Journal of Sustainability Science and Management 2010 Volume 5 (1): 138-150

EFFICIENT SHIPS: SOME PRESENT TRENDS AND PRACTICES

RAJOO BALAJI *1, SAHARUDDIN HAMID[2]

[1]*ALAM, P O Box 29, Wakaf Tengah, 21030, Kuala Terengganu, Malaysia.*
[2]*Faculty of Maritime Studies and Marine Science, Universiti Malaysia Terengganu, 21030, Kuala Terengganu, Malaysia.*

**Corresponding author: rajoobalaji@alam.edu.my*

Introduction

Shipping business trends have generally been cyclic, given the high debt-to-equity ratio of the business. After facing a low, shipping has looked up in the beginning of this century and is reaching new highs. The last decade of the twentieth century witnessed incidents and issues having greater bearing on shipping, particularly in safety and performance optimisation. Since the oil crisis of the seventies in the last century and considering the share of fuel in operating costs going up to 70-75%, the focus has been on fuel efficiency. Also, technological advancement has been trying to keep pace with stricter environmental laws. With rising costs and competition, shipping companies are compelled to reinvent better management techniques. It is imperative such factors are looked at from time to time. The Paper has attempted to highlight some trends of recent decades in ship building, ship's equipment and ship operations. Table1 highlights some advantages for the ship-owner with the current trends.

Table 1. Some General Trends and Advantages

Trends	Reasons
-Shaft Generators -Medium-Speed Engines	-Generators' ratings reduced -Installed power reduced -Increased cargo capacity - Savings in installation costs/ building
-Thrusters -Controllable-Pitch Propellers	-Tug requirements reduced -Better manoeuvrability -Savings in tug charges
-Propulsion Redundancy	-Better reliability, so lesser premiums on insurance
-Heavy Fuel Oil (HFO) for main and auxiliary engines -Manoeuvring on HFO -Load/Sulphur-dependant cylinder lubrication methods	-Diesel oil consumption reduced -Cylinder lube oil consumptions reduced -Savings in lube oil costs
-Engines with lower NOx emissions -Use of low-Sulphur fuels	-Port Incentives

Review of Trends

Ship construction by modules has been in practice for a long time. However, use of computational software has been overwhelmingly adopted in the last two decades only. Scrapping and recycling have developed as supportive industries in the same period. Corrosion is still the major issue, though many exotic materials are being tried out.

Trends in Ship Construction

Propeller and hull designs have been optimised with modern tools such as Computer-Aided Design (CAD) and Computational Fluid Dynamics (CFD). An experienced designer can optimise propeller and rudder, optimise the hull (hard points, dimensions, hull form) with the modern design tools and the gains on building costs and operations can vary from 3-25% (Friesch, 2007). Large ships require less fuel in transporting a unit of cargo and they can be moved faster for the same fuel usage. The method of building a large ship from many separate blocks has increased productivity and highly-evolved software which streamline designing processes, have resulted in lower costs and faster vessel deliveries. Figure 1 shows an award-winning modern liquefied natural gas (LNG) tanker for Samsung Heavy Industries designed with modern software tools. The vessel, apart from being built to gas tanker construction standards, has a design fatigue life of a minimum of 40 years.

