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Optimal Dimension Design for Ship								
- Determination of Op	timal	Diı	nensio	ons of	Bulk (Carrier	(2/2)	
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	BMCR' Syste p, v ₁ = T, v ₂ (L', B', I Non-linear	em Leve Bailding 9, r ₁ = 0, r ₂ D [*] , C [*] ₈ [*] , V	L'.B'.C	" Target Variables " Dummy Variables " Dummy Variables ", P", DMCR" scipling Level 2		System Leve		
$ \begin{array}{c} D \geq T + Freeboard \\ C_{1}/L(B) \leq 0.13 \leq GM \leq 4\pi^{2}(0.4B^{2}/L_{E}D^{2}) \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{1}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{1}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{1}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{1}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ C_{2}/L(B) \leq 0.13 \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \end{array} \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \end{array} \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \end{array} \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array} \\ \end{array} \\ \end{array} \\ \begin{array}{c} D \geq T + Freeboard \\ \end{array}$	1-7 ² (4.5) Discipl	ine Lev	r ₂ , ¥r ₂ +	$(C_{3}^{*}-C_{3}^{*})^{2}+(V^{*}-V^{*})^{2}$ + $(DMCR^{*}-DMCR)^{2}$ $SL_{R_{22}} \leq 0$		CORBA n Object Request Broker	Architecture)	
$C_{2} = 0.00 + 0.125 \text{ (m}^{-1}(2^{-1}(100^{-1})^{2}))$ $E_{12} = L \cdot (0^{-1}T \cdot C_{2}^{-1}(100^{-1})^{2})$ $E_{23} = 0.00 E \text{ GW}$ $E_{23} = 0.00 E \text{ GW}$	R_{1j} $H(D^*,D^*)$ $Min, r_j = (j)$ $+(D^*,D^*)$ St Tr^2) $L_{+}^{+}R_{+}^{+}$	$L^* L^* \gamma^2 + (L^*)^2 + (C_R^* \cdot C_R^*) \leq 0$ $D^* C_R^* = 0$	r·B·) ²	$L_{1}^{\dagger}B_{1}^{\dagger}C_{B}^{\dagger} \rightarrow V_{1}DMCR_{1}E_{1}^{\dagger}$ $\frac{R_{1}}{R_{1}} = V_{1}^{-1}V_{1}^{\dagger}$ $R_{1}^{-} - f(L_{1}^{\dagger}B_{1}^{\dagger}C_{B}^{\dagger})$ $R = f(R_{1}) \leftarrow tagan tolerons$ $P = f(DMCR)$		Windows		
	ation for coll n a distribut	abor ed ei	ative optimi	(n); Optimization Process Max. φ ₀ 2ation ₁ /K ₀ _{(k1} +γg/k φ,))	Discipline Level 1 * T.V: Target variable among discipline le * D.F.V: Disciplinary objective function	Discipline Level 2 es from system level v vels function values which value of each disciplin	Discipline Level 3 which are shared	
Application to an actual problem of shipyard			Manual	Standar	d, single optir	nization	Collaborative	
160,000ton bulk carrier		Unit	design	1.7~1.8%	GA ²	HYBRID ³	optimization	
Cargo hold capacity: 179,000m ³ Ship speed: 13.5knots Design draft: 17.2m Propeller RPM: 77.9rpm	Building cost	\$	60,949,431 (100.0%)	cost reduction 59,888,510 (98.3%)	59,863,587 (98.2%)	59,831,834 (98.2%)	59,831,688 (98.2%)	
64,500,000 Applicable to	L	m	266.00	265.18	264.71	263.69	263.70	
64,000,000 Convergence history naval surface	В	m	45.00	45.00	45.00	45.00	45.00	
B 63,000,000 Collaborative optimization (for best one)	D	m	24.40	24.54	24.68	24.84	24.83	
δ 62,500,000 − − − Multi-start method (for best one) − − Genetic algorithm	C _R	-	0.8276	0.8469	0.8463	0.8420	0.8418	
E 62,000,000 - Hybrid optimization method	Dp	m	8.3000	8.3928	8.4305	8.3999	8.3960	
8 61.000.000 -	P;	m	5.8200	5.8221	5.7448	5.7365	5.7411	
8 60.500.000	A _F /A _O		0.3890	0.3724	0.3606	0.3690	0.3692	
59,500,000 50 10 20 30 40 50 60 70 80 90	CPU time ⁴	sec	-	209.58 (140%)	198.60 (133%)	187.22 (125%)	149.75 (base)	
Generation(Iteration) Number							. 6	



splacement: about 9,000ton ip speed: 20knots Gwen: Displacement, V Variation of main dimensions Estimation of bight registre	Objective function value Fuel consumption	-	3,760.35 re (100.0%)	duction	3.723.80	
Given: Displacement, V Variation of main dimensions L, B, D, T, C _B , P ₀ , A ₀ /A ₀ , n Estimation of light weight	Fuel consumption			(99.5%)	(99.0%)	3,715.80 (98.8%)
L, B, D, T, Cp, Pa, Aq/Ap, n Estimation of light weight		kg/h	3,589 (100.0%)	3,584 (99.9%)	3,556 (99.1%)	3,551 (98.9%)
Estimation of oncichia land	Hull structure weight	ton	3,931 (100.0%)	3,897 (99,1%)	3,891 (99,0%)	3,880 (98,7%)
stimation of speed and power Costimization algorithm	L	m	157.37	157.02	156.74	156.51
Estimation of freeboard "EzOptimizer"	В	m	19.99	19.98	19.82	19.82
Criteria for optimum	D	m	12.70	12.69	12.73	12.84
and hull structure weight Multi objective	т	-	5.61	5.62	5.67	5.80
Optimum ² Yes Optimization	C _B	m	0.510	0.506	0.506	0.508
w = 1 w = 0	P _i	m	9.02	9.51	9.33	9.05
	A _E /A _O	-	0.80	0.65	0.65	0.65
²⁰ W1 W2 Pareto optimal set	n	rpm	97.11	93.49	94.53	93.51
$w_1 = w_2 = 0.5$	Displacemen t	ton	9,074	9,048	9,004	9,001
Selected optimum	CPU time ⁴	sec	-	201.63 (140%)	191.28 (133%)	193.22 (base)
$w_1 < w_2$					•	$w_1 = w_2 = 0.$
$w_1 = 0, w_2 = 1$ <i>Minimize</i>						



Op - D	timal Dime	ension De	esign fo timal I	or Di	Ship) sion	s of	Hat	ch (Cov	er ()	2/2)
Applic	cation to an actual prob	olem				Unit	Manua	al desig	n Op	timizati [B]	ion	Ratio (B/A)
• 180,	000ton bulk carrier	E.			t _n	mm		16		14		87.5%
• Lbp/i • Ts: 1	8/D: 283.5/45.0/24.7m 8.2m			ion	ť,	mm		8		8		100.0%
· Stat	N Come Man	wein charache			b	mm	1	170		160		94.1%
				- 1	а	mm	1	120		111		92.5%
					d	mm	2	220		198		90.0%
1		C-1014-01-000-01-01-01-01-01-01-01-01-01-01-01		- 1	Ν	-		3		3		100.0%
	weight			1	Weight	ton	32	.360	.	28.410		87.8%
	saving			1	σ _{max}	MPa	2	218 1	2% duction	252		115.6%
- HE	YUNDAI				δ _{max}	mm	5.	.532		6.388		115.5%
J. THE					Manual	OPT	Co	mposites	HC	Steel-	Composi	tes HC
Diff.	N. S.			Unit	[A]	[B]	C-1	C-2	C-3	D-1	D-2	D-3
(wei	ght = 32.36ton)	(weight = 28.41ton)	Material		Steel (AH32)	Steel (AH32)	GFRP ¹	GFRP	CFRP ²	AH32 +GFRP	AH32 +GFRP	AH32 +CFRP
450,000	Weight of steel hatch cover		Fabrication method		Welding	Welding	Hand lay up	Vacuum	Vacuum	Hand lay up	Vacuum	Vacuum
400,000	12.30	27.93 28.2 - 30	Weight	ton (%)	32.36 (100.0)	28.41 (87.8)	20.77	21.09	9.60 (29.7)	27.93	28.20 (87.1)	21.85 (67.5)
300,000 (2)	Steel Composites	Hybrid Steel+Composites)	Material cost	\$ (%)	24,653 (100.0)	21,644 (87.8)	89,109 (361.5)	90,438 (366.8)	406,102 (1,647.3)	56,360 (228.6)	57,530 (233.4)	167,360 (678.9)
250,000	20.77 Material cost	21.85 20 gg) tugi	Fuel cost (for 25 years)	\$	419,871	368,620	269,491	273,643	124,560	362,392	365,895	283,504
150,000	Weight	167.360 13 2	CO ₂ emissions (for 25 years)	ton	16,088	14,124	10,326	10,485	4,773	13,885	14,020	10,863
100,000	19 CT 9.6	340 57.530 - 5	CO ₂ cost ³ (for 25 years)	\$	402,194	353,101	258,145	262,122	119,316	347,135	350,491	271,568
0	A R C A C C C C C C	ost of steel hatch cover	Total cost (for 25 years)	\$ (%)	846,718 (100.0)	743,365 (87.8)	616,745 (72.8)	626,203 (74.0)	649,978 (76.8)	765,887 (90.5)	773,916 (91.4)	722,432 (85.3)
* 1: GFRP(Glass Fiber Reinforced Polymer),	2: CFRP(Carbon Fiber Reinfo	rced Polymer), 3: CC	, trea	tment cost							10





6



























































Determination of the Optimal Principal Dimensions of a Propeller by Using the Lagrange Multiplier (1/5)

Find	$J, P_i / D_P$	
Maximize	$\eta_O = \frac{J}{2\pi} \cdot \frac{K_T}{K_Q} - \dots$	→ Because K_T and K_Q are a function of J and P_i the objective is also a function of J and P_i/D_p
Subject to	$\frac{P}{2\pi n} = \rho \cdot n^2 \cdot D_p^{-5} \cdot K$: The propeller	f_Q absorbs the torque delivered by Diesel Engine
Where,	$J = \frac{V(1 - w)}{n \cdot D_P}$ $K_T = f(J, P_i / D_P)$ $K_Q = f(J, P_i / D_P)$	P: Delivered power to the propeller from the main engine, KW n: Revolution per second, 1/sec D _p : Propeller diameter, m P _i : Propeller pitch, m $A_{\rm F}/A_{\rm O}$: Expanded area ratio V: Ship speed, m/s $\eta_{\rm O}$: Propeller efficiency (in open water

Determination of the Optimal Principal Dimensions of a Propeller by Using the Lagrange Multiplier (2/5)

 $\frac{P}{2\pi n} = \rho \cdot n^2 \cdot D_p^{-5} \cdot K_Q \quad \cdots \quad (a) \quad \text{: The propeller absorbs the torque delivered by main engine}$

The constraint (a) is reformulated as follows:

$$C = \frac{K_Q}{J^5} = \frac{P \cdot n^2}{2\pi\rho \cdot V_A^5}$$

$$G(J, P_i / D_P) = K_Q - C \cdot J^5 = 0 \quad \dots \quad (a')$$

Propeller efficiency in open water η_0 is as follows.

$$F(J, P_i / D_P) = \eta_O = \frac{J}{2\pi} \cdot \frac{K_T}{K_O} \quad \dots \quad (b)$$

The objective F is a function of J and P_i/D_p .

