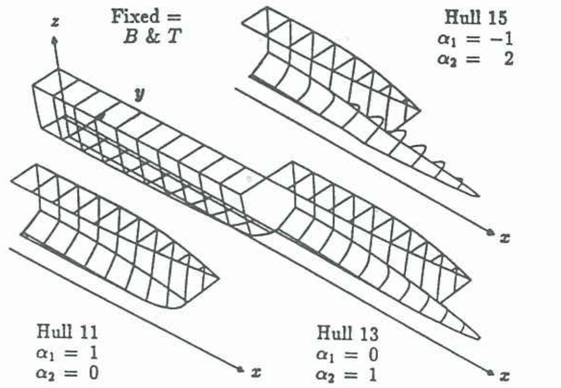


Figure 2: Sections for First Set of Mergers
(b) Pictorial View

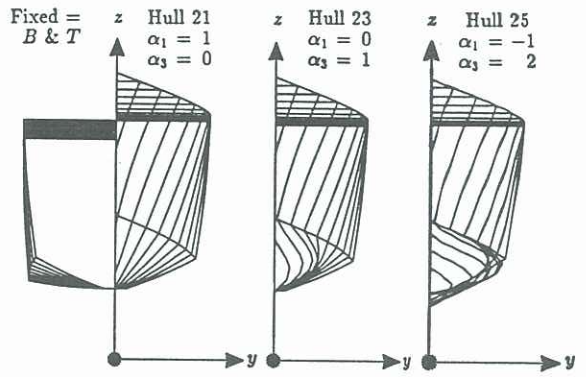


Figure 3: Sections for Second Set of Mergers
(a) Front Elevation

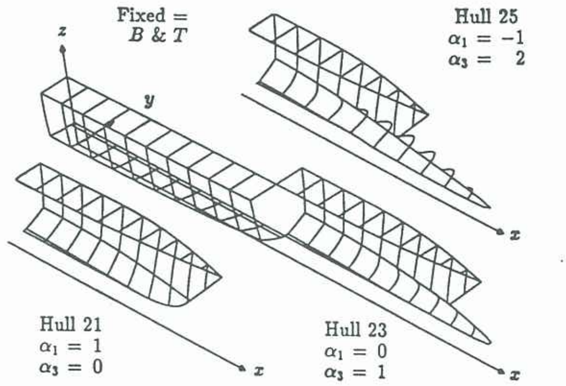
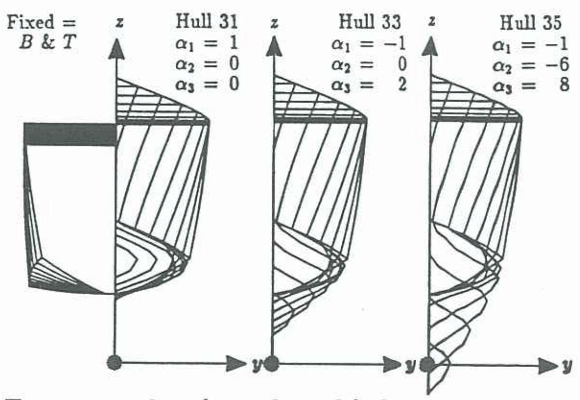
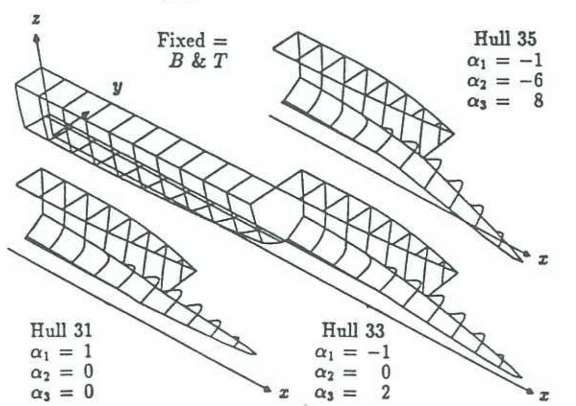


