Forces Acting on the Sail

Most readers would probably find this section of the article much too technical as it requires some prior basic knowledge of the physics of forces and their resolution into right-angled components. It is however a subject that is unavoidable if anyone wishes to have a more in-depth understanding of how a sail actually drives the board forward.

I do not propose to go into the theory of how lift is created in a sail as there are several ways of looking at it and I do not fully undertand them myself. I shall confine the discussion only to two areas - a) the effect of the wind striking the sail at various angles and b) the interaction of the forces of lift and drag.

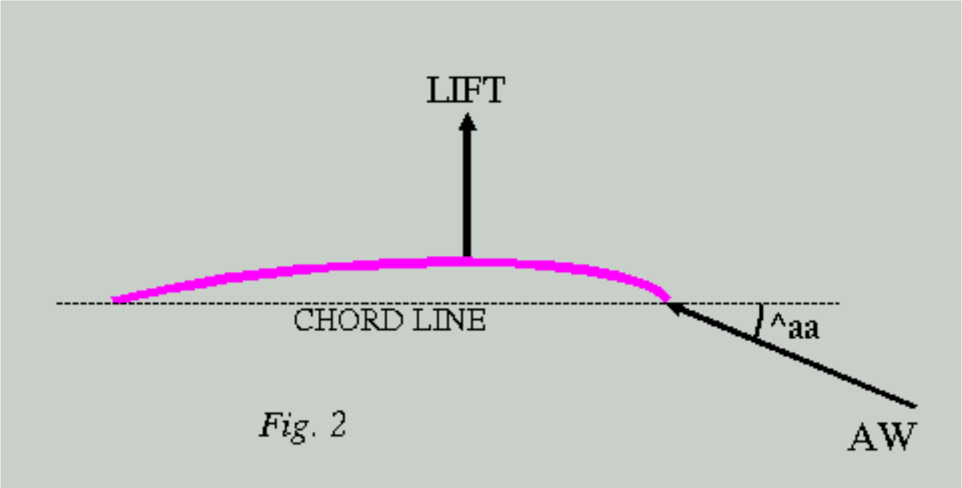

Fig. 2

The diagram above shows the sectional profile of a sail with the mast on the right and the leech on the left. The Chord Line is an imaginery line drawn through the mast and leech of the sail profile. The arrow AW represents the apparent wind. The angle ^aa between AW and the chord line is referred to as the Angle of Attack, a term borrowed from aeronautical engineering. Actually, the way a sail works is very similar to the way an aircraft wing works. The action of the wind on the sail generates lift in the same way as lift is generated when air flows over an aircraft's wing.

If the angle ^aa is zero, very little lift is generated and there is no power in the sail. As the angle ^aa increases, the lift in the sail increases and we feel an increased pull in the sail. The increase in lift is in direct proportion to the increase in the angle ^aa, however if this angle is increased beyond a certain point (about 15 degrees), the sail rapidly loses power and stalls. This is commonly referred to as over-sheeting. Dinghy sailors rely on watching the luff of their sails or on tell tales to warn them of when they are in danger of over-sheeting. Windsurfers are more fortunate. They can feel the loss of pull on the sail and therefore know when the sail has stalled. The sail should be quickly sheeted out to regain power. Experienced windsurfers are constantly trimming their sails to get maximum power from them. This is particularly important in marginal planing conditions and is probably the biggest single reason why some windsurfers can get planing while others cannot.

There are actually two forces acting on the sail. One which we have already talked about is the lift which acts in a perpendicular direction to the Chord Line. The other is the drag on the sail caused by the wind flowing over it. This force acts in the same direction as the apparent wind.

Both lift and drag are proportional to the square of the wind speed, so a wind speed of 20 knots will generate four times the lift and drag as a wind speed of 10 knots.