It is to determine the optimal principal dimensions (J and P_i/D_p) to maximize the propeller efficiency in open water satisfying the constraint (a').

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Determination of the Optimal Principal Di Propeller by Using the Lagrange Multiplie	mensions of a er (5/5)
 Programming by using the Matlab 	$L \to x_1, B \to x_2, C_B \to x_3$
syms L B Cb rami ram2 ui s2 →·	Define the symbolic variable: 7 variables
	Input the constant value.
<pre>1=22.3 11=2+Cps+Cs+L*(B+D) + Cpo+Co+B + Cpm+Cpower+(2+21+B)+V^3 + 0.6119*ram1+B*D + ram2*(B+T+Cb+rho = 2*Cs+L*(B+D) - Co+B = Cpower*(2+21+B)+V^3) +u1*(-Cb+B/(L^2)); 12= Cps+Cs+(L^2) + Cpo+Co+L + Cpm+Cpower*(2+21+L)+V^3 + 0.6119*ram1+L*D + ram2*(L+T+Cb+rho = Cs+L^2 - Co+L = Cpower*(2+21+L)+V^3) +u1*(Cb/L);</pre>	
f3=ram2+L+B+T+rho + u1+B/L; f4=0.6119+L+B+D-360000;	$\longrightarrow \frac{\partial H}{\partial x_3} \dots (3)$
f5=L+B+T+Cb+rho-320000-(Cs+(L^2)+(B+D) +Co+L+B+Cpower+(2+(B+L)+21+L+B)+V^3);	$\longrightarrow \partial H / \partial \lambda_2 (5)$
f6=Cb+B/L-0.1513+(s1^2);	$\longrightarrow \partial H / \partial u \dots (6)$
t7=2+u1+s1; [y1 y2 y3 y4 y5 y6 y7]=solve(f1,f2,f3,f4,f5,f6,f7);	$\rightarrow \partial H / \partial s \dots (7)$ 'solve' is a command for solving the simultaneous equation.
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Determination - Problem Form	of Optimal Principal Dimensions of nulation	a Propeller	
Find	$P_i, A_E / A_O, n, V$	Design Variables	
Maximize	$\eta_O = \frac{J}{2\pi} \cdot \frac{K_T}{K_O}$	Objective Function	
Subject to	$\frac{P}{2} = \rho \cdot n^2 \cdot D_p^{-5} \cdot K_Q$	Constraints	
	$\frac{R_T}{1-t} = \rho \cdot n^2 \cdot D_p^{-4} \cdot K_T$: The condition that the propeller show at a given ship's speed $A_E / A_O \ge K + \frac{(1.3 + 0.3Z) \cdot T_h}{D_p^{-2} \cdot (p_o + \rho \cdot g \cdot h - p_v)}$: The condition about the required min	Id produce the required thrust	
Where	for non-cavitating criterion $J = \frac{V(1-w)}{n \cdot D_P}, K_T = f(J, P_i / D_P, A_E / A_O, A_E / A_O,$	Z),	
🔿 Onti	$M_Q - J(J, I_i / D_P, A_E / A_O, Z), I_h = M_T / ($	2 equality constraints 520 d	
1 in	equality constraint	5 toquality constraints, and	12

Optimizat	;						
	Unit	DDG-51	MFD	MS	GA	HYBRID w/o Refine	HYBRID with Refine
Pi	m	8.90	9.02	9.38	9.04	9.06	9.06
A _E /A _O	-	0.80	0.80	0.65	0.80	0.80	0.80
n	rpm	88.8	97.11	94.24	96.86	96.65	96.64
V*	kts	20.00	19.98	20.01	20.01	19.99	20.00
η ο	-	-	0.6439	0.6447	0.6457	0.6463	0.6528
Δ	LT	8,369	9,074	8,907	8,929	9,016	9,001
BHP	HP	13,601	14,654	14,611	14,487	14,447	14,443
Iteration No	-	-	5	267	89	59	63
CPU Time	sec	-	0.88	38.07	41.92	40.45	41.39





















Unit (1/2)
☑ LT (Long Ton, British) = 1.016 [ton], ST (Short Ton, American) = 0.907 [ton], MT (Metric Ton, Standard) = 1.0 [ton]
 ✓ Density ⇒ [ton/m³ or Mg/m³] e.g., density of sea water = 1.025 [ton/m³], density of fresh water = 1.0 [ton/m³], density of steel = 7.8 [ton/m³]
☑ 1 [knots] = 1 [NM/hr] = 1.852 [km/hr] = 0.5144 [m/sec]
 ✓ 1 [PS] = 75 [kgf⋅m/s] = 75×10⁻³ [Mg]⋅9.81 [m/s²]⋅[m/s] = 0.73575 [kW] (Pferdestarke, German translation of horsepower) ■ NMCR of B&W6S60MC: 12,240 [kW] = 16,680 [PS]
 ✓ 1 [BHP] = 76 [kgf⋅m/s] = 76×10⁻³ [Mg]⋅9.81 [m/s²]⋅[m/s] = 0.74556 [KW] (British horsepower)
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Unit (2/2)











How does a ship float? (2/	′3)								
 Archimedes' Principle The magnitude of the buoyant force acting on a floating body in the fluid is equal to the weight of the fluid which is displaced by the floating body. The direction of the buoyant force is opposite to the gravitational force. 									
Buoyant force of a floating body = the weight of the fluid which is displace ➡ Archimedes' Principle	ed by the floating b	ody ("Displaceme	ent")						
 Equilibrium State ("Floating Con Buoyant force of the floating body Weight of the floating body Displacement = Weight 	ndition") ody W	$\Delta = -W = -\rho_{\rm s}$ G	gV 						
$\begin{array}{l} \textbf{G: Center of gravity} \\ \textbf{B: Center of buoyancy} \\ \textbf{W: Weight, } \Delta: Displacement \\ \rho: Density of fluid \\ \textbf{V: Submerged volume of the floating body} \\ \textbf{(Displacement volume, } \nabla) \end{array}$		B Δ	70						




































































IMO Instruments























Equations of Motion of a Fluid Element - From Cauchy Eg. to Bernoulli Eg.				
	quations of motion f a Fluid Element wton's 2 nd Law ±∑F = (Body force + Surface for Mass ④ Conservation	Lagrangian & Eulerian Description Cauchy Equation $1/2$	Shear force Navier-Stokes Equation $\Phi = 0$	Euler Equation $P + \frac{1}{2}\rho \nabla\Phi ^2 + \rho g z = 0$
	Law			
1 Newtonian fluid: Fluid whose str	ess versus strain rate curve	e is linear.		
② Stokes assumption: Definition of	viscosity coefficient (μ , λ)	due to linear deformation and	isometric expansion	
③ Inviscid fluid				1) RTT: Reynolds Transport Theorem
$\textcircled{\black}$ Irrotational flow	r : c V =	displacement of a fluid particle with respect $\frac{d\mathbf{r}}{dt}$, $\mathbf{a} = \frac{d^2\mathbf{r}}{dt^2}$	set to the time	
(5) Incompressible flow				
* Lagrangian specification of the flow field: a * Eulerian specification of the flow field: a way	vay of looking at fluid mot of looking at fluid motion	ion where the observer follow that focuses on specific locat	s an individual fluid parcel as ions in the space through wh	it moves through space and time. ich the fluid flows as time passes.
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Weight Estimation: Method 4	<u>Weight equation of a ship</u>				
Estimate the structural weight(<i>W</i> .), outfit weight	$\rho \cdot L \cdot B \cdot T \cdot C_B \cdot (1+\alpha) = W$				
(W), and machinery weight (W) in components.	= DWT + LWT (3) Given : DWT - Find : L B T C:				
	Method (4): $LWT = W_1 + W_2 + W_3$				
How can you estimate lightweight more accura	tely?				
We assume that a shin is composed of hull str	ucture outfit and machinery				
Paced on this accumption, the lightweight actim	action would be more accurate				
Based on this assumption, the lightweight estimation would be more accurate, if we could estimate the weight of each components.					
Realized as marked as a structure of the second structure of the second					
<u>Method 4</u> : Estimate the structural weight (<i>i</i>	W_s), outfit weight (W_o), and				
machinery weight (W _m) in compo	onents.				
$IWT - W \perp W \perp W$	7				
$LWI = W_s + W_o + W$	m				
1 :					
$\overset{\bullet}{\bullet}$ How can you estimate W W and W ?					
$\sum_{s} now can you estimate n s, n o, and n m$					
Assume that W., W., W., are dependent on the	principal dimensions.				
<u></u>	<u>,</u>				
	and a b				
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		Kulea	Japan	China
	Steel	17	17	18
Material Cost	Equipment	42	43	47
	Sub sum	59	60	65
Labo	or Cost	27	29	19
Genei	ral Cost	14	13	16
Tota	al sum	100	100	100













