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Green ships. The future of shipbuilding

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Abstract

Molte misure in tema di tutela dell'ambiente marino sono entrate o entreranno in vigore nei prossimi anni e condizioneranno la progettazione e l'operatività dei mezzi navali rendendo necessario, ai fini del rispetto dei nuovi requisiti, il contributo della ricerca e dell'innovazione tecnologica. Obiettivo del paper è evidenziare i più significativi aspetti delle norme vigenti ed in via di elaborazione: dai requisiti definiti dalla Ballast Water Management Convention a quelli in tema di emissioni di NOx, SOx e CO2 previsti dall'Annex VI di MARPOL.

1. Introduction

There is no doubt the shipping sector is experiencing a situation where considerable focus and attention are placed on environmental issues by regulators, charterers, investors, insurers, banks and, last but not least, the public and the media.

Operational pollution from ships can be subdivided into two main categories: sea air pollution and water pollution.

The substances which are recognized as mainly responsible for air pollution can be summarized as follows:

(a) NO_x, SO_x and Particulate Matters, which are generated from the burning of fossil fuels, and VOC, which are released to the atmosphere during cargo operations;

(b) Ozone layer depleting substances, which may be found on board ship, for example in their refrigerating plants, (they include Halon and CFC);

(c) GHG, which are considered responsible for global warming, such as Carbon Dioxide, NO_x, Methane and Carbon Oxide, (they are mainly generated from the burning of fossil fuels) and CFC.

The prevention of operational sea water pollution from ships has been largely dealt with at international level over the last decades, too.

The discharge of oily water from the bilge and cargo area, the discharge of sewage and the disposal of garbage are dealt with in the relevant Annexes of the MARPOL Convention.

The introduction of invasive marine species into new environments by ships' ballast water is regulated by the Ballast Water Management International Convention, which was adopted in 2004, even if not yet in force: however, a certain number of States, such as Australia, USA and Canada, have adopted national requirements applicable to ships operating in their territorial waters.

The Harmful Anti-Fouling Systems Convention (AFS) entered internationally into force on 17 September 2008 with the aim of banning the use of tin based antifouling systems and imposing the use of TBT free paints.

Also hazardous materials used for ships, if not properly managed and when possible recycled, may become another source of pollution for the environment and a health and safety issue for the people involved. These concerns are addressed by the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships not yet into force.

2. Ballast water

The introduction of invasive marine species into new environments, by ships' ballast water or attached to ships' hulls and via other vectors, has been identified as one of the greatest threats to the world's oceans.

Shipping transfers approximately 10 to 12 billion tonnes of ballast water across the globe each year and there are thousands of marine species that may be carried in ballast water: basically anything that is small enough to pass through a ship's ballast water intake. This includes bacteria and other microbes, small invertebrates and eggs, cysts and larvae of various species.

It is estimated that at any one time, from 3,000 to over 4,500 different species are being carried in ships' ballast tanks around the world. The vast majority of marine species carried in ballast water do not survive the journey. However, when all factors are favourable, an introduced species may establish a reproductive population in the host environment and even become invasive, out-competing native species and multiplying into pest proportions. As a result, whole ecosystems are being changed.

In response to the threats posed by invasive marine species, the International Maritime Organization adopted, on 12 February 2004, the International Convention for the Control and Management of ships' Ballast Water and Sediments (BWM Convention).

The BWM Convention will enter into force twelve months after the date on which not less than thirty States, the combined merchant fleets of which constitute not less than thirty-five percent of the gross tonnage of the world's merchant shipping, have become parties to it.

For the time being, it is not yet in force.

When in force, the BWM Convention will apply to ships flying the flag of a Party except:

(a) ships not designed or constructed to carry ballast water;
(b) ships operating exclusively in waters under the jurisdiction of a Party, unless the party determines that the discharge of ballast water from such ships would impair or damage their environment;
(c) warships, naval auxiliary or other ships owned or operated by a Party;
(d) ships with permanent ballast water not subject to discharge.

Exemptions from the management of ballast water may be granted to ships on voyages between specified ports or operated exclusively between specified ports or locations when ballast water is not mixed other than between these ports or locations.

Many treatment systems are available on the market, using different technologies such as mechanical filtration, ultra violet lamps, oxidation, de-oxygenation (using inert gas or CO_2), electrolysis/electro-chlorination, ozonation, ultrasound and so on.

In choosing the most appropriate solution, the designer should consider the dimension of the ballast treatment system, the possible need to increase the power and dimension of diesel generators, the arrangement of new ballast lines, the increased capacity of fuel diesel oil tanks (if more powerful generators are required), the compatibility between the protective coating and the active substances that may be used by the treatment system to kill the harmful aquatic organisms.

