The Great Propeller Side-Thrust Mystery

Why Your Prop Pushes Sideways as Well as Ahead

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It's a peculiar thing, if you stop to think about it. Your boat's propeller—carefully refined and engineered as it is—not only drives you straight ahead, but a bit sideways as well. Of course—skilled boat handler that you are—you're used to this. It's normal, and—on single-screw boats in particular—is a pronounced effect at low or maneuvering speed. Indeed, you've almost certainly long mastered your prop's very definite side thrust, to assist in easing your trusty *Crank 'n Dank,* in to crisp precise dockings.

The Right-Hand Convention

The conventional standard single-screw prop installation is right-hand turning. This means that—as viewed from astern—her prop turns clockwise. A single--screw right-hand wheel always shoves *Crank 'n Dank*'s (or any boat's) stern to port when backing. Similarly, it always pushes her stern to starboard when going ahead. (This, naturally, tends to make her steer a bit to port when going ahead.) Left-hand-wheel single-screw boats behave exactly the opposite. Convention or no, there are enough left-hand single-screw boats around so that , when you take the helm of a new boat, you should always ask which way the prop turns. This can save you embarrassment, to say the least. Twin-screw boats are a bit more complicated, but we'll get to them in a bit.

You can tell a right-hand propeller from a left-hand propeller just by looking at it. As you view the propeller from astern the leading edge of the blades will always be farther away from you (closer to the bow) than the trailing edge. If the leading edge is to your right (viewed from astern), the propeller rotates clockwise and is a right-hand propeller. If the converse is true it is a left-hand propeller.

The great mystery is why the dickens propellers behave this way. It’s not at all obvious, and there are as many explanations for it as you can shake a boathook at. Until recently, I haven’t found one that satisfied me. At last, however, I have. The mystery is—I believe—solved.

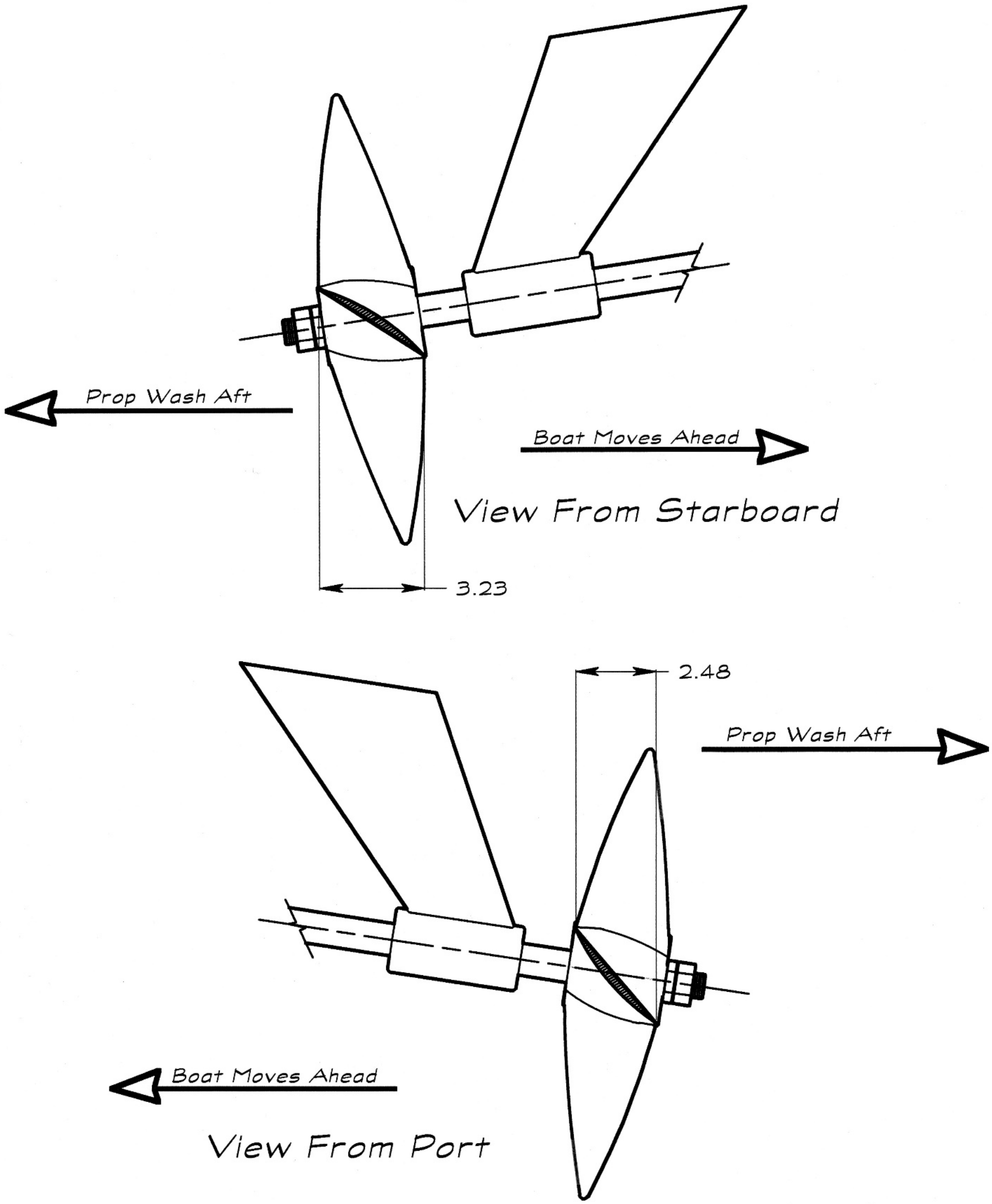
The Simple (And Not So Accurate) Explanation