Pro a L	ocedure of the Deter Deadweight Carrier	mination of Principal Dimensions for
1	•At first, the principal dimensions such as <i>L</i> , <i>B</i> , <i>T</i> , C_B are determined according to the weight equation.	Weight Equation (Physical Constraint) $\rho \cdot L \cdot B \cdot T \cdot C_B \cdot (1 + \alpha) = DWT + LWT$ \checkmark Given: DWT (owner's requirements) \checkmark Find: L, B, T, CB
		V
2	• <u>Next</u> , the depth is determined considering the required cargo hold capacity according to the <u>volume</u> <u>equation</u> .	Volume Equation (Economical Constraints) $V_{CH} = f(L, B, D)$ \checkmark Given: <i>L</i> , <i>B</i> , <i>V</i> _{CH} (owner's requirements) \checkmark Find: <i>D</i>
		V
3	•Then, it should be checked <u>lastly</u> that whether the depth and draft satisfy the <u>freeboard regulation</u> .	Freeboard Calculation (Regulatory Constraints) $D \ge T + Fb(L, B, D, C_B)$ \checkmark Given: <i>L</i> , <i>B</i> , <i>D</i> , <i>T</i> , <i>C</i> _B
		✓ Check: Whether the chosen depth is equal or greater than the draft plus required freeboard or not.
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xample: Swner's	of the Princi Requirement	pal Particulars of t s of the Design Sh	he Basis Ship of hip of 297,000 to	279,500 to n Deadweig	on Deadweight VLCC and ght VLCC	
Desig	n Ship: 297,	000 Ton Deadwe	eight VLCC (Ver	y La <mark>rge</mark> C	Frude oil Carrier) Basis Ship	
		Basis Ship	Owner's Requirements	Remark	Dimensional Ratios	
	Loa	abt. 330.30 m			I/R = 5.41	
	Lbp	314.00 m			E = 5.41,	
Principal	B,mld	58.00 m			$B/T_d = 2.77,$	
Dimensions	Depth,mld	31.00 m			B/D = 1.87,	
	Id(design)	20.90 m	21.50 m		L/D = 10.12	
Deed	IS(SCAILL.)	22.20 11	22.64 (1)			
Deadw	veight (scant)	301,000 ton	320,000 ton		• Hull Form Coefficient $C = 0.82$	
Speed 90% MCR (w	(at design draft rith 15% Sea Margin)	15.0 knots	16.0 knots		• Lightweight (=41,000 to	
	TYPE	B&W 7S80MC			- Structural weight	
	MCR	32,000 PS x 74.0 RPM			$\approx 36,400 \text{ ton } (88\%)$	
-	NCR	28,800 PS x 71.4 RPM			- Outfit weight	
U	SFOC	122.1 g/BHP·h			$\approx 2,700 \text{ ton } (6.6\%)$	
2 F	DFOC	84.4 ton/day		Based on NCR	- Machinery weight	
Cruising Range		26,000 N/M	26,500 N/M		$\approx 1,900 \text{ ton } (4.5\%)$	
Shape of	Midship Section	Double side / Double bottom	Double side / Double bottom		Cargo density = $\frac{\text{Deadweight}_{scam}}{\text{Cargo hold capac}}$	
	Cargo Hold	abt. 345,500 m ³	abt. 360,000 m ³		301.000	
~	H.F.O.	abt. 7,350 m ³			$=\frac{1}{345,500}$	
acit	D.O.	abt. 490 m ³			$-0.87[ton/m^3] > 0.7$	
Cap	Fresh Water	abt. 460 m ³				
Ŭ	Ballast	abt. 103,000 m ³		Including Peak Tanks	Deadweight Carrier	













Determination of the Principal Dimensions of 29 Step 1: - Step 2: Volume Equation (2/2)	Step 3: Freeboard Calculation			
V _{CH} = f(L, B, Given: L=318.85[m], B=58.90[m], V Find: D	$D) = 360,000[m^3]$			
Assume that the <u>cargo hold capacity</u> is proportional to <u><i>L</i>·<i>B</i>·<i>D</i></u> . $f(L, B, D) = C_{CH} \cdot L \cdot B \cdot D$				
$V_{CH} = C_{CH} \cdot L \cdot B \cdot D$				
The coefficient C_{CH} can be obtained from the basis ship. $C_{CH} = \frac{V_{CH}}{L \cdot B \cdot D} \bigg _{Basis} = \frac{345,500}{314 \cdot 58 \cdot 31} = 0.612$				
We use the same coefficient C_{CH} for the determination of depth. $V_{CH} = C_{CH} \cdot L \cdot B \cdot D$				
360,000 = 0.612×318.85×58.90×D				
$\therefore D = 31.32[m]$				
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Step 1: Weight Equation - Method 4 for the Lightweig in Components (5/7)	ght Estimation					
	000) - 207 000 - 0.0414 J/6 (B - D) - 0.1402 J - D					
$L \cdot B \cdot 21.5 \cdot C_{B,d} \cdot 1.025 \cdot (1+0.$	$(002) = 297,000 + 0.0414 \cdot L^{\infty} \cdot (B+D) + 0.1483 \cdot L \cdot B$					
	$+0.0514 \cdot (0.0022 \cdot (L \cdot B \cdot 21.5 \cdot C_{B,d} \cdot 1.025 \cdot (1+0.002))^{2/3} \cdot 16^3)$					
$L \cdot B \cdot C_{Bd} \cdot 22.08 = 297,00$	$00 + 0.0414 \cdot L^{1.6} \cdot (B+D) + 0.1483 \cdot L \cdot B$					
$D_{,a}^{D,a}$						
+0.0001	$2 \cdot (L \cdot B \cdot C_{B,d} \cdot 22.06) = 10 \cdot (0.4)$					
There are 4 unknown	variables $(L, B, D, C_{\rm p})$ with one equation.					
Nonlinear indet	terminate equation!					
Therefore, we <u>have to</u>	assume three variables to solve this					
indeterminate equation	n.					
The values of the dime	ensional ratios L/B, B/D, and C _{B.d} can be					
obtained from the basi	is ship.					
$L / B = L_{Basis} / B_{Basis}$	$B/D = B_{Barging}/D_{Barging}$ $C_{B,d} = C_{B,d,Barging} = 0.8213$					
=314/58	= 58/31					
= 5.413	=1.871					
Fonics in Shin Design Automation Fall 2014. Myung-II Roh	rydleb 18					







Design	Ship: 16	0,000 m ³ LNG C	arrier		
		Basis Ship	Owner's Requirements	Remark	Basis Ship Dimensional Ratios $L/R = 6.31$
-	L _{OA}	277.0 m			E/D = 0.51, B/T = 3.81
_	L _{BP}	266.0 m			$D/I_d = 5.61,$ B/D = 1.67
Principal	B _{mld}	43.4 m			D/D = 1.0/,
Dimensions	D _{mld}	26.0 m			L/D = 10.23
	T _d (design)	11.4 m	11.4 m		• Hull Form Coefficient $C_{p,d} = 0.742$
	T _s (scant)	12.1 m	12.1 m		 Lightweight (=31.000 to
Cargo Hol	d Capacity	138,000 m ³	160,000 m ³		- Structural weight
Service	e Speed	19.5 knots	19.5 knots		$\approx 21,600 \text{ ton } (\approx 70\%)$
	Туре	Steam Turbine	2 Stroke Diesel Engine (×2)		- Outfit weight ≈ 6,200 ton (≈ 20%) - Machinery weight ≈ 3,200 ton (≈ 10%)
Main Engine	DMCR	36,000 PS \times 88 RPM		With Engine Margin 10%	
	NCR	32,400 PS \times 85 RPM		With Sea Margin 21%	Cargo density - Deadweight
SF	юс	180.64 g/BHP·h			$\frac{\text{Cargo density}}{\text{Cargo hold cap}}$
Deadweig	ht (design)	69,000 ton	80,000 ton		$=\frac{69,000}{128,000}$
DFOC		154.75 ton/day			138,000 = 0.5 [top / m ³] < 0.
		13.000 N/M	11,400 N/M		-0.5 [ion / m] < 0.



Determination of the Principal Dimensio - Step 1: Volume Equation (2/4)	NS Step 1: Volume Equation Equation Step 2: Equation Calculation
	$V_{CH} = f(L, B, D)$ Given: $V_{CH} = 160,000[m^2]$ Find: L, B, D
Assume that the <u>cargo hold capacity</u> is pro $f(L, B, D) = C_{CH} \cdot D$	portional to <u>L·B·D</u> . L·B·D
$V_{CH} = C_{CH} \cdot L$	$B \cdot D$
Coefficient C_{CH} can be obtained from t $C_{CH} = \frac{V_{CH}}{L \cdot B \cdot D}\Big _{Basis} = \frac{138,000}{266 \cdot 43.4 \cdot 26} = 0.46$	he basis ship.
$V_{CH} = C_{CH} \cdot L \cdot B$ 160,000 = 0.460 \cdot L \cdot B	D $P \cdot D \cdots (6.1)$
There are 3 unknown variables (L, B, D)) with one equation.
Nonlinear indeterminate equation	n!
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Determination of the Principal Dimensions of 160,000 m³ LNG Carrier - Step 1: Volume Equation (4/4) L = 279.4 [m]We can obtain *B* and *D* from the ratios *L/B* and *B/D* of the basis ship. $B = L/(L/B) \qquad D = L/(L/B)/(B/D) = 279.4/6.129 \qquad = 279.4/6.129/1.669 = 27.3 [m]$ $\therefore L = 279.4[m], \quad B = 45.6[m], \quad D = 27.3[m]$ Creates in Ship Decise Automation Fill 2014. More II Rol















D -	Petermination of the Principal Dimensions (Step 3: Freeboard Calculation (2/2)	Step 1: Volume Equation Step 2: Weight Equation Step 3: Freeboard Calculation				
	At the early design stage, there are few data available for estimation of required freeboard. Thus, the required freeboard can be estimated from the basis ship.	$\begin{array}{l} D_{Fb} \geq T_s + Fb(L,B,D_{mld},C_{B,d}) \\ \text{Given: } L = 279.4[m], B = 45.6[m], D(=D_{add}) = 27.3[m], \\ T_s = 12.1[m], C_{B,d} = 0.773, t_{stringer} = 0.02[m] \\ \text{Check: Freeboard of the ship should be larger than the in accordance with the freeboard regulation.} \end{array}$	nat			
	Assume that the <u>freeboard</u> is proportional to <u>the depth</u> .					
	$Fb(L, B, D_{mld}, C_{B,d}) = C_{Fb} \cdot D_{mld}$					
	$D_{Fb} \ge T_s + C_{Fb} \cdot D_{mld}$					
	The coefficient C_{Fb} can be obtained from the basis ship.					
	$C_{Fb} = \frac{FD}{D_{mld}}\Big _{Basis} = \frac{6.08}{26} = 0.257$					
	Check: Freeboard of the design ship					
	$D_{Fb} \ge T_s + C_{Fb} \cdot D_{mld}$					
	$D_{mld} + t_{stringer} \ge T_s + C_{Fb} \cdot D_{mld}$					
	$27.3 + 0.02 \ge 12.1 + 0.257 \cdot 27.3$					
	27.32 ≥19.11 : Satisfied					
ľ	t is satisfied. However, this method is used for a roug	gh estimation. So, <u>after</u> the main				
d	imensions are determined more accurately, <u>freeboard</u>	needs to be calculated more	914			
a	ccurately through the treepoard regulation.		214			



