SKYSAILS

Cutting Back to Get Ahead

A Review of Fuel Saving Strategies for Ships

by Trevor Morse, Lori Phillips, Kyle Westergard, and Benjamin Smith

[Editor's note: This essay is an edited version of a paper prepared by the authors as part of their studies towards a Diploma of Technology in Nautical Science. We applaud their efforts and encourage other students to consider submission of essays and papers.]

By and large, the greatest expense incurred in the running of a ship is fuel. While the price of fuel fluctuates with the economy, one factor remains a constant throughout: less money spent on the operating costs of a ship means a wealthier company. In addition, less fuel used means fewer emissions and less impact on the environment. This report reviews feasible means of cutting back a ship's fuel bill through current, proven methods, as well as weighing the benefits of technologically advanced methods.

Introduction

Fuel prices have taken centre stage in the shipping industry. Prior to the recent economic downturn, fuel prices rose steadily with a most disturbing spike experienced during the summer of 2008, at which time fuel costs represented as much as 50% of a ship's total operating costs. It is likely that economic recovery will bring back high oil prices; therefore, vessel owners and operators are still faced with the challenge of increasing fuel efficiency to maintain their profitability now and in the future.

Proven Methods for Reducing Fuel Consumption

Methods for fuel reduction are readily available and regularly used by vessel operators. These methods are generally low cost and easily adaptable to most vessel types in a relatively short period of time without the need for major structural alterations or dry-docking. Below we describe three methods commonly applied throughout the industry: voyage planning, antifouling systems, and engine maintenance.

Voyage planning

Voyage planning is an essential and necessary part of any passage. The planning process includes a detailed description of the entire voyage with considerations given to all foreseen navigational challenges. The primary purpose is to provide safety of navigation. However, following a specific passage plan often has economic implications that may undermine the efficiency of a vessel. Many aspects of planned operations have a significant impact on fuel consumption. The most important of these are speed reductions, weather systems avoidance, great circle sailing, navigation of currents, and vessel trim.

Speed Reduction

Speed can be described as the single most important factor in determining a vessel's fuel economy. Speed reduction is an effective way of achieving immediate fuel savings, and it has been proposed that existing ships can save between 15 to 20% on fuel costs by simply considering the speed / fuel consumption characteristics of the vessel and by constantly monitoring the vessel's cost of speed.

The cost of speed can be derived from the direct relationship between speed and a vessel's fuel consumption. Figure 1 displays the speed versus fuel consumption relationship for a 13-metre fishing trawler. At a vessel speed

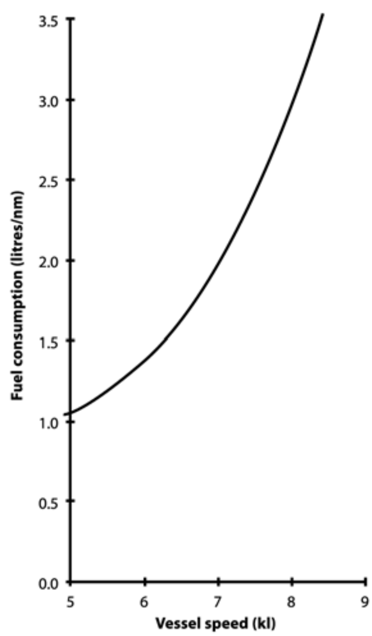


Figure 1: Speed versus fuel consumption relationship for a 13-metre fishing trawler. Source: Food and Agriculture Organization of the United Nations (Aegisson and Endal, 1992).

of eight knots, the trawler is consuming approximately three litres of diesel fuel per nautical mile. However, if the vessel were to reduce its speed from eight knots to five knots, the vessel would only require approximately one litre of fuel per nautical mile. Therefore, a speed reduction of 37% results in a fuel savings of 67%.

The ability of shipping companies to immediately adjust vessel speed provides considerable flexibility to offset high fuel prices. For example, the Stena Line ferry division combated high bunker costs in 1985 by reducing vessel speeds from 19.8 knots to 18.7 knots, resulting in a cost savings of 23%. However, speed reductions are not always the perfect answer for reducing fuel costs. One disadvantage is an increase of air pollution from ships' engines operating below design parameters. In the case of a large container ship designed for 25 knots at 70,000 kW main engine power, a speed reduction to 20 knots would require just 50% power and represent a total nitrogen oxide emissions increase of 40 tons per year.