Figure 3: Sections for Second Set of Mergers
(b) Pictorial View



Fugure 4: Sections for Third Set of Mergers
(a) Front Elevation



Fugure 4: Sections for Third Set of Mergers
(b) Pictorial View

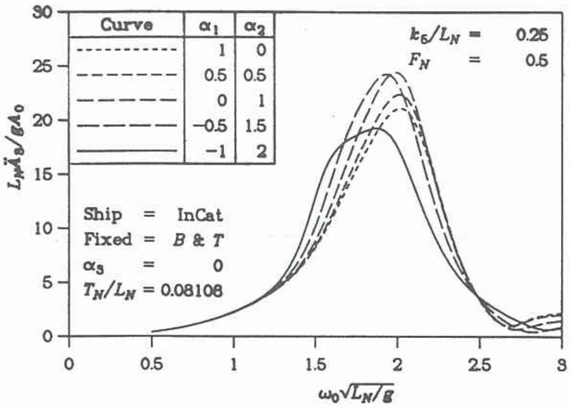


Figure 5: Response Curves for First Set of Mergers (a) Heave Acceleration

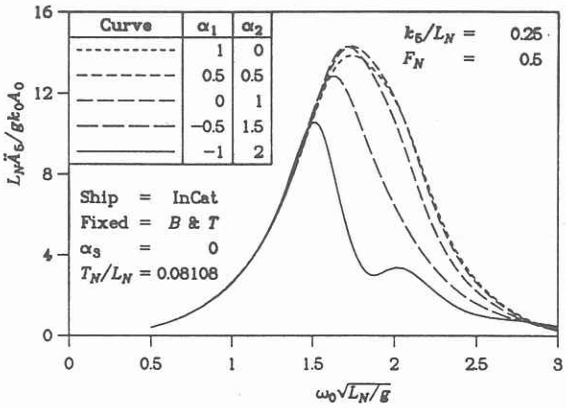


Figure 5: Response Curves for First Set of Mergers (b) Pitch Acceleration

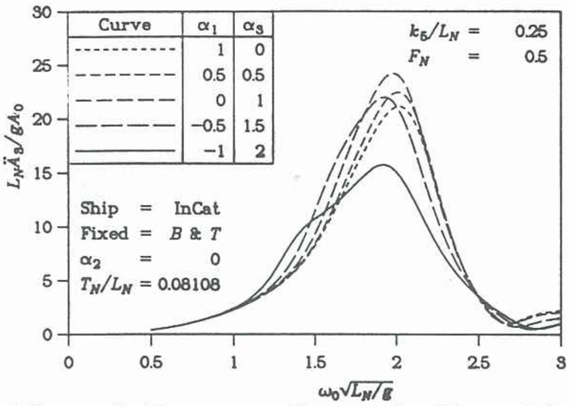


Figure 6: Response Curves for Second Set of Mergers (a) Heave Acceleration

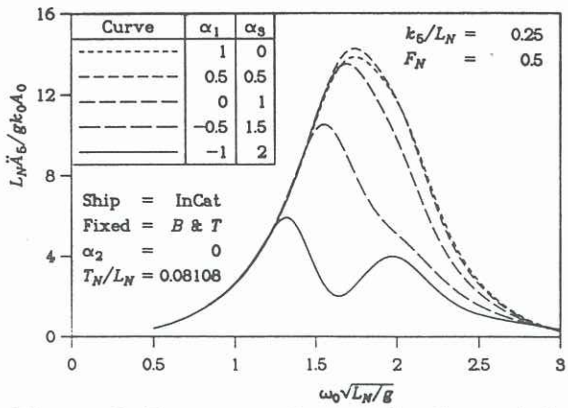


Figure 6: Response Curves for Second Set of Mergers (b) Pitch Acceleration

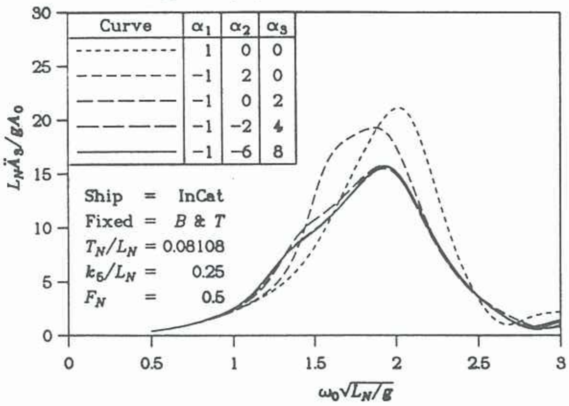


Figure 7: Response Curves for Third Set of Mergers (a) Heave Acceleration

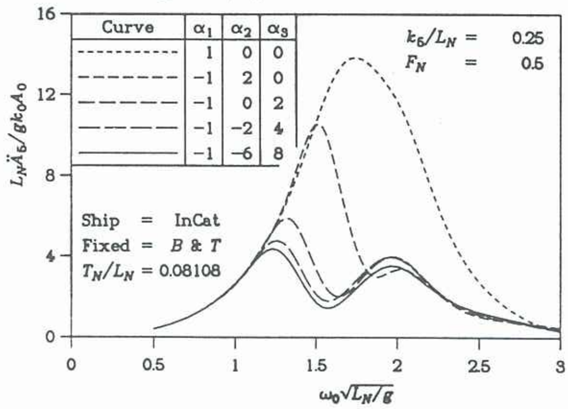


Figure 7: Response Curves for Third Set of Mergers (b) Pitch Acceleration

REFERENCES

BERGER, S.A., WEBSTER, W.C., TAPIA, R.A., AND ATKINS, D.A.: "Mathematical Ship Lofting", *J. Ship Research*, Vol. 10, No. 4, pp 203–222 (December 1966)

BÉZIER, P.: *Numerical Control: Mathematics and Applications*, John Wiley & Sons, Inc., New York, 240+xvi pp (1972)

DOCTORS, L.J.: "HYDROS: Integrated Software for the Analysis of the Hydrostatics and Hydrodynamics of Marine Vehicles", *Proc. Tenth International Maritime and Shipping Symposium (Ship-Shape 2000)*, University of New South Wales, Sydney, New South Wales, Vol. 1, pp 373–392 (November 1993)

LETCHER, J.S.: "Fairline Methods for Computer-Aided Hull Design", Presented to the Society of Naval Architects and Marine Engineers (Southeast Section), 12 pp (January 1984)

SALVESEN, N., TUCK, E.O., AND FALTINSEN, O.: "Ship Motions and Sea Loads", *Trans. Society of Naval Architects and Marine Engineers*, Vol. 78, pp 250–279, Discussion: 279–287 (December 1970)

SOARS, A.J.: "Twenty-Metre T.D. Catamaran Lines Plan", Drawing 899/1-2, Incat Pty Ltd, Chatswood, New South Wales (February 1987)

THEILHEIMER, F. AND STARKWEATHER, W.: "The Fairing of Ship Lines on a High-Speed Computer", David Taylor Model Basin, Applied Mathematics Laboratory, Report 1474, 21+ii pp (January 1961)