SURFBOARD HYDRODYNAMICS PART III: SEPARATED FLOW

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Still at the Pipeline, and still those perfect peeling lefts (it's been a long winter). You're ready for it though: got the bottom of the board perfectly sanded and clean; you have minimum rocker in your new stick; you've worked a slight dihedral into the center of the board; you've even programmed yourself for the perfect angle of attack (about 4½°). You've removed your foiled fin, too, just on a hunch, and stuck in your new, round finger fin.

Then the line-up and the perfect wave cranking up like a studio prop on cue. You stroke and take the drop: perfect angle of attack, rails releasing perfectly, Vee parting the water beneath the board nicely, everything working fine till the lip of the curl catches up, swats you like a fly across the neck, and proceeds over you like the aft section, screws churning, of the Queen Mary.

On the beach sits your foiled fin. Bad hunch.

In Parts I and II, laminar and turbulent flow, and the generation of pressure due to the motion of the board were discussed. As you may recall, the average motion of the water past the board in both laminar and turbulent flow was along lines essentially parallel to the surface of the board. For certain types of shapes, pressures may be produced which tend to oppose the flow of water along these lines, and the flow may break away or become "separated." An example of such a flow is illustrated in Figure 1. A general characteristic of separated flows is that they are usually produced by an abrupt contraction in the shape of the board; for example, high rails, or considerable kick at the tail of the board. Such flows are usually accompanied by large increases in the drag of the board.

Another example of separated flow is the stalling of an airplane wing, which is analagous to the stalling, or "breaking free," of a surfboard fin. The difference in the flow pattern for a fin at a small angle of attack, and a stalled fin is illustrated in Figures 2 a, b. In Figure 2a, the point of separation is very close to the rearmost portion of the fin. However, as the angle of attack (and hence the lift) is increased, an angle is reached where the point of separation abruptly moves forward, as in Figure 2b. In addition to an increase in drag, the lift (component of force perpendicular to the direction of motion) suddenly decreases, and the fin is "free."

In Figure 2c, the flow around a cylindrical fin is shown. As can be seen from the figure, the flow around this fin is always separated, and such shapes have enormous drag compared with streamlined shapes. As an example, let us compare the two fins of Figures 2 c, d. The foil of Figure 2d has the same thickness as the diameter of the cylinder, but is about eight times as long. At zero angle of attack, as when dropping in, the cylinder has about thirty times the drag of the foil. Even at an angle of attack slightly below the stall angle, the drag of the foil is only about half that of the cylinder, and at this point it is generating about eight times as much lift (in this case a sideways force toward the face of the wave) as the cylinder is producing drag (the cylindrical fin is incapable of generating lift and requires that the board "drift" at some angle). From this example, it is clear that the pressure drag from the separated flow must be quite appreciable since the foil has about eight times the area of the cylinder, and hence much more skin friction drag (but much less total drag). Obviously an ellipse falls somewhere between these two cases.

In general, for two fins of equal area, the fin with the larger aspect ratio (see figures 3 a, b) will produce more lift for a

