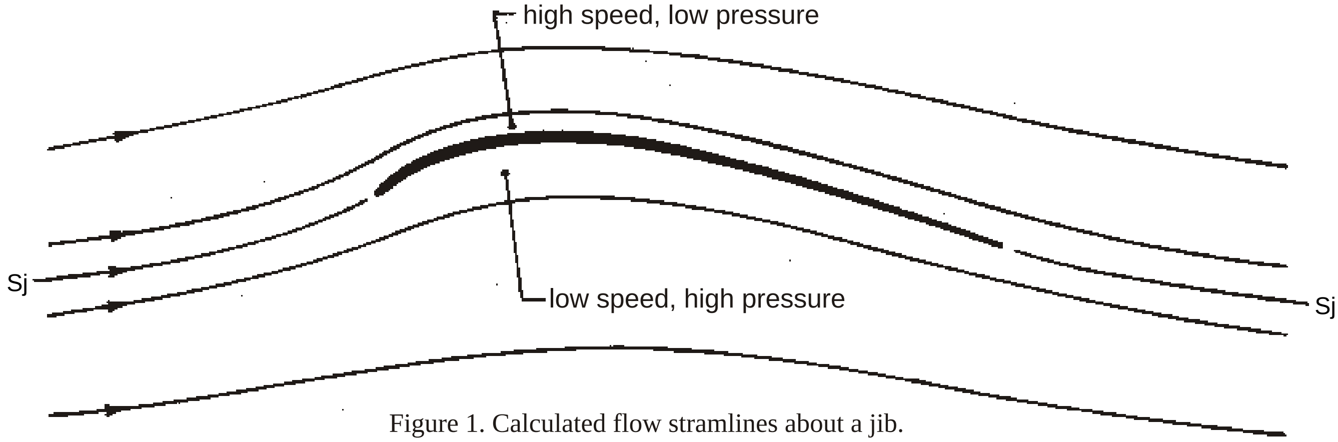

Figure 1. Calculated flow stramlines about a jib.

If we look at the streamlines in Figure 1, we see that sometimes they get closer together and at other times they spread farther apart. It is quite obvious that when two streamlines get close together or close to the airfoil surface, the air will have to speed up to get through the smaller area and the air pressure will be lower. Where the streamlines get farther apart, the air slows down and the air pressure becomes greater.

Now this is all quite simple, but it is important to note that before we can apply Bernoulli's equation, we must first know how the air flows about the airfoil. We must know where the streamlines go. The sailing literature is full of these types of drawings. Unfortunately, they are just that, drawings of where the particular author *thinks* the air goes.

Figure 2 is typical of the airflow diagrams used in the books to explain the slot effect. There are a number of things wrong with this drawing, but I'll just mention the more obvious ones here. First, note that the stagnation streamline for the mainsail (S_m) shows a slight amount of upwash (bending of the streamline leeward to meet the sail). The air knows that it is approaching the sail and it starts to change direction even before it gets to the sail.

However, in Figure 2 the stagnation streamline drawn for the jib has no upwash at all. Apparently the wind knows that it is approaching the main but it doesn't know about the jib! That cannot be and this is the crux of the problem. The streamlines for both the jib and the main must show the proper effects of upwash. This cannot be determined by guesswork.

However, that's not all that is wrong with Figure 2. Look at the streamlines marked A and B on each side of the stagnation streamline for the main. Out in front of the sail, the A and B streamlines are the same distance from the stagnation streamline so the airspeed is the same in both tubes of air; but by the time they reach the leech of the main, the lee streamline, A, is closer to the leech than is the windward streamline, B. We would, therefore, have high-speed, low-pressure air on the lee side of the leech stagnation streamline, and air with a lower speed and higher pressure on the windward side.

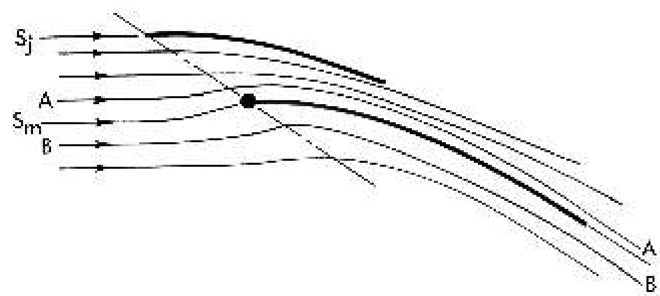

Figure 1. Typical wrong slot-effect drawing.

This situation cannot exist in the real flow about a sail. Instead, the entire flow about the sails would adjust itself so that the airspeed and pressures are the same on both sides just downstream of the leech. The streamlines should be equally spaced on both sides of the leech if they are equally spaced out in front of the sail.

Another important requirement is that the spacing of streamlines right at the leech of the main must be the same as the spacing of these streamlines out in front of the sails. In other words, the airspeed at the leech of the main must be about the same as the freestream speed. I am assuming the sails are properly trimmed and have no flow separation. You will see the reasons for this leech recovery-speed requirement in a later article (and also why it does not apply to the jib).

Check some of the drawings in your own sailing books. See whether the streamlines at the leech are drawn properly. Also, check the stagnation streamlines leading to both the jib and main for upwash. None of the drawings I have seen has both the upwash and leech streamlines drawn properly. Since these erroneous streamline drawings do exist, it is easy to see why the venturi explanation of the slot effect has persisted for so long (that is, a wide stream of air seems to enter the slot between the sails and simply speed up as the slot gets smaller).

Figure 3 shows a very accurately calculated set of streamlines about a main and jib combination. Contrast it with Figure 2. Note that the stagnation streamline for the jib (Sj) turns leeward as it approaches the luff and that it has more of this upwash than does the stagnation