"Greener" Ships Through Systems Engineering

By Donald MacPherson

Naval Architect Donald MacPherson's approach focuses on optimizing systems, well before the optimization of individual components.

"Pragmatic hydrodynamics" has long been a core element of the HydroComp brand. Our mission is to provide technical software and consulting services that can be used to confidently determine answers to the big performance questions, such as:

- *How much power is needed to meet a speed requirement?*
- *What are the proper power and gear ratio of the engine and transmission that I need to purchase?*
- *What are the characteristics of a proper propeller for the mission?*
- *What is the nature of a vessel's existing performance, and how can it be improved?*

We answer these questions by focusing on the engineering of an optimized system, before the optimization of components. This sharp attention to "systems engineering" is the direct result of our experience over nearly three decades of involvement with the prediction and management of vessel and propulsor performance.

As most engineers are taught in school, systems engineering is the assembly of various available components to deliver the best system. Unfortunately, in the current revolution that is the "greening" of ship performance, it has been my observation that our industry has lost sight of the system and has become enamored with tweaking components. To consider components before looking at the system leaves a lot of "green" on the table.

The Importance of the System

One of our consulting services is "forensic analysis," helping clients determine why a vessel is not performing as it should. For these cases, we are interested in the propulsion system that is made up of component equipment. It is a most curious thing to listen to the various component equipment builders as they describe the same problem vessel. Each thinks that their component is being unfairly singled out as the cause for the problems:

- *A boat can't make speed? The engine builder says that their component is blamed for not producing the power it should. They are accused of component failure.*
- *Is there excessive noise and vibration at the stern? The propeller builder states that their component is indicted as generating too much cavitation and being no good. This is another perceived failure of a component.*

In all but a few cases, the components are fine. Engines (with exception) produce the power that they claim. Although they are a complex mechanical assembly, each engine is generally evaluated on a test bed before delivery.

Propellers are a single piece of bronze, and have no moving parts. Propeller companies typically have thousands of propellers in service, developed over time by an in-house design staff with years of experience. How bad can the design of a contemporary propeller really be? (It is important to note that there have been, and will continue to be, propeller manufacturing issues for smaller stock propellers that often require the point-of-purchase supplier to inspect and "fair" the propeller. However, this is largely understood today to be a practical reality within the typical delivery process.)

The problems that we see are almost universally with the system – and therefore, the most effective path to achieve "greener" overall ship performance is to start with the system. We need to look past the temptation to acquire the flashiest new component. We already have well-designed components, but they are simply not being assembled properly into a cohesive system that meets the intended objectives of the vessel. Put the initial focus on the system.

So, how do we get the "greenest" vessel in practice (and not in theory)? We need to first lay a solid underpinning of an effective and stable system, one that can take advantage of the best components. From our perspective at HydroComp, there are two principal considerations that lead to solid systems – suitable computational tools and appropriate early-stage design decisions.

Tools for Systems Analysis

It may seem counter-intuitive, perhaps, but some of the newest types of computational tools are actually the least effective in evaluating the system. In days past, we worked with simple charts and looked to prior jobs to make sense of what was needed. We went into the project knowing what worked last time, and then perhaps we pushed the envelope a little bit. The tools were all systems-focused, and provided quantitative answers to fundamental questions:

- *How fast can I go before drag makes operation really expensive?*
- *How much engine do I need to make sure that I can reach the contract speed?*
- *What are the characteristics of the propeller that I need to provide?*

Our HydroComp NavCad software is an example of a contemporary "systems tool" that is elegant, comprehensive, and an accurate way to achieve an understanding of the system and to specify what is needed from the components. It provides the means by which a naval architect can first evaluate the system, and then begin to drill down into the specification of the components.

Appropriate Early-Stage Systems Engineering Decisions

Careful decision-making early in the design process is the other foundation for the "greenest" system. Let me offer two quotes that every naval architect should learn:

"By the time of the first design review, performance, cost and schedule will have been determined to the first order, because all of the critical assumptions and choices will have been made. The really serious mistakes occur in the first day." **[1]**

"Fifty percent of a product's life-cycle costs are determined by the results of the project's first five percent." **[2]**

Put another way, early decisions such as selection of propulsor type (propeller vs. waterjet), hull shape (round bilge vs. hard chine), or stern design (shaft angle, propeller clearance) will lock you into the major cost-drivers and a system configuration. It is during these early system-level investigations that the big vessel design and performance questions are answered:

- *What are my overall efficiencies going to look like?*
- *Do I have enough power to make speed?*
- *What are the implications of shaft angle and propeller clearance on hydroacoustics and noise?*

If these are not carefully evaluated in the first few cuts around the design spiral, then it makes no difference how good a component might be – the system will fail.

Another driver of "green" decision-making is proper expectation of deliverable performance. I cannot tell you how many poorly performing vessels started with someone's unrealistic belief in an achievable vessel speed, in which there was no physical justification to hold these beliefs. Even the most rudimentary system analysis would have exposed that these expectations were unrealistic and unattainable.

Component Optimization

So what about component optimization? While optimization is critical for the "strategic" (product model) design of the component itself, it is not necessarily germane to the "tactical" (right here and right now) systems analysis of a ship design. Don't get me wrong, optimized component design – whether that be the hull, engine, or propulsor – is absolutely crucial to the evolution and improvement of the component itself, and ultimately the system. Given available components, however, proper systems engineering insures that you get the most out of the whole. We are almost always better off with a well-functioning system of good components, than a poorly functioning system of outstanding components.

Let me cite a consulting project from some years ago. This was a classic case where a hull, engine, and waterjet were individually well designed, but they functioned poorly as a system. By improving the interaction of components via modest redesign of the hull and selection of a different waterjet model, the vessel achieved speed with substantially reduced delivered power, fuel consumption, and emissions. A "green" success!

Summary

When seeking the path to "greener" performance, the first step should not be to fine-tune the component. It should be to improve the system, just as we did for the example cited above.

Are you really serious about saving fuel and reducing emissions? Then make sure that the hull, propulsor, transmission, and engine are well matched to the mission and operational profile of the vessel. Improved engineering of the system will provide a greater reduction in fuel and emissions than by optimizing an individual component by a few percent. First, get the system right. Then, and only then, should you look to improve and optimize the system's components. You will be in a much better place to take advantage of what the component designers and builders can deliver for you.

[1] - Eberhardt Rechtin, The Synthesis of Complex Systems, IEEE Spectrum, 1997.
[2] - Business Week, "A Smarter Way to Manufacture", 1990.

The Author

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