SURFBOARD HYDRODYNAMICS PART II: **PRESSURE**

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Back at Pipeline; perfect peeling lefts, and this time you're prepared. You've cleaned the scabs of wax off the bottom of your board and fine-sanded it to further reduce skin friction drag.

You take off on your round-bottom, high-rail surfboard, and knife across the slick wall. White water explosion, and you're nailed just short of making the wave.

The wind has picked up by the time you reach shore, and there is a little chop on the wave surface. You pick up your flat, rockerless, dropped-rail model and paddle back out, hoping for more speed. Your board skips, hitting the high spots, and you shift your weight back slightly to regain control. But you've lost your speed, and it's suck, throw, pound and swim.

You've just taken two wipeouts that might have been avoided had you reversed the order of your surfboard selection.

In Part I: Drag, the difference between laminar and turbulent flow was discussed, and comparisons of skin friction drag for several surfaces were made. *In contrast to friction drag—which is relatively insensitive to the shape of the board—pressure, wave, and spray drag result from variations in the pressure over the board's surface; and this, in turn, is dependent on its shape.* Calculation of the pressure distribution is greatly complicated by the fact that the board is at the interface of two fluids—air and water—of vastly different viscosity and density. Although it is usually necessary to use model (or full scale) tests to obtain quantitative results, qualitative features of the flow (and hence drag) can be obtained from basic hydrodynamics.

The weight of the surfer and the board is supported by two types of lift forces—buoyant lift (resulting from the displacement of water) and dynamic lift (resulting from pressures generated by the passage of water under the board). As the speed of the board increases above 4-6 mph, pressure forces are generated which cause the board to rise part way out of the water. For velocities greater than about 7-8 mph, this dynamic lift is the primary means of support, and the board is said to be planing. Since the friction drag is dependent on the wetted area, the friction drag is reduced as the board rises. For planing watercraft, the most desirable trim angle is a compromise between minimizing the friction drag and reducing the drag produced by generating dynamic lift (figure 3).

The angle commonly, but erroneously, referred to as the trim angle is the angle that the board makes with a horizontal line (angle "b" in Figure 1a). Henceforth, we shall refer to it as the visual angle. In order to generate dynamic lift, the bottom surface of the board must make an angle with respect to the surface of the water (angle "a"). This occurs as the tail of the board is depressed below the surface of the water. This angle is referred to as the "angle of attack" or "trim angle," and determines the relative amounts of friction and pressure induced drag. Angle "c" is the direction determining angle. In the case of Figure 1a, decreasing this angle will cause the board to rise in the wave; conversely, increasing the angle will cause the board to move toward the bottom. In our illustration, angle "c" is such that the board maintains the same position on the wave.

There are three basic forces acting on the surfboard:

