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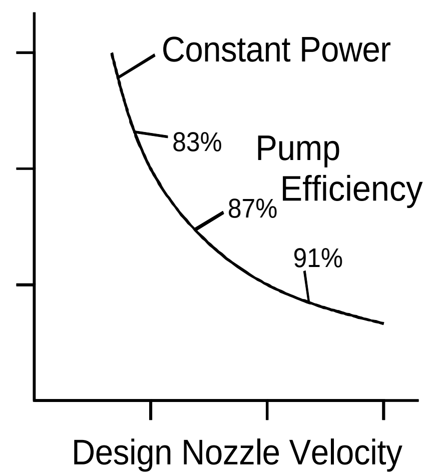
Fast Ship Propulsion

The Relative Unimportance of Pump Efficiency

There has been some confusion about the importance of pump efficiency in marine jet propulsion. In fact**, a less efficient pump can be the heart of a much more efficient propulsion system,** because so much more power is lost in other parts of the system that using a less efficient pump can save a lot more power elsewhere. This strategy results in much more versatile and efficient propulsion for variably loaded rapid ocean transports, patrol/interdiction vessels, and littoral combat ships.

Let's start with low speed operations, acceleration, and maneuvering. The following graphic shows the relationship between pump efficiency and propulsion efficiency.



The resulting thrust force from a given amount of hydraulic power is the best measure of propulsion efficiency. It is clear from this that **the highest thrust force results from the design based on the lowest pump efficiency due to the much higher fluid power transfer efficiency.**

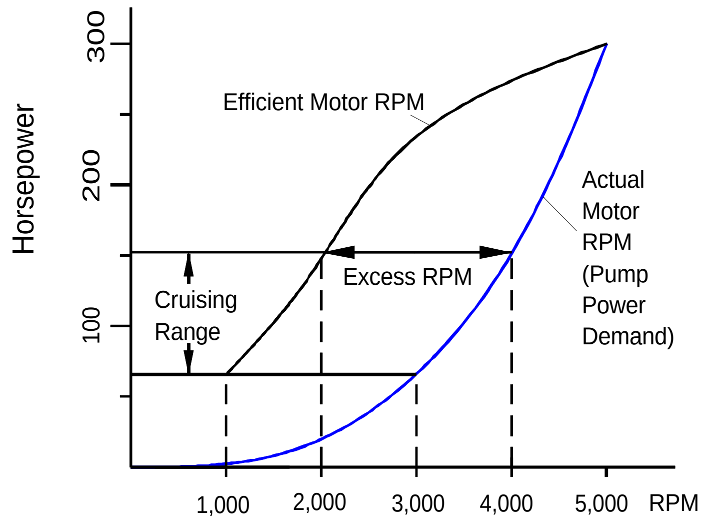
Propeller pumps move more water at lower efficiency. Mixed-flow pump designs are more efficient moving less water at a higher pressure, as is common in the designs of the conventional marine jets. The most efficient pump produces less than half the propulsion force produced by the least efficient pump with the same amount of power. At low speeds, fluid power transfer efficiency is much more important than pump efficiency.

> For those that want to review the basics of propulsion fluid power transfer, we have the momentum equation Ft = mV (Force x time = mass x Velocity) from which F = MV, where F is the thrust force, M is the mass flow rate m/t and V is the nozzle velocity of the marine jet. The Energy equation is E = (mV^2)/2 and Power P = E/t = (MV^2)/2. From dividing these relationships F/P = 2/V or F=2P/V. This is the relationship plotted in the graphic.