Design Ship: 4,100 T	EU Container Carr	ier	Parts Chin
	Basis Ship	Owner's requirements	Dimensional Ratios
Principal Dimensions LOA LBP	257.4 m 245.24 m	less than 260.0 m	L/B = 7.62 $B/T_d = 3.19$
Bmld Dmld	32.2 m 19.3 m	less than 32.25 m	B/D = 1.67
Td /Ts (design / scant)	10.1 / 12.5 m	abt. 11.0 / 12.6 m	L/D = 12.71
Deadweight (design / scant)	34,400 / 50,200 ton	40,050 / 49,000 ~ 51,000 ton	$C_{B_d} = 0.62$
Capacity			Lightweight (=16 000 t)
Container on Deck / in Hold	2,174 TEU / 1,565 TEU	abt. 4,100 TEU	Structural weight
Ballast Water	13,800 m ³	abt. 11,500 m ³	$\sim 11000top(\sim 68\%)$
Heavy Fuel Oil	6,200 m ³		- Outfit weight
Main Engine & Speed			$\approx 3,200 \text{ ton} (\approx 20\%)$
M/E Type	Sulzer 7RTA84C		- Machinery weight
MCR (BHP × rpm)	38,570 BHP × 102 RPM		$\approx 1,800 \text{ ton} (\approx 12\%)$
NCR (BHP x rpm)	34,710 BHP × 8.5 RPM		Deadweight _{scant}
Service Speed at NCR (Td, 15% SM)	22.5 knots (at 11.5 m) at 30,185 BHP	24.5 knots (at 11.0 m)	Cargo density = $\frac{1}{Cargo hold capac}$ Deadweight
DFOC at NCR	103.2 ton		$=\frac{V_{\text{container}} \times N_{\text{container}}}{V_{\text{container}} \times N_{\text{container}}}$
Cruising Range	20,000 N/M	abt. 20,000 N/M	$=\frac{50,200}{46.9.3,739}$
Complement (Crew)	30 Person	30 Person	$= 0.29 [ton/m^3] < 0.7$




























JUDIAL 231

Determination of the Principal Dimensions of 4,100 TEU Container Carrier - Step 1: Volume Equation (11/11)

5. Principal dimensions (*L*, *B*, *D*) determined by the arrangement of containers in cargo hold (N_L , N_D , N_B):

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$N_L = 27$ [Bays]	$N_B = 11$ [Rows]	$N_D = 7$ [Tiers]
$L = 7.14 \cdot N_L + 54.52$	$B = 2.523 \cdot N_B + 4.447$	$D = 2.604 \cdot N_D + 1.072$
$= 7.14 \cdot 27 + 54.52$	$= 2.523 \cdot 11 + 4.447$	$= 2.604 \cdot 7 + 1.072$
= 247.76[m]	= 32.2[m]	=19.3[m]
: $L = 247.76[m]$,	B = 32.2[m],	D = 19.3[m]

Determination of the Principal Dimensions of 4,100 TEU Container Carrier (- Step 2: Weight Equation) Step 1: yought (- Step 2: Then, block coefficient ($C_{B,d}$) is determined by the weight equation. $\int c L \cdot B \cdot T_d \cdot C_{B,d} \cdot (1 + \alpha) = DWT_d + LWT$ $\int c devised of the shell appendiage allowance$ $<math>= 0002^{\circ}$ $\left(1 + \alpha = \frac{Displacement}{Moulded Displaced Volume}\right|_{Max} = \frac{49,848.7}{49,652.7} = 1.0039$ $\int Given: L = 247.76[m], B = 32.2[m], D = 19.3[m], T_d = 11.0[m], DWT_d = 40,050[ton], V_s = 24.5[knots]$ $f = 10005 C_{B,d}$ $V = 10005 C_{B,d}$







Step 2: Weight Estimat Method 4 for the Light in Components (4/5)	tion tweight Estimation	Step 1: Volume Equation
$W_{s} = C_{s} \cdot L^{1.6} \cdot (B + D)$ $W_{o} = C_{o} \cdot L \cdot B$ $W_{m} = C_{m} \cdot NMCR$	$C_s = 0.032$ $C_o = 0.405$ $C_m = 0.047$ <i>NMCR</i> = 0.0025 · $\Delta^{2/3} \cdot V_s^{-3}$	$\begin{split} \rho \cdot L \cdot B \cdot T_{d} \cdot C_{g,d} \cdot (1 + \alpha) &= DWT_{d} + LWT \\ \text{Given: } L &= 247.76[m], B = 32.2[m], D = 19.3[m], T_{d} = 11.0[m], \\ DWT_{d} &= 40.050[ton], V = 24.5[knots] \\ \text{Find: } C_{g,d} \\ \text{Method 4: } LWT &= W_{s} + W_{o} + W_{m} \end{split}$
$L \cdot B \cdot T_d \cdot C_d$	$_{B,d} \cdot \rho \cdot (1+\alpha) = DWT_d + W_s + W_o + W_o$	W_m
$L \cdot B \cdot T_d \cdot C_d$	$_{B,d} \cdot \rho \cdot (1+\alpha) = DWT_d + C_s \cdot L^{1.6} \cdot ($	$(B+D) + C_o \cdot L \cdot B + C_m \cdot NMCR$
$L \cdot B \cdot T_d \cdot C_d$ $L \cdot B \cdot T_d \cdot C_d$	${}_{B,d} \cdot \rho \cdot (1+\alpha) = DWT_d + C_s \cdot L^{1.6} \cdot (1+\alpha) = C_m \cdot (0.0025 \cdot (L \cdot E_s))$	$B + D) + C_o \cdot L \cdot B$ $V_s^3)$ $(B + D) + C_o \cdot L \cdot B$ $B \cdot T_d \cdot C_{B,d} \cdot \rho \cdot (1 + \alpha))^{2/3} \cdot V_s^3)$
$247.76 \cdot 32.2 \cdot 11.0 \cdot C_{B,d} \cdot 1.02$	$25 \cdot (1 + 0.0039) = 40,050 + 0.032 \cdot 247$ $+ 0.047 \cdot (0.0025 \cdot (24))$	$7.76^{1.6} \cdot (32.2 + 19.3) + 0.405 \cdot 247.76 \cdot 32.2$ $7.76 \cdot 32.2 \cdot 11.0 \cdot C_{B,d} \cdot 1.025 \cdot (1 + 0.0039)^{2/3} \cdot 24.5^{3})$
$90,306 \cdot C_B$	$_{d} = 40,050 + 11,181 + 3,233$	
	$+0.047 \cdot (0.0025 \cdot (90, 306 \cdot C_{B,d}))$	$)^{2/3} \cdot 24.5^3)$
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Determination of the Optimal Principal Dimensions of a Ship by Using the Lagrange Multiplier (2/5)



Determination of the Optimal Principal Dimensions of a Ship by Using the Lagrange Multiplier (3/5) • By introducing the Lagrange multipliers λ_1 , λ_2 , u, formulate the Lagrange function H. $H(L, B, C_{B}, \lambda_{1}, \lambda_{2}, u, s) = f(L, B, C_{B}) + \lambda_{1} \cdot h_{1}(L, B, C_{B}) + \lambda_{2} \cdot h_{2}(L, B, D) + u \cdot g(L, B, C_{B}, s) \quad \dots (e)$ $f(L, B, C_B) = C_{PS} \cdot C'_s \cdot L^2 \cdot (B+D) + C_{PO} \cdot C_o \cdot L \cdot B + C_{PM} \cdot C_{power}' \cdot \{2 \cdot (B+L) \cdot T_d + L \cdot B\} \cdot V^3$ $h_1(L,B,C_B) = L \cdot B \cdot T_s \cdot C_B \cdot \rho_{sw} \cdot C_a - DWT_{eiven} - C'_s \cdot L^{2.0} \cdot (B+D) - C_o \cdot L \cdot B - C_{power}' \cdot \{2 \cdot (B+L) \cdot T_d + L \cdot B\} \cdot V^3$ $h_2(L, B, D) = C_{CH} \cdot L \cdot B \cdot D - CC_{req}$ $g(L, B, C_B, s) = \frac{C_B}{(L/B)} - 0.15 + s^2$ $L \to x_1, B \to x_2, C_B \to x_3$ $H(x_1, x_2, x_3, \lambda_1, \lambda_2, u, s)$ $= C_{PS} \cdot C_s' \cdot x_1^2 (x_2 + D) + C_{PO} \cdot C_o \cdot x_1 \cdot x_2 + C_{PM} \cdot C_{power}' \cdot \{2 \cdot (x_2 + x_1) \cdot T_d + x_1 \cdot x_2\} \cdot V^3$ $+\lambda_{1}\cdot[x_{1}\cdot x_{2}\cdot T_{s}\cdot x_{3}\cdot \rho_{sw}\cdot C_{\alpha}-DWT_{given}-C_{s}\cdot x_{1}^{2}\cdot(x_{2}+D)-C_{o}\cdot x_{1}\cdot x_{2}-C_{power}'\cdot\{2\cdot(x_{2}+x_{1})\cdot T_{d}+x_{1}\cdot x_{2}\}\cdot V^{3}]$ $+\lambda_2 \cdot (C_{CH} \cdot x_1 \cdot x_2 \cdot D - CC_{reg})$ $+u \cdot \{x_3 / (x_1 / x_2) - 0.15 + s^2\}$...(f)JUDIOD 247 Ship Design Automation, Fall 2014, Myung-II Re

