ENERGY EFFICIENT SHIP OPERATION

SHIP-BOARD ENERGY MANAGEMENT

Ship-board Energy Efficiency Measures in Brief:

Optimized ship handling
- Optimized trim
- Optimized ballast
- Optimum use of rudder and autopilot

Optimized propulsion condition
- Optimized hull
- Clean propellers
- Optimized main engines

Optimized auxiliary systems and machinery
- Fuel management
- Boilers and steam system
- Maintenance for energy efficiency
- Engines and machinery load and utilisation management

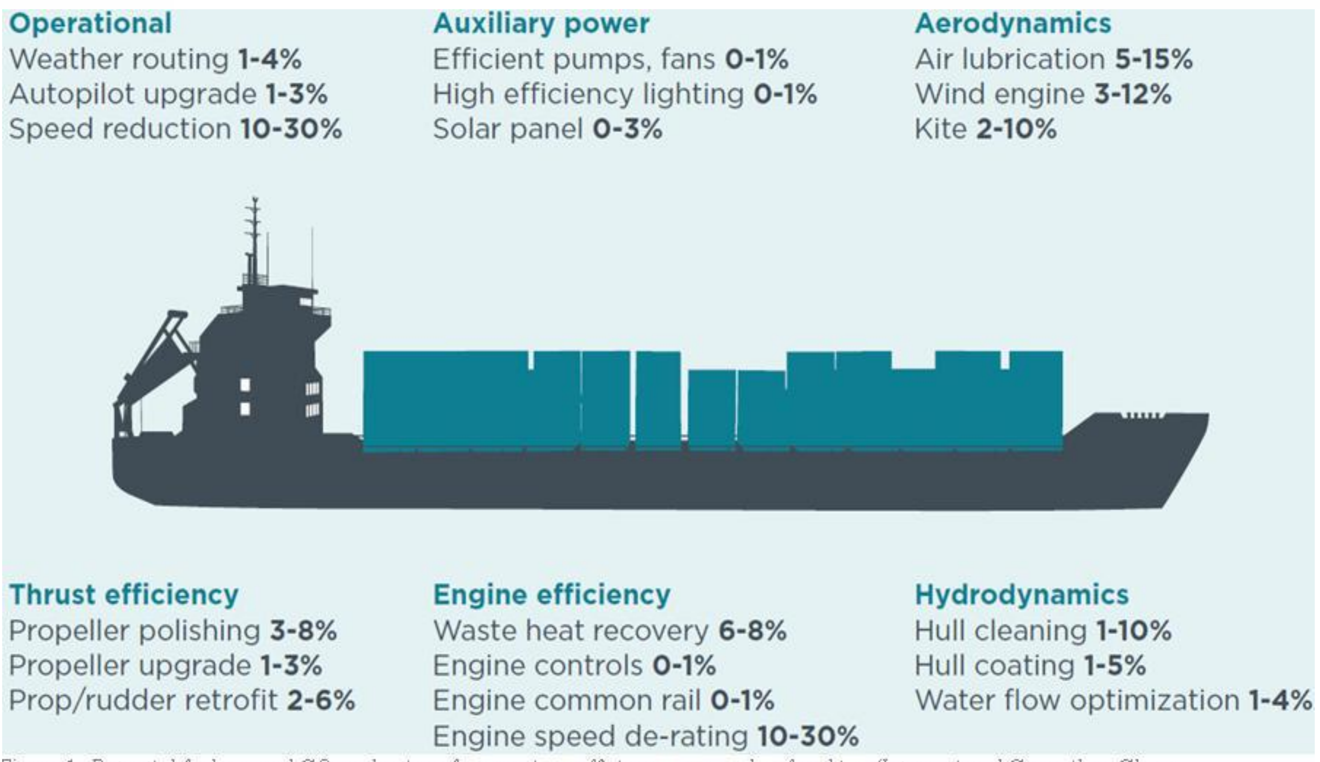


Figure 1: *Potential fuel use and CO_2 reductions from various efficiency approaches for ships (International Council on Clean Transportation (ICCT, July 2013). Long-term potential for increased shipping efficiency through the adoption of industry-leading practices.*

Role of Ship-Board Personnel

- **Master:** Most effective role on ship energy efficiency though ship operations and personnel management.
- **Chief Officer:** Significant roles on energy management via the cargo and loading operations, ballast and trim optimisation and aspects of hull and propeller maintenance.
- **Chief Engineer:** Significant roles on all technical issues including engines, boilers and auxiliaries.
- **Second Engineer:** Very effective role on energy management as the most engaged person in the day to day engine room including maintenance activities.

