DESIGN AND NUMERICAL STUDY OF HYDROFOILS

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Contents

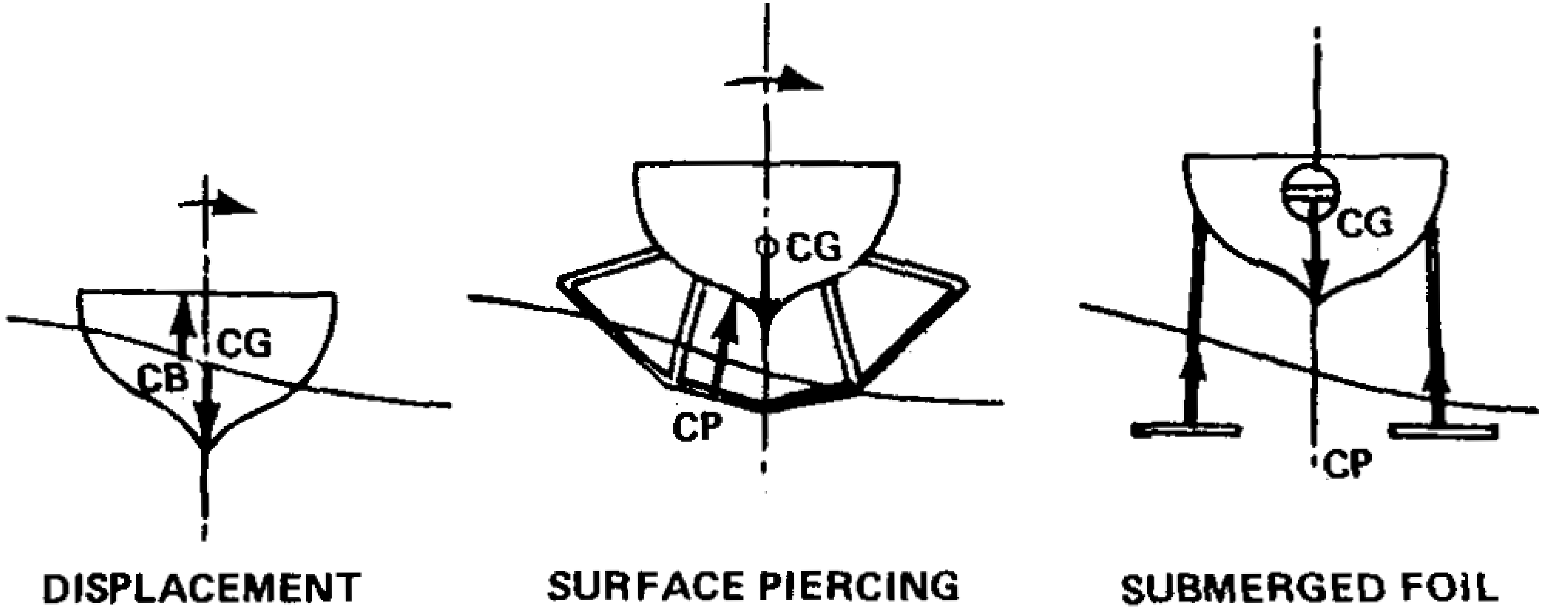
1. Introduction
    - Hydrofoils
        - Types
        - Configurations
        - Typical Dimensions
2. Design
    - Design Parameters
    - Forces on a hydrofoil
    - Geometry- Cross Section
    - Solutions
    - Numerical Optimisation
    - Basic Control Parameters
3. Project Objectives
4. References

Hydrofoils

- Wing- like structures that lift a ship’s hull out of water.
- Supported by hydrodynamic lift rather than by hydrostatic buoyancy.
- Reduces drag by reducing wetted area.
- Eliminates the instability effects of waves on the hull.
- First patented in the late 1880s; first test run in 1894- Meacham Brothers.

Hydrofoil Types[1]

- Two general classifications:
    1. Surface Piercing
    2. Submerged



Hydrofoil Types

<u>Surface Piercing</u>

- Portions of the foils are designed to extend through the air/ sea interface.
- Encountering a wave- ship pitches or heaves and brings its weight and lift to balance.
- Self stabilization where water acts as the damper.
- For high speed operations an active control system is used.
- Rougher ride.

Hydrofoil Types

Submerged

- Operate underwater at all times.
- Not self stabilizing- hence control is necessary.
- Uncoupled from effects of waves.
- Attains high speeds in any sea conditions, and still be comfortable for the crew.