Now, the standard simplified explanation is that the water at the bottom of the propeller is a bit denser and freer to flow (there's no hull above it) than at the top of the propeller. This makes the lower blades a bit more effective, so the propeller and the stern "walk" sideways in the direction of rotation. Since it’s simple and it sounds reasonable, I’ve used this explanation myself on occasion. The only problem with all this is that it doesn’t hold up to careful analysis. The fact is that water is, relatively speaking, incompressible. The water at the bottom of the propeller is—for all intents and purposes—no denser than it is at its top. Further—though the hull above the prop does restrict water flow slightly—if there’s proper tip clearance, the effect will be slight.

The Inclined-Shaft Explanation (The P-Factor)

So what is the answer to the great mystery of propeller side thrust? Well, a much better explanation relates to blade pitch and shaft angle. Take a look at the drawing "side Thrust From Shaft Angle." This show's the same propeller, on its angled shaft, but viewed from both the port and the starboard sides. We've chosen a four-bladed prop so all the blades are at right angles to each other (to make things easier to visualize), and—as shown here—the port and starboard blades have been captured at the moment they're exactly horizontal. Since this is a right-hand wheel, the right hand blade is moving down, and the left hand bladed is rotating up.

If the shaft were horizontal, then the pitch of the two blades—relative to the horizontal (the direction of motion)—would be the same. With the shaft angle, however, this is not the case. You can see that the starboard blade advances further (in this case, 3.23 inches) than the port blade, which only advances 2.48 inches. What this means is that the starboard half of the propeller disk is doing somewhat more work than the port side. Essentially, this moves the center of pressure on the propeller off a bit to the right—to starboard. Since the center of pressure's off to starboard of our *Crank 'n Dank*'s centerline, then it will push the bow to port—exactly the phenomenon found in all right-hand props. In reverse, the effect is also reversed, and the stern is swung to port (the bow is swung to starboard). Because this all relates to pitch, the effect is sometimes termed the *P-Factor.*



Side Thrust From Shaft Angle

Avoiding High Shaft Angles

This change of pitch from port to starboard with shaft angle, is one of the principle reasons that too much shaft angle isn't a good thing. The uneven blade loading that results can cause vibration. Generally, shaft angles under 15 degrees are acceptable but over this are not. Angles under 12 degrees are excellent.

