№ 4 |2012 June

www.shipandoffshore.net

Ship&Offshore

The international publication for Offshore & Marine Technology

Propeller maintenance

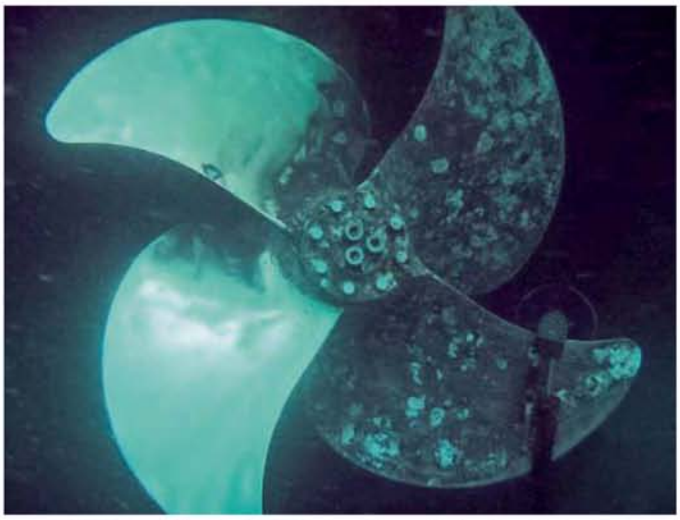
FUEL CONSUMPTION A ship's propeller represents only a very small fraction of the vessel's wetted surface area. Yet the effects of a rough propeller on the vessel's fuel consumption are comparatively large. Remedies for a rough propeller are not only simple and quick to execute, they can also represent a fast, high return on investment, writes David Phillips from the Hydrex Group.

New propellers can be relatively smooth or rough as a result of their manufacture. They invariably become rougher during service. The main reasons for increased roughness include the following general categories:

- marine fouling
- calcareous deposit (chalk layer)
- impingement attack
- corrosion
- cavitation erosion
- mechanical damage from impact with objects
- improper polishing or cleaning.

Most propellers are made of a bronze alloy and are uncoated. The tip of a propeller can be travelling at speeds of 100-120 kilometres per hour through the water, which contains salt and other abrasives. The propeller is also a cathode in the electrolytic cell created by hull and propeller. The dynamics of the propeller in the water create cavitation. Marine growth attaches to the propeller as it does to any other object immersed in the water. Thus a number of different elements damage and roughen the propeller's surface and reduce its efficiency. The salt water corrodes the bronze through a chemical reaction. Electrolysis causes erosion and also results in the build-up of a rough calcareous deposit. Cavitation damage shows up in the form of a pitted surface. Biofouling in the form of slime, weed, barnacles and other organisms adds to the surface roughness.

The impingement attack consists of the abrasives in the water acting against the rapid motion of the propeller, affecting the tips and leading edges. The tips in particular are likely to come in contact with solid objects of one type or another, causing mechanical damage.



A smaller propeller, half-fouled and rough, half-polished

These different causes tend to work together, with each source of roughness complementing the other and accelerating the propeller's decline in overall smoothness. The rougher a propeller gets before the condition is remedied, the more rapidly further roughness will accrue.

Effectively dealing with one source of roughness will diminish the effects of the others. By frequent maintenance, the overall decline can be greatly diminished.

Effects

A rough propeller results in a fuel penalty for the ship. How large that penalty is depends on the degree of roughness. In practice it is not very easy to separate the fuel penalty arising from propeller roughness from the fuel penalty associated with a rough and fouled hull. Very often one sees figures for combined hull and propeller fouling fuel penalties. Nevertheless, there is data available that gives an indication of the fuel penalty solely due to propeller roughness. In the book "Marine Fouling and its Prevention" by the Woods Hole Oceanographic Institution (1952), tests involving the destroyer USS McCormick are described. In seven months out of dock, the average fuel consumption to maintain a given speed was up to 115.8% compared with an unfouled hull and propeller. After the propeller was cleaned, consumption dropped to 105.5%, showing that the propeller fouling/roughness alone resulted in a 10% increase in fuel consumption.

During the "Green Ship of the Future" seminar at the Asia Pacific Maritime exhibition in Singapore in March 2010, Christian Schack of Denmark's FORCE Technology stated that the added annual fuel consumption of a Panamax container ship due to propeller fouling may be up by 5-6%.