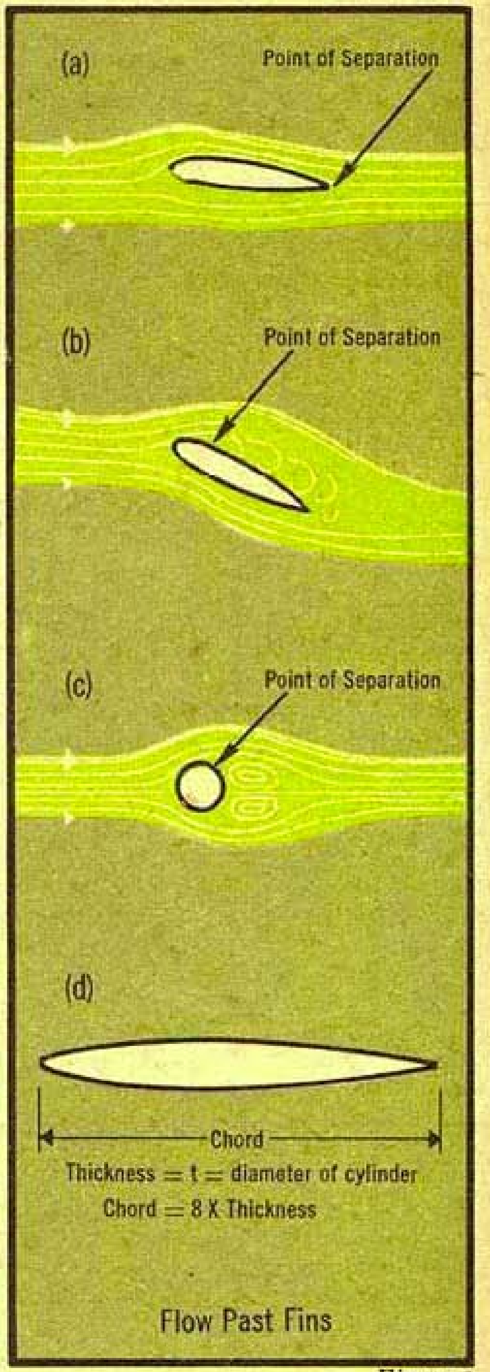
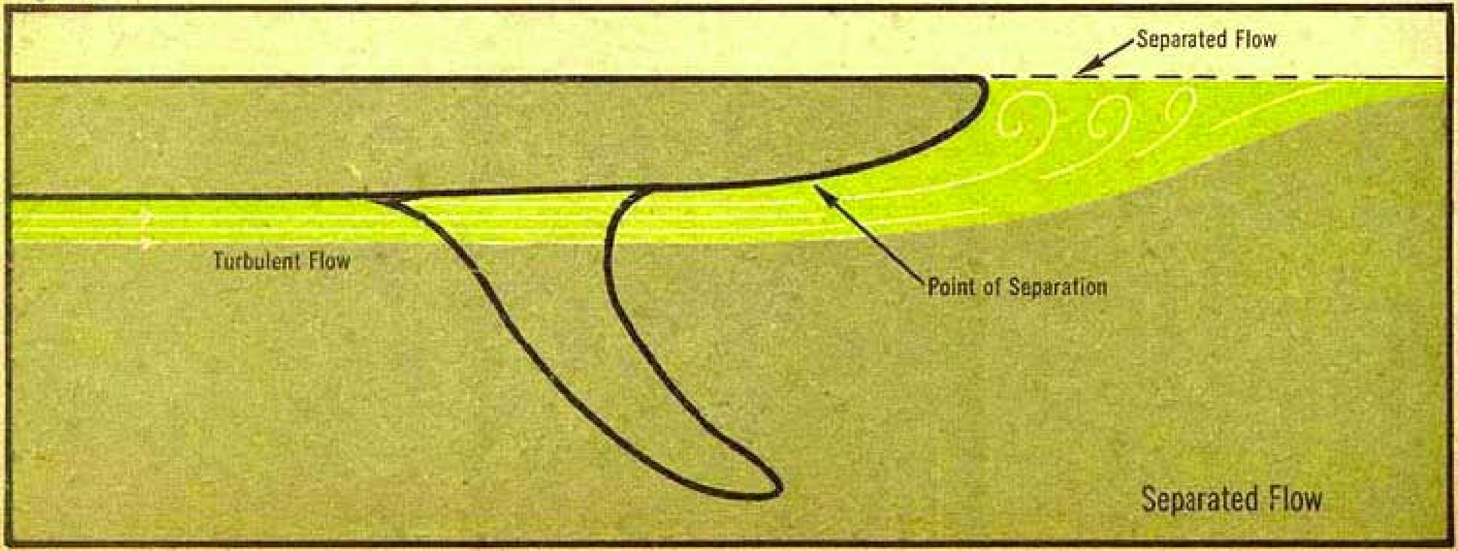