Weather Systems Avoidance

Weather analysis is an important factor for voyage planning. Selecting a specific route to either avoid or navigate through a weather system will have direct impact on how much fuel the vessel will burn. Weather systems avoidance, often referred to as weather routing, is the practice of choosing a vessel's optimal route to get to point A from point B based on weather forecasts, sea conditions, and the vessel's sea-keeping characteristics. These decisions can be made under the professional judgment of the Master or by advanced weather prediction models. Modern weather routing systems incorporate sophisticated algorithms that combine weather and wave forecasting with a vessel's sea-keeping characteristics. The resulting computer-generated weather routes offer significant advantages to the cost-conscious vessel operator.

Weather routing services have proven themselves useful for trans-ocean voyages. Captains using weather routing services have often reported higher speeds, less bunker consumption, and a better estimated time of arrival despite longer distances travelled. However, weather routing also has its limitations in practical use dependent upon the type of passage. Weather routing is not particularly useful for short passages less than 1,500 miles, passages navigationally restricted by land, or during passages where weather is not expected to be a significant factor.

Figure 2: Great circle sailing versus weather routing on a typical trans-Atlantic voyage.

Great Circle Sailing

A great circle route is simply the shortest route between two points anywhere on the earth's surface. Thus, masters typically must choose the appropriate application of weather routing or great circle routing to achieve maximum efficiency. Figure 2 shows the difference in distance between a great circle route and a weather route on a typical trans-Atlantic voyage. In this example, the optimal route offering the most fuel economy is the weather route (green line). In the North Atlantic, the most efficient route is often one which takes a vessel to the south of the great circle route because of regular occurrences of adverse weather and sea conditions common in higher latitudes.

Navigation of Currents

Ocean currents are another factor in route selection and voyage planning. Choosing a route that will take advantage of natural currents or avoid opposing currents can have a significant impact on the amount of fuel a vessel will consume during a voyage. For example, it is beneficial for west-bound vessels in the Pacific Ocean to remain south of 22°N for the majority of the passage despite the increased distance when compared to the great circle route because the increased distance is offset by a favourable westerly current. Research has shown that a 16 knot ship could expect fuel savings of 2.5% or more by strategically routing through measured current patterns.

Vessel Trim

Navigators can also increase their fuel efficiency by monitoring the effects of trim on a vessel's speed. A vessel's trim is important because it directly relates to the amount of resistance acting on the hull. Fuel savings can be achieved by determining the best operational trim at different loading conditions and applying the appropriate ballast to maintain that trim.

The advantages of optimizing trim can be very ship-specific and depend upon design factors unique to each vessel. The Stena Line ferry division decreased their bunker cost by 1% simply by operating their vessels at zero trim in accordance with design drafts. Teekay Shipping Limited takes their optimal trim analysis to a higher level by evaluating their vessels' fuel efficiencies at all trim and loading conditions, thus accounting for changes of hull shape at different draughts. By applying the results, Teekay was able to obtain 2 to 5% fuel savings among their ships.

For some ships, it is possible to assess optimum trim conditions during a voyage but for others it is not possible because design factors may predominate. Similarly, weather conditions also become a factor when selecting the appropriate trim for a voyage. Ultimately, the amount of potential fuel savings by applying appropriate trim will depend heavily on the vessel type and the nature of the vessel's trade.

Antifouling systems

'Fouling' is the growth of marine organisms on a ship's hull. When fouling builds up on a hull, it will increase drag, which in turn leads to more power being needed to move the vessel through the water, and more fuel consumed. From the first launching of a vessel, an increase of power of about 1% yearly is required in order to maintain its initial equivalent speed. This loss can be minimized with proper care and maintenance of the hull, and with the application of coatings to inhibit the growth of marine organisms. Fouling has been shown to contribute as much as 7% increase in fuel consumption after only one month.

Antifouling Paints

Two types of second generation antifouling coatings are self-polishing paints and foul release paints. With traditional antifouling paints, biocide release can be reduced or prevented by formation of a surface layer of salt leachate residue. Self polishing paints do not develop this layer; therefore, the biocide can be used to its full potential beyond the normal four year duration of traditional antifouling paints. Alternatively, non-stick or foul release coatings contain no biocides at all. These paints use silicones and fluoropolymers to produce surfaces to which fouling organisms will not stick, or can be easily cleaned off by brushing, water spray, or the vessel's own movement through the water. With foul release paints, normal service life is seven to ten years, with a touch-up at the five year mark. Foul release coatings have been proven to be effective under even the worst conditions, such as the tropics. Foul release coatings also have been found to result in fuel savings due to less friction created on the hull. Manufacturers state that foul release paints can reduce hull resistance by 4 to 6%.

