Review in Ballast Water Treatment Regarding Methods of Treatment, Volume, Time and Corrosion of the Tank

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Abstract. Nowadays over 80% of global trade volume is transported by ships. The ballast water is used in all voyages, at least half of each every journey is undertaken with additional water aboard to compensate for the absence of cargo. Ballast water contains a variety of organism including bacteria and viruses and the adult and larval stages of the many marine and coastal plants and animal. Whilst the vast majority of such organisms will not survive to the point when the ballast is discharged, some may survive and arrive in their new environment. They can have a serious ecological, economic and public health impact on the receiving environment. Ballast water treatment maintaining the ecosystem of the oceans, so we must the best individual and adequate method of treatment, after ship type and service. We will also add data from Ansys software regarding the ballast free concept.

1. Introduction
The ballast water is an essential component for the draft, the stability the trim and the stress of vessels with and without cargo. A ship has many ballast tanks, can over 20 ballast tanks. During the ballasting process living organisms and microorganism (bacteria, small invertebrates, microbes, eggs, cysts and larvae of various species) enter into the ballast tank together with ballast water and some sediments. Ships often take on ballast water in one port and carry such ballast to other ports where it is discharged. The ballast water and sediments contain living organism which, despite the harsh conditions in the ballast tank and piping systems, survive to compete with native species in the port of discharge. If the non – native organism have few natural predators or other natural controls they may become invasive and danger the local ecosystem, sometimes dramatically. Furthermore, there is a risk of spreading diseases trough ballast water [1].

Current rules on ship ballasting
The potentially damaging effects of ballast water discharges have been recognized not only by the International Maritime Organization but also by the World Health Organization, which is concerned with the role of ballast water as a disease-promoting agent for the spread of bacteria epidemic.

The choice of the best method to minimize risk depends on several factors, in particular the type of bodies concerned, the degree of risk, environmental acceptability, economic and environmental costs and the safety of ships.

At the 1973 Conference, the issue of ballast water was raised in the specific context of the transport of dangerous pathogens to humans. The Conference adopted a resolution stating that ballast water loaded from waters containing bacteria susceptible to spreading epidemic diseases when discharged into the sea may generate the risk of spreading epidemics in other countries.

This Conference called on both the International Maritime Organization and the World Health Organization to undertake studies on this issue, building on data and proposals from governments.
Experts conducted these studies and the result arose in 1976 when a German scientist, Prof. H. Rosenthal, published a study on the risks associated with the transfer of alien species to fisheries and aquaculture through ballast water. Its conclusion was that fishing areas located near major waterways are at risk of transferring disease through ballast water.

Over the next decade, more and more foreign species have been introduced around the world. In the late 1980s, Canada and Australia are among the countries that have had special problems created by these unwanted species. This issue was part of the concerns of the Marine Environment Protection Committee (MEPC) of the IMO.

At its 31st session in 1990, the MEPC (Marine Environmental Protection Committee) established a Ballast Water Working Group with the task of developing directives to deal with the problem of invasive alien species.

Resolution MEPC.50 (31) entitled "International Directives on the Prevention of the Introduction of Aquatic Organisms and Unwanted Pathogens due to Discharges of Ballast Water and Sediments by Ships" was adopted in 1991.

The purpose of these Directives was to provide Administrations and Port State authorities with guiding principles on methods that minimize the risk of introducing invasive alien species through ballast water and sediment from ships.

From an ecological point of view, the uncontrolled discharge of ballast water is manifested through changes in biological biodiversity and ecological processes due to the introduction of marine species.

The economic impact of uncontrolled discharges of ballast water is reflected in the fishing activity and other commercial activities that are affected because natural resources are being destroyed by the invasion of harmful marine species.

The invasion of marine marine organisms has an unfavorable impact on human health, which can cause serious illness and even death due to the harmful effects it has on the aquatic environment and the resources it contains.

If this issue has not been taken into account with particular vigilance, it must be given special importance, given the development of the world fleet with increasingly powerful ships.

Pollution caused by uncontrolled decontamination by commercial vessels is not well seen by public opinion, fully aware of the recent pollution events.

Also aware of these issues, major international organizations have been working for many years to regulate this issue.

The ballast water collected from a coastal area can exchange at mid ocean with deep seawater during the voyage, but the operation of ballast water exchange is unsafe to the ship structure and the crew because the ship may lose the stability. So, the need for a safe and nowadays cost-effective alternative treatment technology is increasing. Further, note that California law sets a final discharge implementation date of 1 January 2020 that specifies zero detectable living organism for all size rangers in the ballast discharge stream [2].

