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MariEMS Learning Material – Technical Upgrade and Retrofit

This is the 7th compilation by Professor Dr Reza Ziarati on the work of the EU funded Erasmus + MariEMS' partners and material researched by Chief Engineer Mohammed Haque. The material is composed from Chapter 12 of the learning material.

12. Technical Upgrade and Retrofit

One effective way of improving the energy efficiency of a ship is to upgrade ship-board technologies to more energy efficient ones. Upgrading of technologies is not a ship-board activity but nevertheless, the ship-board staff could always engage in proposing such technologies. For this reason, this topic is covered under this chapter.

A number of technology upgrades can be considered for energy efficiency. It should be noted that applicability of such technologies will depend on ship type, ship size, operation profile and other factors. Thus the decision making for each technology will need to go through the normal process of technical feasibility aspects and economic cost-effectiveness analysis for the specific ship that is under consideration. The technologies described here only shows a good sample, but the list is not comprehensive as there are other potential technologies that may be included.

12.1 Devices forward of Propeller

12.1.1 Mewis Duct

The Mewis Duct developed by Becker Marine System and other similar devices are designed for installation forward of the propeller as appendages. They have successfully been adapted for the larger scale commercial vessel. **Figure 12.1.1** shows such devices.

Figure 12.1.1 – Mewis Duct [Becker Marine Systems]

Since its introduction to the market in 2010, the Mewis Duct has gained acceptance by both ship owners and ship builders. A large number of vessels of the order of few hundreds are currently fitted with this sort of duct. They are mainly used on tankers and high block coefficient ships.

It is claimed that the Mewis Duct produces energy saving through three major impacts:

- **Wake field equalisation:** The installed duct straightens and accelerates the hull's wake into the propeller and also produces a net forward thrust.
- **Reduction of propeller hub vortex:** An improved flow behind the duct significantly reduces the propeller hub vortex with corresponding thrust deduction, leading to improved thrust and better inflow to the rudder.
- **Contra-rotating swirl:** Due to individually placed fins, a pre-swirl in counter direction could be generated, reducing the rotational flow losses of the propeller.

The way it improves the propeller efficiency is via a better streamlined and directed flow into the propeller thus reduces the propeller losses. The level of energy saving is claimed to be about up to 8%; however this maximum potential may be applicable to certain ship types and designs. The potential saving for each vessel will depend on a number of factors and thus any decision should be made on a ship-specific basis after performing a good deal of ship hydrodynamic analysis and model tests.

12.1.2 Wake-equalising duct

The wake-equalizing duct consists of one half-ring duct with foil-type sections attached on each side of the after body forward of the propeller (see **Figure 12.1.2**). The half-ring duct accelerates the flow into the propeller in the upper quadrant on each side and retards the flow in the lower quadrants. This results in a more homogeneous wake field in front of the propeller, while the average wake is almost unaltered. The improved power consumption that is obtained from well-designed wake-equalizing ducts can be attributed to the following:

a. Improved efficiency because of more axial flow and a more homogeneous wake field;

b. Reduced resistance because of reduced flow separation at the after body;

c. Orientation of duct axes so that the inflow to the propeller is given a small pre-rotation;

d. Improved steering, due to straightened flow over the rudder and more lateral area aft.

Similar to Mewis Duct, it is placed to the fore of the propeller with the aim of accelerating water in-flows. This device is ideally suited to vessels with full hull forms (such as tankers) and containers operating at lower speeds (under 19 knots).

Figure 12.1.2 – Typical wake equalising duct [Scheneekluth]

12.1.3 Pre-swirl stator

These are stators located at the fore of propellers as shown in **Figure 12.1.3**; acting like guide vanes for the flow into the propeller. The aim of guide vanes is to eliminate or reduce the cross-flow that is often observed in front of the propeller. These vanes are fitted in front of the propeller on both sides of the sternpost. The vanes straighten the flow in the boundary layer in front of the propeller, thereby improving its efficiency. Cross-flow appears mostly in ships with stern bulbs and full hull forms that operate at relatively low speed. The benefit is therefore largest for tankers and bulk carriers. The improvement decreases with decreasing fullness of the hull form.

Thus pre-swirl stators (guide vanes) aim to provide a favourable pre-rotation of the water flow into the propeller. They are alternatives to ducts as explained above.