Patent Pending

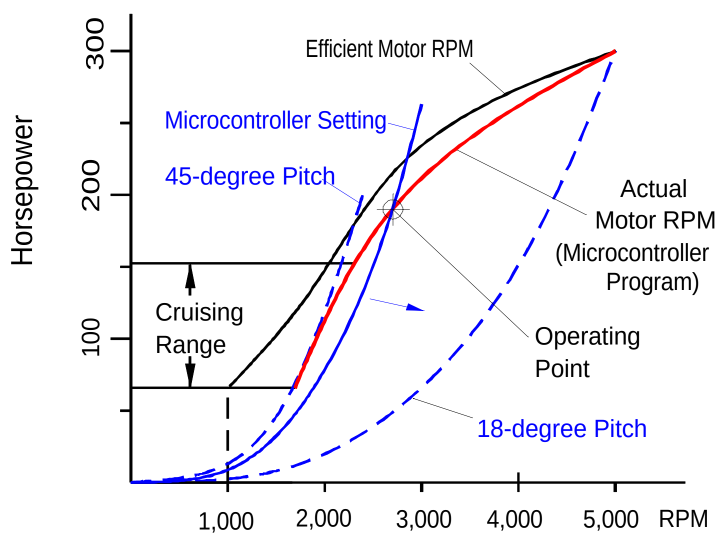
You might think that systems based on the most efficient pump design would make a comeback in steady state cruising operation. In fact, the gains in fluid power transfer efficiency still exceed the losses in pump efficiency. In addition, the power demand curve of the most efficient pump results in very inefficient motor operation, which causes far more power to be lost in the motor operation than is saved by having the most efficient pump. This is summarized in the following graphics:

Design Based on Efficient Mixed-flow Pump



You can see that the motor must run at nearly twice its most efficient RPM to deliver power to the efficient pump. This results in 20% to 30% more fuel consumption. The more efficient total system again uses a less efficient pump that can provide continuously variable power transmission to operate the motor more efficiently. The following graphic shows the more efficient motor power demand curve resulting from this compromise.

Design Based on Variable-pitch Propeller Pump



This is the design motivation for the Variable Marine Jet. In exchange for an 8% less efficient pump, the programmed power demand curve results in 20% to 30% fuel savings. This is in addition to fluid power transfer savings of 30% to 40%, as discussed above, because the Variable Marine Jet following the programmed curve has lower jet velocity at lower speeds. In summary, both motor efficiency and the fluid power transfer efficiency are substantially improved by this system strategy, which results in twice the thrust per fuel BTU input. These propulsion efficiency gains are 7 to 10 times the loss resulting from reduced pump efficiency in the variable pitch propeller pump. The increased thrust available at midrange speeds is also valuable for increased maneuverability and sea keeping.

Well then, the design based on the most efficient pump must come into its own at the top design speed? Yes, but only if the system is operated at the speed required for the current load. Unfortunately, the most efficient speed for the efficient-pump system rises as the load increases. To operate efficiently with an increased load would take much more power and is therefore contrary to normal operation, wherein the vessel usually operates at lower speed with a larger load. This common strategy causes the efficient-pump system to operate even less efficiently than it would at constant speed. You can see why such marine jets are most popular in high-speed ferries, where the load and transit speed are nearly constant. It is also easy to see why they won't work very well in variably loaded rapid transports, patrol/interdiction vessels, or littoral combat ships, which must operate at various speeds and maneuver as required by lading and operational circumstances.

The narrow range of efficient operation of the efficient-pump system at high speeds results from the importance of inlet duct efficiency, which rises approximately as the square of the vessel speed. At high speeds more power is commonly lost in the inlet duct than is lost in the pump, so inlet duct efficiency becomes more important than pump efficiency. A dynamically adjusted variable inlet duct is required to reduce these losses for a broader range of efficient operation. This invites the use of a larger pump and nozzle for better fluid power transfer efficiency. Then a dynamically adjusted variable nozzle is required to maintain efficient pump operation. These were the subjects of the first three MJTC Patents.

It is worth noting that inlet losses are proportionate to the system flow rate and to the square of the vessel speed. The Variable Marine Jet acts to reduce the system flow rate as the vessel speed increases by reducing the nozzle size. It has a large nozzle for high fluid power transfer at low speeds, and a much smaller nozzle at high speeds, where it is important for reducing system flow rate.

In summary, the Variable Marine Jet greatly reduces all of the power losses common in fixed geometry marine jets based on efficient pumps. The 7% or 8% reduction in design pump efficiency is repaid by 30% to 100% gains in propulsion efficiency over most of the operating range. Higher fluid power transfer improves maneuverability and sea keeping. High-speed propulsion efficiency is independent of vessel lading for unprecedented mission flexibility in a variety of High Speed Vessel configurations.