
## SAILS AND WIND

In recent years a great deal has been learned about the relationship between wind and sails. For a long time people thought the wind just pushed the sails. Even though this force was sideways when closehauled, the wedge shape of the keel was supposed to squirt the boat forward. Though not entirely accurate, the theory isn't too far off. The wind exerts both a sideways force and a forward pull on the sail. In simplest terms, the keel keeps the boat from slipping sideways, so all that is left is the forward pull.

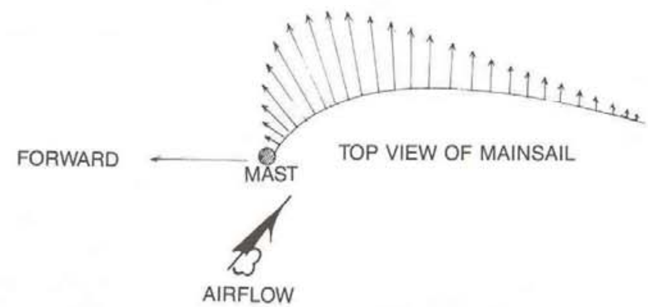


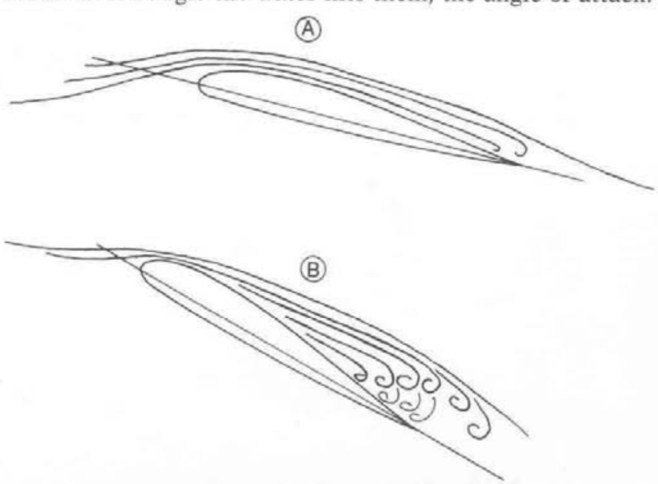

fig. 33

The forward pull is caused by air flowing over the surface of the sail as it does over an airplane wing. Air splits and passes on either side of an airplane wing. The air on the upper side of the wing has greater velocity than that of the lower side because of the angle of attack and an airflow called circulation effect.

Daniel Bernouli discovered in 1738 that this increased velocity meant a corresponding decrease in atmospheric pressure, i.e., suction. This suction acts at right angles to the surface and the amount of suction can be diagrammed as in Figure 33. The longest arrows represent the greatest suction. The higher the velocity on both sides, the greater the suction; and the greater the difference in velocity between the sides, the greater the suction.

This velocity difference is caused by circulation effect. It's a circular flow that reinforces and accelerates flow on the upper side of the wing (the leeward side of the sail). It opposes and decreases the velocity of the flow over the under side of the wing (the windward side of the sail).

Imagine the wing in Figure 34A as symmetrical, instead of asymmetrical. All other lifting surfaces of a yacht are symmetrical—the keel, hull, centerboard and rudder. Yet they can still develop lift because of the angle the water hits them, the angle of attack.




CROSS SECTION OF AIRPLANE WING

fig.34



The deflection of the flow is an action that causes an equal and opposite reaction per Newton's third law of motion. It is similar to the lift children experience when they stick their hands out a car window and tilt them upward. Because of this deflection and circulation flow a flat surface or even a thin membrane such as a sail can create lift and an airplane can fly upside down.

The air has to flow over the surface smoothly and evenly, though. Once the air starts to "separate" from the surface it becomes turbulent. Instead of an even flow, burbles develop that reduce suction. Much of the turbulence is caused by the angle that the airfoil makes with the airflow. This is called the "angle of attack" or "angle of incidence." If the angle is small as pictured in Figure 34A the airflow remains "attached" to the surface for quite a distance back towards the leech of the sail or the trailing edge of a wing. When the angle is increased as in Figure 34B, the airflow detaches earlier and turbulence works its way forward. At a certain angle and speed there is so much separation of flow that the wing no longer develops enough suction or "lift" and a stall occurs. In an airplane the result is dramatic since the aircraft will drop suddenly. A sailboat, however, will just heel over more and slow down.