[Fathom]

DSME system [SPPA]

Figure 12.1.3 – Pre-swirl stator

As shown in **Figure 12.1.3**, in general:

- This arrangement enhances propeller efficiency via fitting of the bladed stators on the hull immediately forward of the propeller.
- The stator improves propeller efficiency via better adjusting the flow into propeller as the same happens in in normal pumps with guide vanes.

- A gain of 4% in propulsion power is claimed by proper tuning of stator blade angle.
- Better cavitation performance and supress of cavitation generated pressure pulses on the propeller is the other advantage.

As with the ducts, the device is especially suitable for the larger ships and hull forms. Its first installation on a 320,000 DWT VLCC has resulted in a 4% reduction in fuel consumption with more installations afterwards.

12.2 Devices Aft of Propeller

The propeller operation involves flow losses that appear at the rear of the propeller in the form of axial flows and rotational flows. The typical levels of such losses are shown in **Figure 12.2** These flow losses mostly appear in the slipstream at the back of the propeller.

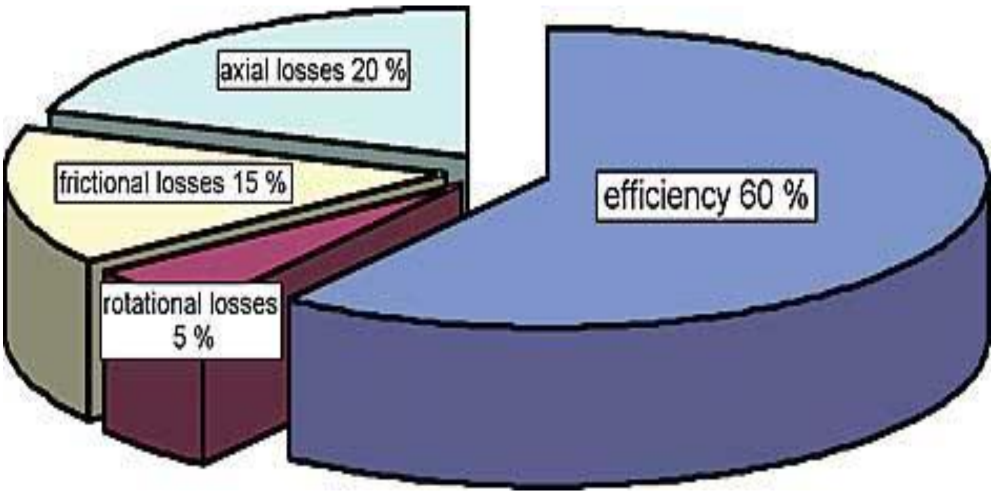


Figure 12.2 – Typical propeller efficiency and losses

There are devices that can be placed at the aft of the propeller to recover some of the lost energy thus increase the overall efficiency of the propeller. These devices are normally cost effective as a retrofit option with a short payback period, provided they are fitted correctly. A number of devices belong to this category. Some of them involve modifications to the rudder. The most important among these devices are described below.

