MANAGEMENT OF BALLAST WATER - BALLAST FREE SHIPPING - THE WAY FORWARD

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Abstract

This article is about minimizing the ill. Effects of ballast water discharges away from its home environment, during the course of the voyage and if possible, eliminate the problem altogether. Ballast water is used to maintain safe operating conditions throughout a voyage. While ballast water is essential for safe and efficient modern shipping operations, it may pose serious ecological, economic and health problems due to the multitude of marine species carried in ships' ballast water. There are hundreds of organisms carried in ballast water that cause problematic ecological effects. Ballast-free ship concept offers a promising alternative that could block hitchhiking organisms and could eliminate the entire requirements for expensive sterilization equipment like costly filters, ultraviolet irradiation, chemical biocides and other technologies. Ballast Free shipping is not without practical challenges. One practical suggestion minimizing these challenges is introducing the hybrid ballast free system, which immediately solves the ballast water volume constraint problem while reducing the strength and resistance penalty.

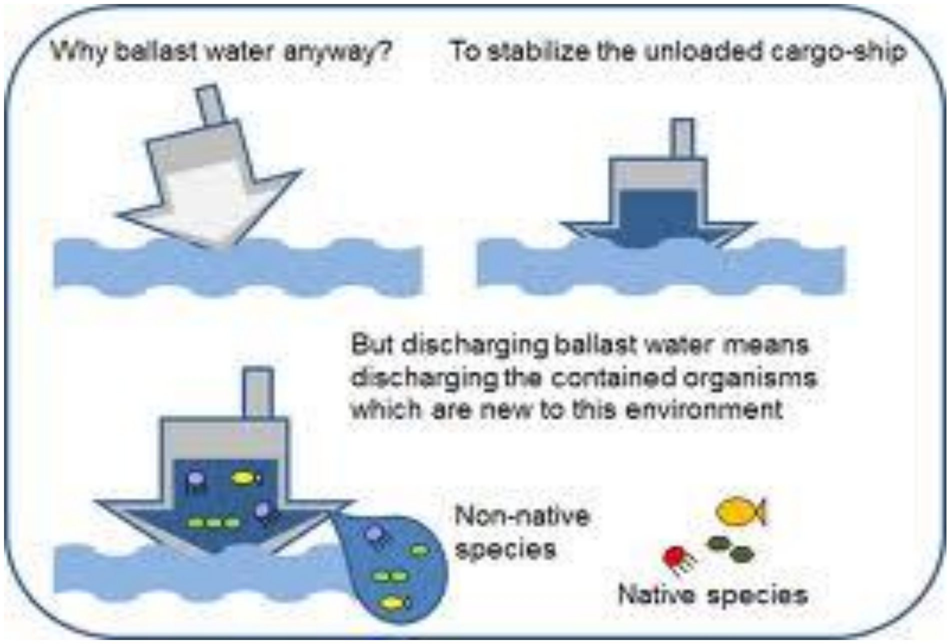
Keywords: *Ballast water, BWM Technology, Treatment Technology, Ballast Free Ships, HAOP.*

Introduction

Since the introduction of steel-hulled vessels around 120 years ago, water is used as ballast to stabilize vessels at sea. Ballast water is pumped-in to maintain safe operating conditions throughout a voyage. This practice reduces stress on the hull, provides transverse stability, improves propulsion, maneuverability and compensates for weight loss due to fuel and water consumption. While ballast water is essential for safe and efficient modern shipping operations, it may pose serious ecological, economic and health problems due to the multitude of marine species carried in ships' ballast water. These include bacteria, microbes, small invertebrates, eggs, cysts and larvae of various species. The transferred species may survive to establish a reproductive population in the host environment, becoming invasive, out-competing native species and multiplying into pest proportions.