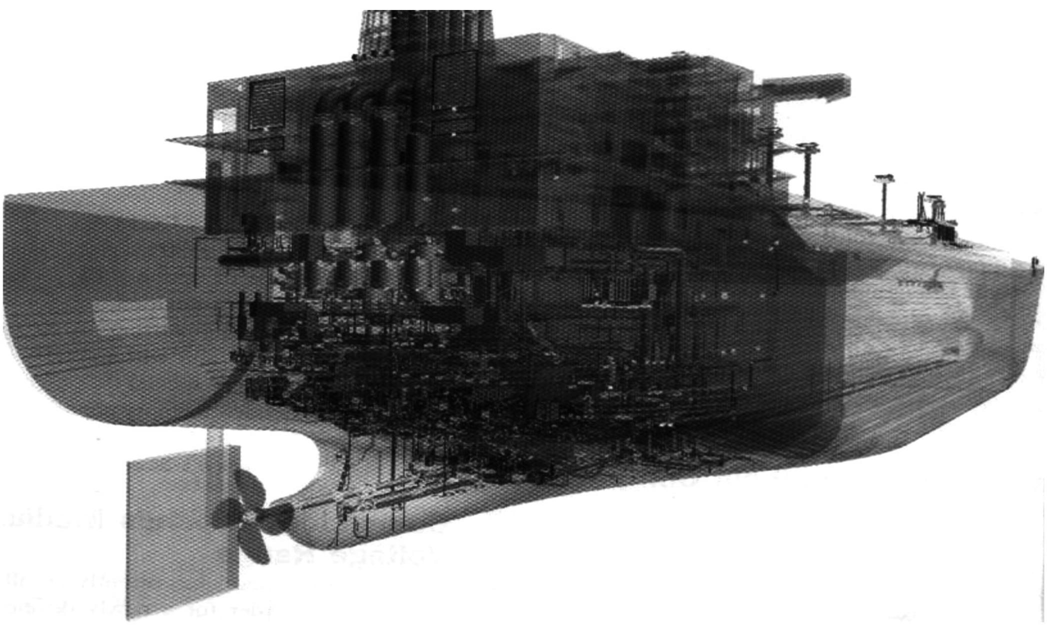

Figure 1 LNG Carrier design using modern software, Smart Marine 3D
(Source: Marine Reporter 2007)

Table 2 shows the cost allocation for a very large crude carrier (VLCC) being built in a major Japanese or Korean shipyard. Steel prices have shown an increase of more than US$100 last year and the costs of new ships have been on the rise. Labour costs depend on shipyards but can be assumed to have remained steady. The overall trend shows increasing prices for ships. Tanker prices have shown a steady increase, as can be seen from Table 3 which projects average figures for the last 4 years.

Table 2. Ship Building Costs Allocation (Source: McQuilling Services 2008)

Estimated Prices	**2002 US$65million**		**2008 US$150 million**	
	%	**$M**	**%**	**$M**
Materials	**46.0%**	**30.0**	**50.0%**	**75.0**
Steel	18.5%	12.0	27.0%	40.0
Main Machinery,	18.5%	12.0	15.0%	23.0
Equipment & Auxiliaries	9.0%	6.0	8.0%	12.0
Piping, Painting etc.,				
Labour	**46.0%**	**30.0**	**22.0%**	**32.5**
General Expenses & Administration	**8.0%**	**5.0**	**6.0%**	**9.0**
Overheads & facilities	6.4%	4.0	4.7%	7.0
Commissions	1.0%	0.6	1.0%	1.5
Design	0.6%	0.4	0.3%	0.5
Profit	0%	0.0	22%	33.5
Total	**100%**	**65.0**	**100%**	**150.0**

Table 3. Cost of Tankers (Source: Poten & Partners 2008)

Vessel Price Assessments $M						
All new builds	**2008 March**	**2008 Avg.**	**1 year ago**	**2007 Avg.**	**2006 Avg.**	**2005 Avg.**
VLCC	149.0	147.5	130.0	135.9	124.1	120.8
Suezmax	91.0	90.1	81.5	84.7	76.3	74.1
Aframax	73.0	72.8	66.0	68.1	63.1	61.4
Panamax	67.0	64.8	54.0	56.1	53.1	51.4
Handymax (coated)	52.0	52	47.0	49.1	45.8	46.8

With Common Structural Rules (CSR) in place, eventually, while all tankers will be double hulled, lessening the danger of large spills, other traditional vessel types of bulk carriers and container vessels also will have similar structure. Corrosion in such builds is a matter of concern because of the extra steel. For corrosion prevention, anodes have been employed in ballast-water spaces, but their effectiveness depends on immersion of the metallic surfaces and amount of time after filling. The effectiveness rating being about 70%, coatings have been the next recourse. Coatings being expensive, a method getting notice is de-oxygenation (removal of oxygen, the primary corrosion promoter) by venturi-oxygen-stripping. Already installed on actively-trading ships, the system mixes low-oxygen inert gas produced by a typical inert-gas generator with incoming ballast and inerting the tanks while deballasting. The oxygen reduction is good enough to avoid oxygen-based corrosion and also suppress the growth of Sulphate-Reducing Bacteria (SRB), which is another source of corrosion.

