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A Classification Perspective on the Future of Ship Design and Technology

Enrico Brina

Abstract

La cantieristica navale deve oggi affrontare nuove sfide in tema di costi di gestione delle navi e di tutela dell'ambiente marino. Crescono le dimensioni e la complessità delle navi. Il costo dei carburanti spinge alla ricerca di maggiore efficienza energetica. Le nuove tecnologie, i nuovi materiali, i combustibili alternativi giocano come fondamentali fattori di innovazione. L'evoluzione delle tecnologie configura peraltro nuove problematiche in tema di sicurezza e tutela ambientale, per rispondere alle quali il contributo degli Enti di classificazione può risultare decisivo.

1. Economic drivers and regulatory mandates: a new focus on “sustainable” vessels

New marine and offshore designs are boundary pushing. Vessels are larger, more complex and their capabilities are constantly expanding. For an example, many offshore units are designed to operate in substantially deeper waters than ever before. These designs require greater alignment between research, design, construction, operation and maintenance.

New environmental regulations and self-regulatory innovations developed by industry promise continued enhancements in ship and equipment designs. New designs should focus on protecting the environment and promoting energy efficiency without compromising safety.

Currently, the market is experiencing a rather unique merging of the commercial desires of shipowners and the more idealistic demands of regulators.

Ship-owners prefer a ship that provides optimum performance and identifiable savings on running costs especially if it can be delivered at a competitive price. Ship designers are challenged to produce a new generation of environmentally-friendly ships in support of new regulations that offer shipowners exactly the type of improved performance that they want. And as shipowners strive to establish a balance between design and operational issues that provide the desired gains in efficiency and environmental compliance, classification societies endeavor to strike a balance between supporting environmental initiatives and promoting the safety of the ships and protecting the safety of their crews.

The slowdown in ordering new ships that we are facing today will have many financial implications but from the point of view of the ship designer the slowdown offers an opportunity for the development of new designs and it creates a need for innovative technologies to improve the performance of the vessels. If we consider the evolution of marine transportation since the end of World War I, the major developments have included the introduction of specialized ship types – such as containerships, pure car/truck carriers and LNG carriers – as well as a continued increase in vessel size. There has also been much attention on hydrodynamics and structures. The developments in sea keeping and finite element analysis have enabled designers to use methods based on first principles instead of empirical formulations to analyze larger and larger structures.

Today the focus is on the energy efficiency and environmental technology. This emphasis is driven in part by new global and regional policies to limit and control emissions and discharges from ships. The other key driver is increasing fuel costs that encourage owners and operators to look for ways to reduce fuel consumption.

Given these policy and commercial drivers, we can certainly understand industry's interest in and demand for environmentally friendly and energy efficient designs. This focus on "sustainable" vessels by stakeholders throughout the industry provides us the opportunity to think creatively and to offer advances in ship design on a scale that has not been experienced in quite some time.

2. Technical and infrastructure issues and increasing vessel dimensions

In capitalizing on the economies of scale, vessels have grown in all categories – T-2 tankers to ULCCs; bulk carriers from 20,000 dwt workhorses to the 400,000 dwt ore carriers; cruise ships have gone from a few hundred passengers to floating cities of 7,000 passengers and crew; LNG carriers from 70,000 cubic meters to nearly 270,000 cubic meters; and containerships from the first generation 1,200 TEU vessels to the latest order of 18,000 TEU capacity. The development of these mega containerships offers a perfect example of new designs which leverage the economies of scale both for cost and energy efficiency.

Mega containerships should be verified by rational classification society rules augmented by first principles engineering analysis, including the following issues:

- non-linear sea loads due to hull forms with large bowflare and overhanging stern;
- slamming, stern slamming, whipping and springing;
- high stresses and deformations induced by torsional moment due in part to the larger open deck areas;
- the possibility of parametric roll which has been encountered by containerships with large bowflare and overhanging stern;
- shaft alignment taking into account hull deflections;
- vibration from 14 cylinder engines and large propellers.