12.2.1 Propeller Boss Cap Fin (PBCF)

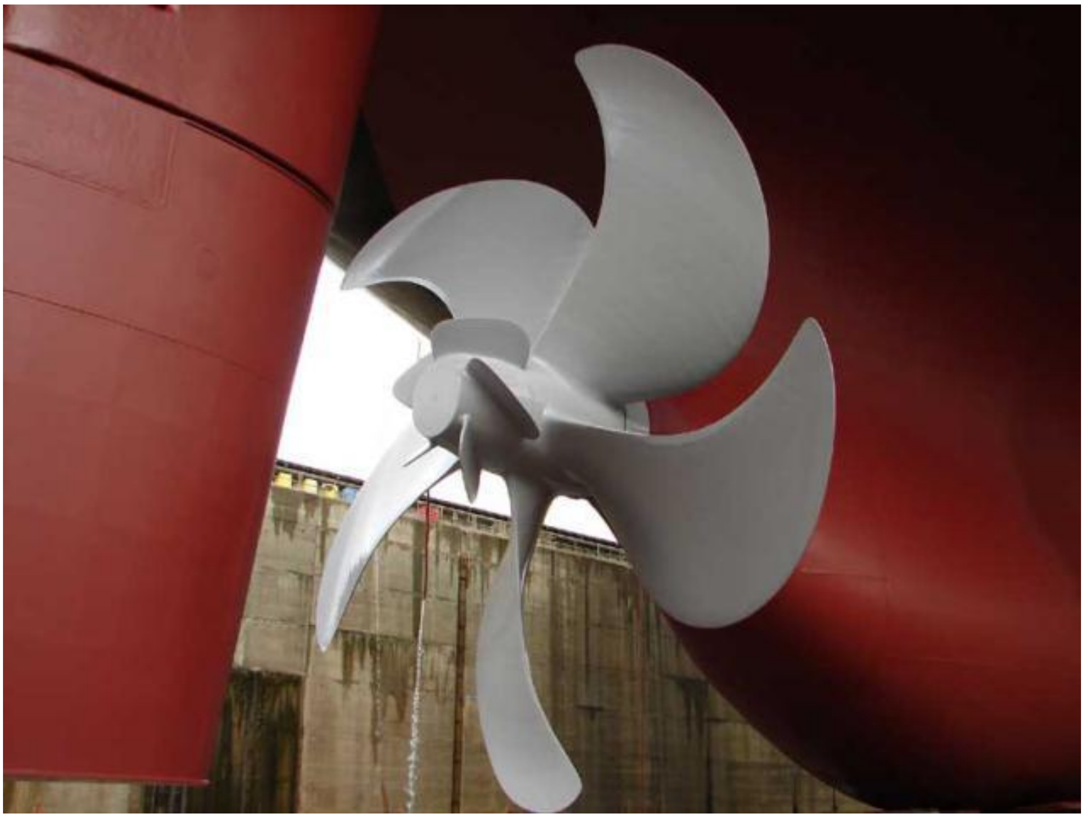
One of such devices is the Propeller Boss Cap Fin (PBCF) (see **Figure 12.2.1**) that can be added to the propeller's rear in place of the normal boss cap. This performs the function of recapturing some of the rotational energy lost by the propeller.

PBCF consists of small fins attached to the propeller cap. It was first developed and manufactured at the end of 1980s and so far has had some few thousands installed on ships worldwide. Therefore, there is significant experience with this device. The PBCF is relatively low-cost and non-complicated additions to a propulsion system. The return on investment of one year or so has been claimed and with installation time of only few days without the need to dry-dock.

The following are to a large extend the agreed benefits of using such a device:

- PBCF eliminates or reduces the hub vortices generated. As a result, PBCF can play an important role in reducing propeller generated noise and vibration.

- It is suitable for slow speed vessel.
- PBCF boost propulsive efficiency by about 5% and ship fuel efficiency by about 2%.
- PBCF can be retrofit easily to an existing ship.



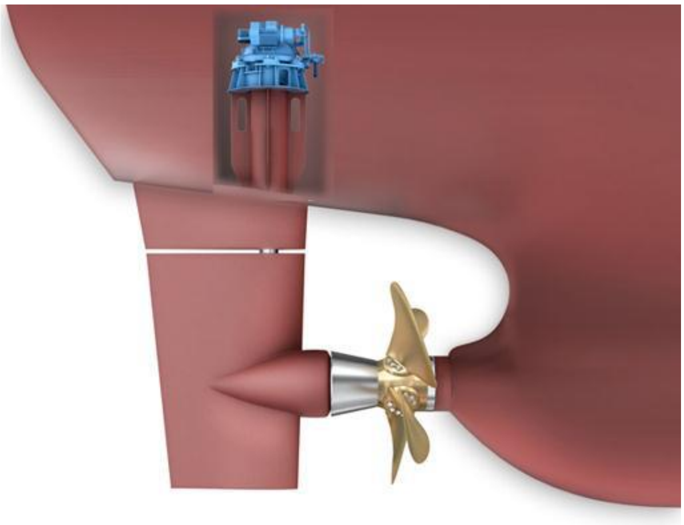
[Fathom]

[MOL Techno-Trade]

Figure 12.2.1 – PBCF at the back of propeller

12.2.2 Integrated propeller and rudder units

As the name implies, the propeller and rudder are designed as an integral unit. Part of the design is a bulb behind the propeller that is fitted to match similar configuration on the rudder. There are a few patented designs for such an arrangement (see **Figure 12.2.2** as main examples). The effect of these units has been reasonably well documented in tests on models and in full-scale trials. A reduction of about of 5% in required power of the vessel for design speed can by typical savings. The units are applicable to general cargo vessels, RoPax vessels and container vessels operating at relatively high speed. As with all other devices that impact ship hydrodynamic and resistances, the choice must be done after significant flow analysis and testing as the claimed savings are not universal. However, the potential for such a savings always exists for certain ship types and sizes.