Determination of the Optimal Principal Dimensions of a Ship by Using the Lagrange Multiplier (4/5) $L \to x_1, B \to x_2, C_B \to x_3$ $H(x_1, x_2, x_3, \lambda_1, \lambda_2, u, s) = C_{PS} \cdot C'_s \cdot x_1^2(x_2 + D) + C_{PO} \cdot C_s \cdot x_1 \cdot x_2 + C_{PM} \cdot C_{power} \cdot (2 \cdot (x_2 + x_1) \cdot T_d + x_1 \cdot x_2) \cdot V^3$ $+ \lambda_1 \cdot [x_1 \cdot x_2 \cdot T_s \cdot x_3 \cdot \rho_{ws} \cdot C_a - DWT_{given} - C_s \cdot x_1^2 \cdot (x_2 + D) - C_s \cdot x_1 \cdot x_2 - C_{power} \cdot (2 \cdot (x_2 + x_1) \cdot T_d + x_1 \cdot x_2) \cdot V^3]$ $+ \lambda_2 \cdot (C_{Cur} \cdot x_1 \cdot x_2 - C_{req}) + u \cdot [x_3/(x_1/x_2) - 0.15 + s^2] \dots (f)$ • To determine the stationary point (x_1, x_2, x_3) of the Lagrange function H (equation (f)), use the Kuhn-Tucker necessary condition: $\nabla H(x_1, x_2, x_3, \lambda_1, \lambda_2, u, s) = 0$. $\frac{\partial H}{\partial x_1} = 2C_{PS} \cdot C'_s \cdot x_1 \cdot (x_2 + D) + C_{PO} \cdot C_o \cdot x_2 + C_{PM} \cdot C_{power} \cdot (2 \cdot T_d + x_2) \cdot V^3$ $+ \lambda_1 \cdot (x_2 \cdot T_s \cdot x_3 \cdot \rho_{sw} \cdot C_a - [2 \cdot C_s \cdot x_1 \cdot (x_2 + D) + C_o \cdot x_2 + C_{power} \cdot (2 \cdot T_d + x_2) \cdot V^3])$ $+ \lambda_2 \cdot (C_{CH} \cdot x_2 \cdot D) + u \cdot (-x_3 \cdot x_2 / x_1^2) = 0 \dots (1)$ $\frac{\partial H}{\partial x_2} = C_{PS} \cdot C'_s \cdot x_1^2 + C_{PO} \cdot C_o \cdot x_1 + C_{PM} \cdot C_{power} \cdot (2 \cdot T_d + x_1) \cdot V^3$ $+ \lambda_1 \cdot [x_1 \cdot T_s \cdot x_3 \cdot \rho_{sw} \cdot C_a - C'_s \cdot x_1^2 - C_o \cdot x_1 - C_{power} ' (2 \cdot T_d + x_1) \cdot V^3]$ $+ \lambda_2 \cdot (C_{CH} \cdot x_1 \cdot D) + u \cdot (x_3 / x_1) = 0 \dots (2)$ Determination of the Optimal Principal Dimensions of a Ship by Using the Lagrange Multiplier (5/5) $L \to x_1, B \to x_2, C_B \to x_3$ $H(x_1, x_2, x_3, \lambda_1, \lambda_2, u, s) = C_{PS} \cdot C'_s \cdot x_1^2(x_2 + D) + C_{PO} \cdot C_s \cdot x_1 \cdot x_2 + C_{PM} \cdot C_{power} \cdot \{2 \cdot (x_2 + x_1) \cdot T_d + x_1 \cdot x_2\} \cdot V^3$ $+\lambda_1 \cdot [x_1 \cdot x_2 \cdot T_s \cdot x_3 \cdot \rho_{sw} \cdot C_{\alpha} - DWT_{given} - C_s \cdot x_1^2 \cdot (x_2 + D) - C_o \cdot x_1 \cdot x_2 - C_{power}' \cdot \{2 \cdot (x_2 + x_1) \cdot T_d + x_1 \cdot x_2\} \cdot V^3]$ $+\lambda_2 \cdot \left(C_{CH} \cdot x_1 \cdot x_2 \cdot D - CC_{req}\right) + u \cdot \left\{x_3 / \left(x_1 / x_2\right) - 0.15 + s^2\right\} \quad \dots (f)$ • Kuhn-Tucker necessary condition: $\nabla H(x_1, x_2, x_3, \lambda_1, \lambda_2, u, s) = 0$ $\frac{\partial H}{\partial x_3} = \lambda_1 \cdot x_1 \cdot x_2 \cdot T_s \cdot \rho_{sw} \cdot C_{\alpha} + u \cdot (x_2 / x_1) = 0 \qquad \dots (3)$ $\frac{\partial H}{\partial \lambda_{1}} = x_{1} \cdot x_{2} \cdot T_{s} \cdot x_{3} \cdot \rho_{sw} \cdot C_{\alpha} - DWT_{given} - C_{s} \cdot x_{1}^{2} \cdot (x_{2} + D) - C_{o} \cdot x_{1} \cdot x_{2}$ $-C_{power}' \cdot \{2 \cdot (x_2 + x_1) \cdot T_d + x_1 \cdot x_2\} \cdot V^3 \cdots (4)$ $\frac{\partial H}{\partial \lambda_2} = C_{CH} \cdot x_1 \cdot x_2 \cdot D - CC_{req} = 0 \quad ...(5)$ $\frac{\partial H}{\partial u} = x_3 \cdot x_2 / x_1 - 0.15 + s^2 = 0$...(6) $\frac{\partial H}{\partial s} = 2 \cdot u \cdot s = 0, \quad (u \ge 0) \quad \dots(7)$ $\nabla H(x_p, x_2, x_3, \lambda_p, \lambda_2, u, s)$: Nonlinear simultaneous equation having the 7 variables ((1)~(7)) and 7 equations ➡ It can be solved by using a numerical method! 1901ab 249 s in Ship Design Automation, Fall 2014, Myung-II Ro









al particu ^r	lars of a deadw	eight 150,000 ton bulk carri	er (parent ship) and ship o	owner's requirements
	Item	Parent Ship	Design Ship	Remark
	L _{OA}	abt. 274.00 m	max. 284.00 m	
	L _{BP}	264.00 m		1
Principal	B _{mld}	45.00 m	45.00 m	1
Dimensions	D _{mld}	23.20 m		1
	T _{mld}	16.90 m	17.20 m	1
T _{scant}		16.90 m	17.20 m	1
Deadweight		150,960 ton	160,000 ton	at 17.20 m
Speed		13.5 kts	13.5 kts	90 % MCR (with 20 % SM)
TYPE		B&W 5S70MC		
M	NMCR	17,450 HP×88.0 RPM		Derating Ratio = 0.9
Ē	DMCR	15,450 HP×77.9 RPM		E.M = 0.9
Γ	NCR	13,910 HP×75.2 RPM		
F	SFOC	126.0 g/HP.H		
c	TON/DAY	41.6		Based on NCR
Crui	sing Range	28,000 N/M	26,000 N/M	1
Midship Section		Single Hull Double Bottom/Hopper /Top Side Wing Tank	Single Hull Double Bottom/Hopper /Top Side Wing Tank	
	Cargo	abt. 169,380 m ³	abt. 179,000 m ³	Including Hatch Coaming
C	Fuel Oil	abt. 3,960 m ³		Total
Capacity	Fuel Oil	abt. 3,850 m ³		Bunker Tank Only
	Ballast	abt. 48,360 m ³	[Including F.P and A.P Tank

۸inim	ization of Shipbuil	ding Cos	t				
		Unit	MFD ¹⁾	MS ²⁾	GA ³⁾	HYBRID ⁴⁾ w/o Refine	HYBRID ⁴⁾ with Refine
G	DWT	ton			160,000		
	Cargo Capacity	m ³			179,000		
Ē	T _{max}	m			17.2		
Ν	V	knots			13.5		
	L	m	265.54	265.18	264.71	264.01	263.69
	В	m	45.00	45.00	45.00	45.00	45.00
	D	m	24.39	24.54	24.68	24.71	24.84
	C _B	-	0.8476	0.8469	0.8463	0.8427	0.8420
	D _P	m	8.3260	8.3928	8.4305	8.4075	8.3999
	Pi	m	5.8129	5.8221	5.7448	5.7491	5.7365
	A _E /A _O	-	0.3890	0.3724	0.3606	0.3618	0.3690
E	Building Cost	\$	59,889,135	59,888,510	59,863,587	59,837,336	59,831,834
	Iteration No	-	10	483	96	63	67
	CPU Time ⁵⁾	sec	4.39	209.58	198.60	184.08	187.22







Mathematica Optimal Prin	al Formulation of a Problem f	or Determining Ship	
Find	L, B, D, T, C_B	Design Variables	
Minimize	BHP[HP](or FC[kg/h]) or Hull Structure Weight[IT]	Objective Function	
Subject to	* Equilibrium condition of displacement and weight $L \cdot B \cdot T \cdot C_B \cdot \rho \cdot (1 + \alpha) = \Delta = LWT$	Constraints + VL	
	* Requirements for displacement(9,000ton class) 8,900 [LT] $\leq \Delta \leq 9,100$ [LT]		
	* Requirements for speed-power $P/(2\pi n) = \rho \cdot n^2 \cdot D_P^5 \cdot K_Q$		
	$R_T / (1-t) = \rho \cdot n^2 \cdot D_P^{-1} \cdot K_T$ $A_E / A_O \ge K + \frac{(1.3 + 0.3Z) \cdot T_h}{D_P^{-2} \cdot (p_o + \rho \cdot g \cdot h - \sigma)}$	$(-p_v)$	
	* Miscellaneous design requirements $L^{l} \leq L \leq L^{u}, B^{l} \leq B \leq B^{u}, D^{l} \leq D \leq D^{u}$	$\leq D^u, C_B^l \leq C_B \leq C_B^u$	
	0.98 (L / B) parent ≤ L → Optimization problem having 5 unknowns, 1 and 7 inequality constraints	$/B \le 1.02 (L/B)_{pa}$ 3 equality constraints,	rent 259

CASE 1: Mi	nimize f	uel consum	ption (f ₁)				
	Unit	DDG-51	MFD	MS	GA	HYBRID w/o Refine	HYBRID with Refine
L	m	142.04	157.68	157.64	157.60	157.79	157.89
В	m	17.98	20.11	19.69	19.47	19.60	19.59
D	m	12.80	12.57	12.67	12.79	12.79	12.74
Т	m	6.40	5.47	5.57	5.69	5.68	5.63
C _B	-	0.508	0.520	0.506	0.506	0.508	0.512
Pi	m	8.90	9.02	9.38	9.04	9.06	9.06
A _E /A _O	-	0.80	0.80	0.65	0.80	0.80	0.80
n	rpm	88.8	97.11	94.24	96.86	96.65	96.64
F.C (<i>f</i> ₁)	kg/h	3,391.23	3,532.28	3,526.76	3,510.53	3,505.31	3,504.70
H.S.W	LT	3,132	3955.93	3901.83	3910.41	3942.87	3,935.39
Δ	LT	8,369	9,074	8,907	8,929	9,016	9,001
Iteration No	-	-	6	328	97	61	65
CPU Time	sec	-	3.83	193.56	195.49	189.38	192.02

Optimization Result for							
ne Mini	mizai	tion of F	iuli Stru	cture w	eight		
CASE 2: Mi	nimize ł	null structure	e weight (f.)				
	Unit	DDG-51	MFD	MS	GA	HYBRID w/o Refine	HYBRID with Refine
L	m	142.04	157.22	155.92	155.78	155.58	155.56
В	m	17.98	20.09	20.09	20.12	20.10	20.09
D	m	12.80	12.72	12.66	12.63	12.66	12.67
т	m	6.40	5.64	5.63	5.61	5.65	5.66
C _B	-	0.508	0.510	0.506	0.508	0.508	0.508
Pi	m	8.90	8.98	9.42	9.04	9.46	9.45
A _E /A _O	-	0.80	0.80	0.65	0.80	0.65	0.65
n	rpm	88.8	97.40	94.06	97.29	93.93	93.98
F.C	kg/h	3,391.23	3,713.23	3,622.40	3,618.71	3,603.89	3,602.60
H.S.W (<i>f</i> ₂)	LT	3,132	3,910.29	3,855.48	3,850.56	3,844.43	3,844.24
Δ	LT	8,369	9,097	9,014	9,008	9,004	9,003
Iteration No	-	-	7	364	95	64	68
CPU Time	sec	-	3.91	201.13	192.32	190.98	192.41