While the technical issues for constructing mega containerships may be readily overcome by advanced engineering analysis, there remains infrastructure issues associated with their use. These issues have to be considered during the design stage. For example, there are a growing number of container terminals that can receive mega containerships of the size up to the Emma Maersk, the largest container vessel currently in service, with a capacity in excess of 15,000 TEU. If we are to take full advantage of the economies of scale provided by ships like the Emma Maersk, then industry collectively needs to address the limitation imposed by container terminals.

However, there are additional challenges to realize the economics of scale benefits. First, the basic commercial considerations – these large ships must receive enough cargo to transport. The vessels have to have the ability to efficiently exchange substantial numbers of containers in a single port of call. At present we find there is container congestion at some European terminals. We also need to address on-dock rail connection so that they function as a high-volume intermodal gateway. There is also the provision of having sufficient containers on a scheduled basis – for example, easy access to loaded containers in China ports. Finally, we need to have the installation of gantry cranes with sufficient outreach which is 60 m or 22 rows of on-deck containers.

3. Design challenges and energy efficiency

There are a number of design challenges that are primarily related to the energy efficiency of these mega-containerships. Examples of these design issues are:

Minimum Ballast or Ballast Free Designs: Due to unique trading patterns, large containerships have the best potential to be designed to carry minimum or no ballast water for all container loading conditions.

Minimum Fuel Consumptions: For large containerships routinely traveling over 15 knots, the latest development of new types of coatings has demonstrated promising fuel efficiency gains over conventional anti-foulings.

Optimum Positioning Protected Fuel Oil Tanks: There are design alternatives for the protection of fuel oil tanks to comply with new requirements of MARPOL Annex I Reg. 12A. The optimum solution is to be decided with due consideration to longitudinal strength and the maximum number of TEU spaces in hold and above deck.

Design for Operation Flexibility and Structural Integrity: Hull scantlings of large container carriers are significantly influenced by the design still water hogging bending moment envelope which in turn is related to the minimum ballast water carriage concept, optimum protection of fuel oil tanks and the design container loading conditions discussed above.

Maximum Container Handling Efficiency: Faster container handling time at terminals is being attempted by the industry with some mixed results. Notably the open top concept with no on-deck lashing gears required can be explored for larger containerships. Novel container stacking and control of structural deflections can be achieved. Automatic twistlock concepts should be further improved for desired handling efficiency without compromising container securing safety at sea.

System Innovations: Energy efficiency can be gained through design planning. Waste heat from exhaust gases, which is utilized to power on-board generators, can reduce fuel consumption by up to 10% for ultra large containerships. With more reefer cargoes being transported by ultra large containerships, provision of power demand for reefer container systems and layout can be made for possible future upgrade. Energy efficiency of reefer machinery can be further improved, including water-cooled reefers as these boxes are a major part of the onboard electric load. Machinery, control and monitoring systems in ultra large containerships can be greatly automated for a smaller complement. As the accommodation block can be 12 stories high, ergonomics and crew habitability are part of essential design principles.

Broadening the view of achieving energy efficiency across multiple ship types, we will find that energy efficiency can be divided into design efficiency and operational efficiency.

Design efficiency will determine the baseline for the performance of the ship and therefore is extremely important. In simple terms the design efficiency can be improved by maximizing the cargo carried and by minimizing the energy used. IMO has developed a comparative measurement for design efficiency – the Energy Efficiency Design Index (EEDI). IMO's objective is to stimulate innovation and increase the energy efficiency of new ship designs. The Index provides a measurable method to express the CO2 emissions by Installed Power x Specific Fuel Consumption x Conversion from fuel burned to CO2 emitted in relation to the ship's cargo carrying capacity such as ton-miles or capacity multiplied by speed. The basic concept is that a future ship's EEDI has to be equal to or less than a reference EEDI value. Since this is a design target, it is intended for new ships. The EEDI is only a measurement of the efficiency in one condition which may or may not be an actual operating condition of the vessel.