Promas efficiency rudder [Ship Technology]

[VICUSdt 2015]

Figure 12.2.2 - Integrate propeller rudder

12.3 Ducted Propeller

The ducted propellers, as the name implies, refer to a two-component propulsor consisting of a propeller located inside a nozzle (duct) as shown in **Figure 12.3.1**.

[Chatterjee 2012]

Kort Nozzle [FathomShipping 2012]

Figure 12.3.1 - Ducted propeller

Compared to the conventional propeller of the same diameter and thrust, the ducted propeller arrangement allows a larger mass of water to be supplied to the propeller, improving the operating conditions around the propeller, thus its improved efficiency leads to corresponding potential for reduced power and fuel used by the ship propulsion.

Although, the reported benefits claim of the range of 5–20% is generally high, similar to Mewis Duct, it may have significant positive impact on certain ship types and designs. On the negative side, use of additional appendix in the form of a duct will increase the skin frictions thus flow resistances. Additionally, ducted propellers are prone to fouling of the system that may lose some of the advantages. As a result, there may be more need for propeller and duct underwater cleaning. This is regarded as one of their main weaknesses.

Ducted propellers are suited for ships operating at high propeller loadings, such as tankers, bulk carriers, tugs and different offshore supply and service vessels. The advantages of the ducted propellers in addition to fuel efficiency, could also include aspects such as reduction of propeller cavitation, vibrations and noise, better manoeuvrability if used with azimuthing thrusters and more safety for the propeller for example in ice operation or while grounding.

12.4 fore-Body Optimisation and Bulbous Bow

Fore-body optimization includes consideration of the bulb design, waterline entrance and so on. The reason is that when a ship sails, the fore-body generates waves. These waves then hit the front side and increase the ship resistance and thus required power. The faster the ship sails, the more is the wave making resistance and the more energy it needs to overcome the waves.

A properly designed bulbous bow thus reduces wave resistance by producing its own wave system that is out of phase with the bow wave from the hull, creating a cancelling effect and overall reduction in wave making resistance (the concept is shown in **Figure 12.4.1**). A bulbous bow works best at a certain speed range and is sensitive to ship draft as well. If the ship sails at a different speed and draft ranges than the ones the bulbous bow is designed for, the bulbous bow has no, or in the worst cases even a negative effect.

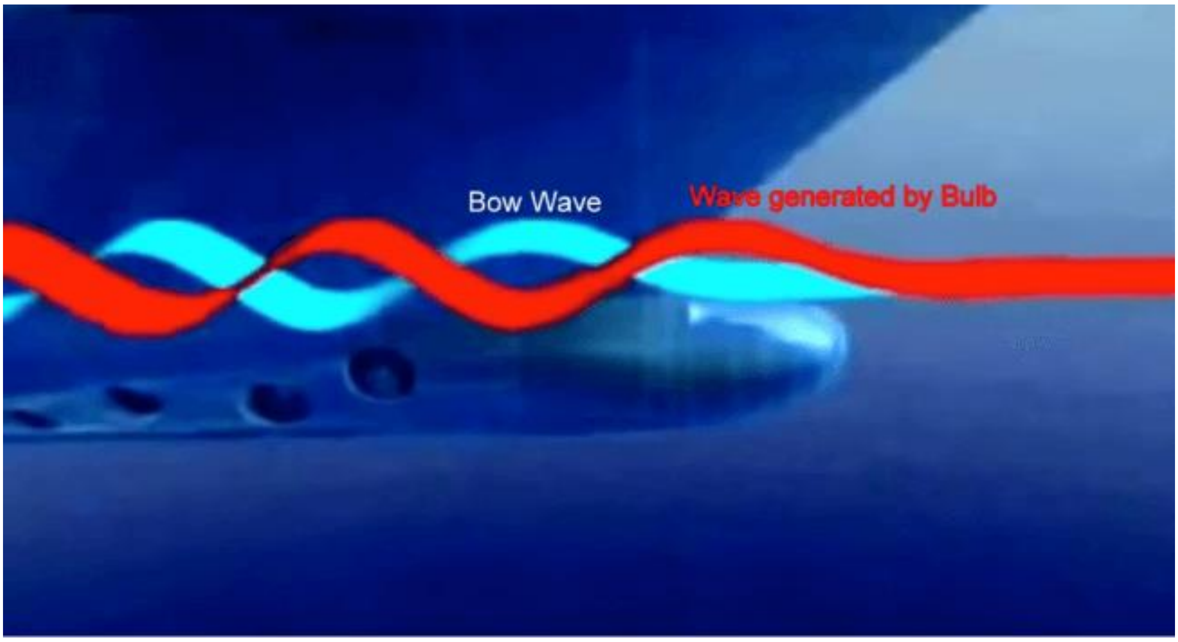


Figure 12.4.1 – Concept of bow waves and bulb waves that cancel each other [http://www.marineinsight.com/naval-architecture/why-do-ships-have-bulbous-bow/]