Hydrofoil Configurations

John Sebastian

Contents

Introduction

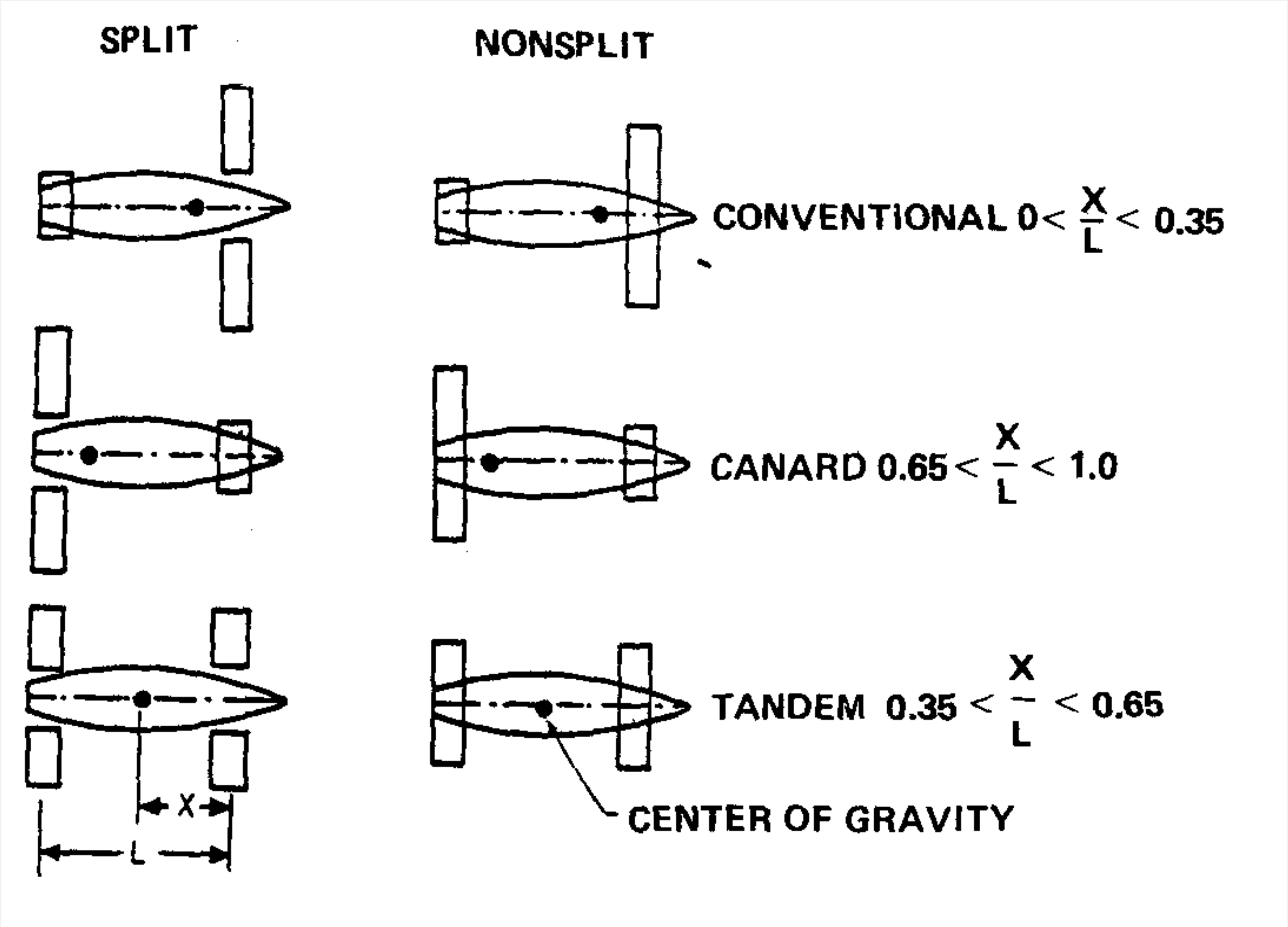
Design

Objectives

References

- <u>Canard</u>- 65% or more of weight is supported on the fore or aft foil.

- <u>Tandem</u>- relatively equal weight distribution on both foils.