On the construction materials front, Titanium usage is increasing, particularly in high-flow and corrosive systems such as sea-water systems and heat exchangers. Teflon (Poly Tetra Flouro Ethylene) and Tufnol (Poly Ether Ether Ketone) have found wider applications in gaskets, packing and bearings. Ceramics and ceramic-metal composites are finding application in engine components. Plasma-coated piston rings, satellite and nimonic alloy valves have improved the life of components. Propellers, shafts and military ship hulls are being built with carbon fibre entirely. Yet it may be said that employment of composites on large vessels has remained limited to auxiliary applications rather than hull.

Trends in Machinery Design

Machinery design trends may be grouped under two broad categories of main propulsion: engines and auxiliaries. In both groups, diesel engines have been intensely focussed upon, since the majority of the prime movers have been diesel engines. Other auxiliaries include all other shipboard supportive systems.

Engines

The general trends have been towards increased compression ratio, delayed timing, adapted exhaust-valve timing and redesigned combustion components, which are measures aiming not only to meet standards for emissions but also to increase power-to-weight ratios and hence the fuel efficiencies. Figure 2 displays the increased trends in piston speeds and mean pressures. Both medium and slow-speed marine diesel engines are employing electronics not only for monitoring but also for controls, such as fuel injection and timing variation etc.

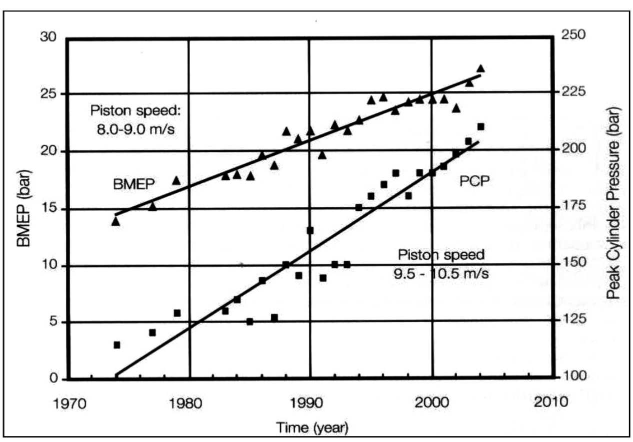

Figure 2. Trends in Peak and Mean Effective Pressures-Medium-Speed Engines (Source: Marine Propulsion & Auxiliary Dec2007/Jan2008)

Structural components have undergone few basic changes. Hydraulically/pneumatically-operated exhaust valves with variable timing are being employed on large engines. Exhaust-valve thermal distortion has been overcome by employing mechanisms which rotate the valve, thus maintaining an even temperature of the valve.

In a typical diesel engine, the heat losses in the exhaust stream can be pegged at 30-32% and modern systems are registering a recovery of about 50% of this loss. This augments the overall efficiency to about 55-60%. Steam generation by placing an exhaust gas economiser in the path of the exhaust gases is an existing concept for recovering this waste heat. The limitations to such recoveries have been the lower limit of temperatures resulting in greater corrosion, size of plants, control of evaporation, fire risks and, most importantly, the amortisation period. New approaches are trying to maximise this recovery with improvements on the engine side.

Air intake to turbochargers, if drawn from outside the engine room rather than from inside as found in conventional systems, will result in lower air-intake temperatures. The turbochargers are matched for this lower intake temperature, thereby increasing the exhaust energy. Internal bearing designs, better blade and impeller materials and swept-back blade design are some design changes effected in turbochargers. The modern turbochargers have about 10% excess energy at higher engine-operating range and this is being utilised for electrical power generation (Knudsen, 2007). Two-stage gas entry controls, nozzle ring with adjustable vanes and secondary fuel-burning are some other innovations being applied to turbochargers.

Cylinder lubrication methods are based on loads and sulphur content of fuels. Optimised dosage and innovated injection principles such as Alpha Lubrication of M/s MAN B&W and Swirl Injection Principle of M/s Hans Jensen have resulted in consumption being lowered to 0.5-1.0g/bhph levels.

On the vibration front, hydraulic engine bracings, compensators and dampers incorporated in flywheels are being employed. The Variable Injection Timing (VIT control) of fuel injection has reduced Specific Fuel Consumption (SFC) levels considerably.