Design of the bulbous bow involves significant level of flow and hydrodynamic analysis. A bulb with a reverse pear shaped section is primarily effective at the design condition; pear-shaped bulbs work best for drafts below the design draft (i.e. ballast draft or partial load draft) and cylindrical shaped bulbs offer a compromise solution [ABS 2013].

A V-shape may be introduced at the base of the bulb to mitigate slamming impact loads. Faster and more slender vessels favour larger volume and forward extension of the bulb (more pronounced bulbs). Fuller ships such as tankers and bulk carriers are often arranged with bulbs having a large section area and V-shaped entrance, such that it behaves as a traditional bulb at loaded draft and acts to extend the waterline length at ballast draft [ABS 2013].

Commercial vessels normally do not operate solely at the design draft, thus, compromises in the bulb design are needed to provide good performance over the expected range of operating drafts and speeds. Depending on operation profile of a ship, retrofitting a new bulbous bow could be quite attractive from energy efficiency point of view. Maersk Lines has reported fuel savings of over 5% by modifying the bulbous bow from the original shipyard design that was optimized to the design draft [Jonathan Wichmann]. This change took place because of the reduction in operating speed of the vessels relative to their design speed for slow steaming. This provided more favourable performance over the anticipated actual operating profile compared to design assumptions.

Retrofit of bulbous bow simply involves the cutting off of the old one and replacing it with the new design. This takes place in shipyard and during dry dock (sees **Figure 12.4.2**). As mentioned, this has practiced by major liner operators due to the need for changes to ship operation profile.

Figure 12.4.2 – Bulbous bulb retrofit on Maersk ships [Jonathan Wichmann]

12.5 Waste Heat Recovery

Waste heat recovery can be carried out to produce hot water, steam or electricity from the hot exhaust gases or hot water from engine cooling systems. The main candidate areas of waste heat recovery are from exhaust of the engines where the temperature is high. Also, low grade heat recovery from engine cooling system is possible and need to be considered for specific ship applications.

Exhaust gas economisers are the usual waste heat recovery system currently used on many ships. This is a shipbuilding issue and not subject to retrofit. Also, more sophisticated exhaust gas steam system with steam turbine is used in larger ships; this is not normally a subject of retrofit but mostly applicable to new buildings. For ships in operation, the scope for extra heat recovery needs to be reviewed, and generally if lower grade heat is needed on-board, then waste heat recovery system could be used.

12.6 Auxiliary Machinery and Systems

12.6.1 High efficiency electric motors

Electric motors are not 100% energy efficient but generally have energy efficiency that could be anything from 75% to 95%. Thus choice of energy efficient electric motors for a ship will make energy saving over the long term. These days, there are standards for energy rating of electric motor and efforts are made to make these motors more energy efficient. **Figure 12.6.1** shows an example of rating practiced by Europe.

