Special Performance Considerations for Boats with Electronic Control Engines

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ABSTRACT

An engine is more than just its rated power and RPM. Every engine model exhibits unique performance characteristics which can greatly affect the overall performance of a vessel. Understanding this and properly evaluating the nature of the *hull-propulsor-engine equilibrium* is critical to a successful installation.

Recent trends in the performance characteristics of contemporary engines have made it necessary to take a bit more care in their selection. Electronic control (EC) engines have pushed theses performance trends even further. This paper will offer technical guidance to determine situations – during acceleration or towing, for example – that that should be reviewed with greater scrutiny if an EC engine is to be considered.

INTRODUCTION

Let me make it clear from the outset that this is not an indictment of electronic control (EC) engines. It is an examination of why there are a growing number of instances where boats with EC engines are having difficulty performing as expected. The cause of the problems are not with the engine, per se – they are with a design and analysis process that resulted in an incorrect engine selection. A fictional example (that has been derived from real circumstances) may help to illuminate one type of problem.

A new owner of a sport-fishing boat with two EC engines takes her out for the first time. As a day of low speed cruising comes to a close, he points the boat into a strong head wind to make their way home. He pushes the throttles forward to get her up to full speed, but finds that she is “stuck” at about half the rated RPM – and the boat is not picking up speed. Over the next few minutes, the speed of the boat increases little by little. Finally, it feels as if something slips and the engines begin to turn up to a reasonable speed. Along with higher engine RPMs, the boat now begins to accelerate as she should and the rest of the trip is uneventful.

The first thought is to blame the engines. But this is not necessarily appropriate. As a troubleshooter for such problems, we are seeing them more often and the problem is simply a case of using the wrong engine model to do the job.

THE EC ENGINE’S PLACE IN HISTORY

EC engines have brought remarkable opportunities to our maritime world. Fuel savings, customization of engine output and increased power are all results of this new technology. I’m reminded, however, of the old cliché that "no good deed goes unpunished".

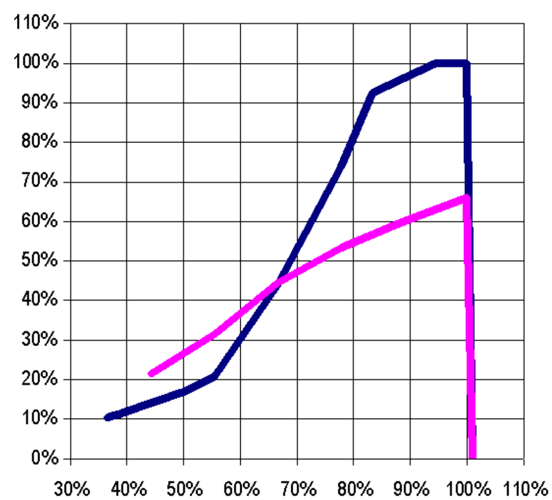

Figure 1. 8-cylinder Engine Comparison Mechanical Control and Electronic Control

By exploiting electronic control, manufacturers have been able to pull some 20% to 40% more power from a basic engine package. The plot above (Figure 1) illustrates this increase by comparing the power curve of a 1980's 8-cylinder mechanical control engine to that of a contemporary EC engine with the same number of cylinders, size and weight. (The performance figures have been normalized to 100% of power and RPM.)

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Power-to-weight ratio has not been the only advance, fuel consumption data for these two engines show a 3% to 4% reduction with the newer EC engine. Add to this the derivative performance gains due to the reduction in engine weight – and thus vessel weight – and we can easily see how EC engines make a valuable contribution to vessel performance and fuel economy.

THE HYDRODYNAMIC PROBLEM

As designers and builders have begun to take advantage of newly discovered power, it is often forgotten that the engine is but one player in a *hull-propulsor-engine* equilibrium (Figure 2). The engine is attached to a transmission and propeller – and all parts of the system must work together in a properly coordinated manner. The consequences of choosing an engine model without evaluating the entire system vary from annoying to rather dramatic.