After more than 14 years of complex negotiations between IMO Member States, the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention) was adopted by consensus at a Diplomatic Conference held at IMO Headquarters in London on 13 February 2004. The Secretary-General of IMO stated that the new Convention represents a significant step towards protecting the marine environment for the present and future generations. The Convention requires all the ships to implement a Ballast Water and Sediments Management Plan. The ships will have to carry a Ballast Water Record Book and will be required to carry out ballast water management procedures to a given standard. Parties to the Convention are given the option to take additional measures that are subject to criteria set out in the Convention and to IMO guidelines[1].

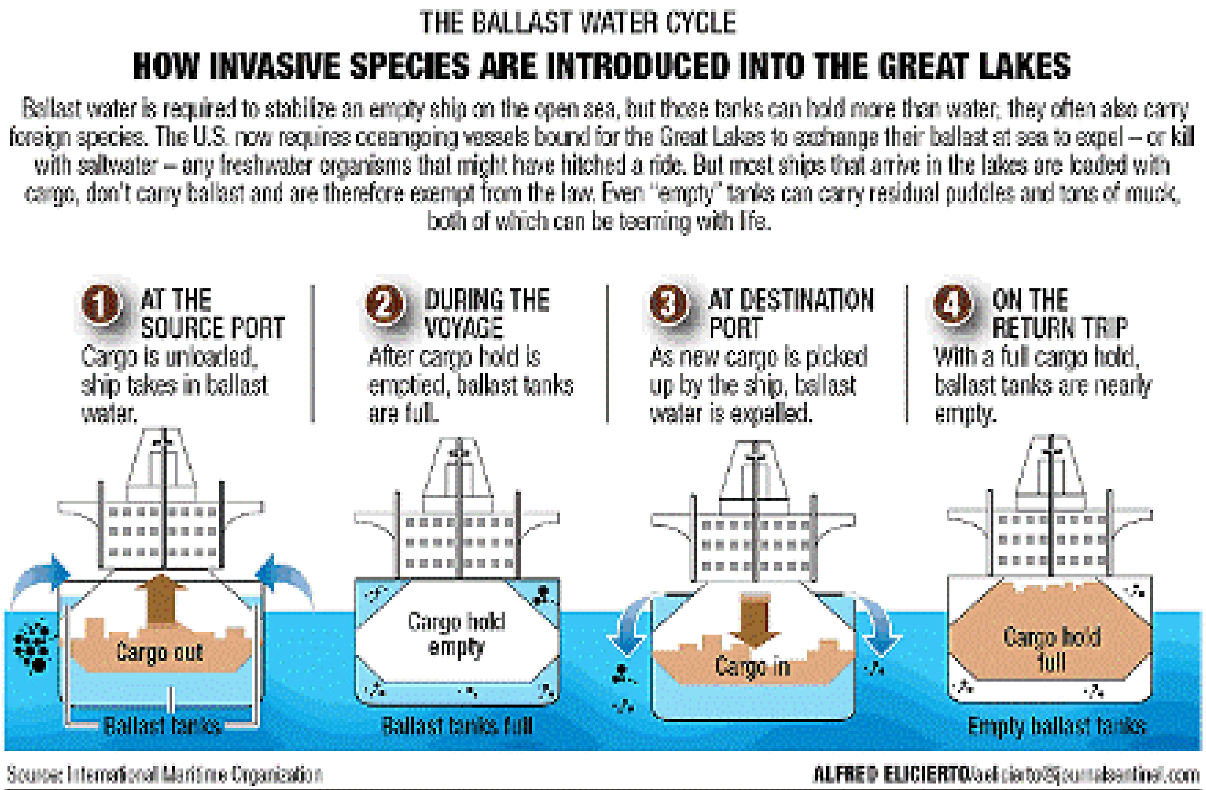
Need For Ballasting



Ballast Water and the Environment

Ballast water discharge typically contains a variety of biological materials, including plants, animals, viruses, and bacteria which can cause extensive ecological and economic damage to aquatic ecosystems, along with serious human health issues including death. There are hundreds of organisms carried in ballast water that cause problematic ecological effects outside of their natural range. The International Maritime Organisation lists the ten most unwanted species as[2]