A man told me one time that he and his friends, newly introduced to the sport of sailing, decided to forego all nautical lingo in favor of flying terms. He claimed they were much more descriptive. For instance, he said when the sail luffed they would say, "Pull it in, it's stalling."

As we can see from the foregoing, they had their terms backwards. The sail stalls if it is trimmed in too tight. If a sail is eased to the point just before it luffs, we can be certain it isn't stalled and is properly trimmed. A luff is easy to see because the leading edge of the sail is flapping. *A stalled sail, however, looks the same as one operating at maximum efficiency.*

So that's the reason for the basic rule of sail trimming: EASE THE SAIL UNTIL IT LUFFS AND THEN TRIM IT IN JUST ENOUGH TO STOP THE LUFF. This is a good rule for beginners, but after you have sailed for a while you may find, especially on reaches, the need to trim in a little past this point to get maximum drive from the sail. The judgment depends a great deal on wind strength. In lighter winds you can trim in tighter before separation and turbulence occurs. Of course, the tighter you trim in, the more sideways is the driving force. So although greater than before, it may be transmitted more into detrimental heeling than into beneficial forward driving force.

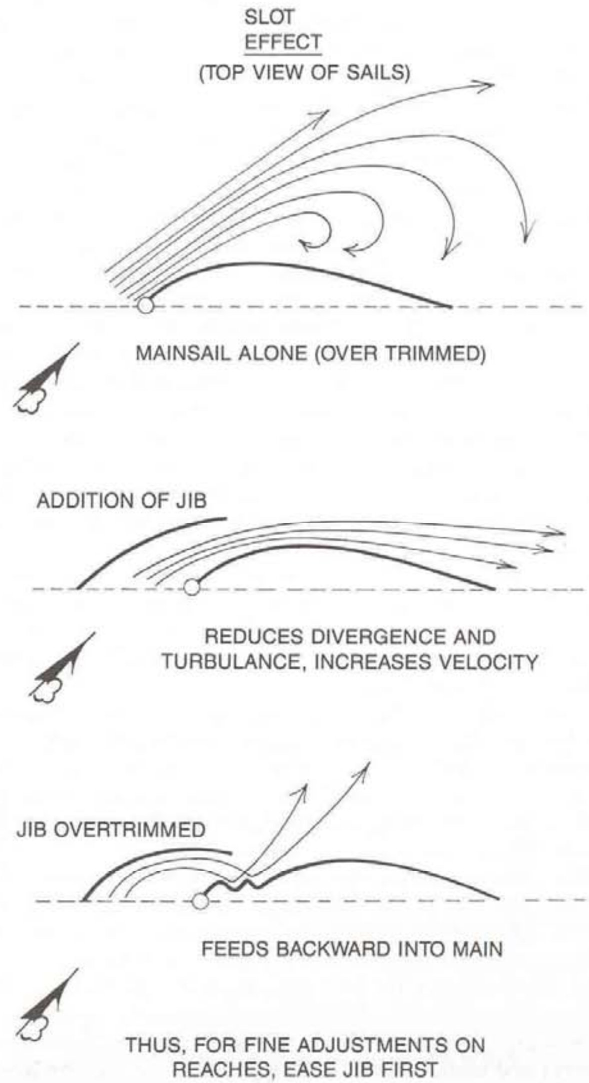



fig.35



## Slot effect

Boats with jibs have added advantages over those without. First, the jib is a very efficient sail since there is no mast in front of it to disrupt the airflow. Second, it bends and funnels the air behind the main. The funneling action tends to increase the speed of the air flowing past the leeward side of the main. By using an accurate hand held wind speed indicator, anemometer, you can actually measure the difference in the velocity of the air flow on the lee side of the mainsail with and without a jib. The velocity is substantially faster in the slot between the main and jib than when the jib is down. This increases the suction and efficiency of the main. As we have mentioned before, the faster the air travels, the less it can bend around the sail curvature. Luckily, the jib not only speeds up the air, but bends it aft so it can follow the main curvature more easily. This velocity increase and bending is called "slot effect," the "slot" being the opening between the main and the jib. The result is that though a boat can sail under just mainsail or just the jib, the combination of main *and* jib add up to greater effectiveness than the sum of each alone.