The ship's efficiency can be improved by:

- reducing energy losses (engine, hull, propeller);
- reducing speed which reduces power;
- increasing capacity without increasing required power;
- developing innovative technology (for example wind and solar power).

The "biggest losers": engine losses and hull resistance can provide the best opportunity for future improvements. In reality, however, every improvement counts and should not be neglected. Machinery losses for the containership and tanker amount to half the total and this energy loss is primarily associated with waste heat. Energy losses associated with the hull represented about a third of the total and they are generally tied to various forms of resistance.

The propeller continues to be a focus for energy efficiency improvements and the use of advanced computational fluid dynamics or CFD has become a tool to improve propeller efficiency. CFD enables designers to study the wake quality and the proportion of different losses – axial, rotational and frictional – which then allows the designer to select and analyze corrective actions.

CFD has become a standard tool for designers who want to optimize the hull form or the propeller design and its use will only increase in the future.

The reduction in hull frictional resistance is another area of continuous study. Some promising areas of research and development include:

- new low friction coatings;
- surface technologies which create a virtual air cushion effect around the hull;
- air lubrication by various methods.

4. New technologies, materials and alternative fuels as innovation factors

There are many exciting new technologies that are under development and may have future applications for ships, such as the use of nano-engineering for surfaces and coatings. Nano-coating technology is based on the property of "super-hydrophobicity" – which means the ability to repel water. This was first studied in connection with the so-called lotus leaf effect. Nano technology is the study of the controlling of matter on an atomic and molecular level. It is basically "molecular manufacturing."

Another promising area of research is the application of sensor technology for ship navigation. It is possible that the ships of the future may follow favorable currents to minimize their energy use. Carbon capture, which is already used in land-based applications, may also be feasible on board ships if we strive to develop zero-emission ships.

A large part of the main engine's energy is lost through waste heat in the exhaust and elsewhere within the propulsion system. Capturing and using that waste heat provides another potential application of nano-technology. Nano-engineered surfaces have the ability to significantly enhance heat transfer. Enhancements in phase-change heat transfer can be achieved by nano-engineering that causes increased nucleation rates of a liquid or vapor passing through pipes or across a surface.

These new concepts have strong possibilities for application within new high-efficiency heat exchangers, boilers, evaporators and condensers, including marine heat exchangers.

Virtually every aspect of the ship's design, machinery and outfitting has the potential to contribute towards greater energy efficiency.

One aspect, if it can be shown to be cost effective and structurally sound, is the application of high-strength, lightweight materials within the design. The aim is to maintain or increase the strength of the ship structure while reducing the overall weight. These materials are characterized by higher strength but with reduced ductility. Although these steels offer unique capabilities to the design of high strength, light weight ship structures, characterizing their mechanical and fracture properties is essential for their safe use.

In particular, the lower ductility necessitates a thorough fracture analysis of the structure.

Containerships have been the test laboratory for these steels, particularly their application in the high stress areas around the hatch corners of large containerships. Steels of 460 MPa yield strength, commonly called H47 steel and of up to 80 mm thickness are now being used. This need for the newer high strength steels can be expected as the design of containerships continues to grow in size.

Composites are another lightweight material that holds promise for much wider application on future ships.

Composites have been around in the commercial sector and in the aerospace industry for many years.

Recreational watercraft and patrol boats are manufactured almost exclusively of composites as well as automobiles and now even large commercial jet aircraft have a high composite ratio. Traditional recreational watercraft composites are typically a combination of a fiberglass woven reinforcing material impregnated with a polyester liquid resin, a material usually referred to as Fiber Reinforced Plastic or FRP. However, there are many new marine composites being developed consisting of more advanced materials for both the reinforcing material and the resin, which change the chemistry and mechanical characteristics of the composite, making it more appropriate for ship applications. It is also possible to think of some of the new sandwich plate approaches that use two thin steel plates with a sandwich core as another method for using composites to retain strength while reducing weight. Some of the advantages of composites include favorable corrosion resistance and strength to weight ratio, good fatigue life, mostly nonmagnetic properties, the ability to take on complex geometries, thermal insulation and sound dampening.