Hydrofoil Configurations

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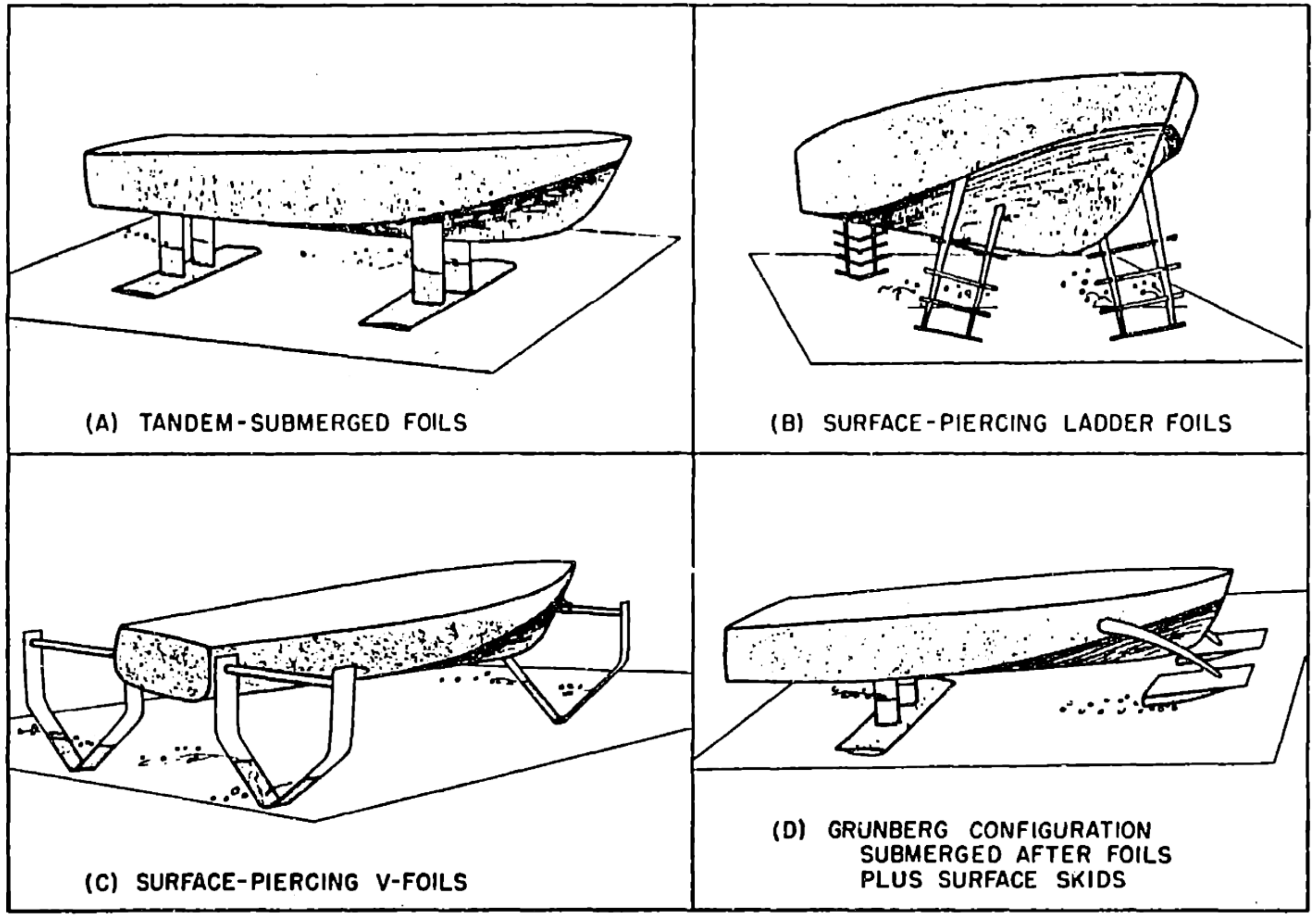


FIG. 1.—TYPICAL HYDROFOIL CONFIGURATIONS

Typical Dimensions

Rakheta, German passenger hydrofoil boat; 1961

	Raketa
LOA	88 ft 5 in
Beam	16 ft 5 in
Draft	5 ft 11 in
Displacement	27 tons
Passengers	58
Cruise Speed	32 knots

Design Parameters[1]

1. Geometry
   - Chord
   - Camber
   - Thickness
   - Span

   - Aspect Ratio, AR = $\frac{Span^2}{Area}$
2. Angle of Attack (AoA)
3. Flow Speed -
   - Reynolds Number, Re = $\frac{\rho \cdot v \cdot D}{\mu}$
4. C_D, C_L
   - Froude Number, Fr = $\frac{U}{\sqrt{gh}}$

Forces on a hydrofoil

- **Lift:-** calculating the lift coefficient [1]