## Heeling

For many reasons, some of which will be covered later, "heeling" is an enemy to the sailor. If a boat is closehauled, the sail trimmed in tight, many of the force arrows point sideways, as in Figure 36A. In other words, there is a large sideways push result-

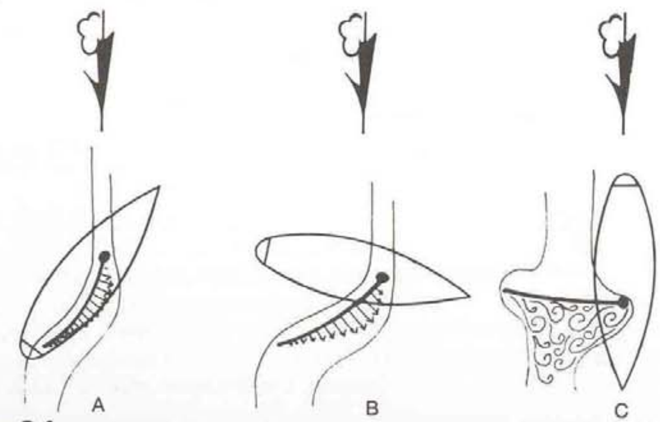



fig.36

ing in the boat heeling (leaning over). As the sail is eased out for a reach (Figure 36B) the arrows start to line up more with the course of the boat. The result is less heeling and more forward pull. A reach, therefore, is usually the fastest point of sailing.

It may appear that you're sailing faster when closehauled, because there's a great deal of commotion. The boat is heeling over, plowing through the seas, and the wind seems stronger because you're moving towards it. When you fall off to a reach, the commotion quiets down. You're sailing across the wind and the sea and neither seems as powerful. The boat is more upright because the pull of the sails is more forward. Carrying this one step further, you might think that a run would be even faster because the wind and the boat are both going in the same direction. On a run, though, the wind can't flow over both sides of the sail which is necessary for any suction to develop on the leeward side of the sail. So the wind is just pushing the boat. As you can see in Figure 36C there is pure turbulence behind the sail downwind. Were a jib present it would be "blanketed" by the main; i.e., no wind would be reaching it because of the main being in between it and the wind.

When the wind velocity increases to the point where a given boat on a reach is "overpowered," heeling excessively in comparison to forward drive, a faster point of sailing would then be a run.



## Wind Shifts

For the highest efficiency, sails must be adjusted so they make just the proper angle to the wind. Since the wind is constantly changing direction, this means the sails must be constantly adjusted to the various shifts.

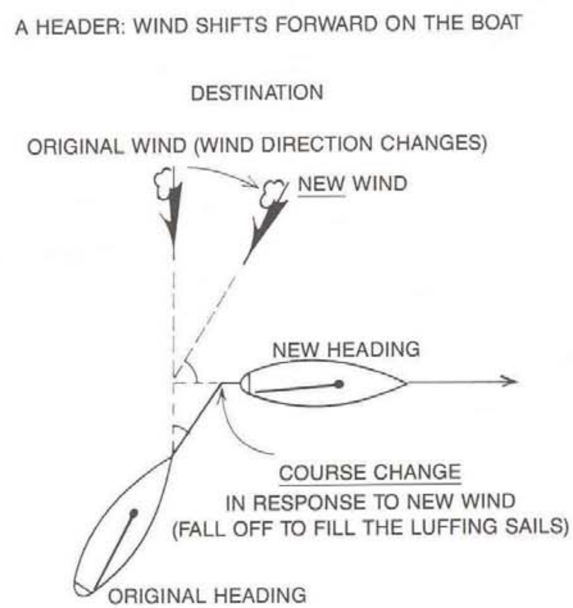



fig.37

A shift of the "true" wind direction, the actual wind, is called either a "header" or a "lift" depending on the relationship of the shift to the heading of the boat. Figure 37 shows a boat closehauled on the port tack. If the wind shifts more towards the bow of the boat, causing the sails to luff, necessitating a change of course away from the wind to keep them filled, the boat has been "headed" or has "sailed into a header."