Figure 2

Figure 1



given amount of drag. This is a result of lateral flow from the high pressure side, around the tip, to the low pressure side of the foil. As a result of this flow, a whirlpool, or "tip vortex" is formed (the "vee". formations of flocks of birds are related to this effect) and the overall pressure difference (and hence the lift) is reduced. Unfortunately, high aspect ratio fins have at least two disadvantages, the loss of lift at the stall point is more abrupt (therefore less controllable), and they tend to "catch rails" when sliding through soup due to the longer lever arm tending to roll the board. It might be noted that flex near the tip of the fin has much the same effect as reducing the aspect ratio. Plan forms other than elliptical, and swept-back designs also tend to have less lift; however, other considerations (such as kelp) have a large influence.

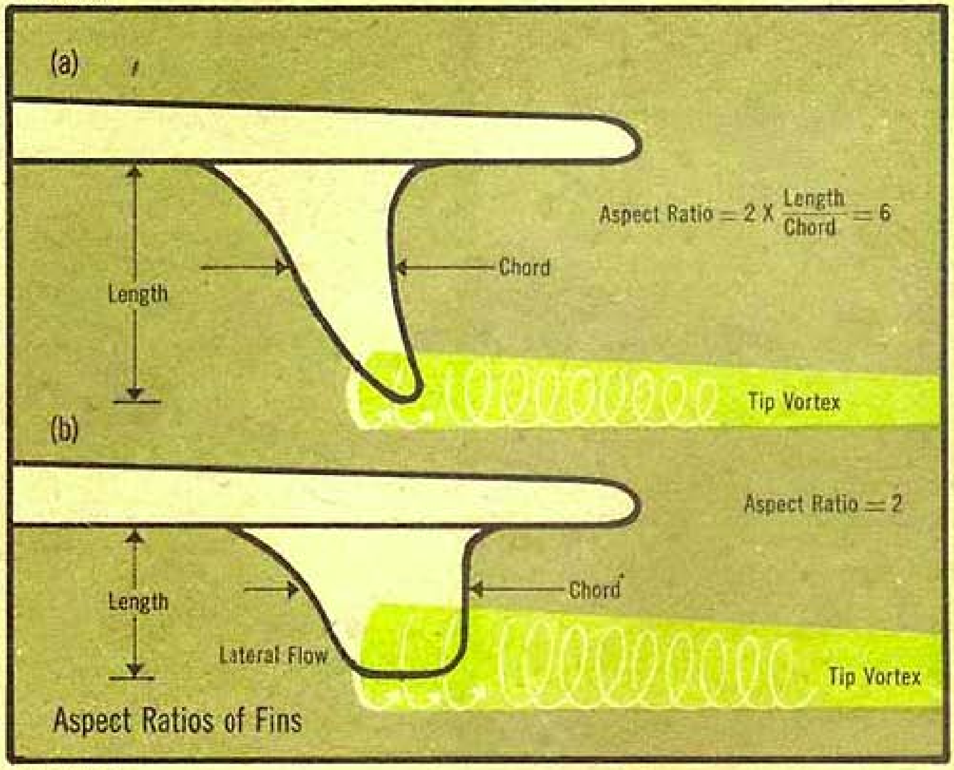
As mentioned in Part II, the ratio of the width to length of the board (the aspect ratio of the board) influences the amount of lateral flow across the bottom of the board. When "taking the drop," a short, wide board will accelerate faster than a longer, narrower board of the same area (and, of course, the same rails and rocker). However, when in trim on a wave, the situation is not clear since only part of a wide board may be in the water, and the plan form has an influence on the angle of attack of the fin. This can easily be seen from Figures 4 a, b (the shapes of the boards have been exaggerated to make the difference clearer). It may be that to match the board to a particular wave, one should either change the fin size (thus changing the angle of attack for a given amount of lift), or have a fin whose orientation can be varied with respect to the centerline. I am currently experimenting with a board which I hope will trace out the flow over various portions of the board, including near the fin, for various states of trim, and this should help to shed some light on the situation.