In Chapter 7 of "Advances in marine antifouling coatings and technologies", the authors, T. Munk and D. Kane, estimate that increases in fuel consumption from normal propeller fouling range from 6% to 14%, citing Haslbeck, 2003.

Furthermore, the authors cite increased performance after the propellers have been polished on container ships: The propeller polishing at six-month intervals resulted in fuel savings of five tonnes per day at an average cruising speed of 24 knots.

In its "Naval Ships' Technical Manual", the US Navy estimates that approximately 50% of fuel savings attained by full hull cleaning can be attributed to the cleaning of propellers and shafts.

In "An Introduction to Dry Docking", the authors state that "even a 1mm layer of accumulated fouling or calcium deposits on a propeller will significantly increase its roughness, and within 12 months or so can increase an ISO class I to an ISO class II, or a class II to a III. This causes large increases in fuel consumption. Practical figures and elaborate tests indicate a 6 to 12% gain in fuel consumption in polishing a propeller from a class III condition to a class I condition. Some propellers support marine growth up to 20mm thick, which obviously has a major effect."

Based on information available, it can be seen that propeller surface roughness from fouling and surface deterioration can cause a fuel consumption penalty of somewhere between 5 and 15%.

At current fuel prices, the fuel penalty from a rough propeller adds up to a lot of money. So the possible savings from keeping a ship's propeller clean and smooth are significant.

Current propeller maintenance practices

Shipowners/operators, technical superintendents and those responsible for keeping ships operating efficiently are aware that there is a fuel penalty associated with rough, fouled propellers. It is common for some maintenance measures to be in force to take care of this.

These measures usually consist of scheduled propeller polishing. Often this is done only when a ship is dry-docked, which in most cases is too infrequent to keep a propeller operating at optimum efficiency.

Some vessel operators therefore schedule in-water propeller polishing once or twice per year, which in most cases is still not frequently enough.

While most ship propellers are bare metal, research has been done to try to remedy some of the propeller's inherent problems through the application of various coatings. While no universal, fully workable and tested solution has yet been placed on the market, this line of research shows promise.

If a propeller is not maintained frequently enough, economic and environmental problems ensue. The economic problem is the additional fuel penalty, which could have been avoided had the propeller been cleaned or polished sooner. This results in additional emissions of CO_2, NOx, SOx and particulate matter.

Restoring a very rough propeller to its original state (or close to it) requires grinding away a considerable amount of the material itself, mostly copper but also zinc, nickel and other metals. While the amount of material removed from a single propeller may be relatively small, when multiplied across all the propellers used in the entire world fleet, polishing can represent a significant emission of heavy metals and thus pollution and contamination of water column and sediment.

Badly done polishing with a polishing disk or grinding wheel can create a rougher surface than that of the new propeller, leaving scratches that not only increase the propeller's roughness but also facilitate attachment of fouling organisms. The infrequency and poor quality of cleaning or polishing are the major drawbacks of current propeller maintenance practices.

If done early enough, the propeller can be cleaned with a rotating brush and abrasive material removing almost no metal, preventing the effects of cavitation damage from spiralling and avoiding the formation of calcium deposits. This early attention can speed up the cleaning process considerably, extending the life span of the propeller and preventing the emission of heavy metals. This approach also eliminates the dangers of a roughened surface due to inexpert grinding and polishing.

Economically, the fuel saving from the timely cleaning of a propeller outweighs the cost. The cleaning can be combined with a general hull inspection by divers, making it even more economically viable.

To establish the best practices for uncoated propeller maintenance, a routine for propeller cleaning must be found that permits rapid, easy (and therefore economical) propeller cleaning and is frequent enough to minimise the fuel penalty from propeller roughness and fouling.

As stated in "Marine Propellers and Propulsion" by John Carlton, "With regard to the frequency of propeller polishing, there is a consensus of opinion between many authorities that it should be undertaken in accordance with the saying 'little and often' by experienced and specialised personnel."