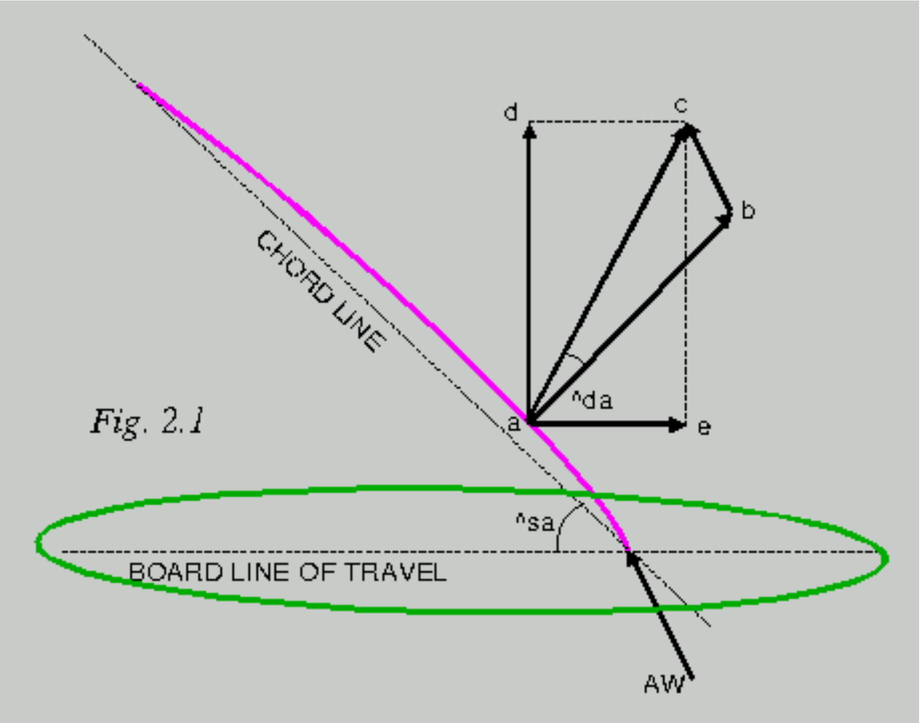

Fig. 2.1

In the above diagram, a-b is a vector which represents the magnitude and direction of the lift generated in the sail. b-c is a vector which represents the magnitude and direction of the drag on the sail. These two forces added up vectorially will result in a combined force represented by vector a-c. There is an angle between a-b and a-c, shown as ^da which I will call the drag angle. The higher the drag, the larger will be this angle.

The force a-c can be resolved into two forces, one in the direction of travel of the board - the forward component represented by a-e, and the other at right angles to it - the lateral component represented by a-d. It is the forward component that is of interest to us because that is what drives the board forward. The other tries to push the board sideways. The angle at which the sail is sheeted in, i.e. the angle between the Chord Line and the board line of travel, is shown as ^sa in the diagram. What is important to note is this, that as the sail is sheeted out, the forward component becomes larger and the lateral component becomes smaller. Conversely, as the sail is sheeted in, the forward component becomes smaller and the lateral component becomes larger. When angle ^sa is equal to angle ^da, the forward component is zero and there is no force on the sail to drive the board forward. When the angle ^sa is smaller than angle ^da, the forward component is negative and the board will move backwards.

It follows from this discussion that, for the same forward component of force, a sail with less drag will have a smaller drag angle and can therefore be sheeted closer in as compared with a sail with higher drag. Such a sail can therefore be sailed closer to the apparent wind at a higher speed.

The interaction of lift and drag also explains a commonly known fact, that in strong winds a small sail will go faster than a large one. What happens is that a sailor using a large sail becomes overpowered and he cannot fully sheet the sail in. The angle of attack is, say, only two thirds of optimum. The drag, on the other hand, remains practically unchanged. The ratio of lift to drag is drastically reduced and the sailor experiences a loss of speed. By switching to a smaller sail which the sailor can fully sheet in, the angle of attack will be at an optimum, thus producing a lift which will be about the same as with the larger sail, but the drag on the smaller sail will be a lot less. There is therefore a greater forward component of driving force on the sail and the board travels faster. Of course, a heavier sailor who is able to fully sheet in the larger sail will be able to take advantage of the increase in lift in the larger sail.

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