Economics of Propeller Policies

British Ship Research Association's Evaluation of Three Case Studies

Ships with rough hulls often also have rough propellers, although the reasons for the surface deterioration after a period of time in service are different. In the past researchers, as well as practical ship operators, have focused their attention mainly on the hull maintenance problem.

Poor hull condition has often been cited as the cause of falloff in performance with time in service, although in practice a significant contribution to the reduction in performance may well have been due to propeller roughness. Admittedly, in absolute terms propeller roughness is less important than hull roughness, but in terms of energy loss per unit area, propeller roughness is significantly more important. In economic terms, high standards of propeller maintenance are, therefore, more cost-effective compared with hull maintenance for most ship types and this will be demonstrated in the following set of case studies.

During the last 30 years BSRA has recorded the roughness of over 130 propellers using a purpose-built propeller gauge. Records have been taken on newly fitted propellers and propellers up to 27-years-old and in some cases propeller roughness has been monitored at intervals during service, including before and after re-polishing.

An alternative simplified method of assessing the propeller surface condition is to use a set of replica gauges. The Rubert propeller replica gauges presents six different surface replicas ranging from smooth (A) to very poor (F). One of the principal advantages of using a set of replica gauges is that the propeller surface condition may be assessed by divers when the vessel is in water, therefore allowing more frequent inspections than the normal two or three yearly dry-docking intervals.

Due to the fact that effects of poor propeller surface condition upon speed and power performance are difficult to measure in practice, analytical methods are employed as predictors. BSRA has developed an integrated system of analytical procedures for the modeling of propeller characteristics in 'real flow' conditions behind ships' hulls. This system may also be employed in the analysis of roughness effects upon performance, and is the method of calculation used in the following set of case studies.

Low freight rates have resulted in a number of vessels today operating at speeds well below their design point. Under conditions of prolonged slow-steaming, it may be economically justified to redesign the propulsion system to suit the new operating point. Propeller replacement may be justified for this reason alone and is a topic which is addressed separately.

In the following set of case studies of propeller maintenance and replacement, three principal ship types have been employed, representing different segments of the marine transportation market. They are:

SHIP A:

A 10-year-old VLCC trading between the Arabian Gulf and Europe, steaming at 12 knots in laden condition, 13 knots in ballast. Fitted with a four-bladed, fixed-pitch propeller and a steam turbine main propulsion plant.

SHIP B:

A modern design 45,000dwt bulk carrier trading between the US Gulf and Japan, slow-steaming at 13 knots in laden and ballast condition, fitted with a four-bladed, fixed-pitch propeller and a slow-speed diesel main propulsion plant.

SHIP C:

A 12-year-old 1,600TEU container vessel, operating on the North-Atlantic route at an average speed of 19 knots (3 knots below design point). Fitted with a five-bladed, fixed-pitch propeller and either steam turbine or slow-speed diesel main propulsion plant.

The economic calculations are performed using the BSRA computer-based ship operational model. Ships A and B are typically operated at constant power where the penalties due to propeller roughness result in a speed reduction and, therefore, fewer round-trips per annum and a loss of income. In addition, there is an increase in fuel consumption per round-trip due to the longer time taken.

Containerships normally follow a fixed schedule and are, therefore, essentially operated at constant speed. The penalties due to hull roughness are consequently transformed directly into an increase in fuel consumption.

Principal input variables for case studies

	SHIP A	SHIP B	SHIP C
Crew + fixed + upkeep costs per annum	3,000,000	2,700,000	3,750,000
Port and canal dues per round trip	515,000	90,000	200,000
Freight rate (per tonne or unit)	6,309	18.50	1,600
Round-trip distance (n.miles)	17,605	18,230	8,130
Income	10,600,000	4,200,000	44,000,000
Annual fuel costs	1,100,000	750,000	13,450,000

Typical present-day freight rates are assumed for all three ship types. A fuel price of $185 per ton is used and the economic calculations are performed using a discount rate of 7.5% in real terms. Two different measures of merit are used in the economic calculations; Net Present Value and Discounted Profit to Investment Ration. The latter is effectively a measure of the profit earned for each unit of capital invested and is a useful economic criterion when comparing investments of unequal size.