Of course propeller cleaning can be overdone. However, cleaning a propeller once every month or every two months would in many cases be optimal. If carried out this frequently, cleaning with a relatively soft brush and abrasives is adequate to keep a well-maintained propeller smooth enough for maximum fuel savings. It would prevent the accelerating spiral of cavitation damage plus corrosion plus fouling, which, if allowed to continue uninterrupted, requires major polishing with grinding or polishing wheel and the removal of a great deal of metal into the marine environment should the polishing be carried out in the water. Cleaning propellers "little and often" would be beneficial to the environment as a minimum of copper, zinc, nickel and other heavy metals would be ground off into the water.

Case study

A recent experiment was carried out with a 134m-long cruise ship. The propellers were cleaned with a rotating brush alone, no grinding or polishing disk required, by a diver. It took him approximately 40 minutes to complete the cleaning of the ship's two propellers. The fouling was not very heavy since the propeller is cleaned quite often.

Calculations of subsequent fuel savings showed that on a 30-hour trip from Aruba to Barbados, the ship saved USD 2,100 compared with the same trip with a mildly fouled propeller. The ship consumes 1.6-1.7 tonnes of fuel/hour. The fuel saving as a result of cleaning the propeller was calculated at 6%. A 30-hour trip with an uncleaned propeller would have used 51 tonnes of fuel, equalling USD 35,700 at USD 700 per tonne. Six per cent of USD 35,700 is USD 2,142. In this case the propeller cleaning was carried out by a member of the crew. Had the propeller been cleaned by an outside company, it would not have cost more than about USD 2,000. So the cost of cleaning, even if carried out by a contractor, would have been recouped in the first trip the ship took after cleaning. Since the propeller would not have had to be cleaned again for at least a month or two, the cost of the cleaning would have been recouped many times over.

Cost of cleaning

Obviously the cost of cleaning is a factor that cannot be overlooked. If the savings in fuel costs did not substantially outweigh the cost of propeller maintenance, then one would question the value of frequent propeller cleaning. The cost varies from one location to another and from one provider to another. The need for skilled and competent propeller cleaning and polishing has already been stressed.

Vendors usually charge per propeller size and number of blades. Polishing a four-blade, 6-metre propeller would cost somewhere between USD 1,900 and 3,000. Polishing a six-blade, 8-metre propeller might cost between USD 3,100 and 4,000.

One of the better propeller cleaning vendors charges 15-20% less for propeller cleaning (brush plus abrasives) than for full polishing with grinding or polishing disks. Which method is used depends on how rough the propeller is, and this is determined largely by how often the propeller is polished or cleaned.

As covered in the short case study above, the cost of the propeller cleaning can be recouped in the first voyage the ship makes after the cleaning. Not only is it cheaper to clean than to polish, it also is economically advantageous. Cleaning takes less time than polishing.

Conclusion

Best available practices for propeller efficiency consist of the use of uncoated propellers with frequent, routine in-water cleaning to prevent heavy fouling, the formation of a calcareous deposit layer and the spiralling damage of cavitation erosion and corrosion. Further research is needed into the use of strongly adherent, highly cavitation- and corrosion-resistant glass or ceramic reinforced coatings that can stand up to the extremely challenging conditions in which propellers operate. Until such technologies have been perfected and proven in service, frequent light cleaning remains the best technology available.

References

Woods Hole Oceanographic Institution: "Marine Fouling and its Prevention", US Naval Institute, (1952), pp 32-33

Christian Schack, FORCE Technology (presentation) March 2010.
http://www.greenship.org/fpublic/greenship/dokumenter/APM%20Singapore/7%20Force%20Technologies%20-%20Operational%20initiatives%20to%20reduce%20emissions%20from%20ships.pdf
accessed 16 April 2012.

T. Munk, D. Kane, D. M. Yebra: "The effects of corrosion and fouling on the performance of ocean-going vessels: a naval architectural perspective," Chapter 7 of "Advances in marine antifouling coatings and technologies", edited by Claire Hellio and Diego Yebra, Woodhead Publishing in Materials, (2009) p 161

Naval Sea Systems Command, Naval Ships' Technical Manual, Chapter 081, "Waterborne Underwater Hull Cleaning of Navy Ships," Revision 5, 1 Oct 2006, 081-2.1.1.1

David Martin et al. „An Introduction to Dry Docking" http://www.angelfire.com/rnb/drydocking/home.htm, accessed March 2012.

John Carlton "Marine Propellers and Propulsion (Second Edition)" Butterworth-Heinemann Elsevier, (2007), p 383.