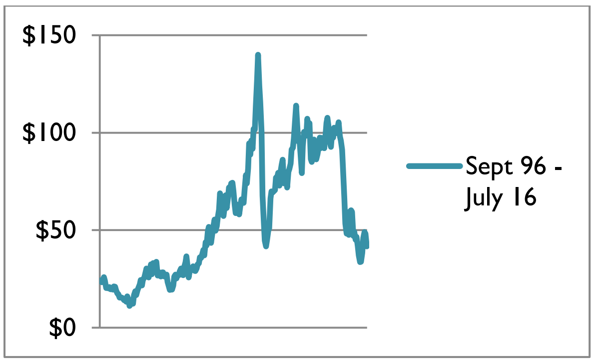
Propeller surface roughness

Introduction

The importance of fuel economy in present day ship operation has been demonstrated many times in recent years. Oil costs have fluctuated for years and are shown in the chart below. The requirement to maintain economical operation is therefore vital.



Notable advances have been made in the achievement of the highest possible propeller efficiency to suit required service operating speeds. In many cases new propellers have been designed and fitted with success to meet reduced power service conditions and these have achieved fuel savings of over 12% in some cases.

The full effect of these measures will not continue to be realised if the propeller is not maintained in a smooth condition. The potential advantages of maintaining both hull and propeller smoothness has motivated considerable theoretical and practical research over the years and a number of important papers have been published on the subject.

The purpose of this paper is to endeavour to identify the types and causes of propeller roughness, to relate degree of roughness to increase in power requirement to meet a given ship speed and thus to additional fuel consumption and cost, to advise on the steps which may be taken to ensure that any increase in fuel costs is restricted to a minimum, and to illustrate the magnitude of the financial savings available.

Causes of Roughness

Some degree of roughening of propeller blade surfaces is inevitable in the normal course of service. The causes of attack may be:

a) Marine growth—primary and secondary

b) Impingement attack

c) Corrosion—chemical and/or electro chemical

d) Cavitation erosion

e) Inexpert maintenance

Marine growth of the animal or vegetable variety forms on the propeller blade surfaces while the ship is idle and the propeller is stationary. In its worst form, i.e. as barnacles, the resultant loss in propeller efficiency is very serious. There will also almost certainly be an increase in power absorption resulting in a fall in propeller RPM, with a tendency to overload the machinery. After a period following re-entry into service the action of the water may remove barnacles and grass from the outer parts of the blade, but examination of used propellers shows that the surface never regains its original smoothness. Thus there is always the secondary effect of marine growth to be suffered until such time as the propeller is properly cleaned.

Impingement attack usually occurs at the leading edges and outer parts of the propeller blades where the circumferential velocities are highest. The effect on the blades is a widespread area of surface roughness of fairly shallow depth. High duty propeller alloys such as Nikalium or Superston offer greater resistance to such attack than Manganese Bronze, Cast Steels or Cast Irons.

The above applies also to corrosive attacks, which can sometimes be minimised by the adoption of properly designed and maintained cathodic protection systems.

Cavitation erosion is usually concentrated on localised, sometimes small, areas of the blade and may be due to cavitation arising from flow irregularities due to an unfavourable wake distribution or to the effects of physical damage to, or incorrect shape of, the blade leading edges. Cavitation erosion can be very deep, in some cases leading to complete wastage of the outer parts of the blades.

The development of surface roughness could be accelerated if the propeller has been ground by inexperienced operators, perhaps using too coarse grinding discs, and if insufficient attention is paid to the correct formation of the blade edge shape.

Definition of Roughness

It is important always to define roughness in the same units preferably using the same parameters, or at least to be able to relate the different kinds of measurement.

The International Standards Organisation lay down requirements for surface finish of propellers in standard IOS 484 part 1 1981 and has the surface requirement of three microns Ra for class S finish and six microns Ra for class 1 finish.

The rate of increase in roughness during service depends on the nature of the trading pattern of the ship, e.g. which ports are visited and the time idle in port, but measurements after service have shown that, physical damage apart, the general surface roughness can easily have increased by 15 microns Ra after 12 months, which, as will be seen later, will have a significant effect on the performance.

