Recent Advances in the Naval Architecture for NIS Control

Prof. Michael G. Parsons
Naval Architecture and Marine Engineering
University of Michigan

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New IMO Requirements

- A 95% volumetric ballast exchange (@ 200nm, 200 m). Effectiveness is still being debated, however.
- Flow-through exchange for three volumes "shall be considered" to meet the requirements
- All ships shall remove and dispose of sediments in ballast spaces
- Management standard for non-exchange: less than 10 viable organisms/m^3 above 50 μm and 10 between 50 and 10 μm
- Indicator microbes: E. coli, Vibrio cholerae, intestinal Enterococci

re: International Convention for the Control and Management of Ships' Ballast Water and Sediments, IMO, Feb. 13, 2004

Idealized Models of Flow-Through Exchange

- No mixing of the new and old ballast water (so-called *plug flow*);
  then one tank volume of flow yields 100% replacement

- *Perfect mixing* of the new and old ballast water at all times -
  then the concentration of old water is given by

  $C(t) = C_i \, e^{-t/\tau}$ where τ = residence time
  = tank volume/inlet flow rate

  after three volumes ($t = 3\tau$), the exchange is 95%
  this is the basis for current rules
  confirmed by *MV Iron Whyalla* tests (rectangular tanks)

Impact of Ballast Tank CFD Research

- This research has shown that CFD can be used to analyze exchange effectiveness and help design better ballast tanks.
- This research has shown that the new IMO rules are flawed and will not necessarily provide the protection assumed.
- This research has demonstrated that the bulk carrier hooper side/wing tank configuration previously recommended in the ship design literature is actually the worst possible choice.

re: Kent, C. P, and Parsons, M. G., "Computational Fluid Dynamics Study of the Effectiveness of Flow-Through Ballast Exchange," *Transactions* of SNAME, Vol. 112, 2004.

summary to appear in IMO Globallast's *Ballast Water News* – future issue circulation to 12,000 policy, biology, and engineering NIS specialists world-wide

The “Ballast-Free” Ship

- Period 2002-2004 (nearing end)
- Development of a new concept of ship design to essentially eliminate the potential for NIS introductions through the ballast water vector
- Investigation of related design and technical research issues associated with this concept

The Ballast-Free Ship Concept

Its origin was in National Research Council's Ships' Ballast Water Operations Committee deliberations :

Question from biologists/ecologists in the:

"Why not just eliminate the use of water ballast?"

Response:

"Water ballast is necessary in the light cargo condition to ensure:

- Transverse stability
- Bow submergence
- Propeller submergence
- Reduce windage for adequate maneuverability, …"

The Ballast-Free Ship Concept (cont.)

- Traditional approach: Add water ballast to increase vessel weight in the light cargo condition
- Paradigm shift: instead of thinking add weight, reduce buoyancy
- **Ballast-Free Ship concept principles**:
  - Replace traditional ballast tanks by longitudinal, structural ballast trunks that extend beneath the cargo region below the ballast waterline.
  - Connect these trunks to the sea through a plena at the bow and the stern. Flood trunks in the ballast condition. Pump out when finished.
  - The natural hydrodynamic pressure differential between the bow and the stern region induces a slow flow in the ballast trunks.
  - **Thus, the trunks are always filled with "local seawater".**
- US Patent #6694908, 2004

The Ballast-Free Ship Concept (cont.)

- Concept advantages:
  - Eliminates the need for costly ballast water treatment equipment.
  - Effective approach even for transport of biota smaller than 50 microns; e.g. Vibrio cholerae
- Concept development requirements: the project research
  - Prove feasibility of concept (CFD studies of available pressure differential, trunk flow development, effect of waves).
  - Investigate resistance and propulsion impacts (model tests).
  - Re-design the internal structure to implement the concept and ensure structural strength adequacy.
  - Assess intact stability, probabilistic damage stability and seakeeping performance.
  - Evaluate economic feasibility.

Summary of Economic Comparison

Change in Required Freight Rate compared to filtration and UV treatment

$$\Delta RFR = (CRF(i, n)\ \Delta P + \Delta A)/C$$

- Ballast-free ship with 7.5% power penalty found in our tank testing and a larger engine + $0.133/t of cargo
- Ballast-free ship with 7.5% power penalty and same engine - $0.023/t, a small savings
- Ballast-Free Ship without any power penalty - $0.204/t, significant

Ballast-Free Ship compared to flow-through exchange +0.165/t

Impact of Ballast-Free Concept Research

This research has shown that:

- The Ballast-Free Ship concept essentially eliminates the transport of foreign ballast water.
- It provides a viable alternative to ballast water treatment systems and ballast exchange; and should be equally effective even with stricter future requirements.
- Hydrodynamic optimization should eliminate most of the added power penalty. Our pending future research.
- This should be a cost effective alternative ($\Delta RFR < 0$) to filtration/UV

re: Kotinis, M, Parsons, M. G., Lamb, T., and Sirviente, A. "Development and Investigation of the Ballast-Free Ship Concept," *Transactions* of SNAME, Vol. 112, 2004.

summary to appear in IMO Globallast's *Ballast Water News* - next issue