Mid Project Report

Preliminary Description of Synthesis Trimaran Mathematical Model

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In fulfillment of the requirements for:
FY 2004 Cooperative Agreement No. N00014-04-2-0003
Agile Port and High Speed Ship Technologies

Project 4
Automated Multidisciplinary Design Optimization Method for Multi-Hull Vessels

Classification: Unclassified

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February 28, 2005

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MOU #07-291504, FY 04 Project 4, Program Element 2.28
Automated Multidisciplinary Design Optimization Method for Multi-Hull Vessels

Task 4.1 Technical Coordination

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This material is based upon work supported by the Office of Naval Research, under Cooperative Agreement N00014-04-2-0003 with the California State University, Long Beach Foundation, Center for the Commercial Deployment of Transportation Technologies (CCDoTT)

Preliminary Description of Synthesis Trimaran Mathematical Model

Scope:

This document describes the process proposed for the "Automated Multidisciplinary Design Optimization Method for Multi-Hull Vessels" and its application to a generic trimaran configuration optimization and illustrating the use of Neural Networks. The baseline configuration is a trimaran consisting of 3 Wigley hulls with the outer 2 hulls being identical. The objective of the multi criteria design optimization is to maximize the cargo capacity of the trimaran, minimize the transportation cost involved and also minimize the structure weight. The process involves the variables and their flow within the sub-systems. The document provides an insight to multi criteria design optimization using design optimization tool.

Nomenclature:

α = (Separation): Ratio of clearance between the center and side hulls
β = (Stagger): Ratio of longitudinal position of side hull
λ_{sh} = Ratio of Length of side hull to Length of center hull
ν = viscosity (m^2/s)
Λ = Ratio of Displacement of Trimaran side hull to Displacement of the Trimaran.
B_{ch} = Beam of center hull, (meters)
B_{sh} = Beam of side hull, (meters)
BM_T^{ch} = Metacentric radius center hull, (meters)
BM_T^{sh} = Metacentric radius of side hull, (meters)
BOL = Beam Overall of the trimaran, (meters)
C_b^{ch} = Block coefficient of center hull.
C_b^{sh} = Block coefficient of side hull.
CC = Capital Cost (£)
CF = Coefficient of friction resistance
CK = Correlation Coefficient
CO = Coefficient of residual resistance
CR = Total Resistance Coefficient
D = Main deck, height of trimaran ship, (meters)
D_{ch} = Depth of center hull, (meters)
D_{sh} = Depth of side hull, (meters)
$DCon$ = Daily Consumption (tonnes/day)
$Displ$ = Displacement – trimaran (m^3)
$Displ_{ch}$ = Displacement – center hull (m^3)

$Displ_{sh}$ = Displacement – side hull (m^3)
DWT = Dead Weight (tonnes)
EHP = Effective Power (hp)
F_n = Froude Number
Fc = Fuel Carried (tonnes)
FC = Fuel Cost (£)
FP = Fuel Price (£/tonne)
GM_T^{ch} = Metacentric height for the center hull (meters)
GM_T^{sh} = Metacentric height for the side hull (meters)
HR = Handling Rate (tonnes/day)
KB_{ch} = Vertical center of buoyancy for center hull (meters)
KB_{sh} = Vertical center of buoyancy for side hull (meters)
KG_{ch} = Vertical center of gravity of center hull (meters)
KG_{sh} = Vertical center of gravity of side hull (meters)
$\mathrm{L_{ch}}$ = Length of center hull, (meters)
$\mathrm{L_{sh}}$ = Length of side hull, (meters)
$miscDWT$ = Miscellaneous Dead Weight, (tonnes)
PC = Port Cost (£)
PD = Port Days (days)
PEC = Propulsion Efficiency Coefficient
RC = Running Cost (£)
RE = Reynolds number – trimaran
RE_{ch} = Reynolds number – center hull
RE_{sh} = Reynolds number – side hull
RES = Resistance of trimaran (N)
RTP = Round Trip Miles (nm)
$RTPA$ = Round trips per year
SC = Ship Cost (£)
SD = Sea days (days)
SHP = Shaft Power (hp)
Sl = Slenderness - trimaran
Sl_{ch} = Slenderness – center hull
Sl_{sh} = Slenderness – side hull
T_{ch} = Draft of center hull, (meters)
T_{sh} = Draft of side hull, (meters)
V = Speed, (m/s)
V_k = Design Speed, (knots)
VC = Voyage Cost (£)
W_m = Machinery & Propulsion Weight (tonnes)

W_o = Outfit Weight of trimaran (tonnes)

W_o^{ch} = Outfit Weight of center hull (tonnes)

W_o^{sh} = Outfit Weight of side hull (tonnes)

W_s = Steel Weight of trimaran (tonnes)

W_s^{ch} = Steel Weight of center hull (tonnes)

W_s^{sh} = Steel Weight of side hull (tonnes)

WS = Wetted Surface – trimaran (m^2)

WS_{ch} = Wetted Surface – center hull (m^2)

WS_{sh} = Wetted Surface – side hull (m^2)

1. Problem Description

1.1 Objective:

The objective function is to minimize the transportation cost, structural weight and to maximize the cargo capacity of the trimaran.