Deck & Engine Room Communications

Good communication between deck and engine departments is essential for all aspects of energy efficiency including cargo operation and machinery use optimisation.

Hull Fouling and Cleaning

Hull fouling and roughness could increase the ship fuel consumption dramatically. Regular in-service cleaning is beneficial if damage to coating is avoided. Regular cleaning of macro-fouling is highly recommended. For partial cleaning, the priorities are with the forward third of hull and areas that have more exposure to light.

For best results, the scheduling of cleaning should be based either on performance monitoring or on regular under-water inspections. Regular inspection, photographs and roughness measurements would be a prudent way to monitor the impact of cleaning and the condition of the coating.

Hull Fouling Rate

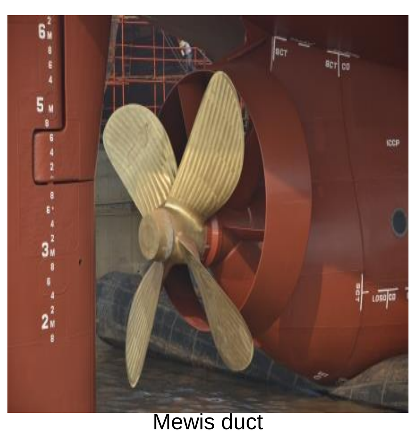
The rate of increase in hull fouling and roughness depends on a number of factors including:

- Initial roughness of the hull
- Quality of hull coating and its resistance to mechanical damage
- Sea water temperature and sunlight
- The salinity of the water and amount of algae in the water
- Ship speed and its operation profile
- Hull maintenance

Propeller Aspects

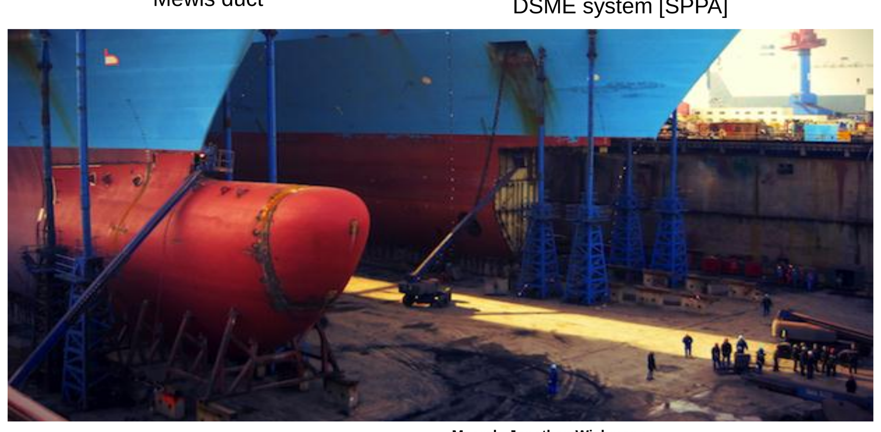
Similar to the hull surface, propellers suffer degradation in performance due to surface roughness that could be due to corrosion and cavitation erosion and impingement attack or normal wear and tear. Improper maintenance can also increase roughness.

Propeller polishing reduces mainly propeller's frictional losses but also its rotational losses. Polishing a roughened propeller surface may result in a fuel saving of up to 3%. Cleaning and polishing of propeller is a cost effective energy efficiency measure.