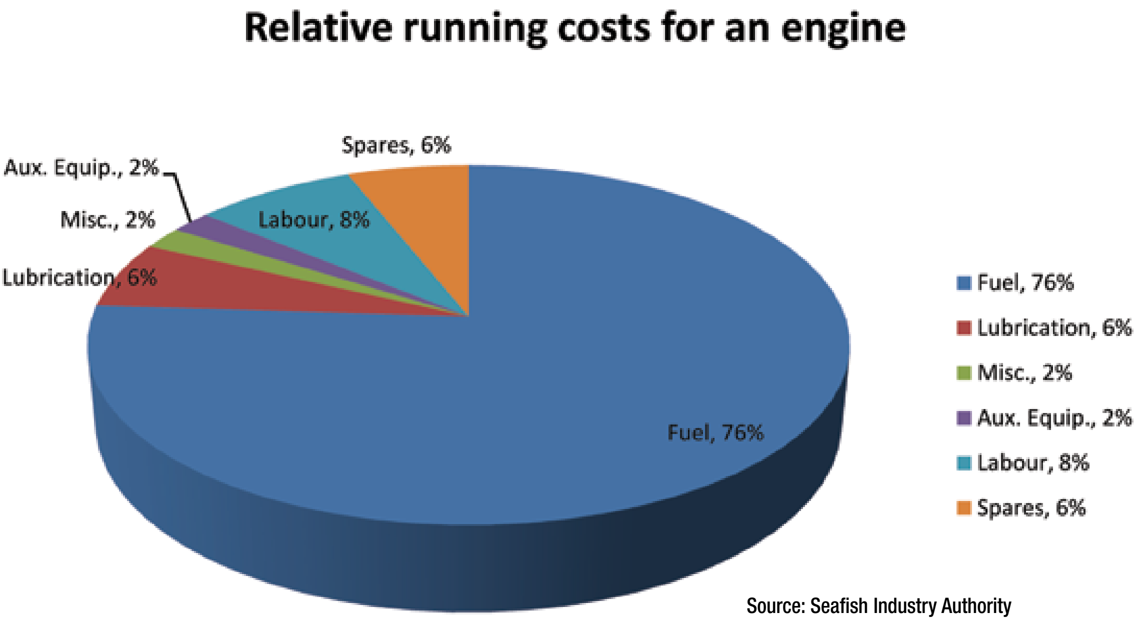


Figure 3: Relative running costs of a ship's engine. Note that fuel represents more than three-quarters of the total cost.

HULL SURFACE TREATMENT

Hull surface treatment (HST) is a method that has been developed to remove fouling from ships' hulls without the use of chemical or abrasive action. This method uses thermal shock to remove fouling. The dead marine growth stays attached to the hull of the ship, and is later removed by current and wave forces while under way. HST allows the hull to be treated without the removal of the antifouling paint and may in fact enhance the active properties of various antifouling paints, thus extending their useful life, thus enabling a longer time period before the need to overhaul a vessel.

Engine maintenance

Maintenance of ships' engines to ensure peak operating performance is another way to improve fuel efficiency. Figure 3 shows the relative running costs of a ship's engine. Note that fuel represents more than three-quarters of the total cost.

To ensure an engine's optimum performance, proper maintenance must be conducted on a regular basis. The characteristics of engine exhaust hold clues to engine performance. Black smoke may mean an overloaded engine, shortage of air, and/or faulty injectors. White smoke could mean defective injectors, improper valve timing, or worn or damaged piston rings (low compression). Finally, blue smoke could indicate burning lube oil due to worn valve guides or a worn or broken piston.

CONDITION MONITORING SYSTEMS

Oil is used to lubricate the internal parts of an engine, thus minimizing wear. However, the lubricating properties of oil deteriorate over time due to ingression of impurities, which could include un-burnt fuel, moisture, and particulate material. This will increase levels of wear on engine shafts and bearings and, in turn, increase the power required to maintain output levels. Monitoring the condition of engine oil and taking appropriate remedial action can increase engine life and ensure maximum operating efficiency. By monitoring the quality of both hydraulic and lubricating oils, signs of potential damage to other components can be established. For

Figure 4: SkySail deployed. This modern adaption of ancient technology harnesses wind as an aid to propulsion by tethering a massive kite to the bow of a vessel.

example, an increase in moisture may indicate failure of seals on cooling units, while a high concentration of metallic particles may indicate worn bearings.

FILTRATION

Oil monitoring will identify potential problems, but filtration will prevent damage from occurring. If a filter is partially blocked or clogged, it will reduce the circulation of the oil. This will cause pumps to use more energy and reduce their ability to remove particles that could be harmful. In this case, the use of a condition monitoring system will indicate the commencing deterioration of lubrication and hydraulic oils. This enables filters to be changed in a timely fashion, thus maintaining a balance between service costs and the quality of oil.