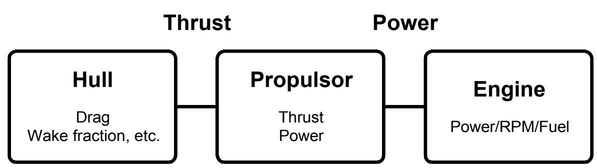

Figure 2. The hull-propulsor-engine equilibrium

For example, on the level of merely annoying, repowering a boat design with a new EC engine requires a properly sized propeller. Trying to maintain the old diameter and shaft line can often lead to noisy cavitation. Sometimes the additional cavitation is so severe that the propeller reaches a point of "thrust breakdown" where it can generate no more thrust, even with more RPM. If a vessel is experiencing this kind of excessive cavitation, you can pile on all of the EC-generated power you want without noticeably increasing speed. New techniques in propeller design have helped to recover some of this available power, but cupping, progressive pitch and variable pitch distribution can only do so much.

A more troublesome installation, resulting from an improper engine, is demonstrated by a boat's hesitation to get up on plane. Many EC engines have a steep drop in their power curves at low RPM. (More correctly, an EC engine has a typically steeper rise in power at high RPM. Regardless, the effect is the same.) During a vessel's acceleration over the "hump", some boats need more power at low RPM than is available from the engine. Slowing the rate of acceleration is about the only way a boat with this problem can work its way over the hump – much to the chagrin of the owner.

For a graphical description of this, let's refer to the plot below (Figure 3). This plot compares a new 8-cylinder EC engine with its 1980's counterpart – a 12-cylinder model with some 30% more weight. Immediately you will notice the difference in the shape of the power curve. The older engine model has significantly more power at low RPM. You will also see a representative "propeller curve". The curve is what we might see for a vessel starting at idle and running up to top speed. This is the "steady-state" curve and does not account for any additional thrust needed for acceleration. Acceleration is achieved only when there is sufficient power available above the "steady-state" propeller curve. You can see how a boat's acceleration could be severely restricted over the low RPM range with the EC engine.

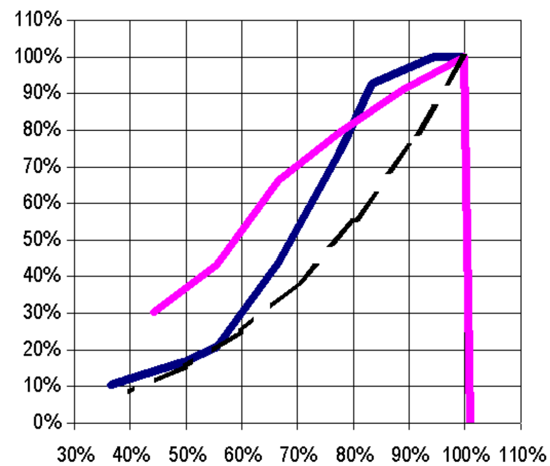

Figure 3. Comparable Engines with Prop Curve

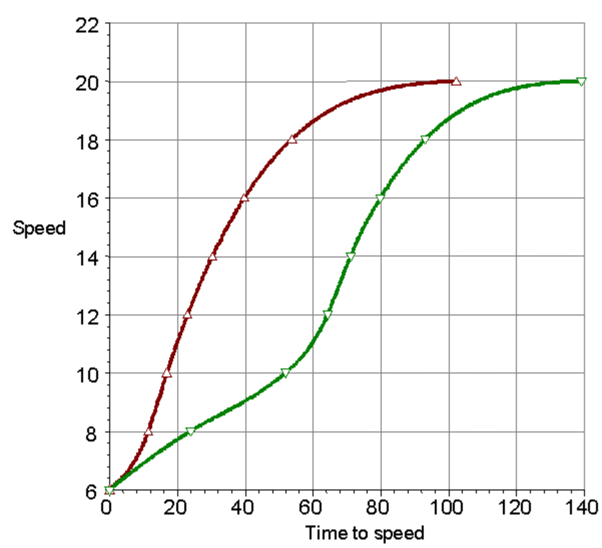

Figure 4. Acceleration Time-to-Speed

Let's look at the results of an actual case which was evaluated with contemporary speed/power software that can predict vessel acceleration. The plot above (Figure 4) shows the effect of a reduction in low-end power. This patrol boat took an extra 40 seconds to get to top speed (20 knots) from idle (6 knots). As you can see, most of the delay occurred in the initial period where the engine has reduced power.

