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To Wax, or Not to Wax

An Engineering Perspective

By Christopher VanEpps

Which is faster? A waxed/polished hull, or a wet-sanded one?

This is a question which "surfaces" (ha, ha) on a regular basis and quite often a wave of psuedo-science based debate swells and threatens to capsize scientific reason. While I don't purport to be the Moses who will read from the tablets of speed and end all the arguments, I have, at least, seen the burning bush of science and would like to share my understanding with the reader.

What follows are some basic aero/hydrodynamic principles and my observations based on same. I would like to thank Bill Mattson, Mike Fahle, Sonny Barber, Mark Michaelsen and several others (my apologies to those I haven't named) on the Hobie Mailing List, for keen insights and anecdotes they've shared with me and I've paraphrased here, as well. They are, as a group, far more experienced sailors than I. Many thanks also, to Brenda Carpenter, MS in Aeronautical Engineering from MIT, for technical editing and BS detection. My apologies to the Mailing List subscribers, for many of them have already seen this information, in one form or another. Those who'd like a refresher and those of you with first-time curiosity, read on. Directions for accessing and subscribing to the Hobie Mailing List may be found elsewhere in OTW.

The real answers can, perhaps, be found in the world of fluid dynamics and a discussion of laminar vs. turbulent flow and the associated boundary layer. Since an in depth study of this is about as fun as a root canal and so dry one must be hooked up to an IV just to read a text, I will take my references, in this first section, from a fabulous book entitled "The Illustrated Guide to Aerodynamics" by H. C. Smith, 2nd Edition. This book reads more like a novel than a text and one doesn't need a mastery of calculus and hieroglyphics to attain enlightenment.

The following rules apply whether a fluid (air or water) is passing around a surface (sail or hull), or the surface passes through a static fluid. In essence, laminar flow occurs when a fluid flows over a surface in a smooth, layered fashion, in which the streamlines all remain in the same relative position with respect to each other. One must observe the phenomena of skin friction and boundary layers to understand flow. The viscous nature of air or water causes it to "stick" to the surface over which it flows; thus the velocity directly on the surface is zero for any velocity of the main air or water stream. Put into our terms, as our hull speeds through static water (water with no velocity) at 10 kts, the water molecule right next to our hull "sticks" to the hull and is "dragged" along at the same 10 kts. Proceeding above the surface, the velocity gradually builds up to free stream velocity (the velocity of the stream if the surface wasn't present at all) at some distance above the surface. In our sailing case, where it is the surface that's moving through the fluid, as one looks at molecules of water in increasing increments of distance from the hull, they gradually go from 10 kts, to 0 kts.. This area between the surface and the point where velocity reaches that of the free air stream is called the boundary layer. The reaction to the retardation of the flow velocity within the boundary layer is called skin friction drag. The thicker the boundary, the more drag.

A turbulent boundary layer is thicker than the laminar. Turbulent flow is marked by streamlines that break up and become all intermingled, moving in a random, irregular pattern. Laminar flow goes through a transition region before becoming turbulent. In terms of efficiency/speed: Laminar = good, Turbulent = bad (in *most* cases, but not all). This transformation in flow can be seen in the smoke rising from a cigarette in calm air. The smoke rises initially in a laminar manner. Then, as it encounters the friction of passing through the surrounding air, it transitions to a turbulent flow. A scientist named Osborne Reynolds found that whether a boundary layer was laminar or turbulent depended on the fluid velocity, the distance downstream, and the fluid's kinematic viscosity. The Reynolds number (Re)= ((fluid velocity*distance from leading edge)/kinematic viscosity) and is used to describe the viscous qualities of a fluid-surface interface. At low Re the flow is laminar and a high Re indicates turbulence. The point at which a laminar flow turns turbulent can be referred to as the Critical Re. In aircraft, since there is a change in Reynolds Number at each location on the wing as one heads down stream from the leading edge, it is customary to use a "characteristic" representative length from which to calculate the number. This keeps us out of calculus. The Reynolds numbers in most sailing applications however, (sail/air; foils/water) are orders of magnitude lower than those associated with aircraft. This is significant. It is important to note, that either an increase in speed, or, more importantly, a significant distance from the leading edge (bow of your boat) can greatly increase the Reynolds Number.