3. Air emissions

3.1. Particulate Matters

Visible emissions, at the start of engines or when a sudden request of power is necessary, are very difficult to control and eliminate.

The black smoke, in operating conditions other than those mentioned above, may be related to the fuel quality and maintenance of engines and their exhaust.

Fuel conditioning, e.g. by means of microemulsion or ultrasound or other means, could be an answer to this problem.

International rules do not give detailed requirements in this regard. An example of a national standard (Alaskan Standard for passenger ships), reported in the following, gives a detailed regulatory framework in this respect.

Visible emissions, excluding condensed water vapor, may not reduce visibility through the exhaust effluent by more than 20 percent:

1. while at berth or at anchor, visibility may be reduced by up to 100 percent for periods aggregating no more than
   - three minutes in any one hour; and

- an additional three minute period during initial start-up of the engines;
2. during the hour immediately after casting off, visibility may be reduced under one, but not both, of the following options:
   - visibility may be reduced by up to 40 percent for that entire hour; or
   - visibility may be reduced by up to 100 percent for periods aggregating no more than nine minutes during that hour;
3. during the hour immediately before the completion of anchoring, visibility may be reduced under one, but not both, of the following options:
   - visibility may be reduced by up to 40 percent for that entire hour; or
   - visibility may be reduced by up to 100 percent for periods aggregating no more than nine minutes during that hour
4. at any time not covered by (1) - (3), visibility may be reduced by up to 100 percent for periods aggregating no more than three minutes in any one hour.

3.2. NOx

The production of NO_x depends mainly on the engine design and its operating conditions, but also on the type of fuel (for example fuel oil or LNG).

According to recent studies, 33% of NO_x comes from shipping and they are considered responsible for acid rains and euthrophication.

Their emission is presently regulated by Annex VI of MARPOL for engines installed after 2000.

New and stricter criteria for NO_x emissions came into force on 1st January 2011.

They are:

(a) lower NO_x emission limits for new engines installed after 2011;
(b) stricter NO_x emission limits for new engines installed after 2016 if they operate in the so-called ECA;
(c) introduction of NO_x emission limits for a defined range of engines installed between 1990 and 1999, for which an approved method of NO_x emission reduction has been approved (the approved method is in general a retrofit kit).

Just to have a look at the numbers, the NO_x emission limits as defined by MARPOL Annex VI are listed hereinafter:

(a) TIER I (1.1.2000 to 31.12.2010 - everywhere)
   - 17.0 [g/kWh] when *n* (number of revolutions) is less than 130 [rpm] (revolution per minute)
   - 45.0 x $n^{(-0.2)}$ [g/kWh] when *n* is 130 or more but less than 2000 rpm
   - 9.8 [g/kWh] when *n* is 2000 rpm or more
(b) TIER II (from 1.1.2011 – everywhere)
   - 14.4 [g/kWh] when *n* is less than 130 rpm;
   - 44 · $n^{(-0.23)}$ [g/kWh] when *n* is 130 or more but less than 2000 rpm;
   - 7.7 [g/kWh] when *n* is 2000 rpm or more.
(c) TIER III (from 1.1.2016 in special areas; outside still valid TIER II)

- 3.4 [g/kWh] when *n* is less than 130 rpm;
- $9 \cdot n^{(-0.2)}$ [g/kWh] when *n* is 130 or more but less than 2000 rpm; and
- 2.0 [g/kWh] when *n* is 2000 rpm or more.

With regard to existing diesel engines, having a power output of more than 5000 [kW] and a per cylinder displacement at or above 90 litres, installed on a ship constructed between 1st January 1990 and 31st December 1999, having a retrofit kit approved and commercially available, they are required to comply with TIER I NO_x emission limits.

While the gap between TIER I and II may be covered by the engine design and operational settings, without the installation of additional equipment and systems, to reach the NO_x emission limits required for ECA from 2016 and after, according to many engine manufacturers, the additional installation of equipment and systems external to the engine seems to be necessary.

Mechanisms are presently available to reduce NO_x emissions such as improved combustion, by means of specific technologies, like fuel micro-emulsion, charge air humidification, direct fuel injection, but, for a substantial reduction, as required by TIER III, Selective Catalytic Reduction devices are to be foreseen.

Thinking in global terms (and not only in gr/kWh), the adoption of energy saving and energy conservation methods is the most environmental friendly solution to put in place, the quantity of NO_x produced being (as well as that of CO_2 and SO_x) proportional to the quantity of fuel burnt.