1. F_G, the force of gravity.
2. F_P, the pressure forces (acting perpendicular to the face of the board).

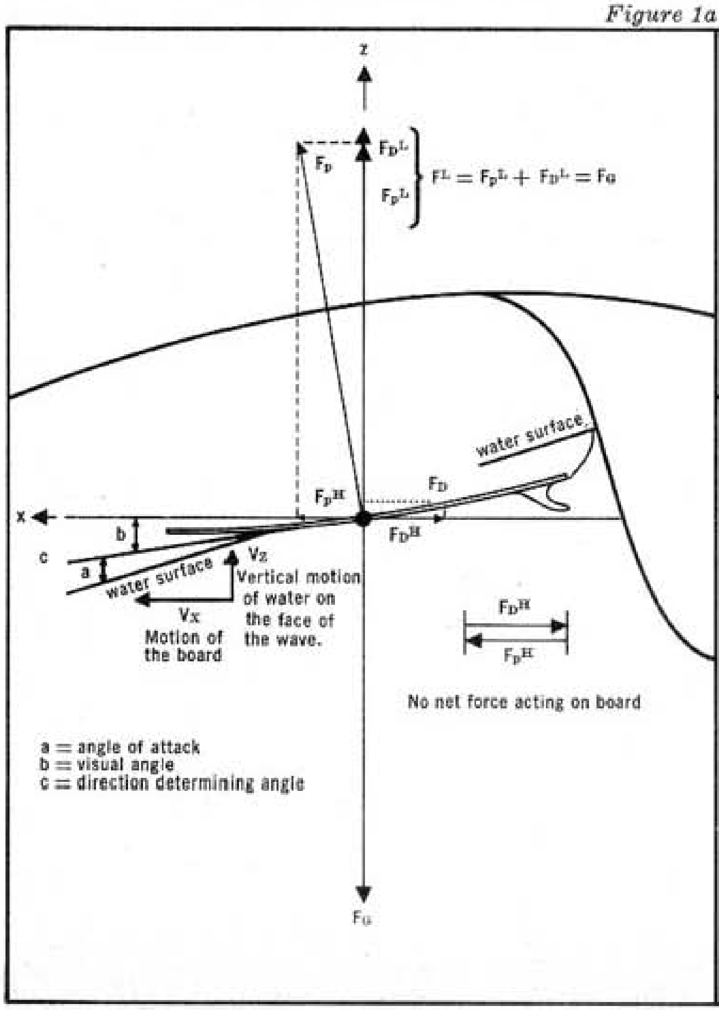

Figure 1a

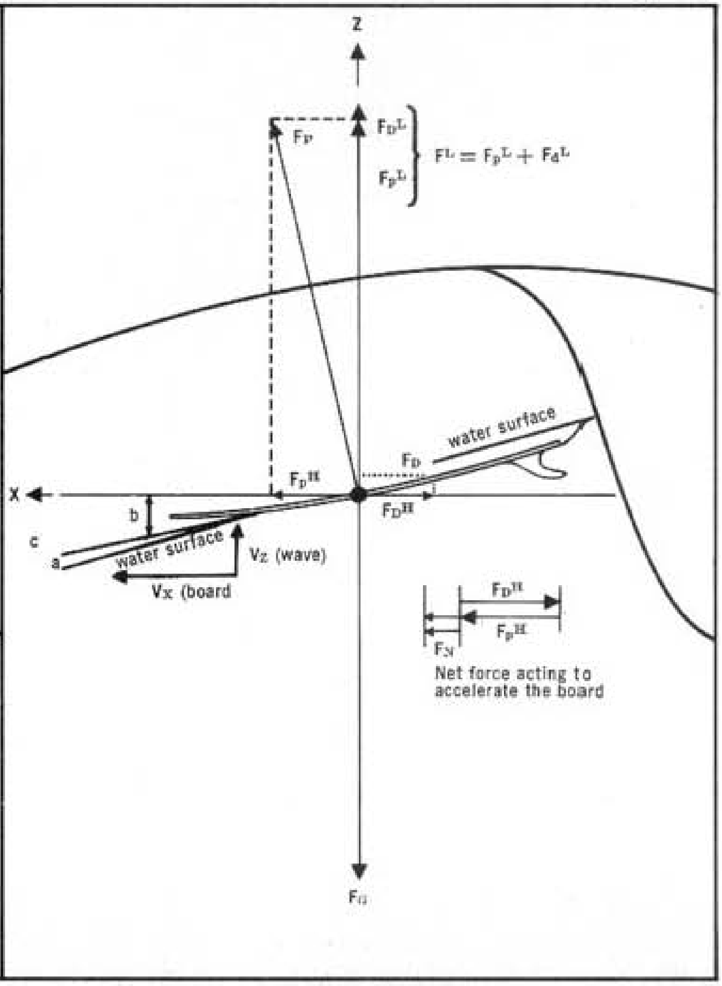

Figure 1b

3. F_D, the drag forces resulting from skin friction, the drag of the fin, and from separated flow. These act along the direction of the board.

Each of these forces can be broken down into a vertical and horizontal component (F_G has only a vertical component) and are labeled F_P^V, F_P^H, F_D^V, and F_D^H respectively. Let us assume that the board is at equilibrium; that is, it is not accelerating or decelerating, but is moving at a steady rate of speed. From Newton's Laws of Motion, the sum of the vertical forces must equal zero, and the sum of the horizontal forces must equal zero. The forces on this figure have been chosen so that this is true. For a given surfboard design, the dynamic lift is approximately proportional to the angle of attack; as the angle of attack increases, the dynamic lift increases. Let us see what would happen if we could design a board which would produce the same dynamic lift as the board of Figure 1a, but at a smaller angle of attack. Furthermore, let us assume that the board is traveling with the same speed and direction on the wave (hence angle c and the drag force, F_D, are the same as in Figure 1a). The resultant set of forces is shown in Figure 1b. It is now evident, however, that F_P^H is no longer equal to F_D^H, so that there is a net force, F_N, acting to accelerate the board to a higher speed. *Therefore, if maximum speed is desired, it is clear that it is desirable to build a board that will produce a given dynamic lift for the smallest angle of attack. For instance, it can be shown that a board with considerable rocker requires a greater angle of attack for the same dynamic lift as a flatter board, and hence will be slower.*