- Cholera *Vibrio cholerae* (various strains)
- Cladoceran Water Flea *Cercopagis pengoi*
- Mitten Crab *Eriocheir sinensis*
- Toxic algae (red/brown/green tides) (various species)
- Round Goby *Neogobius melanostomus*
- North American Comb Jelly *Mnemiopsis leidyi*
- North Pacific Seastar *Asterias amurensis*
- Zebra Mussel *Dreissena polymorpha*
- Asian Kelp *Undaria pinnatifida*
- European Green Crab *Carcinus maenas* etc.



Problems of Ballast Water Transportation

Using water analysis methods and particle size analyzers, it has been found about 4,500 types marine organisms including plants, animals and bacteria are transported per day. It is believed that a marine species invades a new environment somewhere in the world every nine weeks. Apart from the threat that comes with the movement of marine life, there are also issues pertaining to overexploitation of living marine resources and physical alteration and destruction of marine habitats[3 &4]. The introduction and spread of alien invasive species is a serious problem that has ecological, economic, health, and environmental impacts, including loss of native biological diversity. The impacts depend on the origin of the organisms and the location of the point of discharge.[5 & 6]

Ecological Impacts

Should an introduced species become a successful invader in its new environment, it can cause a range of ecological impacts. These include: competing with native species for space and food, preying upon native species, altering habitat, altering environmental conditions (e.g. increased water clarity due to mass filter-feeding), altering the food chain and the overall ecosystem and displacing native species, reducing native biodiversity and even causing local extinctions.

Economic Impacts: Many aquatic invasive species can cause major economic impacts on human society. Direct economic losses to society can be caused by aquatic bio-invasions in a number of ways, including:

- Reductions in fisheries production (including collapse of the fishery) due to competition, predation and/or displacement of the fishery species by the invading species and/or through habitat/ environmental changes caused by the invading species.
- Impacts on aquaculture (including closure of fish-farms & shrimp farms), especially from introduced harmful algae blooms.
- Physical impacts on coastal infrastructure, facilities and industry, especially by fouling species.
- Reduction in the economy and efficiency of shipping due to fouling species.
- Impacts and even closure of recreational and tourism beaches and other coastal amenity sites due to invasive species.(due to water becoming murky or smelly)
- Secondary economic impacts from ecological impacts and bio-diversity loss.
- The costs of responding to the problem, including research and development, purification cost, monitoring, education, communication.

Impact on Human Health: Human health is not left out of the negative effects perpetrated by HAOP (Harmful Aquatic Organisms and Pathogens) introduced through ships ballast water. Some of these harmful aquatic organisms contaminate filter-feeding fishes, making them toxic to humans. When they are consumed, the introduced pathogens may cause diseases in human beings, which may sometimes lead to illness and eventual death. In 1991, toxigenic Vibrio cholerae was detected in oysters and the intestine of fish in Mobile Bay, USA. Analysis was carried out which revealed similarities between the Vibrio cholerae detected in Mobile Bay and the one responsible for a cholera outbreak in South America. A further analysis was carried out on ships ballast water arriving Mobile Bay from South America and the same Vibrio cholerae was detected[7]**.** In 1992, the Great Lakes Ballast Management, the Food and Drug Administration, and the Centers for Disease Control recognized as a public health issue, the contamination of shellfish beds in Mobile Bay by Vibrio cholerae transported in ships ballast tanks entering Mobile Bay from South America.[8]

Another type of species affecting the health of human beings and aquaculture is toxic dinoflagellate which invaded several locations around the world and introduced the human disease called paralytic shellfish poisoning (PSP).This disease was unknown in Australia, New Zealand and the rest of the Southern Hemisphere before 1970. But by 1990, cases of the disease had spread not only to the Southern Hemisphere but also to the Northern Hemisphere. As to the link between the disease, PSP and ballast water, Dobbs and Rogerson pointed out that Dinoflagellate cysts have been reported in abundance in ballast tank sediments of ships arriving in Australia, Canada, New Zealand, United States of America, etc. [9] The ships are from Japanese and Korean ports and Japanese and Korean coastal waters are believed to have wide-spread presence of toxic PSP dinoflagellates.