Shaft-Angle Explanation Problems

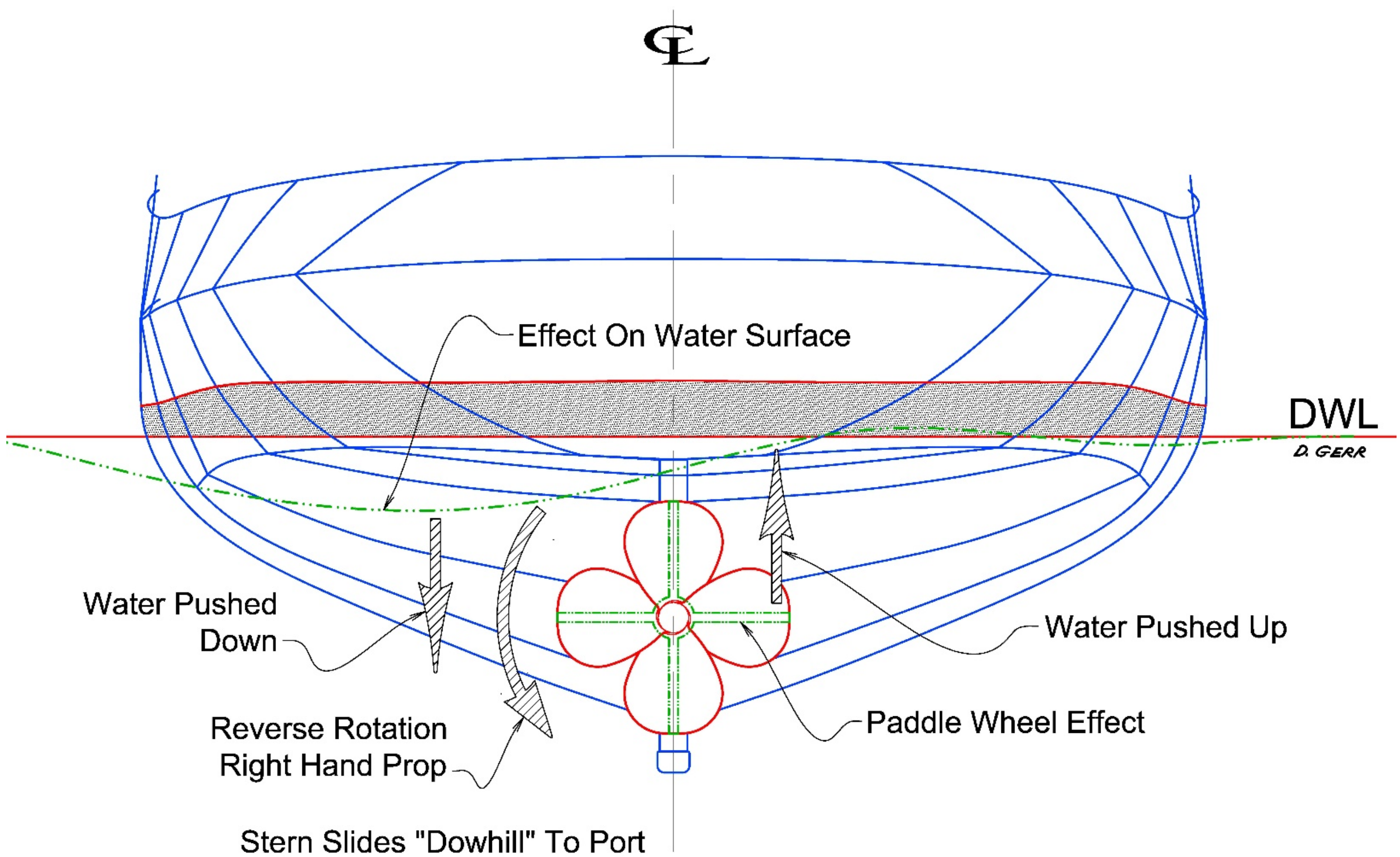
Since this all works out well, and is—indeed—the standard explanation today, you'd think that our propeller side-thrust mystery was solved. Unfortunately, clever as the shaft angle or P-factor explanation is, it isn't the whole story. In fact, I've worked on the engineering of a planing 40-footer that had a 17 degree shaft angle. Though I don't think this is good practice, I'd inherited this set up and found that it worked fine. How come?

My feeling is that the suction ahead of the propeller disc, tends to straighten out the water flow so that it enters the prop at much closer to parallel to the shaft than simple straight-ahead motion would indicate. Thus—in the case of this 17-degree-shaft boat—the water-inflow angle to the prop my well have been closer to 9 degrees than 17.

A more significant problem, though, is that if the shaft-angle explanation of prop side thrust were accurate, then you'd expect to get no side thrust at all from props that were on dead horizontal shafts. This, however, is most definitely not so! Indeed, heavy single-screw tugs and trawlers can have exactly horizontal shafts, yet they experience propeller side thrust more powerfully than almost any other craft. What gives?