It is also interesting to note that a sailboat presents a rather unique aerodynamic scenario, in that it has 3-part boundary along the water line. An airplane wing only has to worry about the wing-air interface. A submarine only has to worry about the hull-water interface. A boat on the surface, however, has to deal with both the hull-water and the hull-air interfaces. This gets tricky right at the waterline and it has been shown that the hull will literally drag air molecules below the surface of the water, against the hull, breaking up flow. This can be seen in the extreme example of the Hobie Tri- foiler where, at 35-40kts, there is so much air being sucked down the foils that the flow starts to cavitate. Cavitation is the rupture of a liquid or liquid-solid interface caused by reduction of local static pressure. Basically, water at the surface saturated with air molecules and other impurities form little nuclei and when the local pressure around them drops drastically, such as when a foil is dragged by quickly, they expand until equilibrium then collapse. Many factors determine the amount of energy released, but in certain cases it is explosive and can pit and damage hydrofoils and propellers, even those made from stainless and titanium. The Tri-foiler has the sail plan for power to go much faster than 35-40kts, but they haven't solved the problem of foil cavitation. Putting vertical fences on the surfaces helps, but doesn't eliminate it. Luckily for Mr. Ketterman when cavitation does occur, section friction drag increases and lift decreases drastically, reducing speed and acting like a natural governor. Lucky also for us, our catamarans are traveling slow enough to not have to worry about hull cavitation, although we may get some pressure drag from small amounts of cavitation in our wakes. Still, it bears remembering that for a some vertical distance along the hull surface below the water line, the immediate substance touching the hull is air, not water. This distance will increase proportionally with hull velocity.

In an unrelated, but hopefully interesting side note: If one looks at the air-sail interface, one must also consider the sail's aspect ratio. Aspect Ratio (AR) is defined as the span divided by the chord of a sail/wing/foil. For a tapered sail or foil AR may be determined by dividing the square of the span by the whole sail area. While total drag has many components (parasitic, induced, friction, etc) and total lift relates more to angle of attack than aspect ratio, it may be generalized that a higher AR sail/wing/foil of the same area will generate the same lift with a considerable reduction in vortex-induced drag. Vortex-induced drag is caused by downwash (sideways wash in sails) causing the air stream to deflect at a different angle than the oncoming air. The lift vector actually gets tilted backwards and that component of lift, in the direction of the airflow, is induced drag. This happens most pronounced at the tips of foils. This is why a lot of the more high performance rigs are specifying square-topped mains. If you let your leach curl in to windward, you're killing your self here!. Unfortunately the longer span of a High AR rig places the loads farther out (or up in sails), resulting in greater bending moments. These must be countered by heavier support structures that add weight and drag of their own. One rapidly reaches equilibrium and thus the 218ft^2 of H16 canvas isn't a single sail 1 foot wide by 218' tall :-).

Drag Queens are generally heavy, don't know much about sailing and their high heeled shoes can poke through your tramp. It’s best to minimize this type of drag on your Hobie as well. But I digress.

Okay, so how does all this relate to and solve the original conundrum?

Perhaps it would help to debunk some of the psuedo-science myths that people use when defending wet-sanding. I’ve heard the golf ball theory used. They say that a dimpled golf ball travels farther than a smooth one. They’re right. They then relate this to the rougher surface caused by the sandpaper, as compared to the smoothness of the wax/polished surface and claim this is faster. They’re wrong. A golf ball is spinning in an airstream caused by its forward motion. A perfectly smooth ball would suffer flow separation very early around its surface, a large wake and subsequently large pressure drag. Remember that Parasitic Drag = skin friction drag + pressure drag. A smooth ball has low skin friction drag, but really high pressure drag, because even though the flow is laminar, it separates from the ball very early. Now, if you put dimples on the ball to roughen the surface, the turns turbulent and the resulting higher energy flow can stay attached to the ball longer, delaying separation, making a smaller wake and reducing the pressure drag. You have traded off the increased skin friction drag against an order of magnitude drop in pressure drag. Thus, the total drag drops and your drive goes farther. Spheres (golf balls) are very special cases, from an aerodynamic point of view. See Figure 1 & Figure 2, below.