1. Minimize Transportation Cost

The transportation cost is the ratio of cost incurred annually to the cargo transported annually. The transportation cost is to be minimized so that more cargo can be transported in less cost. The transportation cost is calculated in pounds (£).
Hence, the objective function is,

Minimize:

Transportation Cost=Annual Costs / Annual Cargo (£)

2. Minimize Structural Weight

The structural weight is the sum of the steel weight, outfit weight and machinery & propulsion weight.

Steel weight (W_s): The parts that add up to the steel weight include main hull structure, superstructure, deck houses, masts, kingposts and foundations.

Outfit weight (W_o): The parts that add up the outfit weight include joiner bulkheads, hawse pipes, deck fittings, cargo booms, hatch covers, anchors, rudder and stock, gallery equipment, non-propulsion mechanical equipment such as deck, machinery, steering engine, generators, ventilation systems, refrigeration systems, hull, piping systems and pumps, and electrical systems.

Machinery & propulsion weight (W_m). The machinery weight is a function of power generated. The structural weight is calculated in tons. The structural weight is to be minimized,

Minimize:

Light Ship=Steel Weight (W_s) + Outfit Weight (W_o) + Machinery & Propulsion Weight (W_m) (t)

3. Maximize Annual Cargo

The annual cargo is the product of payload and round trips per year. The objective function is to be maximized so that more cargo can be transported across.

Maximize:

Annual Cargo=Payload * $RTPA$ (Round Trips per year) (t/yr)

1.2 Constraints:

$0.5 \le \alpha \le 3$

α =Separation: Ratio of clearance between the center and side hulls, meters to Beam of the center hull, B_{ch}, α can vary from 0.5 to 3. Most common is about 0.75. SAIC's trimaran concepts have about 1.0.

$0 \le \beta \le 1$

β= Stagger: Ratio of longitudinal position of the side hull. β=0, if the transoms (aft perpendiculars) of the center and side hulls are at the same line; β=1, if the bows (bow perpendiculars) of the center and side hulls are at the same line. Common practice is to have β to be 0 or 0.5. SAIC's trimaran concepts have 0.

$0.1 \le \lambda_{sh} \le 0.75$

λ_{sh} =Ratio of Length of side hull (L_{sh}) to Length of the center hull (L_{ch}), ($\lambda_{sh} = \mathrm{L}_{\mathrm{sh}} / \mathrm{L}_{\mathrm{ch}}$) can vary from 0.1 to 0.75. Most common in the world practice is 0.2-0.3. SAIC's trimaran concepts have about 0.5.

$0 \le \Lambda \le 0.15$

Λ =Ratio of Displacement of trimaran side hull to Displacement of the trimaran ($\Lambda = Displ_{sh} / Displ_{ch}$). can vary from 0 to 0.15. "0" means non displacement side hulls; "0.15" – is the maximum reasonable figure. Most common in the world practice is 0.03-0.05. SAIC's trimaran concepts have about 0.1.

$L_{ch} / B_{ch} \ge 6$

$L_{sh} / B_{sh} \ge 6$

$L_{ch} / D_{ch} \le 15$

$L_{sh} / D_{sh} \le 15$

$L_{ch} / T_{ch} \le 19$

$L_{sh} / T_{sh} \le 19$

The ratio between length and beam, length and depth, length and draft is referenced from [1]
The ratio for length and beam, length and depth, length and draft has been kept the same for center hull and side hull.

$0 \le T_{sh} / T_{ch} \le 2$

The ratio between draft for center hull (T_{ch}) and side hull (T_{sh}) varies from 0 to 2. '0' means the desired waterline is the same for center hull and side hull of the trimaran.

$3000 \le DWT \le 500{,}000$

Bulk carrier ranges from 3000 to 500000 tons of dead weight.

$0.63 \le C_b^{ch} \le 0.75$

Block coefficient ranges from 0.63 to 0.75. C_b^{ch} is not constrained by the cross sectional shape of the hull so it measures the fullness of the entire displaced volume. If the hull filled the entire block defined by length beam, Draft, the C_b^{ch} would equal 1.