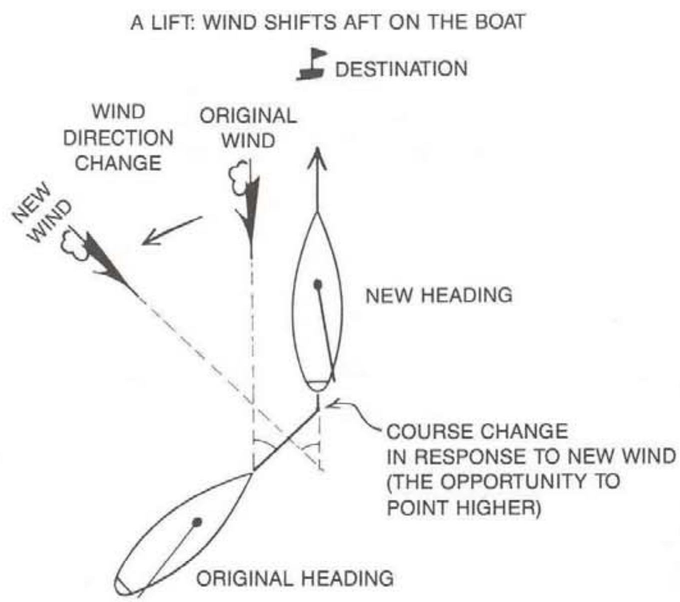



fig. 38

If the wind shifts more towards the stern of the boat, allowing the skipper to steer higher than before, the boat has been "lifted" or is sailing "in a lift."

A header or a lift occurring on a reach means a corresponding sail adjustment—trimming for a header and easing for a lift—while maintaining a constant heading.

A wind shift that is a header for a boat on a port tack is a lift for a boat on the starboard tack. The boat sailing on a lift will reach his desired upwind destination faster than one sailing in a



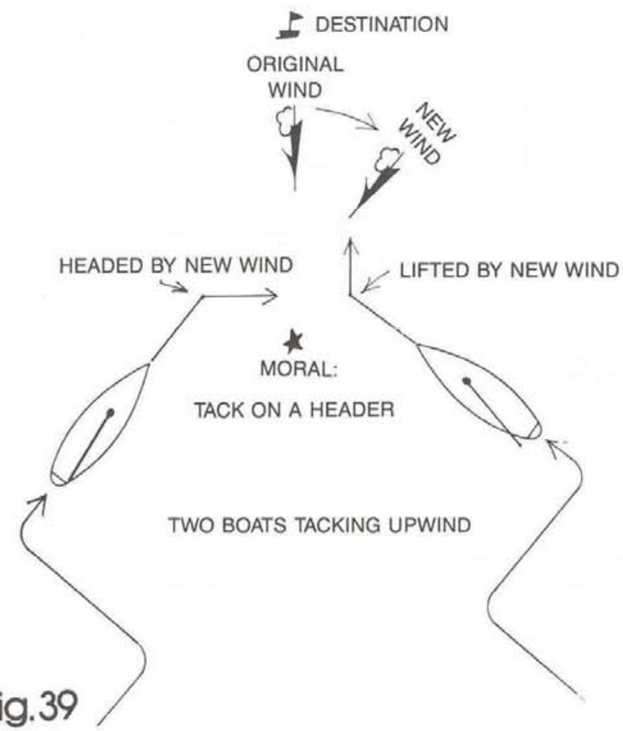



fig. 39

header. A standard sailboat racing axiom, therefore, is "if you're headed, tack."

When a wind shift is described in relation to a compass direction, it is said to be "veering" or "backing." A veering wind is one that is shifting clockwise.