Dual-Fuel Diesel Engines (DFDE) are a recent development targeting the LNG carriers followed by the cruise ships. Combined with higher efficiencies of the diesel engine and cleaner burning option for the Boil-off Gas (BoG), the dual-fuel engines may edge out the conventional steam turbines. Though cost of DFDE systems are at 2-4% over the conventional steam-turbine systems, efficiency is higher by roughly 10% over the traditional system and the consumption also is considerably lowered by nearly 20%. Time between overhauls is expected to become wider and with redundancies offered in models, operations are expected to be smooth.

On the propulsion front, electric propulsion has emerged on passenger ships and is getting extended to LNG vessels. Traditional steam propulsion has rather been the mainstay for LNG vessels while other type of vessels have relied mostly on slow-speed diesel engines which are better suited and more efficient than the steam plants. The naval ships, on the other hand, have seen a combination of options- the COmbined Diesel Or Gas Turbine (CODOG), COmbined Diesel And Gas Turbine (CODAG), COmbined Gas Turbine And Gas Turbine (COGAG) and COmbined Diesel eLectric And Gas Turbine (CODLAG). These employments on military applications have found good favour in the preceding decades. Use of wind sails combined with engine power is also on trial.

Auxiliaries

Amongst other shipboard machineries, separators with purifier-clarifier combined machines accommodating dirtier oils and better centrifugal time phase have achieved lesser particle-size separation and optimal flow rates.

Bio-fouling of sea-water systems is a perennial problem and growth-prevention systems are proving to be effective. Chemical systems have found good usage, but numbers of electrolytic systems are on the increase. The simpler method of current being fed to anodes mounted on sea-chests and strainers which will produce enough ions preventing the larvae from settling is found to be environment friendly. High-capacity hydraulic, motor-driven centrifugal pumps and magnetic motor-pump couplings with no mechanical connection are finding their way on board. Designs of auxiliary machinery have focussed on longer fatigue life, environmental friendliness and less power consumption.

Trends in Ship Operations

Operational Research, computing methods and machines are offering better maintenance, spares inventory and data solutions. On the Malaysian front, the Malaysian shipping major, MISC Berhad has initiated capability-building measures, aimed primarily at reducing the operating costs, particularly on the fuel outgoings. Voyage planning with emphasis on optimised routing, slower speeds wherever possible and adaptive steering control are some initiated measures.

During sea passages, vessels stay on course with control from auto-pilot mechanisms and constant corrections by rudder increase fuel consumption. By adapting a steering control which delays such corrections and allowing time for self adjustment of the vessel, fuel savings have been realised. In long-term approaches, propeller boss-cap fin polishing (removal of marine growth) at regular intervals while the vessel is afloat is being included in maintenance schedules in addition to dry-dock cleansing of hulls.

The Planned Maintenance Schedules have undergone a review. Based on a risk-based matrix, jobs are classified and, accordingly, the period between maintenance overhauls is widened. The critical nature of a job is determined by the dimension of a vessel's experience i.e., number of machinery failures/malfunctions. This approach has added a few jobs but a considerable reduction of unproductive routine jobs which amounts to almost two-thirds of the planned listing, is viewed as a worthy trade-off. About a dozen vessels were put under a pilot study prior to wider adaptation by the fleet.

A saving potential of 4-12% in terms of fuel consumption in voyage management alone has been sighted. Employment of boil-off gas (BoG) on the LNG vessels yielded about 1.5% and extended use of heavy-fuel oils (HFO) on the diesel engines increased savings by 1-4%. In optimising use of diesel generators, 3-10% savings are being claimed. The benchmarks in these approaches has been the operational figures but if the fuel consumption figures are brought closer to the manufacturer's recommendation and industry averages, the savings might get substantial.

Reliability Centred Maintenance concepts supported on computers have been proposed earlier with emphasis on condition-based maintenance rather than being repair-based. Automated data acquisition, reporting and supportive administrative functions for information flow are typical characteristics of such systems (Rasmussen, 1996). Such systems have become a regular feature on most of the vessels.