It is generally recognized that a reduction of NO_x emissions could be achieved by reducing the combustion temperature, but this will also reduce engine efficiency with a higher fuel consumption (to get the same power from the engine) and consequently greater CO_2 emissions.

In the opinion of some engine manufacturers, the only possible solution to meet TIER III limits, in the near future, is to adopt SCR. This has a big impact on the design and arrangement of engine rooms to find the space to accommodate the new device(s) and manage the additives (required for the correct operation of the catalytic reduction system).

The impacts, at different levels, of the new technology to be adopted, in terms of space, cost, reliability, maintainability and easy conduction by the operators is still under consideration by designers, shipyards and device manufacturers.

3.3. SOx

The production of SO_x depends on the type of fuel used on board and in particular on its sulphur content.

According to recent studies, marine fuels contain an average of 27000 ppm of sulphur against the 10 ppm of fuel used in cars.

On the basis of the above numbers, general expectations of the public and media are that some improvement will be put in place.

Sulphur emission is presently regulated by Annex VI of MARPOL, by an EU directive and by national laws already in force or going to come into force in the coming years with stricter limits.

Some examples:

(a) European Union Council Directive 2005/33/EC dated 6th July 2005, from 1st January 2010, sulphur in fuels not greater than 0.1% for all types of ships at berth in European Community ports;

(c) MARPOL Annex VI requires, from 1st January 2015, sulphur in fuels not greater than 0.1% (from the actual 1%) for all types of ships, when operating in the ECA.

(d) MARPOL Annex VI requires, from 1st January 2012, sulphur in fuels not greater than 3.5% (from the actual 4.5%) and a further reduction, subject to confirmation, to 0.5% from 1st January 2020, for all other world areas.

Mechanisms are presently available to reduce SO_x emissions, without using specific low sulphur fuels, such as dry and water based type of scrubbers, in open loop (the water is taken from the sea, used for washing the exhausts and discharged, after a purification / separation process, into the sea) or in closed loop (the water is treated with additives, used for washing the exhausts, purified and processed to be ready to be reused).

The amount of space needed, the additional power required, for example in the case of open loop scrubbers, the additives necessary for the correct operation of closed loop scrubbers, the weight of the dry scrubber solutions are all aspects to be carefully considered in the design of new ships and even more in the case of retrofit works to be performed on existing ships.

Taking also into consideration the possible need to install also SCR devices, as indicated in the previous point 3.2, it seems that the design of new ships' machinery spaces will be challenging and other design choices, for example the use of LNG as fuel, may be solutions to be considered for the future.

3.4. CO_2

At a time when all the world is expected to reduce its GHG emissions into the atmosphere to mitigate global warming, there are expectations from merchant shipping to improve their performance on both new and existing ships.

Regulators are therefore considering the adoption of new mandatory instruments to control GHG emissions of the marine industry.

The world seagoing fleet is of around 90,000 vessels that have an annual fuel consumption of around 350-400 million tons of heavy fuel, which means about 1-1.2 billion tons of GHG emissions into the atmosphere (there is a direct proportionality between energy consumption and GHG emissions).

It seems a very high figure but is in fact less than 4% of the world's total GHG emissions.

Ships transport more that 90% of all goods (measured in ton-miles) but a ship produces less than 3% of GHG emissions compared to an aircraft (an aircraft produces 540 grams of CO2 for 1 ton of cargo per km, against 15 grams by ship).

On the other hand, regulators have forecast an increase in total fuel oil consumption and related GHG emissions from shipping, respectively from 370 million tons of fuel oil in 2007 to 490 million tons in 2020, and 1.1 in 2007 to 1.5 billion tons of CO_2 in 2020.

Despite promoting the innovation of technologies and efficiency gains for new ships, approximately half of the world fleet in 2020 will still be represented by ships already operating or about to be delivered.

For these reasons, regulators' expectations to reduce the carbon footprint by both new and existing ships are very high.

Such expectations, in order to enforce significant energy savings, will likely impact on:

(a) the design and construction of new ships;
(b) maintenance and operation of ships-in-service;
(c) more rational ship management and logistics strategies.

In order to achieve the goal of substantial reduction in GHG emissions from ships, the IMO's MEPC, at its 59th session, agreed to disseminate a package of interim and voluntary technical and operational measures to reduce greenhouse gas emissions from ships, as well as a work plan for further consideration of market-based instruments to provide GHG-reduction incentives for the shipping industry.

An Energy Efficiency Design Index (EEDI) has been identified as a parameter to be considered for new buildings. It will enable designers and builders to design and construct intrinsically efficient ships and will encourage ship owners to invest in energy-efficiency technologies.