Methods of Measurement or Assessment of Surface Roughness

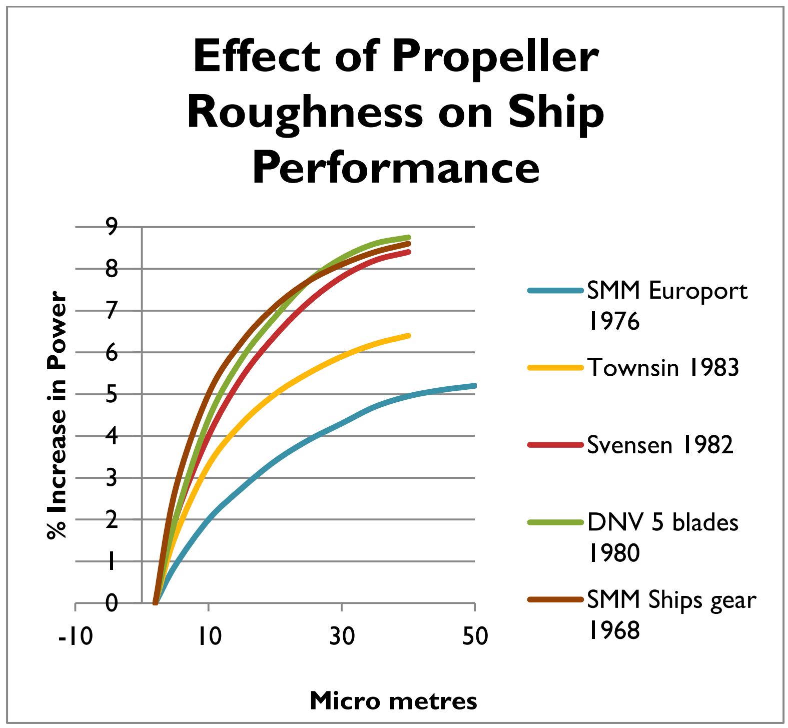
There are a number of surface roughness measurement instruments on the market, some of which may only be used under permanent laboratory conditions. For propeller work a fully portable machine is required which will give a rapid surface roughness measurement. Surface measuring machines are readily available and are highly portable and can be used in the workshop or in drydock.

A more simple method of surface condition assessment is provided by use of a comparator gauge produced, with the assistance of S.M.M., by Rubert & Co. of Cheadle. This is comprised of six samples of surface finish ranging from Ra = 1 micron to Ra = 30 microns. The surfaces represented are very accurate replicas taken from actual propellers. The benefits of this comparator are that it can be carried in the pocket, and a special version can be used underwater if required. With practice a reasonably accurate impression of the surface condition can be assessed, upon which a decision whether or not to service the propeller can be made.

In practice several readings of the propeller roughness should be taken, and it is recommended that these should be at 4 radii, approx. 0.3, 0.5, 0.7 and 0.9R, and at three positions on face and back at each radius, so that a representative average of the overall surface condition may be obtained.

Effect of Propeller Roughness on Ship Performance

Attempts have been made for many years to estimate the penalty in power incurred by increasing propeller roughness. Figure 8 shows an estimate based on model experiments. It was later thought that scale effects may have led to this estimate being on the high side and theoretical studies were made based on vortex theory with increased drag coefficients accounting for blade surface roughness. A typical example of this work is also shown in the diagram and it was considered that this represented a very conservative estimate of the effect of roughness.



More recently many other experts and authorities have been investigating the effect of roughness. Much of this work deals with the varying effects of different types of propeller roughness, including the average slope of the roughness profile and other texture parameters as distinct from the average height of the roughness. This is very valuable research but not yet in a form that can be conveniently applied in the dock bottom or with the propeller in the water.

The estimates of the effects of roughness made recently by three investigators have been transformed to compare directly with the previous estimates, and are also shown in the diagram. These were presented in references 1, 2 and 3. S.M.M. have taken Dr. Townsin's line as representing a moderately conservative estimate for the assessment of cost effectiveness that follows.

It should be appreciated that any of the lines shown may be reasonable estimates in particular circumstances as the effect of roughness will depend on ship speed, RPM, blade area and other ship and propeller characteristics as well as the peakiness and texture of the roughness measured or assessed as being of a particular Ra value.

Blade Surface Maintenance

Overall blade surface wastage caused by impingement or corrosion leads to turbulence which increases the drag of the blade section resulting in loss of efficiency. The development of turbulence intensifies the attack.

If treated at an early stage the roughness can be removed by light and fine grinding with little loss of blade thickness. If maintenance is delayed the increase in depth of the roughening will be accelerated. This means that the loss in efficiency, and thus increase in fuel consumption, will be greater and because more grinding will be necessary the costs of rectification will be increased.

Therefore the rule applying to propeller surface maintenance should be “little and often".

It is normally recommended that grinding and polishing is carried out at every drydocking, but since the periods between drydockings are now being extended from two or three years to five years, it is necessary to consider servicing the propeller while the ship is afloat between the discharge and loading operations. This is feasible providing the ship may be trimmed so as to expose the outer parts of the blades from the water, and adequate floating platforms and appropriate services can be provided.