We are witnessing the most dramatic problems of a mismatched EC engine-based propulsion system when the problem of reduced power at low RPM is extended to a vessel with consistently high "low-end" loading, such as with bollard pull, dynamic positioning (DP), or even running in high wind and seas. The opening story is exactly such a case where both propellers are under heavy thrust loading due to acceleration and seas. These propellers are pulling so much power at low RPM that the engine could not turn up more than about half of its rated value.

Under heavy load, the "steady-state" propeller curve is pushed up and to the left, leading to something that looks like the plot below (Figure 5). In the case of this engine and propeller loading, when pushing the throttle ahead from idle the engine will overload at about 45% RPM (point A). Helmsmen operating vessels with this behavior may run the throttle in and out until the propeller "slips" enough to get around the "shoulder" or "pinch point" (point B).

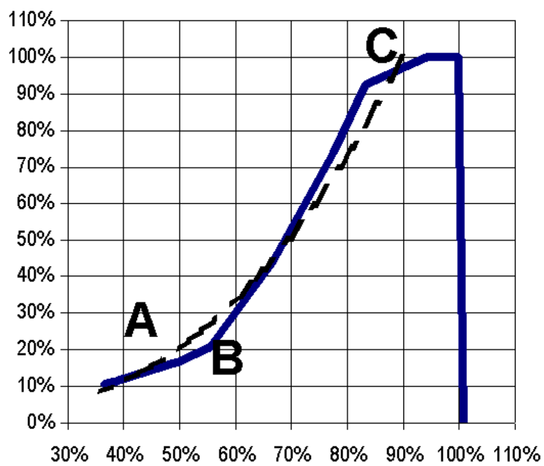

Figure 5. EC Engine Curve with Bollard/DP Prop Curve

This was the case in the opening story. After a period of limited acceleration, the propellers unloaded a bit at the higher boat speed and by tweaking the throttles, the propellers got around the "shoulder" and ran up to about 88% RPM (point C).

(As a side-bar to the topic of vessel acceleration, it is probably useful to mention that surface drives can be particularly problematic. Depending on the type of drive system, the top half of the surface-piercing propeller may not be fully ventilated at low speed. When compared to other propulsors, the immersion at low speed loads the propeller to the extent that it demands a significantly greater low end torque. This clearly suggests that boats considering surface drive systems must have a thorough system analysis, including an evaluation of acceleration.)

ACHIEVING A SUCCESSFUL INSTALLATION

By now, you might have formed the opinion that EC engines are more trouble than they are worth. Nothing could be further from the truth. They uniquely satisfy certain design objectives, and their reduction in fuel rate and emissions (notably NOx gases) have been significant. We simply need to recognize that an EC engine is part of a *system* – with each part shouldering responsibility for success or failure.

One of the features of many EC engine models is the ability to actually program the shape of the engine's power curve. When approaching a problem like those described above, it may be very possible for the engine's EC system to be reprogrammed to provide some additional low end power. This is not always possible, nor will it always solve the problem, but it is something that should be investigated. If additional power cannot be generated in this way, we can best utilize an EC engine with some relatively new propulsors and transmission options:

- special propeller designs that reduce power load at low RPM (flattening the K_Q curve at low J),
- two-speed gearboxes (using the higher of the two ratios during bollard, so that the engine is allowed to turn faster for the necessary propeller RPM),
- or best of all, a controllable-pitch propeller (with complete control through the RPM-power range).

CONCLUSIONS

More so than ever, a true *system analysis* approach is needed when determining required engine power, best gear ratio or optimum propeller parameters for a vessel with EC engines. Make sure that you have evaluated not only the principal speed, but also the entire operating range of the vessel.

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