$0.63 \le C_b^{sh} \le 0.75$

$14 \le V_k \le 18$

$0.2 \le F_n \le 1$

Initial Stability: $GMT/BOL \ge 0.01$

Cargo Mark: $D - T_{ch}$ - TBD

Financing conditions: CC/SC - TBD

1.3 Model and Main variable description:

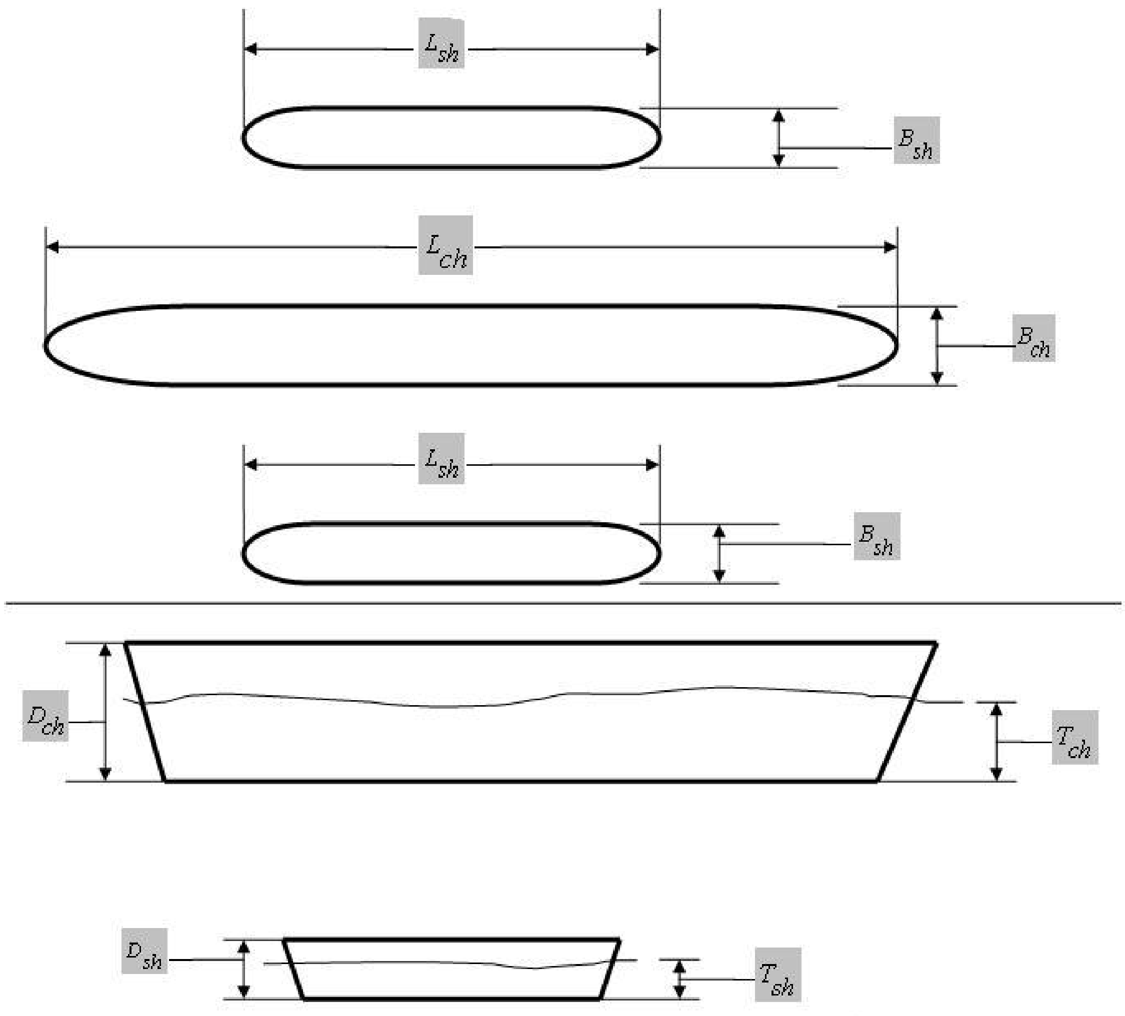


Figure 1

2. Powering

2.1 Formulation:

This section provides an explanation to the formulation in the Powering system. The shaft power has to be determined which will provide propulsion to the trimaran. We first calculate the displacement for center hull, side hull & trimaran.

Displacement is the volume under salt water (m^3). Displacement of center hull ($Displ_{ch}$) is a product of length of center hull, beam of center hull, draft of center hull and block coefficient given by,

$$Displ_{ch} = 1.025 \times L_{ch} \times B_{ch} \times T_{ch} \times C_b^{ch}$$ **---------- Equation 1**

The formula is referenced from [2].

Displacement for the center hull can be calculated from equation 1. Based on which the displacement of trimaran is calculated by

$$Displ = Displ_{ch} / (1 - 2 \times \Lambda)$$ **----------Equation 2**

The formula is referenced from [2]

Λ is the ratio of displacement of side hull ($Displ_{sh}$) to displacement of the trimaran ($Displ$).

Hence the displacement of the side hull can now be calculated by,

$$Displ_{sh} = Displ \times \Lambda$$ **----------Equation 3**

Wetted surface (WS) is a function of displacement and (Λ) and is given as,

$$WS = (Displ)^{2/3} \times \left(-1000 \times \Lambda^2 + 450 \times \Lambda + 80\right)$$ **----------Equation 4**

Now we calculate slenderness for the trimaran and for center hull,

Slenderness of the center hull (Sl_{ch})is the ratio of length of center hull to displacement of center hull,

$$Sl_{ch} = L_{ch} / (Displ_{ch})^{1/3}$$ **----------Equation 5**

Slenderness of side hull (Sl_{sh}) is ratio of length of side hull to displacement of side hull,

$$Sl_{sh} = L_{sh} / (Displ_{sh})^{1/3}$$ **----------Equation 6**

Since we have determined the slenderness for the center and side hull, we now calculate the wetted surface for center hull and side hull. Wetted surface for center hull (WS_{ch}) is a function of Sl_{ch} and $Displ_{ch}$.

$$WS_{ch} = 9.15 \times Sl_{ch} \times Displ_{ch}^{2/3}$$ **----------Equation 7**

The wetted surface for center hull can be approximated by [1]