Advanced Methods for Reducing Fuel Consumption

Advanced methods for reducing fuel consumption are typically more costly than the methods described above, in large part because they normally require the vessel to be refitted with equipment or incorporated as an additional expense into a new build. In addition, not all methods may be applied to all ships. Below we review five advanced methods which are available today: wind assistance, diesel-electric technology, waste heat recovery, hull design, and propeller arrangements.

Wind assistance

One major advance in technology to save fuel is the development of a massive kite tethered to the bow of a vessel. This modern adaptation of ancient technology harnesses wind as an aid to propulsion (see Figure 4).

According to SkySails, one of the leading developers of this technology, the size of the kite can range anywhere from 150 to 600 m^2 (depending on the size of the vessel), and is flown at an altitude of between 100 to 300 m. To align the kite for optimum performance, there is an onboard computer using data transmitted from onboard sensors (GPS, wind direction gauge, anemometer, rudder indicator, and ship's course). Incorporated in the system is a kite manoeuvre control, which is basically an autopilot that allows the computer to know how to manoeuvre the kite. The computer controls the winches to which the kite is attached, and can ease out or take in on the tethers, which change the aerodynamics of the kite, thus controlling the setting of it, and maximizing the force of tow.

SkySails' 2007 figures state that fuel savings from 10 to 35% are achievable. The kite can be flown in winds between Beaufort forces 3 to 8, on courses anywhere up to 50º off the wind and can produce between eight and 32 tons of tow force. Only two prototypes have been tested to date. The costs to acquire and install a SkySails system are significant, and will need to be amortized over a period of years based on fuel savings.

Diesel-electric technology

Diesel-electric propulsion technology has been available nearly as long as the diesel engine. The first diesel engines, at the turn of the twentieth century, were non-reversible, which led to the development of diesel-electric propulsion to make reversing thrust possible. With the development of reversible diesel engines, diesel-electric propulsion was used very little until advancements in electronics systems made it possible to develop diesel-electric into an efficient and economical form of propulsion. The conventional form of the system consists of multiple engines and generators providing power to electric motors driving the propellers. Fuel savings can be as much as 5 to 8% for vessels with varying operational loads; however, it can be as high as 20 to 30% for an Offshore Support Vessel (OSV).

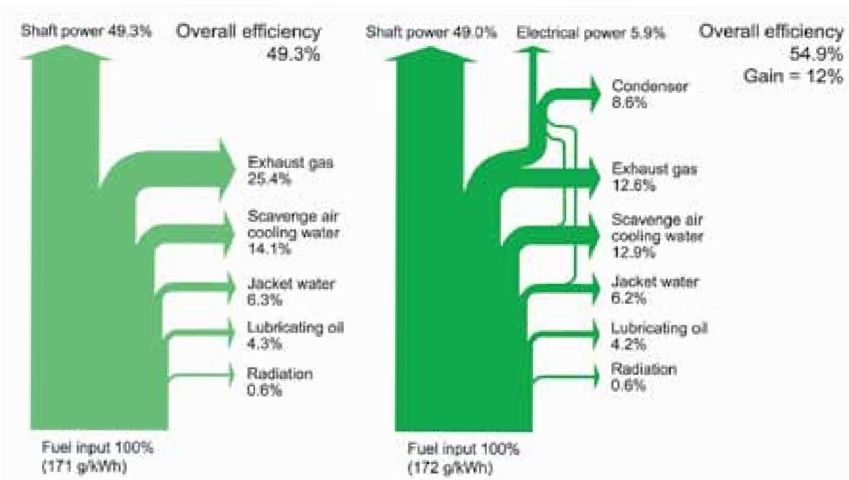
A diesel engine is most efficient at the designed operating speed. Therefore, when less power is required, it is better to shut down one or more engines, rather than reducing the speed of each. For example, it is better to run three engines at design RPMs and shut the fourth down, than run four engines inefficiently at reduced RPMs. The ability to produce only the power needed makes diesel-electric propulsion particularly well suited to vessels with varying operational loads. The main drawback with diesel-electric is that it is less efficient at high load due to power transmission losses. These losses are approximately 8%, while diesel-mechanical losses are approximately 3%.

When fuel prices were lower, diesel-mechanical propulsion was more attractive due to its lower capital cost and simplicity. Due to fuel's impact on operational costs and emissions standards in today's shipping industry, the advantages of diesel-electric propulsion are increasingly attractive to ship owners. Engine manufacturer Wartsila has gone so far as to develop a combined diesel-electric and diesel-mechanical (CODED) propulsion system to incorporate the strengths of both diesel-electric and diesel-mechanical into one system. The combination of diesel-electric and diesel-mechanical propulsion machinery offers the benefits of a pure diesel electric system but without the high transmission losses at high loads. Like diesel-electric, CODED machinery is most suited to vessels with varying operational loads, such as OSVs and ferries. OSV operations include everything from low power stand-by duties to very high power anchor handling and towing. Ferries and similar vessels dock frequently with relatively short sailing distances and these types of vessels can achieve about a 4% reduction in energy consumption as compared to pure diesel-electric.

