OPTIMISING THE PROP – an appraisal by Mike Lucas (22 Jan 08)

1. Introduction.

I have for many years wondered why so many yacht owners complain of not getting an adequate performance out of their engine installation. My time at Marine Projects (Moody & Sigma) was particularly educational in this respect, in that the initial engine and prop spec as produced by the yacht designer, engine manufacturer and prop supplier, rarely optimised the performance of the boat.

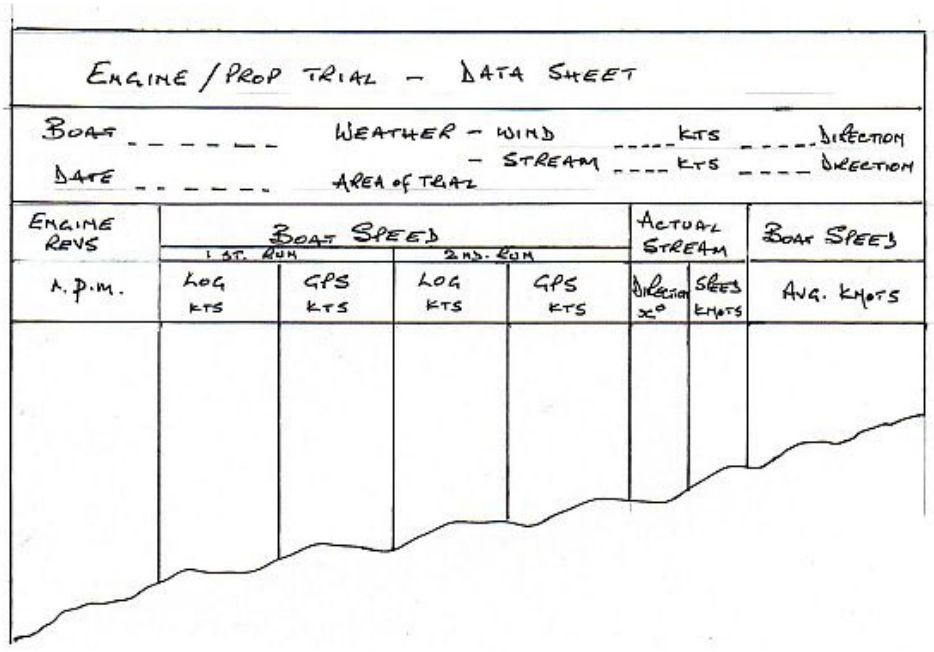
During my time with Sadlers I was not able to explore this in detail, but discovered that adjustments needed to be made to almost every prop specification, as a result of an engine trial. Indeed this must be the starting point, to establish with your present installation whether the boat will achieve what it should and whether this is in accordance with your requirements and expectation. First lesson therefore is to measure as best you can the present situation, before embarking upon a new one!

The final decision on prop specification does depend on a number of further variables associated with blade design and number of blades. As a result I have described a system for an owner to calculate the optimum Reduction Ratio and thereby become involved in the decision on Diameter and Pitch of the propeller. We have added to our experience by accessing the comprehensive data available from Dave Gerr, who has written a really comprehensive book about propellers, which is complex. Thankfully he has also written a most interesting book, which covers not only a simplified approach to the design of props, but many other matters to do with gear and equipment fitted to boats. The two books are called "Propeller Handbook" by Dave Gerr – ISBN 0-7136-5751-0 and "The Nature of Boats" - ISBN 0-87742-289-3.

2. Engine trial

A test should be carried out with the yacht in smooth water with little wind and ideally no stream or tide. Should this stable situation not exist, then it will be necessary to do two runs and average the result. You need to have a typical situation for weight on board the boat and a clean bottom.

Firstly set out a table with several headings being:- engine revs, from tick-over through say 200 rpm steps, up to maximum revs. The next column should be speed through the water, as measured on your log. The next column should be speed as recorded by the GPS, thus giving speed over ground. The difference between these two will either represent inaccuracies in log settings or the effect of wind and tide. Now do a second run in opposite direction so as to compensate for wind and stream. `A final column should be the result of averaging any errors and finally ending up with corrected speed through the water, which is what matters.



3. Hull speed

Maximum speed for displacement craft is determined by the waterline length. Theoretical maximum hull speed does depend upon a fair number of design variables, but broadly speaking it can be established by multiplying the speed/length ratio (approximately 1.4) by square root waterline length. Of course at speed the water line length does increase slightly and some allowance should be made for this in the case of your boat.

Assume a Sadler 34, which has a water line length of 27' 10", will increase to approximately 28.5 feet. The co-efficient for a Sadler 34 is about 1.39 x square root 28.5 = 7.4 knots max hull speed. At this stage accept **7.4 knots** as the maximum hull speed available with a Sadler 34. The speed/length ratio will reduce to about 1.35 for a Sadler 26 and increase to about 1.44 for a Starlight 39.