Since we can calculate the wetted surface of trimaran and for center hull, we can also get the wetted surface of side hull,
We have,

$$WS = WS_{ch} + 2 \times WS_{sh}$$

$$WS_{sh} = \left(WS - WS_{ch}\right)/2$$ **----------Equation 8**

Now, we can evaluate the slenderness for trimaran (Sl),

$$Sl = \left(Sl_{ch} \times WS_{ch} + 2 \times Sl_{sh} \times WS_{sh}\right)/WS$$ **----------Equation 9**

The design speed is given by,

$$V = V_k \times 0.515$$ **----------Equation 10**

We need to calculate Coefficient of friction for the trimaran,

Coefficient of friction is a constant varying with the speed, length of surface and condition of surface. This is usually determined experimentally and applied as if it was constant over the full length of the hulls.

In order to calculate the coefficient of friction, we first calculate Reynolds number for center hull and side hull,
Reynolds number is important in analyzing any type of flow when there is substantial velocity gradient. Reynolds number ($RE = V \times L / \nu$). Where, viscosity is taken as $1.187 \text{ x } 10^6 \text{m}^2/\text{s}$.

Reynolds number for center hull (RE_{ch})

$$RE_{ch} = V \times L_{ch} \times 10^6 / 1.187$$ **----------Equation 11**

Similarly,

Reynolds number for side hull (RE_{sh})

$$RE_{sh} = V \times L_{sh} \times 10^6 / 1.187$$ **----------Equation 12**

Now, Reynolds number for the trimaran,

$$RE = \left(RE_{ch} \times WS_{ch} + 2 \times RE_{sh} \times WS_{sh}\right) / \left(WS_{ch} + 2 \times WS_{sh}\right)$$ **----------Equation 13**

The coefficient of friction (CF) is given by,

$$CF = 0.075 \times \left(\log_{10}\left(RE\right) - 2\right)^2$$ **----------Equation 14**

The correlation coefficient (CK) is,

$$CK \times 1000 = (-0.003 \times L_{ch} + 0.6)$$ **----------Equation 15**

Referenced from [1]

Coefficient of residual resistance (CO) is all resistances affecting a body's motion through the water excepting friction.
Coefficient of residual resistance is a function of slenderness (Sl), separation (α), stagger (β) and Froude number (F_n).

$$CO = f(Sl, \alpha, \beta, Fn)$$

In order to calculate the coefficient of residual resistance, we use neural networks. Neural Networks is development of optimization procedure based on form of artificial intelligence.

The procedure to calculate CO with the use of neural networks is explained in detail in section 2.2

Now, adding up all the coefficients i.e., CF , CO , CK gives total resistance coefficient (CR).

$$CR = CO + CF + CK$$ **----------Equation 16**

Resistance (RES) is a force which acts to stop the motion of the trimaran.
Now, calculating the resistance of trimaran,

$$RES = V^2 \times WS \times CR \times 519.316$$ **----------Equation 17**

We calculate the power generated for the ship, Power is force times the velocity.
Here, force is the resistance,
Hence,

$$EHP = V \times RES / 745.7$$ **----------Equation 18**

Now, the shaft power (SHP)

$$SHP = EHP / PEC$$ **----------Equation 19**

where, PEC is the propulsion efficiency coefficient. The value ranges between 0.65 to 0.7.

2.2 Neural Networks:

Neural network is the development of an optimization procedure based on form of artificial intelligence. In brief, neural network based optimization approach involves generation of training set and validation set. Training set (TS) is a set of known data points (design variables and their dependent variables like objective function and constraints). Validation set (VS) is used for stopping the training.
Create an input.dat file which contains the path & filename for TS, VS on the hard drive, specifies the no of inputs & outputs, TS size, VS size, ntrys, no of candidates, correlation formula, stopping criterion, DBinput and DBoutput columns.

Create dv.data which the evaluator can read. The dv.data file has design variables to evaluate and print the output to the neural network.

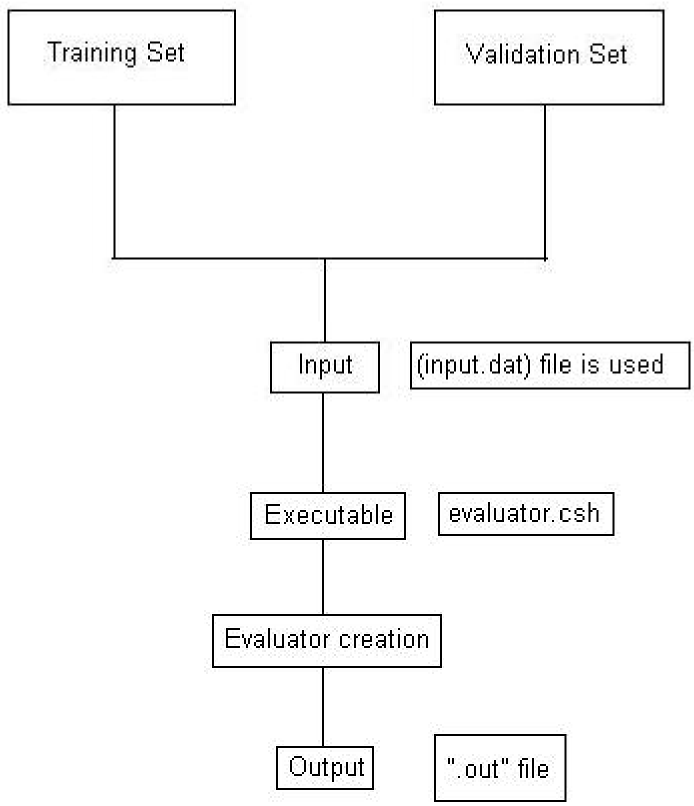


Figure 2

The actual process to generate evaluator for coefficient of residual resistance is given in the appendix 1.