Ballast Water Treatment Technologies and Processes

There are a number of methodologies to treat ballast water in order to limit, eliminate or render harmless aquatic organisms and sediments in ballast water to the extent defined in the ballast water performance standard. The treatment process could be mechanical, physical, chemical or electrical, or combinations of these.[10]

Treatment Technology Type

Mechanical
1. Cyclonic separation (hydrocyclone)
2. Filtration

Chemical treatment and biocides
1. Chlorination
2. Chloride dioxide
3. Advanced oxidation
4. Residual control (sulphite/bisulphate)
5. Peraclean Ocean

Physical disinfection
1. Coagulation/flocculation
2. Ultrasound
3. Ultraviolet
4. Heat
5. Cavitation
6. Deoxygenation
7. Electro-chlorination/electrolysis
8. Electro-catalysis
9. Ozonisation

Physical, Mechanical or Chemical?

- **Solid-Liquid Separation**

The filtration process uses discs or fixed screens with automatic backwashing and is generally effective for larger organisms and particles. The low membrane permeability means surface filtration is not practical, so backwashing is required to maintain flow because of the pressure drop. As a means of removing larger particles, hydrocyclones are a good alternative. These separate the particles through high-velocity centrifugal rotation of the water. Both filtration and cyclonic separation can be improved by pre-treatment in the form of coagulation, but this needs extra tank space and an ancillary power to generate the flocs.

- **Oxidising Biocides**

When diluted in water, chlorine destroys cell walls of organisms, while electro-chlorination creates an electrolytic reaction using a direct current in the water clinically. Both methods are well established and industrially, but are virtually ineffective against cysts unless a concentration of at least 2mg/ litre is used. Ozone gas, which is bubbled through the water, is effective at killing micro-organisms. It produces a bromate by-product and requires an ozonate generator. Chlorine dioxide is effective, particularly in high-turbidity waters. It has a half-life of 6–12 hours but, according to suppliers, can be safely discharged within 24 hours.

- **Physical Disinfection**

When ultraviolet irradiation is used, amalgam lamps surrounded by quartz sleeves produce UV light, which changes the molecular structure of the organism and thereby prevents it from reproducing. The deoxygenation method relies on reducing the pressure of oxygen in the space above the water by injecting an inert gas or inducing a vacuum. The removal of oxygen may also lead to a reduction in corrosion. If heat is employed to treat the ballast water, the water can be used to provide engine cooling while being disinfected.

Ballast Water Treatment System & Installation Issues

- Equipment size, space requirements and location
- Ballasting operation affects / treatment system pressure drops
- Equipment protection (IP rating) and hazardous spaces
- Effect on power requirements
- Impact on ballast tank coatings and ballast pipe corrosion
- Handling and storage of required chemicals
- Operation and maintenance requirements
- Emergency by-pass operation
- Control, warning & alarm requirements

Ballast Free Ships: The Way Forward

The non-ballast or ballast free ships are prototype of a greater paradigm, in accordance with the 1997 International Maritime Organization (IMO), ballast water management Guidelines A.868 (20) and the IMO ballast water convention that approaches ballast operation as the reduction of buoyancy, rather than summing up additional weight to help get the vessel to its required ballast drafts.

Why Ballast Free Ships?

Ballast-free ship concept offers a promising alternative that is both economical and efficient. It creates a constant flow of local seawater through a network of trunks, running from the bow to the stern, below the waterline, thus reducing the potential hauling of contaminated water across the ocean. It could be one giant economic winner by effecting a saving of net capital-cost of about $540,000 per ship. Combined with the expected fuel savings, total cargo transport costs may be cut by $2.55 per metric ton.