4. Prop diameter

Diameter has twice the effect of pitch and this should be made as large as possible, consistent with reasonable clearance between the propeller and the under-body of the yacht - tip clearance should be a minimum of 10% of diameter and ideally a bit more. For the Sadler 34, a 10% tip clearance provides for a **16" diameter prop**.

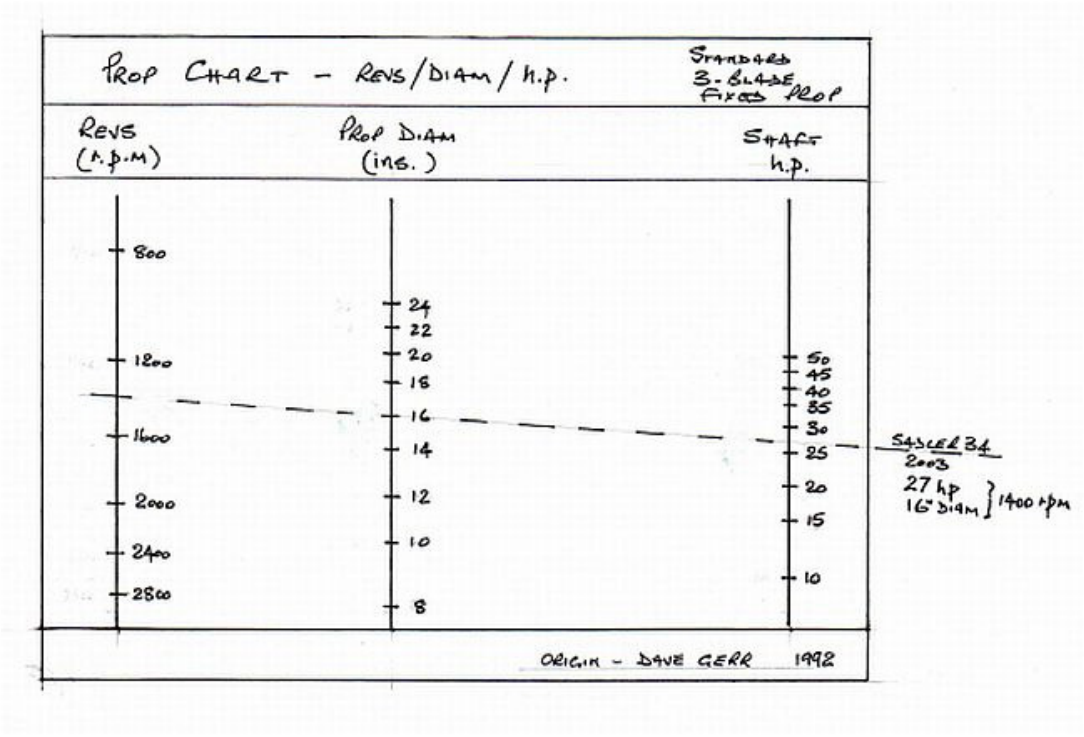
The final decision on prop specification does depend on a number of further variables associated with blade design and number of blades. As a result I have described a system for an owner to calculate the optimum reduction ratio and thereby become involved in the decision on diameter and pitch of the propeller. We have added to our experience by accessing the comprehensive data available from Dave Gerr.

5. Shaft horse power

Rated horse power of a Volvo 2003 is about 29 hp at 3,200 revs. Bearing in mind we wish to overload the engine to the extent of achieving 90% to 95% of peak revs, this gives about 2,900 to 3,000 rpm (say **2,950 rpm**), at which speed, shaft power achieved would be about **27 hp**. There will be small transmission losses which means that the available revs and horse power have all been rounded downwards to compensate for this fact. Object is to provide for modest revs at comfortable cruising speed, but retaining most of the hp to be available when needed – also not to overload engine!

6. Optimum revs (theory)

There is a helpful graph available in Dave Gerr's book (extract shown below), which enables us to establish the optimum shaft speed, given prop diameter 16" and available shaft power at 27hp, being around 1400 rpm (from chart)



7. Reduction ratio

Where a new engine is being considered and the Reduction Ratio needs to be selected, then divide the engine output revs by the intended reduction ratio to give the resulting shaft rpm. If this is within the range of 1,200 rpm to 1,500 rpm then this will be acceptable. Should the resulting shaft revs be outside this range, then consideration should be given to another option for reduction ratio.

In the case of the Volvo 2003, the reduction ratio is **2.4**. Dividing this into the anticipated maximum engine revs of say **2,950** rpm, produces maximum shaft revs of **1,229** rpm – ideal, being within the acceptable bracket.