2. Ballast water treatment, principles

The methods and technologies being considered for ballast water treatment (BWT) can be grouped by basic approach as follow:

- Mechanical systems (filtration or separation) – require redirecting the full ballast flow through filters, hydrocyclones or other separators;
- Physical disinfection (ultraviolet radiation, cavitation, de-oxygenation, etc.) – ultraviolet radiation (UV) and cavitation require processing of the entire ballast flow holding time is not required as treatment is complete once the water passes through the equipment. De-oxygenation can be done at intake to the full ballast flow or directly in the ballast tank with bubblers;
- Chemical treatment (biocides and electrochlorination – these treatments are dosed into the existing ballast piping during intake or directly into the ballast tank. The chemicals must
neutralized or be allowed to become biological ineffective before the ballast water can be considered safe for discharge.

2.1. Mechanical systems

2.1.1. Filtration. Sediments and particles are removed with disk and screen filters during ballast intake. They are often self-cleaning with a back flushing cycle. The waste stream is directed overboard back to the water source. These filtration system create pressure drops and a reduced flow rate due to resistance in the filter elements and the self-cleaning procedures.

2.1.2. Electromechanical separation. Magnetic separation and filtration is used to remove the solid particles.

2.1.3. Heat or cold water. Ballast water can be used to provide engine cooling while being disinfected through heater cold treatment.

2.1.4. Cyclonic separation. Solid particles are separated from the water due to centrifugal forces. Only those particles with a specific gravity greater than that of water can be separated.

2.2. Physical disinfection

2.2.1. Ultraviolet light. UV radiation is used to attack and break down the cell membrane killing the organism outright or destroying its ability to reproduce.

2.2.2. Cavitation/Ultrasound. Venturi pipes or slit plates are used to generate cavitation bubbles and this high energy bubble creation and collapse results in hydrodynamic forces and ultrasonic oscillations, or high frequency noise, which disrupts the cell walls of organisms effectively killing them.
2.2.3. De-oxygenation. Various methods are used to remove the dissolved oxygen in the ballast water and replace it with inactive gases, such as nitrogen or other inert gas. De-oxygenation can require a prolonged period in order to render the organisms and pathogens harmless to the receiving waters.

2.2.4. Plasma. When high voltage and current is applied between two electrodes in the reactor, it create an ionization field then producing a high-energy plasma arc, which causes an extremely rapid risk in pressure, temperature and density flow and generate expansion. When de high-energy plasma produced an intensive pressure shockwave, the target organism are killed by physical damage either by a sudden recoiling of the cell tissue or by micro-eddies created inside the cell.

2.3. Chemical Treatment

2.3.1. Chemical biocides. Packaged disinfectants designed to be dosed into the ballast flow and kill the living organisms by chemical poisoning or oxidation. Typical biocides include: chlorine, chloride, chlorine dioxide sodium hypochlorite and ozone. Residual biocides in the ballast water must meet ballast discharge standards which may necessitate neutralization techniques.

2.3.2. Electrolytic chlorination. Electrical current is applied directly to the ballast water flow in an electrolytic chamber generating free chlorine.

2.3.3. Ozonation. Ozone gas (1-2mg/l) is bubbled into the ballast water which decompose and reacts with other chemicals to kill micro-organism.

2.3.4. Coagulation. The pre-treatment prior to separation to aggregate particles to increase their size. Increasing size of particles increases efficiency of filtration or hydrocyclone separation.

3. System combinations

The treatment differ in methods and rate application, holding time (required for kills rates and safe discharge), power requirements, effect on other ships systems or structure corrosion, inherent safety and costs operation. Most often the efficacy varies with conditions of the ballast water, flow rates (time handling) and inherent volume of water treated. There also issues of water treatment is done intake, while being held on board, at discharge, or combination of the three times. So, filtration or separation with UV radiation are done during ballast loading and discharged are sized for the maximum flow rate in the ballast system. Matching the treatment technology to the ship type and vessel service is the key to designing a successful ballast water treatment system [3].

Fig 2. Mechanical separation with filter and UV light
Although there are approved chemical disinfection only treatment, these are also combined with some form pre-treatment to make them more effective for certain vessel or ballast conditions (fig 3).

Fig. 3 Treatment with filter and hypochlorite

The thermal treatment offers a safe and small cost effective using onboard resources and recycling waste heat. Only in transit treatment with heat can be using for vessels because adequate time is needed to treat all the water [4].

Results from the Ansys analysis indicate a decrease of the forward resistance by 1.75% for a 2 m diameter opening on the initial body analyzed for ballast free ship concept.

Determine the flow rate of the pumps is based on the condition that the volume of the tank of the starboard side will be transferred to the tank of the port side closely matches within a period of one hour. The total volume involved by a pump is 200 m³.