CASE 3: Mi	nimize 1	uel consum	ption (f ₁) & I	null structure	e weight (f ₂)		* w ₁ = w ₂ =
	Unit	DDG-51	MFD	MS	GA	HYBRID w/o Refine	HYBRID with Refine
L	m	142.04	157.37	157.02	156.74	156.54	156.51
В	m	17.98	19.99	19.98	19.82	19.85	19.82
D	m	12.80	12.70	12.69	12.73	12.82	12.84
Т	m	6.40	5.61	5.62	5.67	5.77	5.80
C _B	-	0.508	0.510	0.506	0.506	0.508	0.508
Pi	m	8.90	9.02	9.51	9.33	9.50	9.05
A _E /A _O	-	0.80	0.80	0.65	0.65	0.65	0.65
Ν	rpm	88.8	97.11	93.49	94.53	93.52	93.51
F.C (f ₁)	kg/h	3,391.23	3,589.21	3,583.56	3,556.15	3,551.98	3,551.42
H.S.W (<i>f</i> ₂)	LT	3,132	3,931.49	3,896.54	3,891.45	3,880.74	3,880.18
$w_1f_1 + w_2f_2$	-	3,261.62	3,760.35	3,740.05	3,723.80	3,716.36	3,715.80
Δ	LT	8,369	9,074	9,048	9,004	9,001	9,001
Iteration No	-	-	7	351	93	65	68
CPU Time	sec	-	3.99	201.63	191.28	190.74	193.22

			CASE 1	CASE 2	CASE 3
	Unit	DDG-51	Minimize f ₁ (fuel consumption)	Minimize f ₂ (hull structure weight)	Minimize w ₁ f ₁ +w ₂ f ₂
L	m	142.04	157.89	155.56	156.51
В	m	17.98	19.59	20.09	19.82
D	m	12.80	12.74	12.67	12.84
Т	m	6.40	5.63	5.66	5.80
CB	-	0.508	0.512	0.508	0.508
Pi	m	8.90	9.06	9.45	9.05
A _E /A _O	-	0.80	0.80	0.65	0.65
n	rpm	88.8	96.64	93.98	93.51
F.C	kg/h	3,391.23	3,504.70	3,602.60	3,551.42
H.S.W	LT	3,132	3,935.39	3,844.24	3,880.18
Objective	-	-	3,504.70	3,844.24	3,715.80
Δ	LT	8,369	9,001	9,003	9,001
teration No	-	-	65	68	68
CPU Time	sec	-	192.02	192.41	193.22

























Mathematical Formulation of an Optimization Problem - Constraints (2/6)

☑ Maximum Permissible Deflection of the Hatch Cover

 $f \le 0.0056 \cdot l_g [m]$

where,

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f: deflection [m] of the hatch cover

 l_g : The largest span [m] of girders in the hatch cover

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Mathematical Formulation of an Optimization Problem - Constraints (4/6)

☑ Minimum Section Modulus of Stiffeners of the Hatch Cover

$$M_{\min} \le M_{net} \ [cm^3]$$

where,

 M_{net} : net section modulus [cm³]

 M_{\min} : minimum section modulus, defined as

$$M_{net} = \frac{104}{R_{eH}} \cdot c \cdot l^2 \cdot p \ [cm^3]$$

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Mathematical Formulation of an Optimization Problem - Constraints (6/6)

☑ Geometric Limitations Related to the Shape of the Hatch Cover

$$N(2a+b) < W \quad d \le H \quad 0^\circ \le \theta \le 90^\circ$$

where,

W: width [m] of the hatch cover

D: depth [m] of the hatch cover

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 $\boldsymbol{\theta}\!\!\!$ angle between the plate and stiffener

➡ This optimization problem has total 8 inequality constraints.

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Optimization Program for the Hatch Cover Design - Components (1/5)

☑ Input Module

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- The input module inputs some data for optimization of the hatch cover from a designer.
- The data includes the size (length, width, and depth) of the hatch cover, materials of plate and stiffeners, and so on.
- In addition, the input module generates initial values for design variables and transfers them to the optimization module.

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Optimization Program for the Hatch Cover Design - Components (4/5)

☑ Postprocessor Module

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- In the post processor module, the structural analysis program is executed with the input file from the preprocessor module.
- That is, the role of the module is the finite element analysis.
- In this study, the ANSYS which is one of commercial structural analysis programs was used for the structural analysis.
- After performing the finite element analysis with the structural analysis program, the structural responses such as the stress and deflection of the hatch cover can be acquired.
- The values of the structural responses are written in the output file by the structural analysis program.
- The postprocessor module parses the output file by the structural analysis program, and transfers the values of the structural responses to the optimization module.

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Hatch Cover Design of a Deadweight 180,000 ton Bulk Carrier - Mathematical Formulation t_p, t_s, b, a, d, N Find **Minimize** Weight = $\left[\rho_p \cdot L \cdot W \cdot t_p + \rho_s \cdot L \cdot \left\{(2a \cdot (\cos\theta)^{-1} + b + c) \cdot N + c\right\} \cdot t_s\right] \cdot 10^{-3} [ton]$ $= \left[7.85 \cdot 14.929 \cdot 8.624 \cdot t_p + 7.85 \cdot 14.929 \cdot \left\{ (2a \cdot (\cos \theta)^{-1} + b + c) \cdot N + c \right\} \cdot t_s \right] \cdot 10^{-3}$: weight of top plate and stiffeners Subject to $\sigma_v \leq 0.8 \cdot 315 [N/mm^2]$: maximum permissible stress $f \leq 0.0056 \cdot 3.138 [m]$: maximum permissible deflection $t_{\min} \leq t_p \ [mm]$: minimum thickness of a top plate $M_{\min} \le M_{net} \ [cm^3]$: minimum section modulus of stiffeners $A_{\min} \le A_{net} \ [cm^2]$: minimum shear area of stiffeners : geometric limitation N(2a+b) < W: geometric limitation d < H $0^{\circ} < \theta \leq 90^{\circ}$: geometric limitation Optimization problem having 6 design variables and 8 inequality constraints 7ydlab 294 Automation, Fall 2014, Myung-II Rol s in Ship D

ltem	Unit	Manual design	Optimization result
t _p	mm	16	14
t,	mm	8	8
b	m	0.170	0.160
а	m	0.120	0.111
d	m	0.220	0.198
Ν	-	8	8
Weight	ton	26.225	23.975
Maximum stress	MPa	218	252
Maximum deflection	mm	5.532	6.388





















2 Con ■ 1 ■ 1 ■ 1	npositior Lightweig Most of d ight Estir	ı of Weight (Displacement) ht (LWT) + Variable Load (VL, cargo weight) isplacement becomes the lightweight. nation Method (SWBS* Group of US Navy)
	Group	Item
	100	Hull Structure
	200	Propulsion
	300	Electric Systems
	400	Communication and Control
	500	Auxiliary System
	<u> </u>	Outfitting and Furnishing
	600	5 5 1







⊡ Ex	ample of R	ос	
Priority	Capability	Attributes	Threshold metrics
1	Mission Module	Internal Payload	Sufficient aperture/volume for various mission modules for cover strike or special mission or future advanced ISR vehicles
	Extension	External Payload	Docking interface for external payload (SDV, mine belt, etc.)
2	Stealth	Stealth capable	-
3	C4ISR	ISR	ESM, Decoy, Scope, IR camera, Active/passive/mine detecting sonar/radar
		C4	NCW capable, SATCOM, VLF, HF, VHF, UHF
		Depth	250 m
	4 Mobility Sprint Speed Endurance Range AIP Crews	Sprint Speed	18 knot
		Endurance Range	2,000 nm
4		AIP	14 days (21 days)
		10 (7)	
		Volume	Minimize
-	ASW, ASUW,	Torpedo	6 (8)
5	MIW	Mine	24 (32)
6	SPW	No. special forces	14



Mathematica Optimal Prin	l Formulati cipal Dime	on of a Problem	for Determining
Find	$\mathbf{X} = \{L_{bow}, L_{mid}, L_{a}\}$	$_{ft}, B, D, C_{man}, ASW, C4I, ISP$	$R, MCM, SPW, PSYS, BAT_{typ}, N_g$
Maximize	F ₁ = Performance : Overall measure	ee(X) and of performance	Optimization problem having
Minimize	$F_2 = Cost(\mathbf{X}) \mathbf{a}$	nd $F_3 = Risk(\mathbf{X})$	11 inequality constraints, and
Subject to	. 0050	. Overall measure of this	3 objective functions
$g_1 = atr -$	$ata(\mathbf{X}) \leq 0$: Constraint about the allowable	area
$g_2 = v f f_{\min}$	$-vff(\mathbf{X}) \leq 0$: Constraint about the minimum	free flood volume
$g_3 = vff(Y)$	$\mathbf{X}) - v f f_{\max} \le 0$: Constraint about the maximum	free flood volume
$g_4 = wlea$	$d_{\min} - W_8(\mathbf{X}) \le 0$: Constraint about the minimum	lead ballast
$g_5 = W_8(X)$	$(\mathbf{X}) - w lead_{\max} \le 0$: Constraint about the maximum	lead ballast
$g_6 = V s_{\min}$	$-Vs(\mathbf{X}) \leq 0$: Constraint about the minimum	sustained speed
$g_7 = KWg$	$r_{req} - KWg(\mathbf{X}) \leq 0$: Constraint about the required e	lectrical power
$g_8 = GM_n$	$-GM(\mathbf{X}) \leq 0$	$g_9 = GB_{\min} - GB(\mathbf{X}) \le 0 : $	Constraints about the minimum GM and GB
$g_{10} = E_{\min}$	$-E(\mathbf{X}) \leq 0$: Constraint about the minimum	endurance range
$g_{11} = Es_{12}$	$-Es(\mathbf{X}) \leq 0$: Constraint about the minimum	sprint range 312





Optimization Program for Conceptual Design of Submarine - Overview

☑ Objective

Yielding best or better design alternative (optimal principal dimensions) by using specific criteria ("objective functions") among a number of design ("design variables") alternatives which satisfy all requirements ("constraints")

⊘ Overview

- Yielding best or better design alternatives by applying multi-objective optimization method
- Consisting of 15 modules
 - 13 modules for optimization (3 modules for the calculation of objective functions, 10 modules for the calculation of constraints and for the evaluation of feasibility) and 2 modules for UI (User Interface)
- Configuration of optimization by controlling various parameters
 Population No, Generation No, etc.
- Developed by using C++ language on the environment of Microsoft Visual C++ 6.0