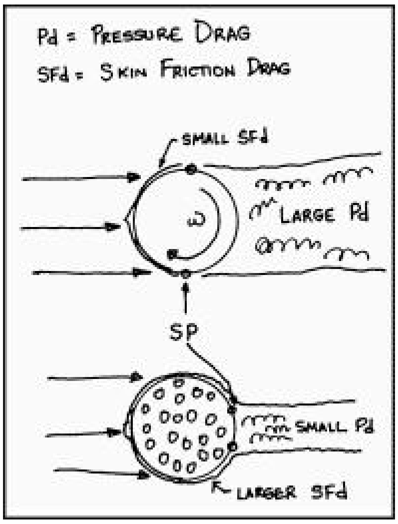

Figure 1. Golf Ball Aerodynamics

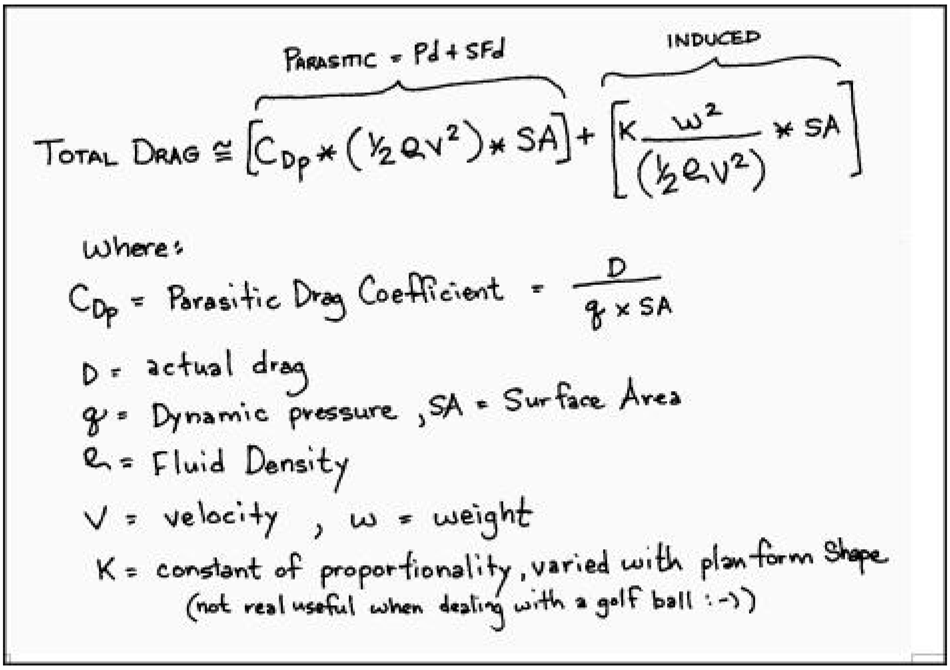

Figure 2 . Basic Drag Equation

Incidentally, tennis balls are fuzzy for the same reasons golf balls are dimpled. I can also explain how the stitches on a baseball are necessary to make them curve, some other time, if you wish. Don't even get me started on a Whiffle™ ball's aerodynamics. That's really scary. Great. Now, here's the difference between the golf ball and your boat and it's subtle, so try to stay with me. You're not sailing a spinning golf ball through air at 120 mph. You're dragging a cigar shaped thing through water at 10-20. If you guess that this makes a difference in the total drag picture, give yourself a cigar. You'd need some pretty big dimples ?. At the speeds your hull(s) is(are) traveling combined with the "roughness" caused by 600-1000 grit sandpaper, you aren't getting squat for lift and even if you did it'd be in the vertical plane and wouldn't help forward velocity unless it caused a planing situation, which it won't. (No this lift would not help you to windward!). All you're getting is the parasitic and induced drag components. The pressure drag component of the equation is small enough compared to the other components as to be ignored. Airplane wings would be completely smooth, waxed and all, in an ideal world. However, engineers put turbulators, vortex generators and other devices on them to "roughen the surface" of the wing. Why? Not to reduce drag and make them faster. It's to increase lift, or improve low-speed stall characteristics and/or to try to reattach turbulent flow before it completely detaches. Any roughening of the surface increases parasitic drag and decreases top speed potential in a foil type surface. The engineers just put up with this cause they have to. Keep in mind all of this theory is in reference to a particular body's Reynolds Number. A Hobie Cat will be operating at a very low average Reynolds Number, so allot of this talk is rendered moot. Just because one has a low Re doesn't mean one experiences laminar flow. Thus the importance of determining the critical Re, which is no small feat. And all talk of fluid dynamics pivot on the viscosity of the fluid involved and water and air aren't even close in viscosity. The bottom line is whatever one has to do to improve the flight of spinning golf ball really has no bearing on a Hobie hull(s) being dragged through the water by its sails.