Condition-monitoring solutions are on the rise. On-board and on-shore drip-oil analysers for lubricating oils with parameter ranges, including base number, catalytic fines and zinc levels, are being used which optimise oil consumption. Satellite-based monitoring systems have appeared the cruise liner Queen Mary 2 being installed with one which provides real-time feedback on levels of vibration, temperature and oil quantity from the podded propellers to both on-board and on-shore monitoring stations. Hand-held crankshaft deflection gauges, improved in-situ probes for measuring bearing wear, piston ring wear are a few modern maintenance tools available. Engine performance-monitoring software may soon become a regular feature on ships.

Cold Ironing or alternative maritime power supply is a concept aiming to reduce emissions. During the port stay, ships shut down their engines and power is provided from shore facilities. The advantages cited are the almost zero levels of SOx & NOx, reduced dry particulate matter (DPM) emissions, improvement in air quality, reduction in noise and availability of ship's machines for maintenance/inspection. The cost comparison for the ship owner will be between employments of cleaner fuel, such as Marine Gas Oil, to the shore power. Presently, such practices are sighted largely in US ports and some European ports.

Anti-fouling paints used in the last few decades released toxins to kill and ward off the marine organisms from attaching to the hull. Further, these toxins enter food chains by contaminating estuaries and coastal waters. The destructive effect on the marine organisms and virtual wipe-out of species has resulted in the ban on the use of Self-Polishing Copolymers-Tri-Butyl Tin (SPC-TBT)-based paints on ships' hulls. Less toxic alternatives, such as silicone-based paints and Flouropolymers, are being employed. The paint roughness has also been reduced to 65-75 microns which is lesser than that of a self-polishing anti-fouling point which is about 125 microns. Fuels savings of about 4.4 – 7.1% while employing silicon-flouropolymer paints have been reported (Willsher, 2007).

The BoG from LNG carriers could only be burnt in boilers but now the capability has been developed for diesel engines. In 2000, ferries and similar vessels with electric thrusters appeared where, power is provided from pure gas-engine generator sets. The use of LNG as regular fuel is finding favour on passenger ships. The limitations which may be cited are provision for storage and bunkering of LNG which presently is costlier considering an equivalent diesel engine burning heavy oil, development of gas engines and safety/risk components. LNG supply-chain economics based on pipeline-gas price, liquefaction & distribution might improve LNG competitiveness to marine gas oil (MGO), even as the price of crude oil increases (Einang, 2007). This assumes significance with regulations lowering the limit of Sulphur content in fuels.

Other emerging areas could be in alternate and synthetic fuels (e.g., di-methyl ether), vegetable oils, and already-advancing bio-fuel technologies. Nuclear, solar and wind energies may find more research in future. Port infrastructure is another developing area. With containerisation trends, port infrastructure and connectivity by rail/road have increased and the logistics front has been witnessing a lot of growth.

Influence of Environmental Issues

Though oil pollution was the reason for marine pollution (MARPOL) regulations, pollution from other forms has also come under the purview. Table 4 displays the present-day ship-sourced pollution hazards. Trends show more activity on the air-pollution front.

Table 4. Ship-sourced Pollution

Air	CO_2, CO, SOx, NOx, Particulate matter, VOCs (Volatile Organic Chemicals), CFCs (Chloro-Flouro Carbons)
Water	Solids (Garbage) Sewage Ballast (Contaminated & transferred with aliens) Bilge Cargo, Bunkers & Accidental discharges/spills Pollutants from anti-fouling paints

Table 5 projects the estimated amounts of harmful emissions from ships. With respect to greenhouse gases like CO_2, it is estimated that shipping generates about 1.4-1.8% of global CO_2 emissions (Holtbecker, 2007). The greater problem is the absorption of CO_2 by the oceans.

The trend has been to enforce stricter regulations while technological solutions are tried out. Table 6 illustrates the methods in practice and where further research is also going on. Trends indicate two main air emission-reducing approaches: design changes to machines and treatment of resultant gases.

A concentrated global effort on air emission control is the High Efficiency R&D on Combustion with Ultra-Low emissions for Ships (HERCULES) Project. This project, involving the major engine manufacturers, equipment manufacturers, institutions and shipping companies, has completed the first stage. Table 7 illustrates the objective and the targets as the multinational cooperative research project enters the second phase.