Propeller Maintenance

SHIP A

Figure 1 presents percentage increase in power requirement against time for the three ship types A, B, and C described above. An average deterioration in surface condition of 8μm per year as determined from the BSRA data bank is used and the calculations also include typical rates of deterioration in surface texture as determined from the same data base. The starting point is a smooth surface condition in year 0. It is of interest to observe that the results in percentage terms are almost identical for all three ship types. Further calculations have shown that the results for each ship type are almost independent of ship speed and loading condition for most normal operating conditions. For practical purposes the same survey can therefore be employed.

The results from the above may be used to calculate the investment return on regular propeller maintenance. An economic comparison is consequently performed between the following two alternative strategies:

Alternative 1:
Propeller polishing every 24 months, restoring blade surface to smooth condition.

Alternative 2:
No propeller maintenance.

In both cases the starting point of the calculations is a smooth surface condition, the calculation period is 6 years and an average deterioration rate of 8µm/year is assumed with a corresponding typical rate of deterioration in surface texture. For ship A the cost of re-polishing the propeller to the smooth condition is assumed to be $8,000 and the corresponding figures for the slightly smaller propellers on ships B and C are $6,000. Table (1) presents the results in terms of Net Present Value and Discounted Profit to Investment of the investment for the three ship types.

Table 1

	SHIP A	SHIP B	SHIP C
Difference in Net Present Value between Alternatives 1 and 2	$49,300	$14,80	$36,800
Discounted Profit to Investment Ratio on the investment	3.8	1.5	3.8

In the case of ship C the results remain the same, irrespective of whether a steam turbine or slow-speed diesel main engine installation is assumed. The specific fuel consumption is higher, but because of the slope of the specific fuel consumption curve, the absolute difference in fuel consumption for a given power increment is the same as for the slow-speed diesel.

SHIP B

As already mentioned, the Rubert Roughness comparator gauges may be used as a simplified method of estimating the propeller surface condition at any point in time during dry-docking or by underwater survey. Grade A on the comparator gauge represents a new propeller, grade B a reconditioned propeller and grades C to F a series of gradually increasing values of surface roughness. To the ship owner or operator the propeller surface roughness estimates are of little value unless they can be associated with corresponding values of power penalties for subsequent transformation into economic terms.

Figure 2 presents results of percentage increase in power against Rubert Grades B to F which have been calculated using the BSRA analysis method and assuming the same level of roughness over the complete propeller blade.

The results from the above may also be sued as basis for calculating the cost in annual terms of excessive roughness relative to Grade A condition. In this particular case, the calculations have been performed for all three ship types at constant speed and constant power to allow a comparison to be made between the different modes of operation. (see Table 2)

Again, the results remain the same, irrespective of whether a steam turbine or slow-speed diesel main engine installation is assumed. In the case of Ship C it is worth noting that for Grade E condition or worse the economic penalty due to propeller roughness over an operating period of two years is greater than the cost of a new propeller.

Propeller Replacement

The efficiency of a propeller may be improved by reducing the number of blades, increasing the diameter and reducing the RPM. Principal constraints are tip clearances and vibration problems.

Over the past two-to-three years a number of large crude oil carriers have undergone modifications to suit slow-steaming operating conditions. The modifications have principally been in the form of de-rating of the main engine to suit a lower operating RPM and replacing the existing propeller with a new one having a larger diameter and fewer blades.

In order to demonstrate the potential benefits which can be achieved from propeller replacement alone, Ship A from the previous case studies of propeller maintenance is used as an example The number of blades remain the same, but modifications are as follows:

* 6.5% reduction in maximum ship speed
* 30% reduction in RPM to suit modified engine conditions
* 15% increase in propeller diameter

This change in propeller configuration results in a net change in fuel consumption of approximately 3%. The cost of a new propeller for this type of vessel is approximately $450,000.

Based upon the same assumptions as used in the earlier case studies the economic return on the investment in the new propeller has been calculated as follows:

* Payback period = $395,000
* Discounted Profit To Investment Ratio of Investment = 0.88

This calculation is for propeller replacement only and ignores the investment in main engine modifications which itself is expected to give an even higher return.

Conclusions

Even for the most badly deteriorated propellers, the power penalty due to blade surface roughness will not exceed 5 to 6%. For most propellers measured after various periods of time in service, the penalty does not exceed 3 or 4%, but due to the small surface areas involved, the return on capital invested in high quality propeller maintenance is of a magnitude several times greater than the costs involved. For some ship types, the cost of a badly roughened propeller is comparable with the cost of a new propeller.

Furthermore, propeller replacement in order to obtain a propeller better suited for slow-speed steaming condition has been shown to be good investment alternative on its own.