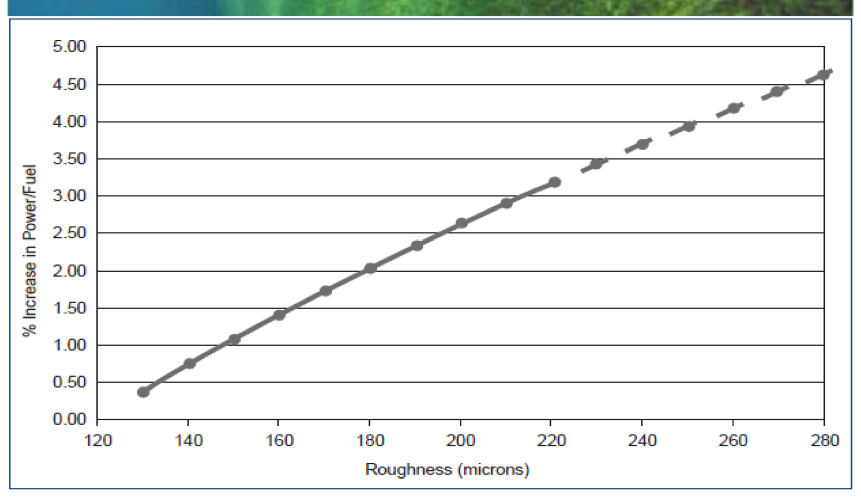


Mewis duct

DSME system [SPPA]



Maersk, Jonathan Wichmann

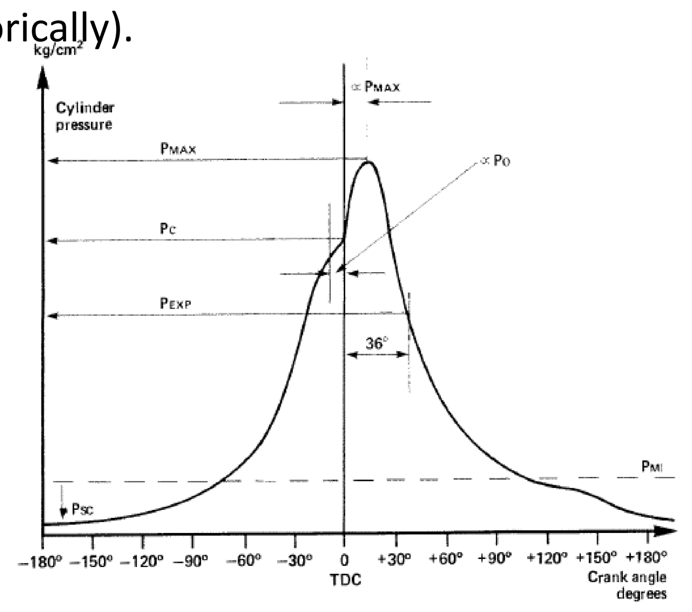


International Paint

Hull fouling and roughness have significant impact on ship resistance

Engines' Condition Monitoring

This is a technique that has been extensively used by shipping industry to safeguard the engines from damage via identifying early signs of engine's anomalies. Engine condition monitoring mainly relies on measurement and analysis of cylinder pressure diagram (or "indicator diagram" as commonly known historically).



Lower than expected cylinder pressure generally means that engine settings are not optimal or its components may be faulty. In practice, other engine process parameters such as pressures, temperatures, turbocharger speed, etc. are monitored to support the above analysis.

Technical Upgrade and Retrofit

There are a good number of "Energy Efficient Technologies (EETs)" that are cost-effective for application to existing ships and could lead to ship-board energy saving. These are devices that could be used:

- **Forward of the propellers** such as various forms of ducts or fixed stators/fins to shape flow into the propellers
- **Aft of the propellers** such as Propeller Boss Cap Fins and efficiency rudders
- **Ship fore body** optimisation such a bulbous bow replacement;
- **Machinery upgrade** such as use of variable speed drives, high efficiency electric motors, etc.

Trim Optimisation

Trim influences ship fuel consumption significantly via changes to ship resistance, with evidence showing that up to 4% savings is feasible via trim optimisation. To optimise trim, the following should be noted:

- The optimum trim is a function of ship speed and draft.
- For certain ship types in particular those with higher speeds, slimmer body, pronounced bulbous bow and flat stern, trim will have more impact.
- Optimal trim is difficult to determine and is established either through extensive model testing or CFD analytical methods.

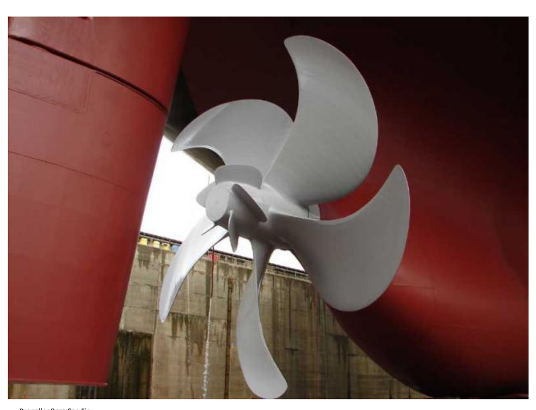
To achieve optimal trim, due consideration should be given to ship loading and its load planning. Operationally, ballast water and to some extent bunker fuel may be used to trim the vessel.