3. Structural Weight Model

This section provides an explanation on the formulation of weights. The structural weight of the trimaran is divided into three types: steel weight (W_s), outfit weight (W_o) and machinery and propulsion weight (W_m).

Steel weight (W_s): The steel weight comprises of main hull structure, superstructure, deck houses, masts, kingposts and foundations. Since we are applying on a trimaran, the steel weight will be calculated for the center hull and the side hull. The steel weight will be the sum of steel weight for the center hull and 2 times the steel weight for the side hull.

$$W_s = W_s^{ch} + 2 \times W_s^{sh}$$ **----------Equation 20**

Steel weight for the center hull:

$$W_s^{ch} = 0.034 \times L_{ch}^{1.7} \times B_{ch}^{0.7} \times D_{ch}^{0.4} \times \left(C_b^{ch}\right)^{0.5}$$ **----------Equation 21**

Steel weight for the side hull:

$$W_s^{sh} = 0.034 \times L_{sh}^{1.7} \times B_{sh}^{0.7} \times D_{sh}^{0.4} \times \left(C_b^{sh}\right)^{0.5}$$ **----------Equation 22**

Substituting the values of equation 21 and 22 in equation 20, we get the steel weight for the trimaran.

Outfit weight (W_o): The parts that add up the outfit weight include joiner bulkheads, hawse pipes, deck fittings, cargo booms, hatch covers, anchors, rudder and stock, gallery equipment, non-propulsion mechanical equipment such as deck, machinery, steering engine, generators, ventilation systems, refrigeration systems, hull, piping systems and pumps, and electrical systems. The outfit weight parts includes all the equipments in center hull and side hull. The total outfit weight is the sum of outfit weight of the center hull and 2 times the outfit weight of the side hull.

$$W_o = W_o^{ch} + 2 \times W_o^{sh}$$ **----------Equation 23**

Outfit weight for the center hull,

$$W_o^{ch} = 1 \times L_{ch}^{0.8} \times B_{ch}^{0.6} \times D_{ch}^{0.3} \times \left(C_b^{ch}\right)^{0.1}$$ **----------Equation 24**

Outfit weight for the side hull,

$$W_o^{sh} = 1 \times L_{sh}^{0.8} \times B_{sh}^{0.6} \times D_{sh}^{0.3} \times \left(C_b^{sh}\right)^{0.1}$$ **----------Equation 25**

Substituting the values of equation 24 & 25 in equation 23, we get the outfit weight.

Machinery and propulsion weight (W_m):

$$W_m = 0.17 \times SHP^{0.9}$$ **----------Equation 26**

The structural weight of the trimaran is the sum of steel weight, outfit weight and machinery and propulsion weight,

Structural weight = $W_s + W_o + W_m$ = $\left(W_s^{ch} + 2 \times W_s^{sh}\right) + \left(W_o^{ch} + 2 \times W_o^{sh}\right) + W_m$

(N.B: The equations 21, 22, 24, 25, 26 have been referenced from [2]).

4. Payload Capacity Model

The deadweight (DWT) that the trimaran can carry is the difference between the displacement of the trimaran to the structural weight of the trimaran.

$$DWT = Displ - lightship$$ **----------Equation 27**

Daily consumption ($DCon$) is the amount of the fuel consumed per day in transportation of the cargo. Daily consumption mainly is a function of the shaft power. The amount of fuel consumed to generate the power. So, we have,

$$DCon = \left(\left(0.19 \times SHP \times 24\right)/1000\right) + 0.2$$ **----------Equation 28**

referenced from [2]

Round trip miles (RTP) is the distance traveled by the trimaran. The distance is measured in nautical miles. The value is assumed as 5000 nm.

$$RTP = 5000$$ **----------Equation 29**

Now, we need to calculate for the number of days that the trimaran will be in the traveling, i.e., sea days (SD)

$$SD = RTP/(24 \times V_k)$$ **----------Equation 30**

Fuel carried (Fc) is the product of daily consumption and sea days, We have,

$$Fc = DCon \times \left(SD + 5\right)$$ **----------Equation 31**

5 extra days have been added to sea days to take into consideration so there is excess stock of fuel.