For instance, a wind that shifts from north to northeast is "veering." A shift from east to northeast is "backing" in that the shift is counterclockwise. A north wind is one that blows from the north. Don't confuse this with *current* which is named for the direction *to* which it flows. A northerly current is one that flows from the south.

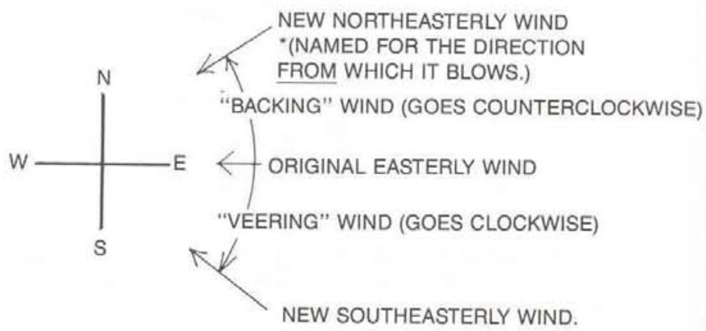



fig.40

The foregoing shifts are changes in the direction of the actual wind blowing over the water. Another type of shift, which also causes the need for sail adjustment is a change in the "apparent wind" direction.

## Apparent Wind

"Apparent wind" is a very simple concept that continues to mystify many people who have been sailing for years.

It is the resultant wind derived from the wind produced by the boat moving through the air and the wind produced by nature—the "true wind." Thus, it is the wind you feel on the boat. Cigarette smoke, telltales, electronic wind direction indicators of cruising boats all show the apparent wind direction. We often get the comment from people the first time out, "You said we sail within 45 degrees of the wind when closehauled, but the wool on the shrouds indicates we're sailing almost into the wind." This is their first experience with apparent wind on a sailboat.

Imagine yourself standing up in a convertible. It is a calm day, so there's no true wind. As the convertible starts forward, you will begin to feel a breeze on your face that increases as the speed of the car increases. At 10 mph you will feel a 10 mph breeze on your face. This is apparent wind.



Now imagine yourself in the same car heading north and there's an easterly wind of 10 mph blowing. This we call true wind. It is hitting the right side of your face. As the car starts forward you will not feel two different winds, one on the side and one on the front of your face, but a resultant wind coming from an angle forward of the true wind. This wind is apparent wind.

By drawing, to a consistent scale, a parallelogram from the boat speed and the true wind, you can determine the force and direction of the apparent wind. Refer to Figure 41. Let's say your boat tacks in 80 degrees. That means the true wind is 40 degrees off your bow. If, for example, the boat speed is six knots and the true wind is twelve knots, measure off the units as boat speed wind and true wind in Figure 41. Then draw a parallelogram, the diagonal of which is the apparent wind. By measuring the length of the diagonal, you can determine the speed in knots of the apparent wind.

In this example (see Figure 41) the apparent wind (the diagonal) measures 17 knots, and bears 27 degrees from your heading versus 40 degrees for the true wind. Notice how the direction of the apparent wind changes with the true wind in the subsequent diagrams. (For the purposes of these diagrams we'll keep true wind speed and boat speed constant, which would only be the case at different points of sailing if the boats were different sizes.)

There are four points that are obvious from these diagrams. First, the apparent wind is always forward of the true wind (unless the true wind is dead ahead or astern). Second, as the true wind comes aft, the apparent wind lessens in velocity. Third, when the true wind is well aft, a small change in true wind direction makes a large change in apparent wind direction. And fourth, when the boat is on a beam reach or closehauled, the apparent wind is of greater velocity than the true wind.

The first point is important when considering when to jibe. Since it is desirable to sail at the slight angle to the wind rather than dead downwind, you may not be heading to your desired destination and will have to jibe to reach it. It's important, therefore, to determine the direction of the true wind and the angle your heading is making with it. If you know you are steering 20 degrees from dead downwind on one tack, then you will be on the same point of sailing when you are 20 degrees from dead downwind on the other tack. The point of jibing should come when your destination bears 40 degrees off your bow from your present heading. The key, of course, is determining the direction of the true wind. By glancing at your telltales and at the wind signs on