Steam System Energy Efficiency Measures

Steam generation (boiler)
- Boiler fouling on the water and gas sides should be avoided
- Boiler excess air should be minimised for optimal value to reduce exhaust waste heat.
- Starting of auxiliary boilers too far in advance of intended use is to be avoided.
- Maximise the use of economiser in place of auxiliary boilers.

Steam distribution system:
- Steam pipes/valves/boilers insulation to be kept in good condition
- Steam leaks are to be identified and stopped.
- Steam trap maintenance should be carried out regularly.

Steam end-use reduction:
- Fuel temperature in storage tanks, settling ad supply tanks shall be kept at acceptable lower levels
- Cargo tank heating to be based on cargo specification and avoid overheating.
- Optimise the use of steam-driven machinery such as steam-driven cargo pumps, steam driven ballast pumps , HVAC system and so on; where applicable.

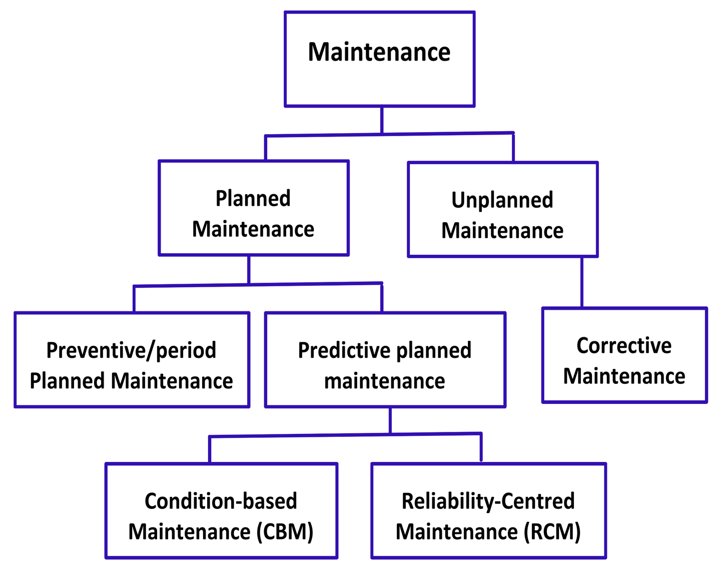


Propeller Boss Cap Fin

Importance of Maintenance

Good maintenance is fundamental for ship energy efficient operation. In particular, good condition of **hull, propeller and engines** are essential for the purpose as indicated on this page. Additionally, other areas of maintenance with secondary impacts include:

- **Steam system maintenance:** For methods, see other texts on this page.
- **Compressed air system:** Air leaks prevention, excessive end-use air consumption reduction, optimal condition of air compressors
- **Mechanical transmission systems:** Shaft and couplings alignment , v-belt slippage reduction, chain and gear alignment, proper bearing lubrication



Auxiliary Engines' Load and Utilization Management

On-board ships, normally two diesel generators are operated for long periods. This leads to engine operation at low load factor; thus causes extra fuel consumption and more maintenance.

The periods for which these conditions are sustained can include:

- All discharge ports;
- Standby periods;
- Tank cleaning periods, if applicable;
- Movement in restricted waters and ballast exchange periods.

A practical method for establishing if engine load is properly managed is through estimation of their load factor or utilisation factor . Benchmarking of this information could indicate if engines are used optimally. Methods to reduce two-engines simultaneous operations are:

- System planning for reduction of electrical load, thus switch off one engine.
- Use of "Power Management System (PMS)" to reduce the use of two engines at low loads each.

Auxiliary Machinery Utilization Management

Operation of multi-machinery systems with a view to avoid extensive parallel operations provides not only opportunities for energy saving but also reduced need for maintenance. This can be done via reducing idling mode of operation, minimisation of the none-productive hours of operation and avoidance of the late turn-off and early turn-on. Additionally, ship-board work planning to reduce the machinery use is another effective method.

Estimation of the machinery "utilisation factor", derived from machinery run hours, will show if a machinery has been over-used unnecessarily.