The miscellaneous weight ($miscDWT$) is twice the square root of the deadweight. It constitutes the fuel weight, no of persons in the trimaran etc,

$$miscDWT = 2 \times DWT^{0.5}$$ **----------Equation 32**

referenced from [2]

The payload is difference between deadweight & fuel carried, miscellaneous dead weight.

$$Payload = DWT - Fc - miscDWT$$ **----------Equation 33**

The port days (PD) is the number of days that the trimaran with the payload can be held at the port.

$$PD = 2 \times \left[(Payload / HR) + 0.5 \right]$$ **----------Equation 34**

referenced from [2]

Round trips per year ($RTPA$) is the ratio of no of days in a year to the sum of sea days and port days,

$$RTPA = 365 / (SD + PD)$$ **----------Equation 35**

The annual cargo is the product of payload to the round trip miles per year. This is one of our main objectives. Annual cargo is to maximized, so that maximum cargo can be transported in minimum trips. This will also reduce the transportation cost involved.

$$AnnualC\arg o = Payload \times RTPA$$ **----------Equation 36**

5. Cost Model

The ship cost (SC) is an estimate that is based on structural weight and the power of the trimaran. The structure weight includes, the material that is used for the trimaran construction. The machinery weight, the outfit weight.

$$SC = 1.3 \times \left(2000 \times W_s^{0.85} + 3500 \times W_o + 2400 \times SHP^{0.8} \right)$$ **----------Equation 37**

referenced from [2]

Capital cost (CC) is the percentage of ship cost. Capital cost mostly depends upon the place (shipyard) where the ship building will be done. Here, The capital cost is assumed to be 20% of the ship cost.

$$CC = 0.2 \times SC$$ **----------Equation 38**

referenced from [2]

Running cost (RC) includes maintenance, annual dry docking, crew & insurance, salaries and wages and the deadweight.

$$RC = 40000 \times DWT^{0.3}$$ **----------Equation 39**

referenced from [2]

Port cost (PC) includes ship docking fees, deadweight and the cost incurred to maintain the ship at the port.

$$PC = 6.3 \times DWT^{0.8}$$ **----------Equation 40**

referenced from [2]

Fuel cost (FC) is the product of daily consumption, sea days and fuel price. This is an estimate of the cost that will be incurred related to fuel purchase at a specified rate, no of days during which the trimaran will be traveling, and the consumption of fuel per day.

$$FC = 1.05 \times DCon \times SD \times FP$$ **----------Equation 41**

referenced from [2]

Voyage cost (VC) is the total cost incurred in the travel i.e., sum of fuel cost, port cost and product of their sum with round trips per year.

$$VC = (FC + PC) \times RTPA$$ **----------Equation 42**

Annual cost includes the sum of capital cost, running cost and voyage cost. Annual cost is the complete cost estimate for the trimaran.

$$AnnualCost = CC + RC + VC$$ **----------Equation 43**

Transportation cost is the ratio of annual cost to annual cargo. Transportation cost is calculated in $ per ton. This is one of our objectives. Transportation cost is to be minimized. In order to minimize the transportation cost, annual cargo must be maximized.

$$TransportationCost = AnnualCost / AnnualC\arg o$$ **----------Equation 44**

6. Stability

Stability is the tendency of a hull vessel to rotate one way or the other when forcibly inclined.

The figure below shows the stability reference points in a hull vessel. For convenience only the center hull is taken in the figure 3 & 4. However, while calculating all hulls are taken.