If the wetted area of the board is roughly constant, the dynamic lift will be a maximum (for a fixed angle of attack) if the average pressure is maximized. *Measurements have been made of the lift produced by planing surfaces with varying amounts of dihedral (or "V"), and it has been found that increasing the "V," decreases the lift that is generated (the "V" keeps the board in the water).* Figure 2 gives a typical curve for the lift generated by a V-bottom planing surface (in terms of the lift generated by a flat surface) for various dihedral angles. *In the forward and middle portion of the board, only one side is in contact with the water, and "V" would have less effect on the lift than at the rear of the board where the entire bottom is in contact.* In some circumstances, "V" in the middle might even reduce the skin friction drag. Near the rear, however, the curve of Figure 2 gives an indication of loss of lift associated with "V." This loss of lift results, in part, from lateral flow across the board. The center of the wetted area of a board must be a region of high pressure in order to produce dynamic lift; however, at the rails, the pressure is equal to one atmosphere, thus serving as a low pressure area. Narrow planing areas, "V," or roundness tend to promote lateral flow from the high to the low pressure areas, thereby reducing the average pressure. For "round bottom" boards, this flow is over a curved surface, so that the pressure is reduced more than for a flat surface (remember the effect of rocker).

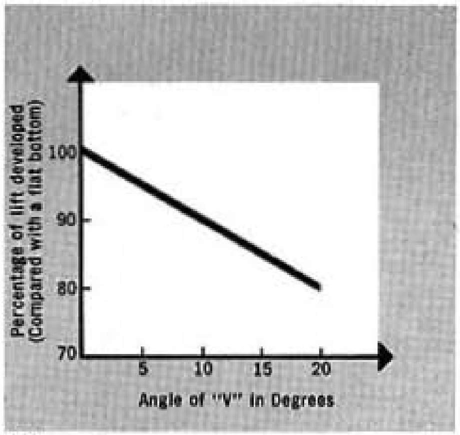

Figure 2

Round rails have the same general effect on the lift as round bottoms, and are particularly detrimental to speed when on the rear portion of the board (more on this in Part III). In addition to reducing the lift, the water tends to remain attached to the board (Coanda Effect), increasing the wetted area and the skin friction drag.

From the results of Figure 1a, 1b, it would seem desirable to reduce the angle of attack to zero and rely entirely on buoyant lift (and a larger board), since this would eliminate the induced drag associated with dynamic lift. From practical experience, this is clearly not the case. The reason is our old enemy, friction drag, since the wetted area is much larger when the board is supported by buoyant lift. Figure 3 shows a typical drag curve (for a fixed board speed) as a function of the angle of attack. Minimum drag for hard edge ("dropped" rails) planing craft generally occurs between three and five degrees. From the diagram, it is clear why nose riding (angle of attack near 0°) is not as fast as moving slightly back on the board. It is also clear that "stalling" is associated with greater induced drag (even though the skin friction drag is decreased).

The obvious, but generally erroneous, conclusion is that a board should have little rocker, a flat bottom and "knife sharp" dropped rails. What we have neglected to consider is the stability and turning of such a board. If a board is flat and almost completely supported by dynamic lift, then any ripple or chop may cause the board to leave the water. Similarly, if the surfer's weight is suddenly shifted back—perhaps to stall—the board may "porpoise." The effect this can have on control is easily imagined. A board that has a somewhat larger percentage of buoyant lift may go through the same chop with considerably less effect. *Except for nose riding, where large dynamic lift is required at the front of the board, it would seem desirable to have some degree of "V," or roundness, since this portion is generally out of the water when in trim, and would not generate as much lift as a flat surface when hitting chop.*

The effect of rail shape on turning and drag will be discussed further in the next article. Also to be discussed are fin design, the influence of "kick" in the rear portion of the board, and some considerations on plan form.

Figure 3