Waste heat recovery

There has been much advancement in diesel engine technology in efforts to decrease fuel consumption and emissions. As a result of these advancements, a thermal efficiency of nearly 50% has been reached in slow-speed marine diesel engines, which means that only 50% of the energy supplied by the combustion of fuel is actually utilized, the remainder being wasted heat. A portion of this wasted energy may be recovered with a new breed of Waste Heat Recovery (WHR) system and used to generate electricity to supplement propulsion, as well as other energy requirements aboard ship, effectively reducing fuel consumption. Figure 5 shows that a gain of approximately 12% of shaft power can be achieved using a Sulzer 12RT-flex96C slow-speed diesel engine as an example.

In the past, WHR technology was available but not in widespread use due to the high initial cost of installation, increased engine room maintenance and, most importantly, the relatively low cost of fuel. Due to the high fuel cost in today's shipping industry, this technology has become increasingly attractive to ship owners who seek to save costs and gain an edge. The advantages of an advanced waste heat recovery system are numerous. It not only provides increased fuel efficiency, but it can also offer a power boost as well as emergency power. The disadvantage of the system is that it is added equipment to be purchased, operated, and maintained. On the other hand, the system replaces the operation of auxiliary generators at sea, and may reduce the number of generators needed on board. It also can provide a vessel and company with a 'green' image, which can be helpful in the freight market. With a fuel saving benefit of 12% and the possibility to carry more cargo, WHR technology may be a very promising step forward for shipping in an industry where fuel costs are a very significant part of operating costs.



WARTSILA

Figure 5: Heat balance and efficiency of Sulzer 12RT-flex96C engine with and without waste heat recovery.

Hull design

The bulbous bow is a tubular shaped piece protruding from the stem of a ship that changes the hydrodynamics of a moving vessel. This technology is widely accepted in the industry and has been fitted on many power driven vessels, both large and small. The initial design for the bulbous bow was developed by David Watson Taylor in 1910 for the United States battleship *Delaware*. Since then, the design has been developed and streamlined to provide optimum performance for ships (see Figure 6).

The bulbous bow aids the ship's movement through the water in various ways. As the hull passes through water, the hull resistance generates a continuous wave on the bow, which progresses to form along the hull as it moves and creates the ship's wake. Figure 7 shows a bow wave created by a container ship. Less resistance means a smaller wake, and an easier passage through water. While the vessel is sailing under a loaded condition, the bulbous bow is slightly underneath and forward of the bow wave and creates its own wave. Because of the different periods of the two waves, when they meet a destructive interference takes place and partially cancels out each wave, thus reducing the wake and the propulsion needed. In addition, as the hull moves, water is forced upwards over the bulbous bow, which creates a downward push on the forward part of the vessel. This downwards push changes the trim of the vessel, helping to reduce the squat drag of the stern. Finally, the bulbous bow reduces the pitching motion of smaller vessels, which in turn reduces the disturbance and drag of the hull as it moves vertically through the water.

Figure 6: A bulbous bow is a tubular shaped piece protruding from the stem of a ship that changes the hydrodynamics of a moving vessel. Developed by David Watson Taylor in 1910, the design has been developed and streamlined to provide optimum performance for a ship.

Figure 7: Bow wave created by a container ship. Less resistance means a smaller wake and an easier passage through water.

The bulbous bow can reduce fuel consumption by approximately 12 to15% (dependent on the underwater hull design of the ship) on ships that achieve speeds of more than six knots. In certain cases, as much as 25% reduction of power has been observed. There are only two disadvantages. First, when the vessel is travelling at lower speeds, the bulb can hinder the ship's performance by creating more wetted surface, which adds drag. Second, if the ship sets its anchor from the stem, the anchor may hit the bulb on its descent, or the anchor rope may chafe on the bow.

Propeller arrangements

The propeller is an important component of the propulsion system of a ship. Therefore, any improvements that will help to reduce the consumption of fuel are desirable. Innovative approaches include reblading of propellers, adding additional parts to the existing propeller, servicing of the existing blades, and/or developing better propulsion technology.