The EEDI provides a figure, expressed in grams of CO_2 per ton mile that measures the attainable energy efficiency of a specific design. It enables the designer to optimize the various parameters at his disposal and provides an energy rating for the new building before it is built.

The index will, therefore, stimulate technical development of all the components influencing fuel efficiency. Through the application of this index, new buildings in the near future will have to be designed and constructed intrinsically energy-efficient.

While the formulation of the index is rather complex, in that it tries to accommodate a wide range of ship types and sizes, the concept is to evaluate the ratio between the ship's emission environmental impact and the benefit to society in terms of ship's transport capability.

The first step forward was to develop a specific baseline for every ship type (EEDI versus deadweight or capacity) and, the second step, the identification by IMO of possible future reduction targets from the baseline values.

After having calculated the Required Index on the basis of the above procedure, the Attained CO2 Index of the ship under construction shall be equal to or less than the Required Index.

The EEDI is an index for new ships and it is not to be used to evaluate the performance of existing ships in respect of their energy efficiency operation.

Two operational measures have been identified by IMO in this respect: the Ship Energy Efficiency Management Plan (SEEMP) and the Energy Efficiency Operational Indicator (EEOI)

The Ship Energy Efficiency Management Plan is a practical tool to assist ship owners and ship operators in increasing the energy efficiency of ships in operation. The purpose of the plan is to encourage application of the many fuel-saving practices currently available.

The most obvious include

(a) improved voyage planning (weather routing/just in time)
(b) speed and power optimization
(c) optimized ship handling (optimization of ballast, use of rudder and autopilot)
(d) improved fleet management
(e) improved cargo handling and
(f) on-board energy management (e.g. engine heat recovery),

to name but a few.

The Energy Efficiency Operational Indicator (EEOI) enables operators to measure the fuel efficiency of a ship in operation. Expressed in grams of CO_2 per ton mile, the indicator enables a comparison to be made between individual ships and thereby facilitates adoption of appropriate measures to reduce energy consumption. More importantly, the indicator makes it possible for operators and crews to monitor the effectiveness of any new measure applied in accordance with the SEEMP.

The EEOI has been implemented on a trial basis since 2005 and the outcome and experience obtained from hundreds of trials led MEPC 59 (July 2009) to approve MEPC.1/Circ.684.

Its structure is very simple and the result of the calculation is a number representing the quantity of CO_2 emitted per cargo unit and nautical mile.

The Guidelines for voluntary use of the ship EEOI (MEPC.1/Circ.684) establish a consistent approach to measure ships' energy-efficiency at each voyage or over a certain period of time, which will assist ship owners and ship operators in the evaluation of the operational performance of their fleet. As the amount of CO_2 emitted from ships is directly related to the consumption of bunker fuel oil, the EEOI can also provide useful information on a ship's performance with regard to fuel efficiency.

The EEOI enables continued monitoring of individual ships in operation and thereby the results of any changes made such as the effect of retrofitting a new and more efficient propeller or the introduction of just in time planning or a sophisticated weather routing system.

Market based instruments, or market based measures, are currently under discussion in IMO to supplement the technical design and operational reduction measures.

Ten proposals have recently been analysed by an IMO ad hoc Expert Group and they describe programmes that would target GHG reductions through in-sector emission reductions from shipping or out-of-sector emission reductions through the collection of funds to be used for mitigation activities in other sectors that would contribute towards the overall goal of reducing global GHG emissions.

4. Fuel saving

4.1. General

Nowadays, the words “fuel saving” are used more and more in the shipping industry.

The reasons are many and varied.

Reduction of fuel costs, which have increased incredibly in the recent past, with an expectation of further increases, compliance with ongoing and future regulations, protection of the environment, preparedness to comply with possible future IMO initiatives (i.e. Market Based Instruments).

In the fuel-saving context, two main approaches are to be considered: the design approach and the operational approach. The first, mainly related to new ships or ships undertaking significant retrofit works, the second to all ships.

4.2. Ship Design

Speaking about ship design, at least three concepts are to be considered: energy saving (save the energy you do not really need), energy conservation (do not waste available energy), alternative source (investigate whether or not a new energy source may be used on board).

Many solutions are available and are discussed under each of the above concepts: hereinafter some examples.

Energy can be saved by adopting appropriate hull forms and appendages, an air lubrication solution to reduce friction between the hull and the sea, high-performance painting (siliconic, fluor polymeric), making the correct choice of engine needed for the particular ship, installing high performance propellers, controrotating propellers, propeller inlet ducts, rudder bulbs and using high efficiency electrical users, including low consumption lights.