8. Pitch (without slip)

Now we know the max boat speed (7.4 knots) and the max shaft revs (1,224rpm), we can calculate theoretical pitch (without slip). First job is to convert boat speed into inches per minute, (since we measure pitch in inches) = 7.4 knots x 100 = 740 feet per minute = 8,880 inches per minute. Pitch = 8,880 inches/min ÷ 1,229 rpm = **7.2 inches pitch (no slip) –** for a 3-blade prop.

9. Slip

Next we should consider that the propeller is working in water (rather than solid matter) and the extent of slip is described in Dave Gerr's book. "Slip" reduces as speed increases and this factor must be applied to the final pitch calculation, which can be summarised for a displacement sailing yacht as follows:

At 5 knots = 55% slip, 6 knots = 50%, 7 knots = 46% and at 8 knots = 42%.

Taking the Sadler at about 7 knots max speed, this will experience 46% slip which means we must multiply the 7.2" of pitch by a factor 1.46 = 10.5" for 3-blade fixed prop. Increase by about 5% for 2-blade prop = **11.0" of pitch**.

10. Summary

The above calculation produces a requirement for a 2-bladed fixed propeller for a Sadler 34 to be 16" diameter x 11.0" pitch. Now this is the point at which one applies practical knowledge and empirical data, which in the case of myself I have established over a good many years. My experience is that the optimum prop for Sadler 34 with a Volvo 2003 engine is 16" diameter x 12" pitch. At this stage my conclusion must be that the above formulae have resulted in a slightly under-pitched prop. I would probably choose to increase to **16" x 11.5"** for a fixed 2-blade and **16" x 12"** for a folding 2-blade.

11. Sea trial

The important next step is to undertake a sea trial, as described earlier in this set of notes and establish whether the prop fitted provides for maximum revs at 90% to 95% of manufacturers peak. In the case of the Sadler 34, do the engine revs peak at say 2,900 to 3,000 rpm?

12. Corrections

If having done the sea-trial, there may be a requirement to adjust or change prop. As a rule-of-thumb, change of 1" diameter will bring about a change of 300 rpm and 2" of pitch will bring about the same change. Hence diameter has a bigger effect than pitch, which is why we need to optimise diameter to achieve the best result.

13. Conclusion

Please understand that the sentiments expressed and the figures shown are my own interpretation of the complex business of working out the prop specification. The purpose of

this note is to encourage yacht owners to take an interest in these parameters, so as to dig deeper and learn more about this interesting subject – so important to achieve the optimum propulsion for your yacht.

I suspect that as I receive feedback in the Discussion Forum and response to the views expressed, I will be able to refine and enhance this approach. Purpose of all this is to help a general understanding and to bring about intelligent questioning of some of the theories expressed. Please accept these notes as the best effort by a practical yachtsman to project the ideas and to give a useful conclusion.

Cross-checks should be made with the engineer doing your engine installation and indeed engine supplier and prop manufacturer.

14. Final thought – 3 blade?

For those of us who go cruising and do not seek optimum performance under sail then it does appear to be an attractive proposition to select a fixed 3-blade propeller. Certainly this will optimise propulsion, but the drag is considerably greater than you might imagine. According to Dave Gerr the drag experienced with a standard 3-blade prop at 8 knots with a 35 foot yacht is about 70lbs - a huge drag on the boat and more than you might imagine. The less efficient 2-blade folder produces a mere 4lbs of drag, so you can see the benefit in terms of sailing efficiency.

To achieve a realistic compromise, an ideal solution is to fit a sophisticated 3-blade folding prop such as Gori or the Brunton feathering, but these are very expensive and have high annual maintenance cost. I suggest that there is much to be said for the feathering type prop and the Darglow max prop is a good example. Perhaps even better is the latest Kiwi feathering prop, which I am now beginning to favour as the optimum choice. The Kiwi prop has several real benefits:

- Light weight and less inertia, results in less wear and vibration
- Combines the sailing performance of a folding prop with the motoring efficiency of a 3-blade fixed (80% to 90% less drag at about 7lbs.)
- Facility for easily adjusting pitch, if you don't get it right first time!
- Reasonable cost, considering the overall performance

We are now carrying out tests on a number of Sadlers with Kiwi props and we already have results of this installation in a fair number of Sadlers, Starlights and Moody's.

A further report on the Kiwi props will appear in the website 'Articles' section during early February. We will publish this subsequent report in the next issue of the Sadler Owners Magazine. MLY can now supply the Kiwi prop direct to the owner with the confidence of performance comparisons and more certainty of establishing the optimum prop specification.

Further updates will be available in the Website – refer Articles section.

Call us 01803 212818 or e-mail for more information – mike@mikelucasyachting.co.uk