An alternative way to reduce CO2 emissions from ships is to use alternative, cleaner, fuels. Alternatives being discussed include LNG, nuclear, fuel cells, bio fuel, solar and wind. The technology is available and tested for LNG in dual fuel engines for gas carriers and the nuclear alternative is being used on navy vessels and some arctic ice breakers. For social and political reasons nuclear will have difficulties of being accepted on commercials ships whereas the LNG option is already been implemented on commercial ships.

So far we have discussed design efficiency but operational considerations for energy efficiency are extremely important for ships in service. There are a number of measures that can be taken to improve efficiency such as voyage optimization, resistance management, machinery optimization and cargo handling optimization.

Each one of these categories includes options to implement depending on the operational profile of the vessel.

Monitoring is an important part of managing operational efficiency and many owners are installing monitoring systems on board their vessels to collect and analyze operational data. Some systems allow this data to be transferred to the office where an owner can have a “mission control center” to monitor the fleet performance.

New technology may be employed in the future in various monitoring activities. For example, the monitoring of a ship’s condition for resistance management could use advanced technology such as Autonomous Underwater Vehicles (AUV). The increased capabilities offered by AUVs with smart sensors and advanced software and hardware has the potential to vastly increase their usefulness in conducting underwater inspections of the hull and carrying out much more effective hull cleaning and propeller polishing.

The energy efficiency issues we have reviewed so far – both the design and operational elements – are also relevant to discussion with stakeholders that are more interested in the environmental performance of a vessel.

A major environmental issue that we have yet to address but is paramount to ship designs of the future is ballast water management. The ballast water and sediments carried by ships has been identified as a pathway for the transport of harmful aquatic organisms and pathogens. Ballast water and sediments taken in one port contain living organisms which, despite the harsh conditions in the ballast tanks and piping systems, survive to compete with native species in the port of discharge. If the non-native organisms have few natural predators or other natural controls and if they are established in sufficient numbers they can become invasive and change the local eco systems, which may impact the economy of the area, sometimes dramatically. In the short term, the solution is to use ballast water exchange and ballast water treatment which will be mandated by the IMO Ballast Water Management Convention and by several regional regulations. Ballast water treatment technology is still evolving and future developments are expected to improve the performance and safety of these systems.

A ballast-free ship is not a new idea. However the concept has never been developed beyond a drawing board. Regulatory and economic incentives may make this technology a reality in the future.

We have discussed design trends which are primarily being driven by commercial considerations and regulatory mandates. Owners and operators are seeking to maximize commercial returns while at the same time conducting their operations in a safe and environmentally sensitive manner.

5. Technological advances and classification

While technological advancements are generally viewed as positive, there can be consequences. As such, we must always recognize that with technological advances we may implicitly or explicitly trade off one risk for another.

This is the area in which classification plays a vital role. Class is able to offer the necessary assistance to operators venturing past the frontier and we can validate novel concepts that will be used in these literally uncharted waters. Class is able to assist the industry transform complicated risk pictures resulting from breakthrough technologies into quantifiable and systematic solutions that address structural and mechanical integrity management requirements without compromising the need for protecting safety and the environment.

It has been the evolution of Classification Rules, driven by the development of new technologies that has provided the industry with safety and environmental alternatives that reduce the overall risk.

Safety must be built on the foundation of historical experience, on analytical methods, on knowledge and on judgment. It must be grounded in the principles of risk and must be integrated and aligned throughout the entire life cycle of a project.

Safety can no longer be implied – it must be understood.

There is no question that:

- there will be more efficient power trains using alternative fuels;
- progress will be made in surface chemistry;
- a new generation of smart sensors will create the capacity for active flow manipulations for optimum performance management;
- there will be a new generation of design tools based on CFD and risk-based decision-making.

These will characterize the professional world of the naval architects of the future and leave their marks on the designs of the future – your designs of the future.

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Enrico Brina
Manager of Engineering
ABS Italy srl
Via Al Porto Antico
16128 Genova
e-mail: ebrina @ eagle.org