Energy can be conserved by reducing the waste heat or using the heat available on board to generate other power, or optimizing on-board systems such as the air-conditioning plant.

In the future, technological developments could lead to improving the contribution to the ship’s power needs from sources that nowadays, when used, supply only a small percentage of the total required power: wind, solar and other alternative sources.

Among the alternative sources, alternative fuels such as LNG, CNG and biofuels are not to be forgotten.

4.3. Ship operation

A good environmentally designed ship but badly operated does not reach the target of minimizing its impact on the sea water, on the air and more in general on the environment.

Also in this case it is useful to identify four concepts to be considered: energy saving (save the energy you do not need during ship operations), monitoring (measure important parameters: if you do not know where you are, how can you reach your target), maintenance (maintain performance) and the human factor (the most important factor to reach any target).

How to save energy during ship operations?

Among all possible choices, the following are listed only as examples:

- speed reduction and optimization,
- itinerary optimization (voyage planning),
- weather routing, etc.

.. and what to measure and monitor?

Fuel consumption, using adequate tools, sensors, computer based system;

- draft & trim, helping the master to keep the most efficient sailing;
- engine emissions, monitoring correct engine behavior.

Fuel saving is an ongoing process and is based on the continuous good performance of all systems involved. Maintenance of hull, propeller, engines and energy consumers is consequently of paramount importance.

Who is the main actor in all this operational part of the fuel saving?

Everybody on board can contribute to fuel saving. Crew environmental awareness (training) and crew motivation in respect of the ship's environmental behavior are the key factors for a successful fuel saving program.

5. RINA GREEN PLUS

In recent years RINA, Italy-based classification society, has further strengthened its commitment to environmentally friendly shipping by launching a new goal-based class notation, GREEN PLUS. The voluntary notation is based on an environmental performance index which covers all aspects of the vessel's impact on the environment, including carbon emissions.

RINA's GREEN PLUS notation has become a watchword for environmental excellence in shipping, anticipating the requirements of MARPOL and other relevant legislation, and placing owners and operators in an advantageous position. GREEN PLUS takes the process of certifying the effort to minimize ships' environmental impact one stage further. It is mainly designed for new vessels which make a significant investment in environmental friendly design solutions by introducing the use of onboard equipment, and operational procedures which contribute to an improvement in environmental performance beyond the minimum levels required by regulation.

Design solutions and onboard equipment include anything which reduces the risk of pollution, or which lowers fuel consumption and air emissions. Innovative engine design, alternative fuels, high-efficiency propellers, optimal hull design and bio-degradable oils all fall into these categories.

Operational procedures covered by a GREEN PLUS notation include those which ensure that design solutions and onboard equipment are correctly used, voyage planning programs resulting in reduced fuel consumption and emissions, or training courses designed to increase the environmental awareness of officers and crews.

The industry needs a notation which demonstrates that the ship meets public aspirations for a lower overall environmental impact. The large number of design solutions, onboard equipment, and operational procedures available in today's industry, together with the general evolution in technological development, dictate a goal-based, rather than a prescriptive, approach. That is why GREEN PLUS has been designed with sufficient in-built flexibility to allow designers the latitude to choose those tools which they deem to be most appropriate, subject to achieving an assigned value in an environmental index.

6. Conclusions

As briefly presented above, many measures to protect the marine environment are already approved and will come into force in the next few years for the reduction of NO_x, SO_x and CO_2 emissions, others are ready to enter into force as soon as they reach the required quorum of signatory flags representing the required minimum fleet tons, such as the BWM Convention.

No doubt all of them will affect the marine industry including the way to design and operate new and existing ships. Research and technological innovation will be necessary to cope with such requirements in a sustainable way.

Appendix

Nomenclature

The following abbreviations and acronyms were used:

Symbol	Definition
AFS	Harmful Anti-Fouling Systems Convention
BWM	Ballast Water Management International Convention
CFC	Chlorofluorocarbons
CNG	Compressed natural Gas
ECA	Emission Control Areas
EEDI	Energy Efficiency Design Index
EEOI	Energy Efficiency Operational Indicator
GHG	Green-House-Gases
GT	Gross Tonnage
IMO	International Maritime Organization
LNG	Liquefied Natural Gas
MARPOL	International Convention for the Prevention of Pollution from Ships as amended
MEPC	Marine Environment Protection Committee
NO_x	Nitrogen Oxides
ppm	part per million
SEEMP	Ship Energy Efficiency Management Plan
SCR	Selective Catalytic Reduction
SO_x	Sulphur Oxides
TBT	TriButylTin
VOC	Volatile Organic Compounds

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