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Optimization Program for Conceptual Design of Submarine Program Modules (2/3) ✓ Modules for Optimization: Total 13 (continued) Tankage module: Module for calculating data related to tanks of the corresponding design alternative Volume module: Module for calculating data related to volume of the corresponding design alternative Resistance module: Module for calculating data related to resistance of the corresponding design alternative Weight module: Module for calculating data related to weight of the corresponding design alternative Weight module: Module for calculating data related to weight of the corresponding design alternative

Optimization Program for Conceptual Design of Submarine - Program Modules (3/3)

☑ Modules for UI: Total 2

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- Input module: Module for inputting some data for optimization of principal dimensions of submarine
- Output module: Module for outputting an optimization result (best or good design alternatives)

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	Unit	Threshold	Target
Number of Torpedoes	E/A	6	8
Endurance Speed	knots	TBD*	TBD
Endurance Range	NM	2,00	0
Maximum Speed	knots	18.	0
Sustained Range	N/M		
Diving depth	m	250)
Personnel	-	10	7
SPW (Special Warfare) No	-	14	
Endurance	day	14	21
Propulsion	-	TBD (AIP is	available)

	ilput Data ibi Almament								
ID	Name	Data Set	War Area	SWBS	WT (ton)	VCG/D (ft)	AREA (ft ²)	Vob (ft ³)	KW (kw)
1	Passive Ranging Sonar and Electronics	1	ASW/MCM/C4I	4	0.13	0.10	25.00	45.00	2.00
2	Flank Array Sonar and Electronics	1	ASW/MCM/C4I	4	0.20	0.45	25.00	55.00	5.0
3	Bow Sonar, Passive, Active, Electronics	1	ASW	7	1.45	0.48	30.00	63.94	20.0
4	Intercept Detection and Ranging Sonar (IDRS)	1	ASW/C4I	4	0.13	0.48	25.00	45.00	2.0
5	Combat Management System (Weapon Control)	1	ASW/ASUW	4	1.50	0.65	30.00	0.00	5.0
6	Torpedo Rooms w/ Torpedo Access, 4x Heavy/2x Light Weight Torpedo	1 (Heavy)	ASW/ASUW	7	22.00 1.50	0.40 0.40	240.00 25.00	360.00 90.00	12.0 1.0
7	Inboard Torpedo Reload (4x Heavy/2x Light Weight Torpedo)	1 (Heavy)	ASW/ASUW	20	6.00 0.67	0.40 0.40	78.00 19.50	0.00 0.00	0.0 0.0
8	External Minelaying Equipment (or Torpedo)	-	ASW/ASUW/ MCM	20	7.00	0.40	0.00	96.00 11.98	0.5
9	Effecter Launcher (CIRCE or SEA SPIDER)	2	ASW	7	5.00	0.80	4.00	0.00	0.5
0	Optronic Mast	1	C4ISR	4	4.00	0.90	4.00	10.00	4.0
11	Radar Mast	1	C4ISR	4	1.50	0.90	4.00	3.00	5.0
12	ESM Mast	1	C4ISR	4	1.50	0.90	4.00	3.00	5.0
13	Combined Communication Mast (VHF, UHF, HF, IFF, GPS)	1	C4I	4	1.00	0.90	2.00	5.00	3.0
4	SHF SATCOM Mast	1	C4I	4	1.00	0.90	2.00	5.00	3.0
15	SATCOM Communication Mast	1	C4I	4	0.50	0.90	20.00	10.00	7.0
16	Pavload Module Mast (w/ Machinegun or UAVs)	1	C4ISR	4	4.00	0.95	0.00	0.00	1.0
17	Underwater Communications	1	C4I	4	0.05	0.85	2.00	1.20	1.0
8	Navigation Echo Sounders	1	C4I	4	0.10	0.40	0.00	1.30	1.0
19	Distress Beacon	1	C4I	4	0.05	0.95	0.00	1.00	0.5
20	Communication Electronics & Equipment	1	C4I	4	1.25	0.65	20.00	0.00	5.0
21	ISR Control and Processing	1	ISR	4	0.50	0.65	50.00	0.00	2.0
22	Imaging Center For Optronic Systems Control	1	ISR	4	0.50	0.65	30.00	0.00	3.0
23	Mine Avoidance Forward Looking Sonar and Electronics	1	MCM	4	0.90	0.30	25.00	50.00	5.0
24	Side Scan Sonar	1	MCM	4	0.10	0.30	15.00	20.00	2.0
25	9 Man Lockout Trunk	1	SPW	1	17.23	0.40	0.00	603.19	4.0

Conceptual Design of a Small Submarine - Input Data for Propulsion System

Description	CCD CAT 3406E	CCD CAT 3412E	PEM 250 kW	PEM w/ Reformer 250 kW	Alkaline 250 kW	Stirling E/G 250 kW
Main Generator Power (kW)	410	690	250	250	250	250
Basic Weight (Iton)	13.7	23.1	4.7	7.2	5.3	7.4
Specific Fuel Consumption (kg/kWhr)	0.213	0.211	3.49	0.31	2.9	0.293
Specific Oxidant Consumption (kg/kWhr)	0.84	0.84	0.44	0.9	0.37	1.022
Specific Argon Consumption (kg/kWhr)	0.03	0.03	0	0	0	0.01
Inboard Fuel Tank Volume per Iton Fuel (ft³/lton) Including Structure	45.15	45.15	0	45.15	0	45.15
Outboard Fuel (Hydrogen) Tank Volume per Iton Fuel (ft3/Iton)	0	0	10.9	0	10.9	0
Oxidant Tank Volume per Iton Oxidant (ft ³ /lton)	36.9	36.9	36.9	36.9	36.9	36.9
Argon Tank Volume per Iton Argon (ft ³ /lton)	29.8	29.8	0	0	0	29.8
Hydrogen Tank Structure Weight (Iton/Iton fuel)	0	0	0.25	0	0.25	0
Oxidant Tank Structure Weight (Iton/Iton oxydant)	0.375	0.375	0.375	0.375	0.375	0.375
Argon Tank Structure Weight (Iton/Iton argon)	0.1	0.1	0	0	0	0.1
Minimum Machinery Room Length Required (m)	1.535	1.913	0	0	0	0
Minimum Machinery Room Width Required (m)	0.995	1.444	0	0	0	0
Minimum Machinery Room Height Required (m)	1.231	1.621	0	0	0	0
Propulsion Machinery Required Volume (m ³)	36.49	61.41	16	32.5	0	0

0.0333 0.0058 0.0113	0.0173 0.0027 0.0032	0.50 0.56 0.87
0.0058 0.0113	0.0027 0.0032	0.56 0.87
0.0113	0.0032	0.87



2 Weight Estimation by U	sing SWBS G	roup	
SWBS Group	Weight (Iton)	VCG (ft, above C.L)	LCG (ft, fwd LCB
100 (Structures)	189.68	-0.04	10.29
200 (Propulsion)	78.41	-2.99	-22.73
300 (Electrical)	16.65	-0.90	-4.96
400 (Command & Control)	30.03	0.23	5.07
500 (Auxiliaries)	71.49	0.18	-18.44
600 (Outfit)	34.25	-0.72	7.00
700 (Delivery Systems)	33.45	3.60	30.00
800 (Lead Weight)	22.66	-4.50	32.50
900 (Variables Weight)	154.62	-1.69	-10.98
Condition A1 Weight	453.96	-0.31	0.36
Condition A Weight	476.62	-0.51	1.89
Normal Surface Condition Weight	631.24	-0.80	-1.26

tual	Design of a Sma	all Suk	oma	arin	е			
ed E	stimation of We	ight a	nd	CO	G			
SWBS	Component	Weight(lton)	VCG(ft)	Moment	LCG(ft)	Moment	TCG(ft)	Moment
NSC Cand A	Full Load Weight + Margin	631.24	-0.80	-505.00	-1.26	-/9/.4/	0.00	0.00
Cond A1	Lightship Weight + Margin	470.02	-0.51	-245.45	0.36	163.68	0.00	0.00
800	Margin	22.66	-4.50	-101.95	32.50	736.31	0.00	0.00
100	Hull Structures	189.68	-0.04	-7.76	10.29	1951.42	0.00	0.00
	- Bare Hull Weight (Wbh)	153.03	-0.05	-7.76	10.50	1606.82	0.00	0.00
	- Foundations Weight (W180)	19.42	0.00	0.00	0.00	0.00	0.00	0.00
	 Payload Structures Weight (Wp100) 	17.23	0.00	0.00	20.00	344.60	0.00	0.00
200	Propulsion Plant	78.41	-2.99	-234.41	-22.73	-1782.00	0.00	0.00
	 Basic Propulsion Machinery Weight (Wbm) 	4.70	1.73	8.14	-30.00	-141.00	0.00	0.00
	 Propulsion Power Transmission Weight (W240) 	17.59	2.00	35.18	-39.00	-686.01	0.00	0.00
	- Battery Weight (Wbattery)	22.41	-6.00	-134.46	-2.00	-44.82	0.00	0.00
	 Propulsion Tank Weight (W2reactks) 	33.71	-4.25	-143.27	-27.00	-910.17	0.00	0.00
300	Electric Plant, General	16.65	-0.90	-14.99	-4.96	-82.64	0.00	0.00
	 Electrical Distribution Weight (Wdist) 	8.11	1.09	8.84	-16.50	-133.82	0.00	0.00
	 Lighting System Weight (Wlight) 	8.53	-2.79	-23.82	6.00	51.18	0.00	0.00
	 Degaussing System Weight (Wdegaus) 	0.00	0.00	0.00	0.00	0.00	0.00	0.00
400	Command + Surveillance	30.03	0.23	7.03	5.07	152.25	0.00	0.00
	 Payload Command & Control Weight (Wp400) 	18.78	0.23	4.39	8.00	150.24	0.00	0.00
	- Interior Communication System Weight (Wic)	4.27	0.23	1.00	0.00	0.00	0.00	0.00
	- Ship Control Weight (Wco)	3.06	0.23	0.72	4.50	13.77	0.00	0.00
	- Command & Control Weight (Wcc)	3.92	0.23	0.92	-3.00	-11.76	0.00	0.00
500	Auxiliary System, General	71.49	0.18	12.87	-18.44	-1318.60	0.00	0.00
	- Auxiliary Payload Weight (Wp500)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	- Auxiliary Environmental Weight (W593)	2.00	0.18	0.36	0.00	0.00	0.00	0.00
	- Auxiliary Fluids Weight (W598)	0.92	0.18	0.17	-23.00	-21.16	0.00	0.00
	- Auxiliary Machinery Weight (Waux)	68.57	0.18	12.34	-18.92	-1297.44	0.00	0.00
600	Outfit + Furnishing, General	34.25	-0.72	-24.66	7.00	239.75	0.00	0.00
	- Hull Outfit Weight (Wofh)	30.65	-0.80	-24.66	7.00	214.55	0.00	0.00
	- Personnel Outfit Weight (Wofp)	3.60	0.00	0.00	7.00	25.20	0.00	0.00
700	Armament	33.45	3.60	120.42	30.00	1003.50	0.00	0.00
	- Payload Ordnance Delivery Systems Weight	33.45	3.60	120.42	30.00	1003.50	0.00	0.00
				4 44 50		462.60		0.00
	Totals and Co's	455.90	-0.51	- 141.50	0.50	105.00	0.00	0.00
	Full Load Condition							
900	Variable Loads	154.62	-1.69	-261.55	-10.98	-1697.47	0.00	0.00
	 Variable Payload Weight (Wvp) 	6.00	-1.00	-6.00	30.00	180.00	0.00	0.00
	- Lube Oil Weight (WF46)	1.00	-4.25	-4.25	-22.50	-22.50	0.00	0.00
	- Fresh Water Weight (WF52)	2.10	-5.50	-11.55	-16.00	-33.60	0.00	0.00
	- Personnel Provisions and Stores Weight (WF31)	0.72	5.00	3.60	27.00	19.44	0.00	0.00
	- General Stores Weight (WF32)	0.3	5.00	1.40	27.00	7.56	0.00	0.00
	- Personnel Weight (WF10)	1.6	5.00	7.75	5.00	7.75	0.00	0.00
	- Fuel Weight (Wfuel)	113.4	-2.50	-283.50	-12.82	-1453.62	0.00	0.00
	- Oxidant Weight (Woxidant)	14.3	7.68	109.88	-26.62	-380.61	0.00	0.00
	- Argon Weight (Wargon)	0	0.00	0.00	0.00	0.00	0.00	0.00
	- Sewage Weight (Wsew)	0.8	-4.25	-3.40	-20.00	-16.00	0.00	0.00
	- Trim Ballast Weight (Wtrimbal)	12.58	-6.00	-75.48	-0.41	-5.12	0.00	0.00
	- Residual Ballast Weight (Wresidual)	1.89	0.00	0.00	-0.41	-0.77	0.00	0.00
	T . 1 . 100	c		102.05		4500.70		0.00
	Totals and CG's	608.58	-0.66	-403.05	-2.52	-1533./8	0.00	0.00

