The concept uncertainties for a bulk carrier that does not require traditional ballast tanks are advancing past concerns about its damage stability and may offer fuel savings as well as a way of preventing the spread of invasive species thru' ballast water. As ballast water is not stored, there is no need to perform ballast water exchange or install onboard ballast water treatment equipment. The design now meets SOLAS and Society of Naval Architects and Marine Engineers (SNAME) guidelines for safety and, despite the extra steel required by the design, is expected to result in a 1.7 percent fuel saving in the light load condition compared with a standard design. Ballast free system for the management of ballast water onboard ship has been thoroughly studied[9, 10 & 11]

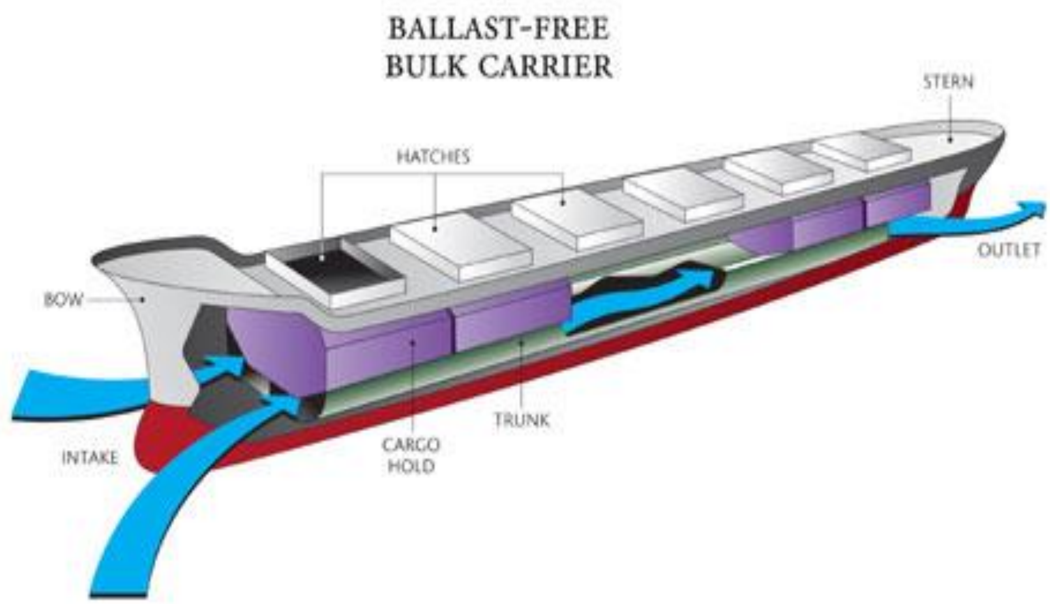


Figure 1**.** The Ballast-Free Ship concept bulk carrier utilizes longitudinal ballast trunks open to the sea rather than conventional ballast tanks. Source: http://www.bairdmaritime.com/

Rather than treat ballast water with onboard treatment equipment, The Ballast-Free Ship concept reconfigures the vessel to create a slow, continuous flow of local seawater through longitudinal ballast water trunks, essentially eliminating the movement of ballast water from one part of the world to another.

The design requires that a typical bulk carrier has a slightly larger depth to provide the needed ballast capacity and maintains grain capacity. The resulting inner bottom is higher, which will facilitate the cleaning of the ballast trunks to minimize the accumulation of sediments. For seaway-size bulk carrier, three trunks would be installed port and starboard on the vessel as shown in the attached comparison of the mid-ship sections of a typical single-hull conventional bulk carrier and a comparable speed and capacity Ballast-Free Ship concept bulk carrier (Refer: Figure 2). The trunks are flooded in the ballast condition and then isolated and pumped dry using conventional ballast pumps when the vessel is ready to load cargo. The detailed design also features the cutaway of most of the floors between the longitudinal at the bottom shell to facilitate the cleaning of the ballast trunks.