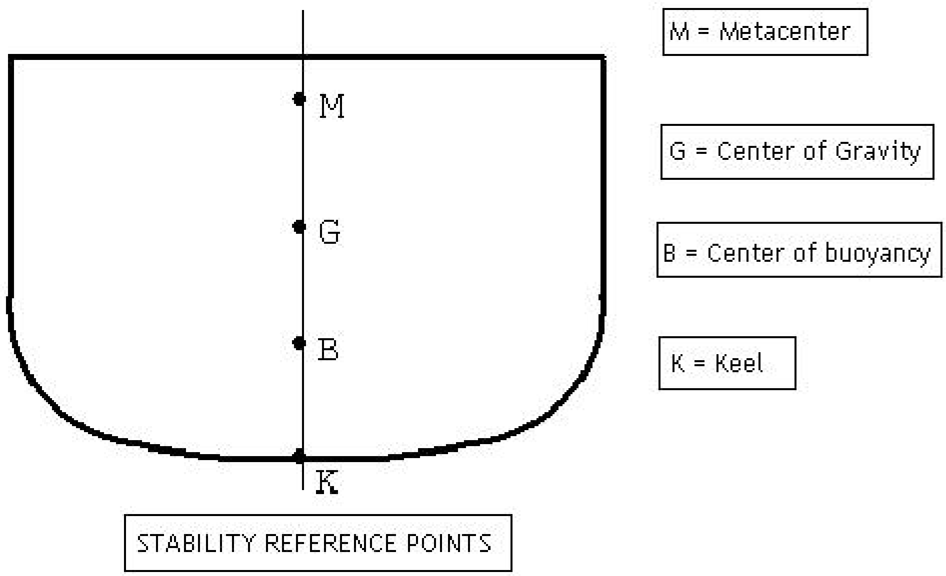


Figure 3

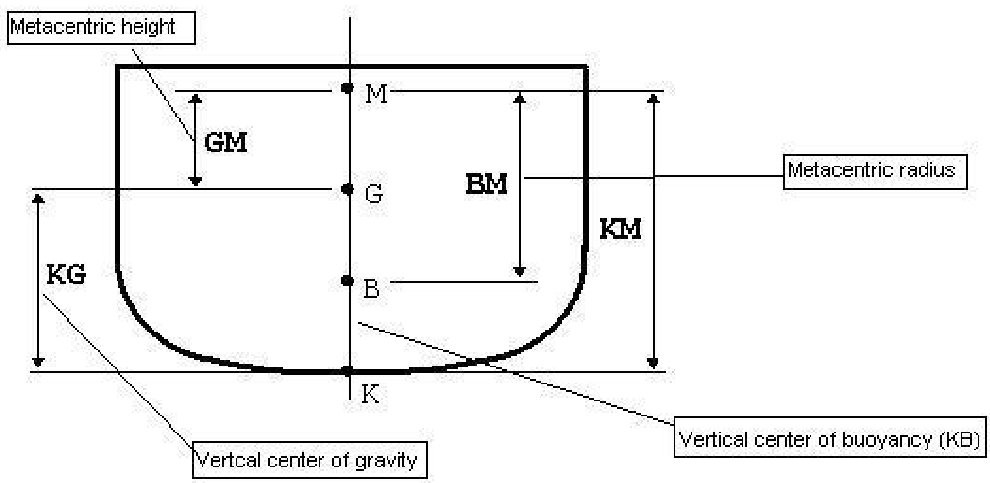


Figure 4

M - Metacenter: As the ship is inclined through small angles of heel, the lines of buoyant force intersect at a point called the metacenter. As the ship is inclined, the center of buoyancy moves in an arc as it continues to seek the geometric center of the underwater hull body. This arc describes the metacentric radius. (refer figure 3)

BM_T **- Metacentric Radius:** The distance between the Center of Buoyancy and the Metacenter. It is actually the radius of the circle for the movements of "B" at small angles of heel. (refer figure 4)

Metacentric radius for the center hull (BM_T^{ch})is calculated as,

$$BM_T^{ch} = (0.085 \times C_b^{ch} - 0.002) \times B_{ch}^2 / \left(T_{ch} \times C_b^{ch}\right)$$ **----------Equation 45**

reference from [2]

Metacentric radius for the side hull (BM_T^{sh}) is calculated as,

$$BM_T^{sh} = (0.085 \times C_b^{sh} - 0.002) \times B_{sh}^2 / \left(T_{sh} \times C_b^{sh}\right)$$ **----------Equation 46**

reference from [2]

G - Center of Gravity: The point at which all forces of gravity acting on the ship can be considered to act. "G" is the center of mass of the vessel.

Vertical center of gravity for center hull (KG_{ch}) is calculated as,

$$KG_{ch} = 1 + 0.52 \times D_{ch}$$ **----------Equation 47**

reference from [2]

Vertical center of gravity for side hull (KG_{sh}) is calculated as,

$$KG_{sh} = 1 + 0.52 \times D_{sh}$$ **----------Equation 48**

reference from [2]

B - Center of Buoyancy: The geometric center of the ship's underwater hull body. It is the point at which all the forces of buoyancy may be considered to act in a vertically upward direction

Vertical center of buoyancy for center hull(KB_{ch}) is calculated as,

$$KB_{ch} = 0.53 \times T_{ch}$$ **----------Equation 49**

reference from [2]

Vertical center of buoyancy for side hull (KB_{sh}) is calculated as,

$$KB_{sh} = 0.53 \times T_{sh}$$ **----------Equation 50**

reference from [2]

K - Keel: The base line reference point from which all other reference point measurements are compared. (refer figure 3)

GM - Metacentric Height: This measurement is calculated by adding vertical center of buoyancy (KB) and metacentric radius (BM) and subtracting vertical center of gravity (KG). GM is a measure of the ship's initial stability.

The metacentric height of the center hull (GM_T^{ch}) is calculated as,

$$GM_T^{ch} = KB_{ch} + BM_T^{ch} - KG_{ch}$$ **----------Equation 51**

The metacentric height of the side hull (GM_T^{sh}) is calculated as,

$$GM_T^{sh} = KB_{sh} + BM_T^{sh} - KG_{sh}$$ **----------Equation 52**

7. Work In Progress

As the title indicates, the above is a preliminary description of synthesis trimaran mathematical model. Following the well established Systems Engineering approach, the outcome of the synthesis level definition will be a set of objectives, requirements and design constraints which will be imposed on subsystems. Like at the system level, the definition of the subsystems involves many disciplines and, therefore, requires a Multidisciplinary Design Optimization approach. In order to achieve the overall objectives of the FY 04 program, the following additional works are planned and /or in progress

- The impacts of wave making interference relative to longitudinal and transverse spacing between hulls on wave making interference is included in the model via the Neural Network. The database generated and used as a Neural Network training set utilizes the MQLT method of reference 1, which among other things models that interference, and was run for a variety of design configurations. Further enhancement of this data base is under review, including possibility of using data from reference 3. This inclusion also highlights the flexibility of the NN approach, where different data from different sources may be combined and effectively utilized. The synthesis model however does not include actual hull shape representations, but rather is defined as a configuration represented by a set of design variables. The hull optimization is restricted to configuration parameters. The actual hull shape optimization task which requires advanced CFD tools capable of reliable wave drag predictions for trimarans along with efficient hull shape prediction techniques will be propose for the next phase of the program. The FY 04 program however will study and outline the detailed process for such implementation.

