TWIN DISC SURFACE DRIVES

Why A Surface-Piercing Propeller?

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SURFACE-PIERCING PROPELLERS

Intuition suggests that a propeller in which the blades are out of the water for half of each revolution will be inherently less efficient than a fully submerged propeller. Surely the steady flow around the continuously submerged propeller blade must work better than the interrupted flow around the blades that splash through the air-water boundary twice with each revolution. But nature sometimes plays tricks on our intuition, and often an unsteady process can outperform its continuous counterpart.

A summary of the principal reasons for the high performance of surface propeller systems relative to conventional installations follows.

Diameter

Traditional propeller design and selection is almost always an exercise in trading off diameter against several other performance limiting parameters. Basic momentum theory tells us that for a given speed and thrust, the larger the propeller, the higher the efficiency. While there are exceptions, most notably the effects of frictional resistance on large propellers, it is generally borne out in practice that a larger propeller will be more efficient than a small one.

Blade tip clearance from the hull, maximum vessel draft, shaft angle, and engine location all tend to limit the maximum feasible propeller diameter to something considerably smaller than the optimal size. While this may at times make life easy for the designer - the diameter is simply the maximum that fits, it can also result in a considerable sacrifice of propulsive efficiency. Or, if these geometric limits on propeller diameter are exceeded, the result can be excessive vibration and damage due to low tip clearances, or a steep shaft angle with severe loss of efficiency and additional parasitic drag, or deep navigational draft that restricts operation or requires a protective keel and its associated drag.

The surface propeller frees the designer from these limitations. There is virtually no limit to the size of propeller that will work. The designer is able to use a much deeper reduction ratio, and a larger, lightly-loaded propeller.

Cavitation

When a submerged propeller blade cavitates, the pressure on part of the blade becomes so low that a near-vacuum is formed. When these cavities collapse, water impacts on the blade surface with a local pressure singularity. The effect can approximate that of hitting the blade with a hammer on each revolution. Cavitation is a major source of propeller damage, vibration, noise, and loss of performance. And although high-speed propellers are often designed to operate in a fully cavitating mode, problems associated with cavitation are frequently a limiting factor in propeller design and selection.

The surface propeller effectively eliminates cavitation by replacing it with ventilation. With each stroke, the propeller blade brings a bubble of air into what would otherwise be the vacuum cavity region. The water ram effect that occurs when a vacuum cavity collapses is completely suppressed by this entrained air. While the flow over a superventilating propeller blade bears a superficial resemblance to that over a supercavitating blade, the vibration, surface erosion, and underwater noise are absent.

Appendage Drag

Rudders, exposed shafts, struts, and propeller hubs all contribute to parasitic drag. Inclined exposed shafts not only produce form and frictional drag, but there is also induced drag associated with the magnus-effect lift caused by their rotation. (There is also a surprising amount of power loss resulting from the friction of the shaft rotating in the water flow. In fact, a net performance increase can usually be realized by enclosing submerged shafts in non-rotating shrouds, despite the increase in diameter.)

Surface propellers virtually eliminate drag from all of these sources, as the only surfaces to contact the water are the propeller blades and a skeg or rudder.

Variable Geometry

When a surface propeller is used in conjunction with an articulated drive system, the vessel operator then has the ability to adjust propeller submergence underway. This has roughly the same effect as varying the diameter of a fully submerged propeller, and allows for considerable tolerance in selecting propellers - or it allows one propeller to match a range of vessel operating conditions. This capability is somewhat analogous to adjusting pitch on a controllable pitch propeller. When the articulated drive is used for steering, the result can be exceptionally good high-speed maneuvering characteristics. On single-shaft applications, drive steering can also be used to compensate for propeller-induced side force, without resorting to an excessively large rudder or skeg.

These are the intrinsic performance advantages of surface propellers. Other desirable characteristics include shallow draft capability, flexibility in machinery arrangement, ease of maintenance and repair, and simplified installation. In some applications involving hybrid propulsion systems, the ability to retract one set of propellers completely clear of the water is an overriding consideration.

The ability to use large diameters and deep reduction ratios is a capability that is just beginning to be exploited. Surface propellers have long been accepted for racing applications, where minimizing appendage drag is the major motivation. In recent years, an increasing number of high-speed yachts and patrol boats have been propelled by surface propellers. Their use for relatively heavy and slow vessels is new. A major obstacle to overcome is the cost of the large propeller and power transmission equipment capable of handling the higher torques associated with the deep reduction ratios. Life-cycle costs, however, especially for commercial vessels with heavy-duty cycles, are extremely favorable.