Some engine innovations of this project include boosting of effective pressures, turbochargers with variable-flow area and multistage, water injection, exhaust-gas recirculation, exhaust gas after treatment with plasma/scrubbers, improved sensors/methods for emission measurement, low-friction engines and innovative control systems.

Table 5. Emissions from Ships (1990 Figures) (Holtbecker, 2007)

Pollutant	**Estimated Amounts**	**Share in Global Emissions (Yearly)**
Sulphur	4.5-6.5 Million Tons	4.0 %
Nitrous Oxides	5.0 Million Tons	7.0 %
CFCs	3000-6000 Tons	1-3 %
Halons	300-400 Tons	10.0 %

Table 6. Air Pollution-Control Methodologies

Air Pollutant	Control Methods
NOx	- Modifications in combustion process Miller Process: Inlet valve open for longer period, Charge air pressure higher but temperature lowered, NOx reduced - FWE: Fuel water emulsion created by physical mixing and homogenising is injected. Combustion temperature peaks are reduced, NOx lowered - Direct Water Injection: Water is injected directly into combustion chamber resulting in lower temperatures & NOX reduction - Humid Air Motor (HAM):Humidification of scavenge air achieving a high percentage of NOx reduction - Selective Catalytic Reduction (SCR): Generation of Ammonia from Urea and injection into exhaust gas before passing through a catalyst unit reduces NOx while Nitrogen & water result as innocuous products - Exhaust Gas Recirculation: Part of exhaust gas (about 15%) is mixed with scavenge air
SOx	- Fuels with sulphur content not more than 1.5% are presently employed in Sulphur Emission Control Areas - DeSOx Scrubbers: Sea water spraying into exhaust gases washing out SOx gases and also the natural alkalinity of sea water countering the acidity of the sulphurous gases
CO_2	- Better combustion components design & Sequestration
CFC, Halons, VOCs	- Phase out the usage, employ alternate refrigerants, - VOC: Recovery Systems are being tried out
Soot & Smoke	- Modifications in combustion process: Common Rail Injection & free selection of injection timing & pressure, independent of load/speed - Fuel Oil Quality Standards: ISO 8217 Standards - Electro-Static Precipitators (ESP), Mechanical Filters, Scrubber Systems

Table 7. HERCULES Project: Comparison of Targets (Source: Marine Engineers Review, Oct 2007)

Objective	Best Available Technology In Service BAT-IS (2003)	2007 Targets	2010 Targets
Reduction of fuel consumption and CO_2 emissions	2-stroke: 170g/kWh (SFC) 4-stroke: 175g/kWh (SFC) IMO 2000 limits (g/kWh)	-1%	-3%
Reduction of NOx (Relative to IMO2000 standards)	17 g/kWh N<130rpm 45 g/kWh 130<N<2000rpm 9.8 g/kWh N>2000rpm (N=Revolutions Per Minute, rpm)	-20%	-30%
Reduction of other emission components (Particulate Matter, Hydro-Carbons)	No limits for marine engines Visible smoke limit FSN 1.1 Opacity 20% (FSN=Fire Smoke Number)	-5%	-20%
Improvement in engine reliability	18000 hours to overhaul of major components	+10%	+20%
Reduction of time to market	5 years	-10%	-15%
Reduction in lifecycle cost -Initial cost -Fuel/Lube-oil cost -Maintenance	Costs depend on engine size	0% -4% -3%	-1% -1% -6%

On the water-pollution front, the latest issue is that of ballast water. The shift of ballast water by the global fleet has been displacing species also and this is causing an ecological imbalance. One simple method being practiced is exchange of ballast water, but it is an additional, time-consuming procedure. Further, such an exchange during voyages depends on sea and weather conditions and it may not be possible to carry out the exchange at all times. Moreover, residual density of first-ballast organisms dilutes the effectiveness of the process. Many other methods are being developed, including treatment with biocides to minute filtration systems. It is reported that demonstrations on toxicity of natural biocides with active ingredient Vitamin K, which occurs naturally in mammals, plants, bacteria & fungi, on aquatic species have been very low and a very low dosage can treat ballast water to International Maritime Organisation (IMO) standards. Such products are starting to find usage on board (MER, 2007). A latest method being tested is to allow water-flow through trunks extending over the length of the ship during the ballast passage, thus providing the weight. The open flow ensures a continuous change of ballast water, avoiding retention of species. On reaching port, sluice valves shut off the trunks and water is pumped out.