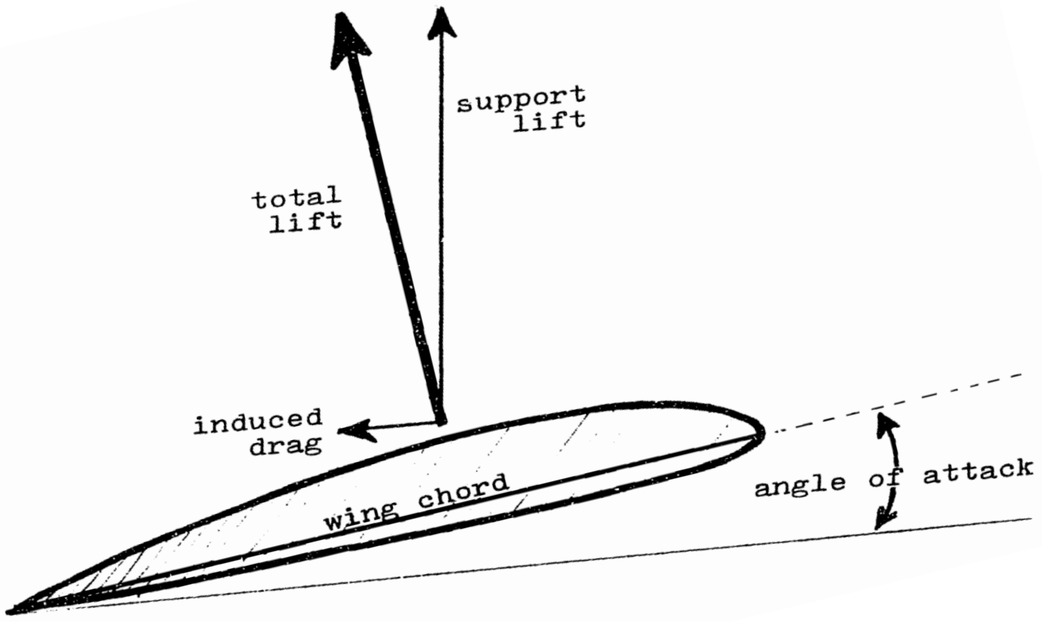
$$\rho \cdot v(y) \cdot \Gamma(y) = C\,(y) \cdot \frac{\rho}{2} \cdot U^2 \cdot c$$

- Polhamus' Lifting Line Theory:

  A lifting surface can be thought of as a bound vortex.

- $$C_L = \frac{L}{\frac{1}{2}\rho U^2 c} = \frac{\rho U \Gamma}{\frac{1}{2}\rho U^2 c} = \frac{2\Gamma}{Uc}$$

- U = Velocity of foil; c = Chord; Γ = Circulation of bound vortex.



Geometry- Cross Section

According to Parkin *et al* [2], aero foil theory can be used to design hydrofoils by similitude.

- The dimensionless numbers characteristic of the flow has to be the same.
- Effect of aspect ratio (AR), angle of attack (AoA), Reynolds Number (Re) can be readily understood.
- Hence existing, reliable codes solving the governing equations for a given set of boundary conditions can be used here as in aerodynamics.

Solutions

1. Inverse Conformal Mapping method – by Lighthill, M.J. [3]
2. XFOIL – Panel Method- by M.Drela et al [4]
3. Genetic and Evolutionary Algorithms [5]

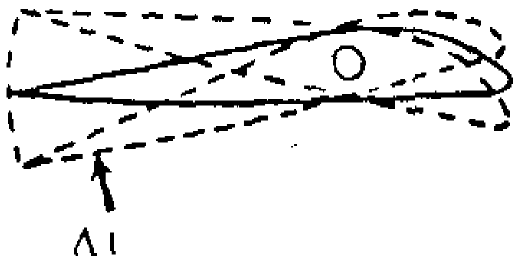
- Design is limited by the effects of the free surface on the hydrofoil.
- These can be accounted for by [2]
    - Double body translation due to Dawson et al.
    - First order linearised approximations by Wu et al.
    - Laitone’s theory based on Ausman’s experimental results.

Numerical Optimization

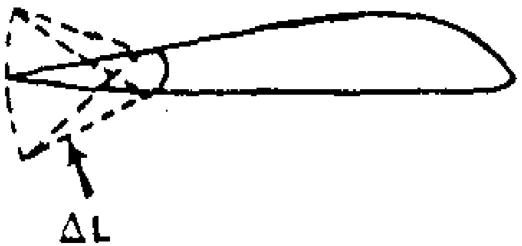
- The wings designed by numerical solutions have to be optimized using CFD [6].
- Advantages of Knowledge of Flow Pattern- Parkin et al [2]:
    - Flow visualization reveals the effect of variables not accounted for and the effect of approximations used.
    - Data for more real- life flow conditions can be obtained by simulation.
- Solver used
    - Fluent[7]
    - OpenFOAM[8]

Basic Control Parameters[1]

- Changing the Angle of Attack (variable incidence).
- Change of Aspect Ratio (Trailing edge flaps)



VARIABLE INCIDENCE CONTROL



TRAILING - EDGE FLAP CONTROL

Project Objectives

- Find the shortest span of split hydrofoils for steady operation of a light boat.
- Study the surface effects on shallow foils.
- Investigate the possibility of using hydrophobic material coating on the foils.
- Acquire data about variation of geometry (AR), and incidence (AoA) for minimal drag and stable lift in different flow conditions.
- Investigate the application of swept foil configuration.

References

John Sebastian

Contents

Introduction

.

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.

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Design

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.

Objectives

References

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