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Hydrodynamics of Advanced High–Speed Sealift Vessels

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Abstract

There is at present great interest in large ships capable of carrying substantial cargo at speeds in excess of 40 knots. At the same time, there are large gaps in our understanding of the hydrodynamics, structural engineering, and economics of high–speed vessels.

Monohulls, catamarans, trimarans, surface effect ships, and air cushion vehicles are considered in the present work. The total resistance of these vessels is divided into separate components which are estimated using different methods. Skin-friction is estimated using Grigson's algorithm which gives much better predictions of flat plate skin–friction than the traditional ITTC method. Wave resistance of displacement hulls is estimated using Michell's thin-ship theory: a similar theory is used for the wave resistance of travelling pressure distributions. Several simple formulae are derived that can be used at the preliminary design stage of catamarans to estimate optimum demihull separation.

Memetic algorithm techniques are used to find vessels with minimum (calm-water) total resistance. Optimal geometric parameters are found for vessels of 1200 tonnes under a variety of geometric limitations and constraints on upright stability, at design speeds of 50 knots and 75 knots. Estimates are made of the principal weight components of the optimal vessels. Empirical formulae for the efficiencies of powerplants and propulsors then enable estimates to be made of the maximum range, the cargo capacity, and the fuel consumption.

ADMINISTRATION

Signed Statement

This work contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

Signed: Leo Victor Lazauskas

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NOTATION

ACRONYMS

ACV	Air Cushion Vehicle
BL	Boundary Layer
HSST	High–Speed Sealift Technology
ITTC	International Towing Tank Conference
SES	Surface Effect Ship
sfc	Specific Fuel Consumption

ROMAN SYMBOLS

A_f	Above–water frontal area of vessel
A_{wp}	Waterplane area
B	Hull beam
B_0	Log law constant in BL calculations
c_f	Planar local skin friction coefficient
C_F	Planar drag coefficient
D	Hull depth (to main deck)
E_1, E_2	Equipment numerals in structural weight estimates
F	Froude number based on ship length
g	Gravitational acceleration
$\overline{GM_T}$	Transverse metacentric height
H_f	Height of freeboard
H_s	Height of superstructure
L	Ship or hull length
p	Pressure
P_e	Effective power
P_s	Shaft power
R_n	Reynolds number
R_1	Reynolds number based on BL displacement thickness
R_2	Reynolds number based on BL momentum thickness
R_A	Air resistance
R_F	Skin friction
R_L	Equivalent lift resistance
R_M	Momentum resistance of air cushion

R_T	Total resistance
R_V	Viscous resistance
R_W	Wave resistance
s_{max}	Range
S	Hull wetted surface area
T	Hull draft
U	Ship speed
w	Distance between demihull centrelines
W	Displaced weight
W_c	Cargo weight (i.e. payload)
W_d	Deadweight
W_e	Empty ship weight
W_f	Fuel weight
W_g	Weight of gas turbine and gearboxes
W_m	Weight of machinery
W_o	Outfit weight
W_p	Weight of propulsion system
W_s	Structural weight
x, y, z	Co-ordinates of a point in the wave field

GREEK SYMBOLS

∇	Hull displacement volume
ζ	Wave elevation
η_p	Overall propulsive coefficient
θ	Wave propagation angle
κ	Von Karman constant in BL calculations
ν	Molecular kinematic viscosity
Π	Coles wake strength parameter in BL calculations
ρ	Fluid density
σ	Ratio of weight supported by sidehulls to the total ship weight
τ	Ratio of weight supported by air cushions to the total ship weight
ϕ	Disturbance velocity potential
ϖ	Wave co-ordinate: $\varpi = x \cos\theta + y \sin\theta$

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