Pollution by oils has been a perennial threat to the oceans. The effectiveness of traditional oily-water separators have been improved with filtration and coalescing systems. Modern sewage systems of aerobic or anaerobic types have become regulation machineries on board.

The other pollutant to water is the ship-generated garbage. The Academy of Sciences of the United States of America estimates the garbage dumping into oceans at about 6.4 million tons per year of which 5.6 million tons are dumped by merchant ships. Incineration has been the conventional solution but with limitations on plastic burning, waste-heat recovery and air pollution.

Noise and vibration, generally referred to as non-mass environmental loads, have also been getting attention. Use of barrier composites, gas engines, reduction of internal noise mechanisms to reduce noise levels and, particularly on passenger ships, the concept of ‘comfort class’ assignment have been in reckoning. Designs have been targeting and achieving levels below IMO limits of <110dB in engine rooms.

On the security front, regulatory practices and training has been the major contributors since security became an issue only in the last decade. Infra-red detectors and electrified fencing on ships are finding usage on some passenger ships.

Future Trends and Issues

On the construction front, building costs are likely to come down as economic slow-down would erode booking orders. The trend of over-booking will also reverse as speculative orders dry up. Present global ship-building capacities appear to be insufficient. Ironically, many European yards have closed down also. This has largely been due to the low-cost options available in the Chinese and Korean yards. Yards with a long-standing history will position themselves for specialised builds, leaving en mass building to the emerging Asian yards.

With the trend towards double-hull construction, the structural steel surface area of the ballast tanks is increased considerably and so are the dynamic loads. On a casual comparison, a single hull VLCC will have about 40000 m^2 of ballast tank area, while a similar double-hull VLCC will have about 200000 m^2. With increase in dynamic loading, the anti-corrosive tank-coatings crack and breakdown faster. The approximate steel wastage on continuously-submerged steel is approximately 0.1-0.2mm/year and ballast-water spaces have higher corrosion rates. Trends show that ballast-water tank repair costs have been significant during dry docking of double-hull vessels.

The real benefits for the environment might be lost if we consider the extra cost on raw materials and emissions from welding and painting. Some real issues of double-hull adaptation will show up only in the coming years. Steel is a crucial cost component driving the prices upwards but the reversal might occur sooner with large additional building capacities being generated.

On the engine front, Brake Specific Fuel Consumption (BSFC) has shown a reduction of over 19% in the last four decades, further reductions being restricted by laws of physics. The DFDE and dual-fuel technologies will be assessed for maintenance costs and operational problems only in the coming years. Alternative energy resources are likely to get greater attention. Wave and wind energy realisations have been showing better adaptability for electrical-power generation. Even with depleting petroleum resources, diesel engines might still remain the best option for propulsive power generation. The trends, however, will be towards fuel efficiency and environmentally least-harming engine research. Use of electronics and subsequent sophistication are likely to continue.

The engine sophistication has already impacted the industry. There have been accidents when ship-board personnel were unable to respond in time for engine problems. The need for specialised training has been addressed by many manufactures and other institutes such as B&W, Wartsila NSD, Framo, Lloyds Maritime Academy etc. These trends are likely to continue, but curriculum changes will follow with the revision of the STCW (Standards for Training, Certification & Watch-keeping). This aspect bears directly with ship operation.

While ship operations target cost effectiveness and profitability, worrisome trends can be noticed on the human factors front. The concept of Unmanned Machinery Spaces (UMS) is favoured by many ship-owners as an effective cost-control measure. This trend continues. Another shift in ship operations is the deployment of riding squads for major maintenance, while the regular ship's staff does the skeletal maintenance. The detrimental effects of this trend include dilution of quality amongst ship's staff and the repercussions of short-manning. Short-manning, fatigue and personnel brought on board from quick and short training programmes are real issues the industry is facing which will be beyond the scope of the present context.

Development of ports and other infrastructure requires land. The pressures have telling effect on underground water and deforestation. Emission-control methods are yet to be proven for long-term applications. Investigations on design, endurance, economy and effects on engine performance and ecological impact are areas getting closer attention. Another factor coming under emission-control is the Volatile Organic Chemical (VOC) emissions from crude carriers which occur while loading, carriage and while discharging where solutions have not been widely adopted.