Reblading of Propellers

When a vessel is first built, it is fitted with propellers of the most advanced design in that current period. A vessel has a service life of about 25 years and, during this time, manufacturers will have improved their designs and improved their abilities to build more efficient propellers. The advance in propeller design corresponds to the operating changes of the vessel. Optimum vessel performance can be maintained by reblading the propeller to the more modern and effective version. Rolls-Royce has undergone several reblades of vessels resulting in "substantial reductions in fuel consumption and a short payback time." The short payback time is an attractive quality making reblading a cost-effective solution. The first reblading Rolls-Royce undertook was in 2005 on the *Stena Germanica*, which operates on the Gothenburg-Kiel route. The results of the upgrade have been successful. "The increase in fuel efficiency has turned out to be about 10% … additional advantages to the customer are that the level of redundancy is increased and maintenance costs are cut." Subsequently, Rolls-Royce rebladed two more Stena ferries: the *Trelleborg* (fuel consumption reduced by 10 to 12%) and *Stena Nordica* (fuel consumption reduced by 17%).

Adding Additional Parts

The enclosure of the propeller within a duct (also known as a nozzle) has also been shown to improve effectiveness. The duct is a slightly tapered, aero-foiled shaped ring that fits around the propeller. As the propeller turns, it creates a high pressure area behind the propeller. This high pressure creates the thrust needed to push the vessel ahead. However, as the propeller rotates, a percentage of the pressure is lost due to centrifugal force, thus creating a loss in propulsion. Adding a duct that is closely fitted around the propeller tips reduces the amount of centrifugal water flow. This, in turn, can have "up to a 5% power savings compared to a vessel with an open propeller" (Wartsila).

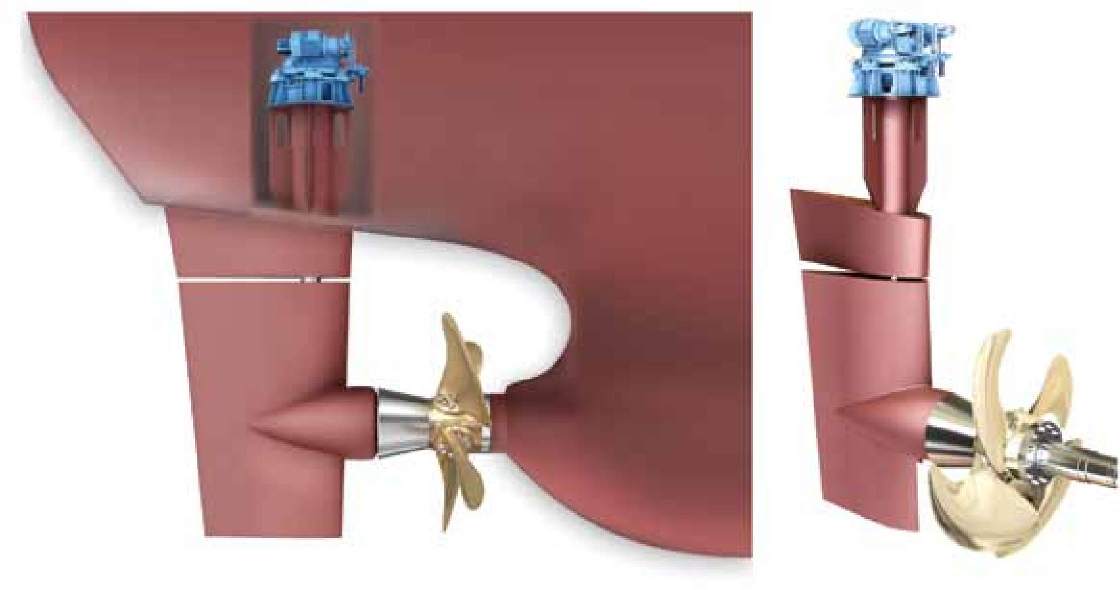
Nozzles have the most significant effect at slow vessel speeds.

SERVICING EXISTING PROPELLERS

With the application for new propeller designs or the reconfiguration of existing ones, it must be kept in mind that in order to maintain their full efficiency potential, the propeller must have laminar flow. With large propellers, roughness can account for an increase in fuel consumption of up to 4% after 12 months of service. Roughness may occur as a result of fouling (marine growth), impingement attack, corrosion, cavitation erosion, or improper maintenance. Propulsion loss due to this increased roughness can vary from 4 to 6%. Grinding and polishing of the propeller blades is usually carried out during scheduled dry docking. It may be noted that with polishing about 75% of the benefit can be obtained by polishing only the outer halves as opposed to the whole blade surface. During dry dock, the cost of polishing the propeller varies with size; however, an average rate is approximately $170 per square metre of blade surface. Thus, the typical cost for a 6.9 m diameter four-bladed propeller with a blade surface area of 19.24 m square would be $6,540. When this cost is compared to a 4% decrease in propulsion efficiency, it becomes negligible.