When a ship moves through the water there is a region of relative positive pressure created near the bow and a region of relative negative pressure created at the stern. This pressure differential is utilized to drive the slow flow through the trunks without the use of pumps. Thus, the trunks will always be filled with 'local sea water' and there will be no transport of ballast in the usual sense. The system is sized, so that the trunk water is changed about once each hour as needed to accomplish the environmental protection goal, without adding excessive resistance to the ship. Computational Fluid Dynamics (CFD) studies using Fluent 6.1 is used to establish the pressure differential expected in the ballast condition. They are also used to show that the flow will initiate and be sustained at the ballast speed.

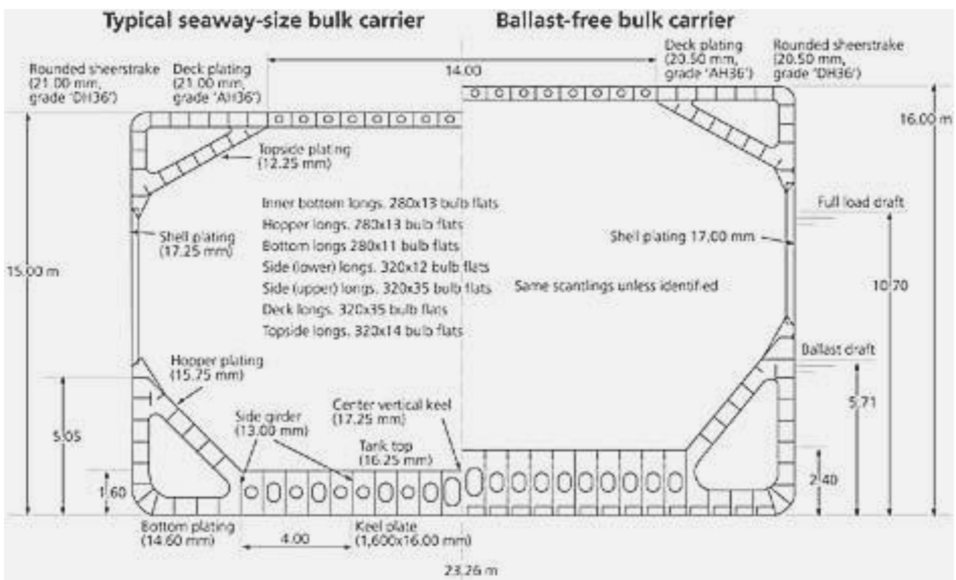
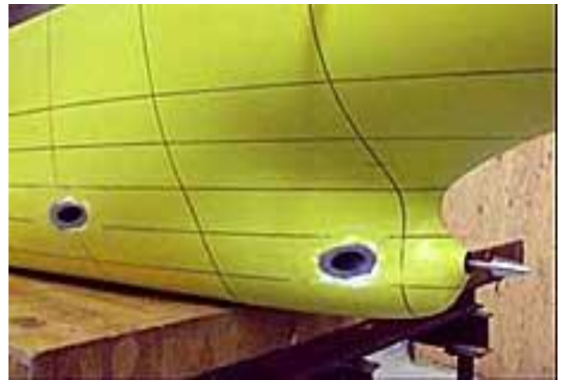


Figure 2. Comparison of mid-ship sections of seaway-size typical and Ballast-Free Concept bulk carriers of the same capacity and speed.

Higher Propeller Efficiency

To maximize the ballast trunk pressure differential, the trunk intake is taken at the center of the bulbous bow at about the 25 per cent design waterline. Even though the use of the ballast trunks would result in the slight increase in the resistance of the ship, the discharge of the trunk flow into the upper half of the propeller disc tends to smooth out the inflow to the propeller circumferentially, allowing the propeller to operate at the higher propeller efficiency. In tests with a five-meter scale model in the University of Michigan Marine Hydrodynamics Laboratory (MHL), the required developed power declined by 7.3 per cent from the no trunk case to the case with the scaled ballast trunk flow being discharged. This situation is similar to the use of Mitsui ducts, which reduces ship required power by diverting flow into the upper half of the propeller disc in order to provide a more circumferentially uniform propeller inflow and improve propeller efficiency.