Some point to the fact that water beads on a waxed surface, while exposed to the air, and this is due (correctly) to a phenomena called “surface tension”. They drown in the shallow end of logic pool by thinking (incorrectly) that this “tension” must “pull” on the submerged hull, slowing the boat down. I must pause to laugh here. If this were actually true, wouldn’t it hold that if you gave that same tenacious water thousands of little scratches to hold onto, it could pull that much harder? Motor oil will bead on a waxed surface and I’ll bet that’s pretty slippery too. Water has a surface tension property, but it’s dependent on the interface. Surface tension may also be broken, as you may be demonstrated by observing the meniscus disappear from a thin column of water, in a graduated cylinder, by adding a drop of liquid detergent. Hmmm, did I say surface tension can be broken “chemically”. Think about that. Discuss amongst yourselves. Luckily for us, what the air/water interface is doing has nothing to do with how it reacts, submerged at the hull/water interface. Not to mention that static and dynamic states have markedly different characteristics and we only care about dynamic flow. Same equations, but drastically different values. Water and air boundaries are completely different. Different densities, different viscosities, just different. The fact that water is beading in the air has no relevance to the discussion. Why do you think your daggerboards, used to balance forces are so much smaller than your sails? Different interface and mediums. The difference in drag, along a 16-20 foot hull, between a wet sanded hull and a waxed hull has never been experimentally confirmed, to my knowledge. That's how minute is the difference. Until someone drags a 600 grit sanded hull through a tank of water, with transducers attached to measure drag, then drags the same hull after waxing and proves a significant drag increase, I must insist that the lower drag will be attained with the waxed (smooth) hull. Frank Bethwaite, on page 263 of his brilliant book “HIGH PERFORMANCE SAILING”, states "...at practical yacht or dinghy speeds, only the bow area of the hull can hope to run with a laminar boundary layer. Under this area the surface should certainly be highly polished. But beyond this zone the flow will become turbulent (remember the Reynolds Number equation and the relation to distance behind the leading edge/bow) and under turbulent flow a highly polished surface will not be any faster than some rougher surface, provided always that the roughness is less than some small fraction of the boundary layer thickness." Central to this is that roughness. I believe the boundary layer thickness to be extremely thin at the hull water interface and while Mr. Bethwaite does not concretely recommend waxing/polishing the entire hull, he doesn’t preclude its success and distinctly promotes leading edge treatment. The key is to have your hull as aerodynamically smooth as possible to keep the flow attached for as long as possible, keeping the transition from laminar to turbulent flow as far downstream from the leading edge as possible.

Conclusions?

An individual who has sailed with and around Dennis Conner (of America’s Cup fame) related a quote to me in which Mr. Conner was asked why he wet- sanded his cup boats. He replied that he had absolutely no idea, but that if he didn’t, he was sure the other teams were and by God he was going to as well, if for no other reason than to level the playing field. It is also postulated that his teams wet-sand to promote team unity and to assure as “fair” as possible a hull form, more than a scientifically based attempt to gain speed. I believe he should wet-sand, then follow up with a silicone-based polish. It is interesting to note that when Dennis lost the Cup to New Zealand and subsequently took the Catamaran (yeah, boy) “Stars and Stripes” to get it back, he was not only wet-sanding, but using a controversial coating (polish) that I believe was called “Shark Skin”. It’s amazing to watch how in their desperation to go 0.001 knot faster, it’s even easier to suck the best sailors into trying every bottle of juice from every snake oil salesman on the globe. The fact is any possible difference that “Shark Skin” could have made, as compared to wet-sanding, or wax, or silicone polish, is so miniscule that it can’t be measured from the noise.