DEVELOPING BETTER PROPULSION TECHNOLOGY

PROMAS is a Rolls-Royce design that adapts the propeller and rudder to the hull as one propulsive unit (Figure 8). PROMAS consists of a tapered hubcap, a bulb on the rudder, and a spade rudder with a twisted leading edge profile. Its main objective is to smooth the water flow as it passes over the rudder. The shape of the rudder converts some of the swirl energy, or turbulence, that is produced by the propeller into additional forward thrust, thus helping to propel the vessel. Rolls-Royce observes for this design "a typical merchant ship hull operating at up to 17 knots, the improvement in efficiency should be in the 3 to 6% region, giving a payback time of one to two years." For a twin screw vessel, it will be a smaller improvement but still sufficient enough to make a financial return. This technology can also be fitted onto vessels wanting to keep their existing rudder. The bulb is fitted, while the propeller is equipped with the special hubcap and new blades. Ships with this upgrade at the



ROLLS-ROYCE

Figure 8: Integrated propulsion system, PROMAS, a design by Rolls-Royce that adapts the propeller and rudder to the hull as one propulsive unit. Its main objective is to smooth the water flow as it passes over the rudder.

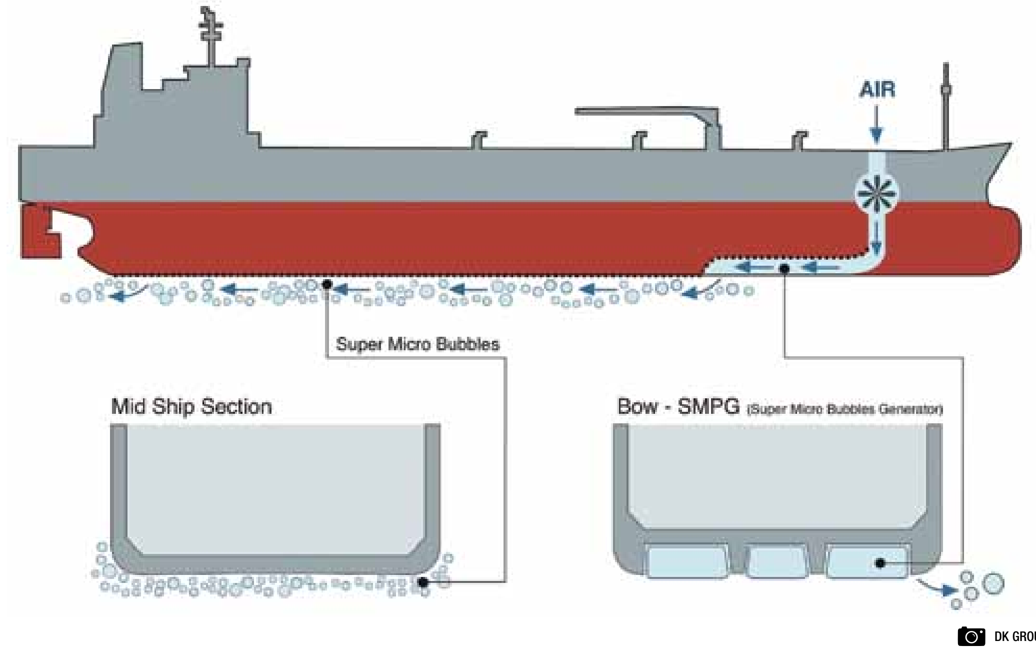


Figure 9: The Dutch company DK Group has developed the Air Cavity System as a means of reducing fuel consumption. The technology is based around the fact that air creates less friction than water. Less friction means less propulsive power is needed to move a vessel at a given speed.

present time have been investigated to show propulsion efficiency of two years with a reduction in exhaust emissions.

Another innovative design is Wartsila's counter rotating propeller (CRP), which consists of a pair of propellers, one behind the other, that rotate in opposite directions. The aft propeller recovers some of the swirl energy in the slipstream that is created by the forward propeller and converts it to forward thrust. Having two propellers increases propulsion resulting in better efficiency than a single propeller. CRPs can either be mounted on twin coaxial counter rotating shafts or the aft propeller can be located on a steerable pod, aft of a conventional shaft line propeller. This type of propulsion has one of the highest documented power savings of up to 10 to 15%.