Two duct discharge locations tested in Marine Hydrodynamics Laboratory.



Location of duct intake in the bulbous bow.

Source: http://www.shipgaz.com/old/magazine/issues/2008/16/article2.php

Features of Ballast Free Ships

- Ballast trunks: Ship ballast tanks are replaced with longitudinal structural ballast trunks consisting of one centre tank, two intermediate tanks and two side tanks which surround the cargo hold below the ballast draft and are connected to an intake plenum and a discharge plenum near the bow and the stern respectively. These ballast trunks are swamped in the ballast circumstance to diminish the ship's buoyancy.
- Hull Shape: V-shaped hull minimizes the resistance and optimizes the propeller conditions in fully loaded and unloaded conditions by reducing the weighted sum of the wetted surface. In lightship condition, it increases the draft from the normal 3-4 meters (with the bow and propeller almost out of the water) of a conventional 300k DWT VLCC.
- CFD tools: Computational Fluid Dynamics (CFD) compare the syrupy resistance of the new design with that of a more traditional design and assist in maximizing the pressure fields in the bow and stern area.
- Propulsion: The twin screw and optimum diameter propellers allow low draught aft in the unloaded condition and ensure high propulsive efficiency by overlapping propeller arrangement. Propulsion power is estimated on the basis of the resistance and propeller analyses.

- Trim and heel: Longitudinal bulkheads provide with moment equilibrium around the longitudinal centre line for all segregation alternatives and prevent large trims to occur during the cargo operations.

Practical issues of the Ballast Free System

Implementation of ballast free system is not without challenges.

Firstly, the potential difficulty has been highlighted.[9] on the constraint of ballast water volume to keep all the tunnels below ballast waterline. The challenge is to maintain the cargo carrying capacity and the same ballast water volume. Proposed rearrangement of the structural double bottom to reduce the buoyancy as can be flooded as submarine.[9]

Secondly, on the issue of loss of ship strength due to the redesigning of the double bottom - ballast free concept is said to have high ability in functions when the ballast water can flow freely through the tunnels without contributing to pressure drop in the flow. The existence of transverse framing system at double bottom causes difficulty for ballast water to flow through the tunnels. The elimination the transverse frames could enhance the flow of ballast water. However, as stressed there would be no classification societies to permit the elimination of all transverse ballast trunk end boundaries within the cargo hold.[9] Furthermore, watertight trunk boundaries would be required at the watertight transverse locations. On the same issue, the longitudinal stiffeners at the tank top and bottom can be replaced with the sandwich panels. This would provide large cross section for the tunnel hence improving the ballast water flow. The sandwich paneling are able to compensates the lost of strength if the longitudinal stiffeners is reduced.[10]

Thirdly, on the issue of ship resistance due to disturbance of discharge of ballast water from outlet plenum on the flow around ship's propeller - the introduction of plenums at the bow and stern of the ship and the location of plenums will affect the resistance of ship and leads to increase of fuel consumption. The location of the plenums are at the point of adequate pressure difference to produce continuous flow through the tunnels. Increasing ballast water flow velocity at discharge location or less time for ballast water exchange, resulted in higher resistance.[9]

Conclusion

Ideal implementation of ballast free system requires careful consideration. Loss of cargo carrying capacity due to ballast water volume constraint, impact to loss of longitudinal strength, and resistance increase are the three practical issues.[9,10,11,12,13 &14] Solutions translate into additional expense in the form of further design studies, extra steel weight and increase of fuel consumption. One practical suggestion minimizing these problems is by introducing the hybrid ballast free system is coupled with the existing conventional ballast system. [9] Hybrid ballast free system immediately solves the ballast water volume constraint problem while reducing the strength and resistance penalty.

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