Go ahead and wax your hull. It will protect it from UV damage, keep it looking shiny and, thanks to Billy Crystal, we all know it’s better to look good than to feel good.

A Hobie Mailing List subscriber made another salient point that, unless you are doing your wet-sanding, on the beach, just before a race, you can rest assured your tow vehicle and trailer will be throwing all manner of road filth on your bare sanded hulls and it ain’t as smooth as you thought once you get to the race. Just a few streaks of tar and all your bets are off. Ever done a comparison of road grime removal between wet-sanded and silicone polished hulls. I have. No contest. Cleaner hulls are faster hulls we can all agree, N’est-ce pas? It’s also been postulated that wet-sanding on the beach the morning of a regatta is used as a psychological tactic. That is if someone sees a competitor paying that close attention to the details of his boat, he/she may begin to question his/her equipment preparation and any doubt one can place in an opponent’s mind on the beach translates to inches on the water. There may be some merit to that argument. Wet-sanding vs. Polishing is also moot the first time you blow a start or a tack, miss a shift, fail to cover a closely matched opponent, or foul someone and have to do a penalty turn(s).

So go ahead and wax your boat. If someone beats you and they wet-sand instead of waxing/polishing, they were a better sailor, not a better boat prepper. Even if it was Dennis Connor. Even the best can be scientifically misled. We won the spring A-fleet series on Cayuga Lake (NY) in a heavily waxed J33 this year. I have race-prepped boats from Sunfish® to Cats for people, including waxing and silicone-based polishes and they have finished no worse and sometimes better (psychological advantage?) than ever in regattas.

I believe the most important part of this debate, whether you personally decide to wet-sand only, or follow up with polish/wax, is the attention to detail either process brings. This is where gain can be achieved. By this I mean that a sailor/crew that expends the time and energy to painstakingly go over every inch of his/her hull(s) in preparatory obsession will necessarily be in tune with all his/her vessel’s nuances and idiosyncrasies and, I believe, this attention naturally flows to the rest of the sailing experience and the entire experience is heightened. Kind of Zen-like? One will also spot potential trouble spots sooner. That’s why most motorcycles you see are always spotless. A rider’s life may depend on mechanical integrity and a good way to stay in touch with that is to clean and preen. This has nothing to do with “having a faster boat”. Adjusting the “nut on the end of the tiller” through conscientious, contemplative time in the butt bucket is the only real way to do that.

I admit there are arguments to be made in opposition to mine that can sound pretty convincing. The only “fact” in this debate is that it is still just that. Most aerodynamicists will admit it’s still as much of an art as a science and the more we learn and understand, the less we realize we understand and the more we have to learn. The bottom line is that, as long is there is argument and the differences are microscopic anyway, I’m willing to err on the side of making my boat prettier and easier to maintain and, at the same time, will spend more time on the water, practicing skills.

For those who may be curious at this point, here is what I do to my boat (H16):

I wet sand, by hand, all the way up thru 500, 600, 800, 1000, and on to 1200 or 1500 grit 3M papers. I rub each grit of sandpaper in one direction only. Obviously you don't want to sand through the gelcoat, so prudence is essential here. Then, as I switch to the higher number paper, I rub at a 90 deg. angle to the previous. In this way, I can easily see when the tiny scratches from the previous paper have been removed. I keep alternating as I go up. Then I apply 3M Fine-Cut rubbing compound with a 7" orbital buffer. This removes the rest of the sanding swirl marks. I proceed with a good quality polishing compound (3M, or Turtle Wax) and finish with a silicone- based polish (Starbrite Boat Polish, McGuiar's #53/#53 Boat Polish, or Eagle Poly-1; whatever I have in the shop). I generally don't wax/polish the topside of the decks because it's virtually impossible to get the white residue out without gasoline and a flame thrower. I have discovered a silicone-based product from Black Magic®, called Professional Protectant™, that when applied to the decks, leaves an ultra-glossy, non-fading, UV protecting shine that lasts for weeks and makes the non-skid look like new. It's a simple spray on/wipe off process. Yes, it's possible I have to much spare time and, after all this, I still get my head handed to me on the race course, but it's not the hull prep of my boat that's to blame.

Now, if you'll excuse me, I'm going to go put some time in on the water. See you there.

Cheers,
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