1. The minimum flow rate shall be calculated from the pump.
2. The calculation of the diameter of the tubing. In view of the speed of the fuel manifold is 3.5 m/s.
3. Choose the routing of calculation which involves the most difficult conditions for the operation of the pump
4. The calculation of the load H on the route.
5. The calculation of the coefficient of friction hidrodinamica linear (dimensionless), $\lambda$: 
6. The calculation of the hydraulic losses on the route and the deduction of the load on the installation.

The choice of the communication pump tanks
we have chosen the stabilization pump Marine Hoppe Type H250 with a capacity of 250 m3/h.

The calculation of the drive power of the electric motor

drive power measurement of the electric motor is calculated with the following formula:

\[ P = \frac{P \cdot Q \cdot Y}{\eta \cdot 1000} \, [kW] \]

The calculation of the moment of inversion and stabilisation force is useful to determine the inversion as determined by the force of gravity, \( \gamma \Delta \) and force the veil, \( P \) using the formula:

\[ M_{\text{max}} = g \cdot \Delta \cdot l = g \cdot \Delta \cdot GM_T \cdot \tan \varphi = 9.81 \cdot 62000 \cdot 10^3 \cdot 3.195 \cdot 0.052 = 101.04 \cdot 10^6 \, Nm \]

\( g = 9.81 \) m/s – Gravitational acceleration;
\( \Delta = 62.000 \) t – The displacement of the vessel;
\( GM_T = 3.195 \) m – The ship's metacentric height;
\( \varphi = 3^\circ \) – Tilting of the ship, the angle at which the pump enters into circulation.

Boundary conditions are:
- The inlet of the domain is a constant speed one, speed is 2 [m/s];
- The outlet of the domain is a constant pressure one, with relative pressure 0 [atm];
- The border is defined to be “free sleep wall”;
- The ship is defined to be “smooth wall”

The speed and pressure distributions resulting from the simulated situation analysis are shown in figures 5 and 6.

Fig. 5. Distribuție viteze pe planul XOZ
Fig. 6. Distribuție viteze pe planul XOZ
4. Consideration for selection of treatment system

The owner/operator must make a considered for the ballast water treatment that best suits the demands of the ship and service taking and cruise ship. As the data indicates (table 1,2) there is a wide range of ballast capacities and pumping rates common to the commercial ship sector.

**Table 1.** Ballast water capacity & Ballast pump rates for bulk carrier.

| Type/Size range | Capacity [mc] / Representative pump rate [mc/h] |
|-----------------|-----------------------------------------------|
| Handy < 60,000dwt | 18000 /1300                                  |
| Panamax < 60,000-90,000dwt | 35000 /1800                           |
| Capesize ≥120000dwt | 65000 /3000                           |

**Table 2.** Ballast water capacity & Ballast pump rates tankers.

| Type/Size range | Capacity [mc] / Representative pump rate [mc/h] |
|-----------------|-----------------------------------------------|
| Handy < 35,000  | 6,500 /1,100                                   |
| Handymax-Aframax 35000÷12,0000dwt | 31,000 /2,500                           |
| Suezmax 160,000 ÷180,0000dwt | 65,000 /3,000                           |
| VLCC 200,000 ÷320,000dwt | 90,000 /5,000                           |
| ULCC ≥ 320,000dwt | 95,000 /5,800                           |

Notably, the ballast vessels regularly sail in ballast only conditions without cargo. Their pump rates are designed to allow full load or discharge in a fixed period of time to facilitate rapid port turnaround times (12÷24 hours). The proper size of a treatment system depends on the amount of ballast that has treated at any given port, more so than the total ballast capacity or maximum flow rate. Another ballast practice issue that impacts treatment selection is how accumulated mud and silt in the ballast tanks is addressed. This residue itself can contain invasive species even when tank is empty of water. Even if ballast is loaded locally it can become contaminated by the residue in the tank. This may necessitate the treatment of ballast water on discharge as well as loading. If there is little mud accumulation and the tanks are cleaned regularly this may be less of a concern and the treatment system can be selected accordingly.
5. Conclusions

The life of a ship is determined by the life of the ballast tanks. The inside of a ship’s ballast tank is one
the most corrosive environments on earth. Sea water acts as a catalyst for oxygen to cause steel to rust.
The most important set of factors in selecting a suitable treatment system, after ship type and service,
are the operating characteristics and requirements of the individual treatment technologies. We
presented also the related project of ballast free ship in Ansys simulation and results are presented. So,
these technologies differ in method and rate of application, scalability, required holding time, power
and related system requirements, impacts on corrosion and inherent safety. Information presented in
this paper will determine how important each of these factors in selection process.

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