Paddle-Wheel Effect

Well, the shaft angle explanation is certainly part of the story, but the other part has to do with the density and friction (viscosity) of water. Because of these two properties, water doesn't flow easily through a restricted space. As far as I know, this density/viscosity explanation was first thought out by L. Roy Murray, a professional ship pilot who'd spent many years studying big ship behavior (again, vessels with roughly horizontal shafts).



The Paddle Wheel Effect
(Exaggerated)

The Pressure Builds Up

What he realized works out as follows: Our trusty *Crank ‘n Dank*’s prop blades are (as we’ve seen) angled to produce thrust. Though, most of this blade angle drives the water aft, some small percentage of this acts like a paddle wheel, with the blades lying parallel the shaft. Of course, in this case, the blades on the starboard side (on a right-hand wheel) will be pushing some water down into the ocean. On the port side, however, the blades will be pushing some water up against the hull. Here—due to density and friction, the water can’t escape as quickly as it’s being churned up. In other words, the port-side blades are building up a mass of water along the underside of the port side of the hull aft. At the same time, the starboard blades are forcing water away from the underside of the starboard side of the hull aft. What the prop is doing is creating a lopsided hill underneath the stern. The water level’s a bit higher under the port side than under the starboard. Since gravity’s still pulling down on the hull, the stern slides sideways down the hill off to starboard. This effectively pushes the stern to starboard and the bow to port—exactly the effect of propeller side thrust.

Greater Effect at Low Speed

More impressive is that this explanation accounts for why the propeller side thrust is greater at low speed and during maneuvering. It’s before your *Crank ‘n Dank* has gathered way, that this paddle-wheel effect is most pronounced. In fact, once old *Crank ‘n Dank* gets up to speed, the rapid rearward flow of the water reduces the paddle-wheel effect to a minimum—the nascent hill of water is carried away aft in the flow before it has much effect. (This is also why prop side thrust is more pronounced on displacement-speed hulls.) When you maneuver at low speed—starting and stopping and reversing—there's very little fore-n-aft flow, however. Instead, much of the prop's first few seconds of work goes almost entirely into this transverse paddle-wheel churning. Again, large slow turning props experience greater side thrust than small high-speed wheels. This too is explained by the paddle-wheel effect—the large slow moving blades throw more of a transverse paddle-wheel wash. Of course, the example above is for going ahead, it works properly when going in reverse as well. In this case, the paddle-wheel effect builds up a hill on the starboard side (on a right-hand prop), which slides the stern to port. This is shown on the illustratoin "Paddle-Wheell Effect."

Twin-Screw Paddle-Wheel Effect

Naturally, the same effect occurs on twin-screw craft. In this case—with contra-rotating props—the effect is canceled out. If you run under a single engine; however, the paddle-wheel effect will be the same, for each prop. Going ahead on the starboard wheel only, on a twin-screw boat, would build up pressure under the inboard starboard hull bottom. This cancels out some of the off-center starboard wheel's tendency to steer to port. Similarly, in reverse, the pressure will be built up to the outside of the underbody to starboard, and will back you to port, even more strongly than the off-center wheel alone. The left-hand port wheel—conversely—will build up pressure on the underside of the port side going ahead, which will drive the stern to starboard and push the bow to port. This somewhat cancels out the starboard-only prop's off-center tendency to drive the bow to starboard. In reverse, the starboard wheel will build up a pressure hill under the far outboard port corner of the stern. This will slide the stern to starboard. Backing with the left-hand port screw only, will thus force the stern to starboard even more than the off-center shaft location would suggest.

The Propeller Side-Thrust Mystery Solved

The paddle-wheel or density/viscosity model explains propeller side thrust at last. Add in the shaft angle (P-factor) model and you have the full, combined solution to the great propeller-side-thrust mystery.

A Chartered Engineer and Fellow of the Royal Institution of Naval Architects, Dave Gerr is a naval architect based in New York City. A lecturer a SUNY Maritime College, Gerr is the author of *Propeller Handbook*, *The Elements of Boat Strength*, *The Nature of Boats*, and *Boat Mechanical Systems Handbook*, all published by International Marine/McGraw-Hill. Information on Gerr's design firm, Gerr Marine, can be found at www.gerrmarine.com.