🔺 с	ommand Window 😽 🗕 🗆 🗾
Weight Estimation of Floationg offshore Structure using th Genetic Programming (GP) is an evolutionary approach to op Through this GP symbolic regression, you could find out the estimating weight model for floatin, Firstly, you also declare the function set that you want to u Lastly, input the genetic parameters for GP. Press any key 	e GP (P) imization. g offshore. in 'data.csv'. ise. 1. Set input data.
Define function set used in genetic programming ['times', 'minus', 'plus', 'divide', 'sqroot', 'sin', 'cos If you use 'times' insert '1' else '0' : 1 If you use 'plus' insert '1' else '0' : 1 If you use 'plus' insert '1' else '0' : 1 If you use 'divide' insert '1' else '0' : 1 If you use 'sqroot insert '1' else '0' : 1 If you use 'sgroot insert '1' else '0' : 1 If you use 'sin' insert '1' else '0' : 1 If you use 'cso' insert '1' else '0' : 1 If you use 'cso' insert '1' else '0' : 1	^{7, 'exp']} 2. Define function set. Supported function set: plus, minus, multiply, divide square root, sine, cosine, exponential

Command W	indow 🗢 – 🗆
Define genetic parameters for developing the estimation model	
Enter the Population Size : 1000	3 Define genetic parameters
nter the Max. Generation : 20	- Repulation size
The sum of rates should be equal to'1'	- Maximum generation
inter the Reproduciotn rate : 0.6	- Reproduction crossover mutation rate
nter the Crossover rate : 0.2	- Maximum depth of trees
nter the Mutation rate : 0.2	
nter the Max. depth of trees : 5	
Population size: 1000 Number of generations: 20 Ournament Size: 30 Max tree dept: 5 Sing function set: TIMES MINUS PLUS RDIVIDE PSQROOT SIN COS EXP Number of inputs: 11 Constants range: [-20 20] Jsing fitness function: regressmulti_fitfun.m Heneration 0 Hest fitness: 2317.6845	4. Calculate.





Generation of Weight Estimation Model for FPSO Topsides - Input (1/2)													
☑ Past records for FPSOs from the literature survey													
	L [m]	B [m]	D [m]	T [m]	Hull weight [ton]	DWT [ton]	Storage capacity [MMbbl]	Oil production [MMbopd]	Gas production [MMscf/d]	Water processing [MMbwpd]	Crew	Topsides weight [ton]	
Akpo	310	61	31	23	70,500	303,669	2.00	0.185	530.00	0.420	220	37,000	
USAN	310	61	32	24	75,750	353,200	2.00	0.160	500.00	0.420	180	27,700	
Kizomba A	285	63	32.3	24	56,300	340,660	2.20	0.250	400.00	0.420	100	24,400	
Kizomba B	285	63	32.3	25	56,300	340,660	2.20	0.250	400.00	0.420	100	24,400	
Greater Plutonio	310	58	32	23	56,000	360,000	1.77	0.220	380.00	0.400	120	24,000	
Pazflor	325	61	32	25	82,000	346,089	1.90	0.200	150.00	0.380	240	37,000	
CLOV	305	61	32	24	63,490	350,000	1.80	0.160	650.00	0.380	240	36,300	
Agbami	320	58.4	32	24	68,410	337,859	2.15	0.250	450.00	0.450	130	34,000	
Dalia	300	60	32	23	52,500	416,000	2.00	0.240	440.00	0.405	160	30,000	
Skarv-Idun	269	50.6	29	19	45,000	312,500	0.88	0.085	670.00	0.020	100	22,000	
Clarkson, 2012, Th Kerneur, J., 2010, 3 pics in Ship Design	larkson, 2012, The Mobile Offshore Production Units Register 2012, 10th Edition, Clarkson erneur, J., 2010, 2010 Worldwide Survey of FPSO Units, Offshore Magazine is in Shin Design automation e Ell 2014 Municol II Boh												

iene Inp	era ut	ati t (io (2)	n /2	of <u>?</u>)	V	Veig	jht	Esti	ima	tio	on	Mode	l for Fl	PSO Topsides
ন ১	ام	<u>م</u>	ti	on		: in	itial	inde	anai	ndor	ht -	var	ables		
							inciai	maa	sper	luci		var	abies		
					Thuil weight Dani	UWI (ton)	Stronge capacity p DMM660 0	CM production p MMbood] [Gat roduction MMac(/d)	Water processing [MMbwpd]		inpodes Deni		_	
Akpo	310	61	31	- 23	70,500	303,660	2.00	0.185	530.00	0.420	220	37,000			
USAN	310	61	Ð	24	0.00	151/00	7 00	0180	500.00	0.470	180	27,700			
Kizorniba A	285	63	32.3	24	36,300	340.000	2.20	0.250	100.00	0.120	100	21.100			
Kizombe B Greater	285	63	32.3	25	56,300	340,660	2.20	0.250	400.00	0.420	100	24,400			
Plutonio	310	58	32	23	56.000	360.000	0 1.77	0.220	380.00	0.400	120	24.000			
Pacifior	525	61	52	25	82,000	546,085	3 1.90	0.200	150.00	0.380	240	37,000			
Aghami	120	58.4	υ	24	68,410	11/354	215	0.2%	450.00	0450	130	31,000			
Duliu	300	60	32	23	52,500	416,000	2.00	0.240	440.00	0.405	160	30,000			
Skarv-Idun	269	506	28	19	45,000	\$12,50	088	0.085	6/0.00	0.0/0	100	22,000			
								lten	าร			Inde	nendent	Variables	Dependent Variabl
								псп	15			mac	pendent	Variabies	
							Princip	oal di	mens	sions	L	., В,	D, T, H_L	WT, DWT	
								Capa	city			S _	c, o_p, g	_P, W_P	T_LWT (to be estimated)
							Mi	scella	neou	IS			CREV	v	
LWT: Hull P: Water p	light	t wei ssing	ight∣ g [MI	[ton] Mbw	, DWT: /pd], T_	Dead LWT:	weight [to Topsides v	on], S_C: S weight [to	torage c n], CREV	apacity [N V: Crew n	1Mbb umbe	ol], O_P: er	Oil production	[MMbopd], GP: Gas	production [MMscf/d]
															Judlab





















						HYPPID		
	Unit	Actual Ship	MFD	MS	GA	w/o Refine	with Refine	
Building Cost	\$/m	-	21,035.254748	20,637.828634	20,597.330090	20,422.478135	20,350.28689	
<i>x</i> ₁	mm	800.0	787.038274	811.324938	780.000000	810.000000	810.3701321	
<i>x</i> ₂	mm	800.0	762.891023	799.038243	750.000000	800.00000	800.1282732	
x3	mm	780.0	743.313979	787.034954	770.000000	790.000000	789.0923943	
x_4	mm	835.0	814.142029	833.909455	820.000000	830.000000	834.838424	
x5	mm	770.0	756.434513	772.349435	790.000000	780.000000	780.002092	
<i>x</i> ₆	mm	16.5	16.983723	16.203495	16.000000	16.000000	16.390923	
x ₇	mm	16.0	16.829142	16.043803	16.500000	16.000000	15.989044	
<i>x</i> ₈	mm	15.5	16.020913	15.390394	16.000000	15.500000	15.432091	
<i>x</i> ₉	mm	17.0	17.329843	17.039439	16.500000	16.500000	17.139433	
x ₁₀	mm	14.5	15.001923	14.324335	15.000000	15.000000	14.780908	
x ₁₁	mm	13.5	14.192834	14.240495	14.000000	13.500000	13.550214	
x ₁₂	mm	14.5	15.123051	15.403945	14.500000	14.500000	14.500130	
x ₁₃	mm	17.0	16.902832	16.849387	16.500000	17.000000	17.010902	
x ₁₄	mm	14.0	14.784034	14.739454	15.500000	14.500000	14.309324	
x ₁₅	mm	14.0	15.129430	14.448504	15.500000	14.500000	14.588917	
x ₁₆	mm	14.5	14.824045	14.940584	15.000000	15.000000	14.789992	
Iteration No	-	-	8	912	93	64	70	
CPU Time	sec	-	2.90	293.28	272.91	265.06	267.92	

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