- The synthesis model as it is presented is overly simplified (for the purpose of demonstration of the method), particularly relative to structural representation and stability /seakeeping and payload capacity. These aspects of the MDO will be expanded and strengthened by the following work being pursued

    - Implementation of more elaborate formulas (when appropriate) in the synthesis level model

- Replacing the formulas by Neural Networks similar to the approach used for powering. The NN training set has to be constructed to include as much detailed as possible relative to global bending loads and life fatigue performance for a range of operating parameters. At the present, this data will be based on some existing available data with statistical extrapolators for structural and seakeeping characteristics. Realizing the limitations of such data however, we plan to use data available at NSWCCD for this purpose in the next phase of the program. For an accurate prediction, Neural Networks have to be trained with data that are both sufficient in terms of the number of data points and are distributed properly (along Latin Hyper cubes). Therefore, we plan to develop a carefully designed data base running NSWCCD's VERES (for motions predictions) and SPECTRA codes (for structures) for this purpose. Initial discussion (agreement) with NSWCCD for this work has already been concluded.

- The other important aspect of FY04 work underway (by SAIC) is the development of the processes for subsystem definitions and optimization. Comprehensive methods for these tasks are obviously extremely complex, involving hundreds of parameters, objective functions (often contradictory with other subsystems) and constraints. Each subsystem requiring sophisticated software and modeling approaches. FY04 program seeks to develop

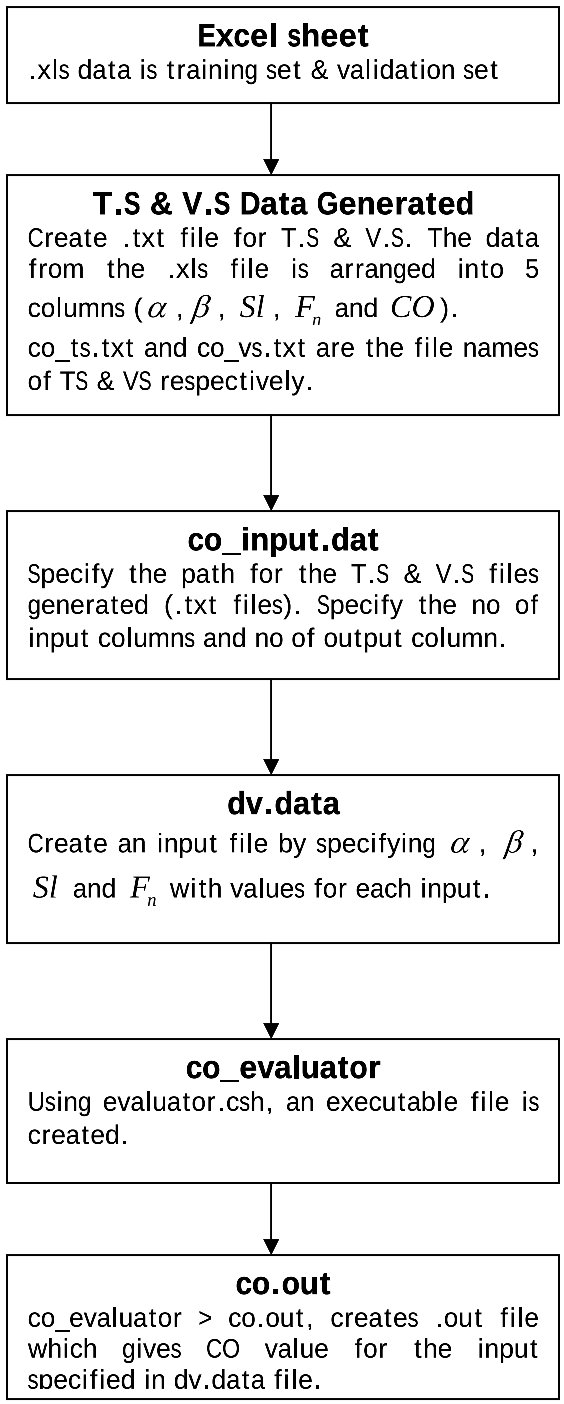
  - Process of power, stability and seakeeping predictions where calculation modules will be identified and their algorithms will be explained.
  - Developing the process of generating a tool which defines a suitable finite element model for the multi-hull configurations of interest, generates an appropriate set of load conditions and sizes the structural elements to meet the critical loads.
  - Developing an approach that will link the hull configurations examined to an overall payload capacity fraction which will be used in the optimization process to rank all the various hull configurations.

These processes will be integrated into an overall MDO tool in the next phase of the program.

- Improvement in the implementation and description of Neural Networks

Appendix 1

The process to generate evaluator for coefficient of residual resistance.



Reference Documents:

Ref 1: Igor Mizine, SAIC Nov 2004.

Ref 2: "Formulation of Multicriterion Design Optimization Problems for Solution With Scalar Numerical Methods," *Journal of Ship Research,* Vol48, No.1, pp61-76, March 2004.

Ref 3: Zafer Elcin, "Wave making resistance characteristics of Trimaran Hulls", M.S. Thesis, NPS, Dec 2003