It is common to put some kick into the tail of a board in order to allow nose riding. Putting curvature into the bottom near the rear can produce an area where the pressure on the bottom of the board is less than the (atmospheric) pressure acting on the top. Further forward, the dynamic pressure (discussed in Part II) is pushing upward, so that the situation is somewhat like a teeter-totter with the surfer at one end, the high pressure area, the pivot, and the low pressure area (near the rear) pulling down at the other end. Since, as we have seen, separated flow may occur when this kick is too pronounced, it is desirable to limit this kick to as little as is necessary. Excessive kick can even be harmful to nose riding, since it causes unnecessary drag, thus slowing the board. This, in turn, decreases the pressure difference between the upper and lower faces of the board, reducing the supporting force at the tail of the board.

The methods used to obtain maneuverability are highly dependent on the type of wave and the style of the particular surfer (forward leaning turns obviously use the bottom surfaces of the board differently than turns where the weight is distributed more onto the rear feet). In general, some of the elements contributing to speed in a board must be sacrificed in order to make a maneuverable board, but this does not mean that a board must be slow in order to be highly sensitive and maneuverable. For relatively fast waves, introducing rail rocker (either through "V" in the tail of the board, or with more elaborate bottom shapes) appears to be a good compromise. With slow waves, the board may be in a state of semi-planing (particularly when turning from the top of the wave), and there appear to be two general approaches: making the board as efficient a planing surface as possible so that planing is maintained to lower speeds, or designing the board to function more efficiently when bouyancy forces are comparable with dynamic pressure forces (semi-planing). In the latter case, fuller rails and more kick in the tail are the usual approach.

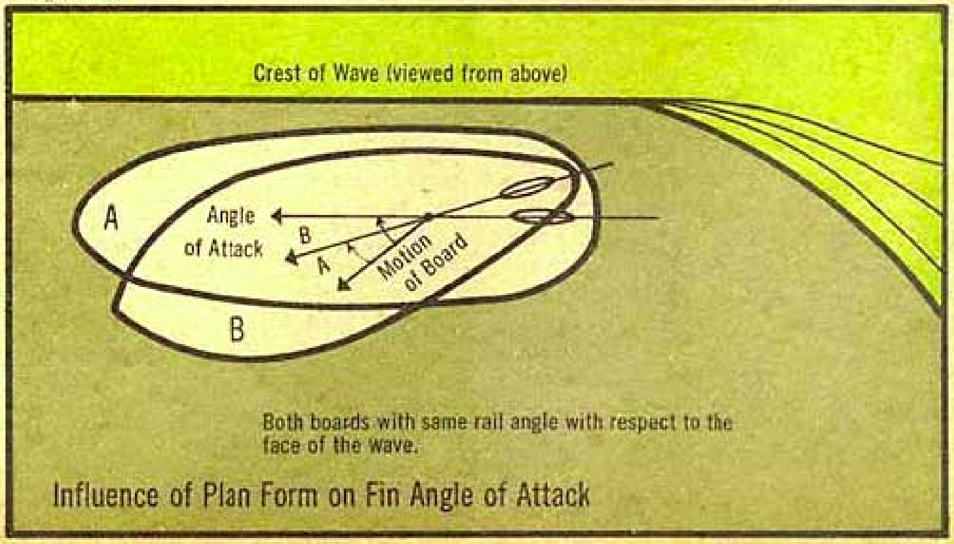
In closing, I would just like to remind you that the study of the flow over the surface of a board is very complicated, and the use of analogies with boat and aircraft designs can easily be carried too far. One of the best ways to get a feeling for the basic flow patterns, etc., is to watch the motion of the water (from various angles) in surfing movies and photos. Some of the more useful factors to look for are the entry point of the rail into the face of the wave, the extent to which the bottom surface is covered with water, the exit point of the face of the wave from the bottom of the board, the angle the board makes with respect to the surface of the water (not necessarily with the horizon), and the magnitude (and direction) of the spray pattern. Most off all, think about your observations.

Figure 3



Aspect Ratios of Fins

Figure 4



Influence of Plan Form on Fin Angle of Attack