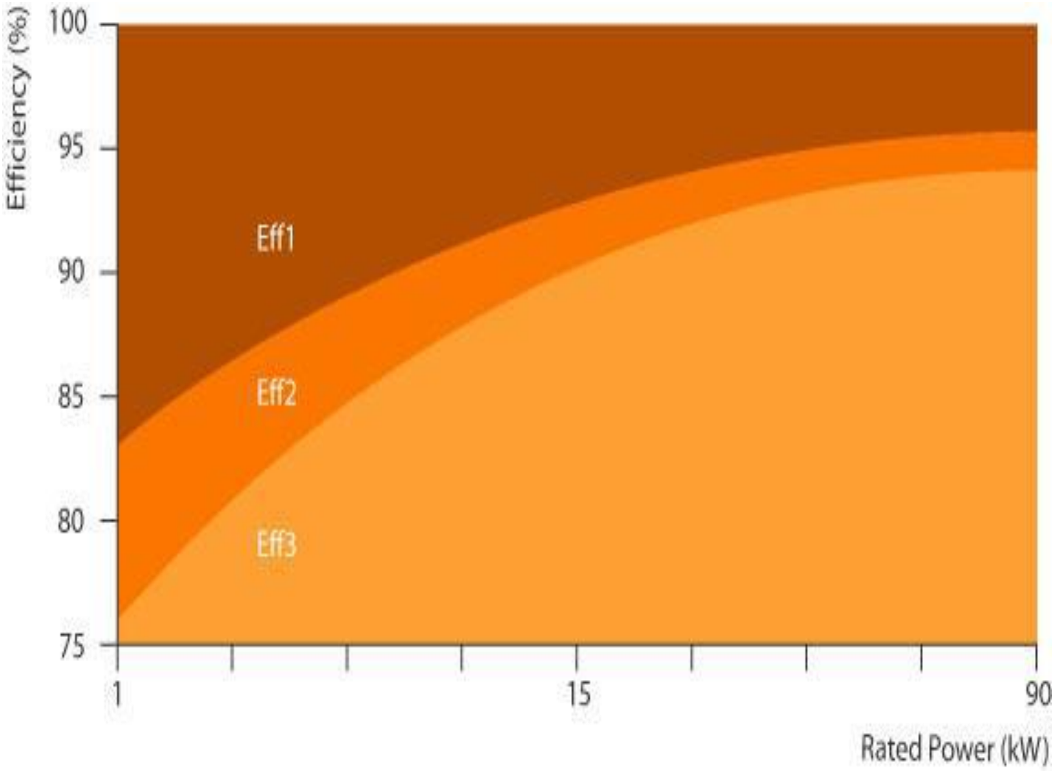


Figure 12.6.1 – Example of energy efficiency rating of electric motors

In choice of electric motors for ship, the idea of energy efficiency needs to be taken into account early and during the shipbuilding stage. For existing ships, when an electric motor needs to be replaced due to maintenance requirement, procurement of an energy efficient electric motor should be considered.

12.6.2 Fuel oil homogenisers

Fuel sludge may constitute up to 1% of fuel used on board. The sludge disposal is normally done either via burning on board (incinerator) or transfer ashore. The whole process is waste of energy and money. Finding ways of reducing sludge thus could be desirable.

A homogenizer assists the process of fuel homogenizing and thereby a reduction in sludge level. It also helps with the supply of more uniform fuel to combustion systems. The main job of a homogenizer is to create a uniform structure of all solid and non-solid materials present in heavy fuel oil. A homogenizer also breaks down large water elements into small homogenous structure, resulting in an emulsion consisting of water molecules spread evenly throughout the whole fuel.

A homogenizer mainly works by agitating and milling of the fuel. Agitation can be done by using a mechanical arrangement which pumps the liquid through an orifice plate. Such a system is shown in **Figure 12.6.2**. Agitation can also be done by an acoustic medium which uses ultrasonic frequency to agitate a surface over which the liquid is pumped.

Figure 12.6.2 – Typical homogeniser

A conventional homogenizer is like a milling machine which churns the liquid as it passes through it. The design consists of fixed stator housing with a rotor which is generally driven by a motor. The mating surface of stator and rotor has specially designed channels. Both rotor and stator are conical in shape and have a specific clearance between them through which the fuel is passed.

Moreover, the design is made in such a way that the liquid accelerates as it moves through the channel, making the dissolved components uniform in nature. It should be noted that although the unit looks like a pump, it doesn't have a pumping unit. A separate pump needs to be installed to pump the fuel through the system.

The operation of a homogeniser has the following advantageous effects:

- Reduction in sludge production (up to 75% has been claimed but a number of 50% is more realistic). This causes an increased amount of burnable fuel, thereby fuel saving and fuel cost. Also, this reduces the cost of disposing of the sludge.
- Influence on purifier efficiency.
- Less wear and tear of engine components.

In case, a homogeniser is used for some water emulsification into fuel, it could positively impact exhaust pollutants as well. Both NOx and smoke reduction can be achieved if the system is used for water-fuel emulsification.

12.6.3 Other technologies

There are other technologies that may be used for upgrade and retrofit that includes:

- Energy saving lamps.

- Card controlled or occupancy sensors lighting system for accommodation.
- Variable speed drives for pumps, fans and compressors.
- HVAC system control upgrade and also pre-cooling of incoming air using outgoing cold air.
- Engine de-rating: This is a significant area and only applies for extreme slow steaming.

12.6.4 References and further reading

The following list provides references for this section and additional publications that may be used for more in-depth study of topics covered in this section:

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