Refining changes and conversion processes have resulted in poor quality of HFO (Rulf, 2007). The push towards greater production of distillate fuels has resulted in refineries increasing the thermal and catalytic-conversion units. This has aggravated related operational problems. Denser heavy-oils usage certainly is economical but is proving to be troublesome in terms of purification and engine condition. Bunker-monitoring systems, onboard blenders etc., to bring in better fuel compatibility are already in employment but the trend has been towards deterioration of fuel quality. The latest move by IMO is projected in Table 8. The move aims at controlling the air-pollution levels but the cost and demand for distillate fuels will result in phenomenal increase in ship running costs.

Supply of such refined petroleum to meet the heavy demands of marine engines is an issue which could be a worrying factor. The industry responses have been largely speculative. There will definitely be a serious shift of focus on how the production of petroleum products will measure up to the demands.

Table 8. IMO Initiatives on Fuels to Reduce Air Pollution

Year	Sulphur Limits in Fuel Oils	Remarks
March, 2010	1% Sulphur cap in ECAs	Only Marine Diesel Oil (MDO) can have this reduced Sulphur (HFO with 1% Sulphur will be very costly and difficult to procure)
2012	3.5% Sulphur cap in areas other than ECAs	Use of HFO will continue for a while
2015	0.1% Sulphur cap in ECAs	Only MGO can have this reduced Sulphur (MDO can possibly be as low as 0.5%)
2020	Global cap of 0.5% Sulphur in fuel oils	Ships will run on MDO in open seas and burn MGO in ECAs (Emission Control Areas)

Conclusion

Innovations and improvements have touched all aspects of shipping from small crafts to large carriers. Better profitability is the reason for the drive towards improvements in engine and equipment designs. Trends indicate that fuels and environment have been the influencing factors in design changes, whereas operational issues have been influenced by costs. The future trends might not be much different.

Sustainability of the planet depends on energy resources. Energy and environment will be influencing factors for any industry. Shipping, being a supportive industry, will also depend on these. Construction, machinery design and ship operations will base their correction measures on these factors only. While the world races to find new energy sources, the degradation of the environment from earlier and existing sources continues. The innovators must remember this, and the future quests must address the environmental concerns, making the efforts comprehensive.

References

Einang, Per Magne. (2007). A Gaseous Solution, MER Propulsion 2007, abridged version of Paper presented in 2007 CIMAC Congress, Vienna, pp.53.

Friesch Jürgen, Hollenbach Uwe Dr. (2007). Efficient Hull Forms-What can be gained? STG Conference on Ship Efficiency, *1st International Conference*, Hamburg.

Holtbecker Rudolf. (2007). *Emission control*, two-strokes, MER 2007 Digest, Based on Paper by David Brown *et al.,* pp.20.

Knudsen Thomas S. (2007). Exhaust gas for power generation, How efficient are the state-of-the-art methods? STG Conference on Ship Efficiency,*1st International Conference*, Hamburg.

Marine Reporter. (October 2007). pp.52.

MER September. (2007). *Ballast water treatment*: Alien Invaders-nowhere to hide, pp.33.

Rasmussen M, Moen H. (1996). The role of information technology for reduction of maintenance cost, ICMES 96, paper 14, Vol 108, 4, IMarE Conference, Safe and Efficient Ships: New Approaches for Design, Operation and Maintenance, pps. 85 - 91.

Rulf Ing Dr. (2007). Marine fuel oils-problems and alternatives, STG Conference on Ship Efficiency, *1st International Conference*, Hamburg.

Schlemmer-Kelling, Ing Udo Dr. (2007). The Environmentally-friendly medium speed engine, CIMAC 2007, Marine Propulsion & auxiliary machinery, Dec-Jan 2007, pp.33. Tankers, New Building Prices, No.5, 6 Mar 2008, McQuilling Services, pp.1. Weekly Marine Project Report, (7 Mar 2008). Poten & Partners, pp.3.

Willsher, John. (2007).The Effect of biocide free foul release systems on vessel performance, STG Conference on Ship Efficiency, *1st International Conference, Hamburg.*