This comment applies to any servicing operation and it is strongly recommended that work of this nature should always be placed in the hands of experts who are sympathetic to the needs of the propeller designer requiring the maintenance of a "fair" surface and accurate blade edge formation. Inexpert grinding may in fact increase the effective roughness of a surface rather than reduce it. In addition coarse grinding cuts provide a more secure base for marine growth thus further increasing the possibilities of fouling.

While it is desirable and cost effective, whenever conditions permit, to polish the entire surfaces of the blades, when it is not possible it is worth remembering that about 75% of the benefit is obtained by polishing only the outer half of the blades. if the blades have roughened significantly and drydocking is not envisaged in the near future, it is well worth polishing the tips of the blades if the ship can be trimmed suitably to expose the outer half of each blade.

Translation to Fuel and Cost Savings

The effect of the improvement in propulsive efficiency on the annual fuel consumption depends on the following factors:—

1) Average service power

2) Mean specific fuel consumption

3) Days at sea per year

4) Fuel price per tonne

The figure on the next page shows a diagram from which it is possible to estimate the annual fuel cost savings by inserting the actual values of the above variables.

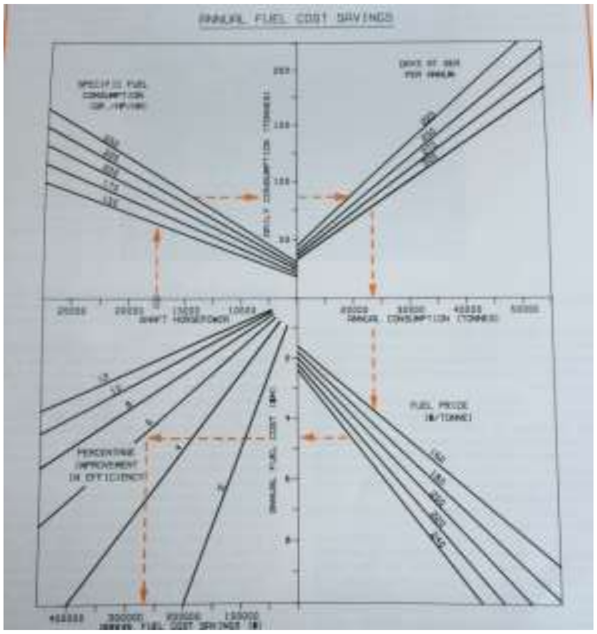
Two typical examples, for a bulk carrier of 64000 DWT and a 1400 TEU container ship, are tabulated below.

Ship type	64 K Bulker	1400 TEU
Engine	Diesel	Diesel
Average power kW	7870	13975
Average SFC	110	170
Consumption/day	40	105
Days at sea	250	300
Fuel price /t	$280	$280
Annual costs	$2.8 m	$6.76m
% savings after polish	3%	3%
Annual savings	$84,000	$203,000
Daily fuel savings	$336	$676

Rate of Return of Polishing Costs

The cost of grinding and polishing varies depending on the condition of the propeller surface, the situation p of the propeller, (e.g. on the shaft, in drydock or afloat, or ashore), and the labour charges at the servicing location. However a worldwide average rate might be about $250 per square metre of blade surface P area, and assuming that both face and back of the subject propellers have been treated at this rate, the costs would be as follows:—

Ship type	64 K Bulker	1400 TEU
Prop diameter	6900 mm	7000 mm
Blade area	20 m^2	25 m^2
No of blades	4	6
Cost of polishing	$10,000	$12,500



It will be seen that the grinding and polishing costs in these cases would be returned in 30 and 19 days of operation respectively even if only a 3% average improvement in performance is obtained. Even when allowing shipyard costs for staging and any special travelling costs to the site, the pay-back time will be so small, and the rewards so great, that maintenance work of this nature should never be overlooked in the future as has frequently happened in the past.

Conclusions

Whether or not it is considered necessary in the long term to change the propeller design to suit a revised operating condition, there is no doubt that very significant fuel cost savings are available for a very small outlay by grinding and polishing the propeller.

It is more cost effective to carry out propeller maintenance at closely spaced intervals, because the costs will be less and the rate of wear on the propeller blade surface will be reduced.

It is very important that the work is performed by expert labour employed by propeller manufacturers or their accredited service agents.

REFERENCES

1. R.L. Townsin, W.E.G.E.M.T. 1983 "Bottom Condition and Fuel Conservation"

2. 0. Fagerjord, Det Norske Veritas, Paper Series No 80 P022 October 1980 "Possibilities of Improving Propulsion Efficiency"

3. TE. Svensen, I.Mar.E. 1982 "Techno-Economic Reasons for Selecting Fuel-Saving Priorities"