The Dutch company DK Group has developed the Air Cavity System (ACS) as a means of reducing fuel consumption in order to make ships more environmentally friendly. The technology is based around the simple fact that air creates less friction than water. Less friction means less propulsive power is needed to move a vessel at a given speed. The ACS works by generating a layer of air "… between the hull and the water, allowing the vessel to effectively 'glide' through water, reducing hydrodynamic resistance" (DK Group). The air is blown through the forward part of the hull via a series of automated valves and compressors and, as the ship moves along, the air goes into a streamlined hollow along the bottom of the ship that is designed to accommodate the maximum surface area of air possible. When the air reaches the after end of the cavity, it is dispersed by pathways to either side in order to avoid propeller cavitation or steerage loss. The output of air is automated to ensure that the ideal volume and pressure is maintained to correspond with the vessel's speed (see Figure 9).

The ACS is estimated to save up to 15% fuel consumption on flat bottom, box shaped vessels such as bulk carriers and tankers. On finer hull ships like liquid natural gas carriers and container vessels, an estimated 7 to 9% fuel savings are expected. The reduction of the required fuel the ship needs has the added benefit of increasing the cargo-carrying capacity of the ship. This is achieved by either adding cargo to replace the weight of the no longer required fuel, or by having smaller machinery spaces due to the reduction of propulsive power needed. Due to the reduction of friction, the vessel's manoeuvrability is increased and, if an emergency stop is required, by stopping the compressors, the sudden friction due to water reduces the distance that is needed by as much as 50%. Another benefit of ACS is the reduction of sea growth clinging to the bottom of hull. This is due to air displacing water in the cavity, which prevents the growth from beginning. According to DK Group, the energy needed to generate the air will consume approximately 0.5 to 1% of the ship's output power.

Conclusions

There are many fuel saving methods that ship owners and operators can use to offset rising fuel costs. Each method has associated advantages and disadvantages. The methods that are ultimately chosen will vary considerably among different ship types and their respective trades. Generally, conventional methods (voyage planning, antifouling systems, and engine maintenance) can be easily adapted to any existing vessel. Speed reductions produce significant fuel savings and can be deemed most flexible for achieving immediate results for all vessel types. Other voyage planning methods, such as weather systems avoidance, great circle sailing, navigation of currents, and vessel trim, offer marginal fuel savings potential, depending heavily on the type of vessel and its particular trade.

Other conventional methods for fuel reduction, such as antifouling systems and routine engine maintenance, are time tested and true methods to reduce fuel costs and obtain better ship performance. The fuel savings achieved through regular hull and propeller cleaning far outweigh the costs of performing the service and the associated down-time for the vessel. Similarly, routine engine maintenance and condition monitoring systems produce engine efficiencies and fuel savings that outweigh the additional costs of labour, replacement parts, and vessel down time.

Advanced methods for reducing fuel consumption represent higher initial costs of implementation for vessel owners and operators. These methods are either incorporated into new ship designs or adapted to existing vessels through major refitting or dry-docking. As with conventional methods, advanced technologies have a wide range of applications and their effectiveness varies considerably among different ship types and their respective trades. SkySails technology and DK Group's air cavity system each offer considerable fuel savings when applied to new vessels or when adapted to existing vessels. However, the fuel savings must be amortized against the initial cost of the systems. Also, vessels using the SkySails or air cavity systems take on a financial risk because the technologies have not yet been fully proven. However, the additional risks may pay off if ship owners and operators are able to achieve significant fuel savings and gain a competitive advantage. Alternatively, the bulbous bow is an advanced hull design feature well established as a method for decreasing fuel consumption at higher speeds. It can be incorporated into new-builds or retrofitted to an existing hull. Again, the savings must be used to amortize the cost. Waste heat recovery systems and diesel-electric propulsion systems are examples of advancements in engine technology that offer better fuel efficiency on board ships. Both systems offer increased fuel economy and a proven track record for reliable service. The systems are expensive to install, but companies using the technologies have shown significant decreases in fuel costs. The waste heat recovery system is beneficial to companies looking for overall engine efficiency, and the diesel-electric system is best for companies that wish to have increased fuel efficiency at all levels of output power. The usefulness of each method is dependent on the application for which it is intended.

The best overall strategy for cutting fuel costs depends on the vessel type and the trade for which it operates. Conventional methods for fuel reduction are particularly good for achieving predictable levels of fuel savings in the short term, but may not provide the highest levels of fuel savings necessary to capture a competitive advantage. Advanced methods offer additional savings beyond those achieved through current methods and offer competitive advantages in the longer term that, at least initially, must go to amortizing the cost of the initial investment. In the end, both the company (profitability) and the environment (sustainability) win out.

MARINE INSTITUTE

Trevor Morse, Lori Phillips, Kyle Westergard, and Benjamin Smith prepared this paper as part of their studies towards a Diploma of Technology in Nautical Science at the Fisheries and Marine Institute of Memorial University. They have recently graduated and advanced into their chosen profession.

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