The Double Head Rig

"Arvel Gentry explores the benefits of s staysail"

By Arvel Gentry

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The double head rig is experiencing a revival. One area in particular is its use on level class, or ton boats, to improve their beating and close reaching performance in light and medium winds. To keep their rating down, these boats frequently are measured with a 150% genoa instead of a 170% to 180% headsail. The 150% is great for medium-to-strong winds but when the wind drops, many of the boats suffer from a lack of sail area. The double head rig, with a high cut jib topsail and genoa staysail, is a popular way of trying to get back some of the lost sail area.

I have applied aerodynamic analysis techniques to the double head rig, and hopefully the conclusions presented here will shed some new light. If nothing else, you will see why the staysail is such a sensitive sail to handle.

To understand the effect of adding a staysail, we must move in for a close-up and study in detail the flow streamlines between the genoa and the main. An accurate streamline drawing is essential to obtain a true understanding of this sail interaction problem.

Figure 1 shows an accurately calculated set of streamlines about a jib topsail and mainsail combination under beating conditions (without the staysail). This is the same basic sail combination I have used in earlier parts of this series except that the mainsail is sheeted in 2.5° closer to the centerline, and the genoa is let out 5°. I did study the flow with the genoa out only 2.5°, but the conclusions did not vary from those presented here. Other sail angles and shapes might give differing amounts of sail interaction but I rather doubt that significantly different conclusions would be reached.

If you were going to add a staysail between this jib topsail and the mainsail, just where would you put it? Let's first assume the staysail has its luff at point A in Figure 1 and that it is sheeted so that it has a shape indicated by the line A-B. You can see this shape lies exactly along an existing streamline in the flow between the topsail and the mainsail.

Therefore, even though this staysail will hold its curved shape like the other airfoils, the pressures will be the same on both sides of the airfoil and it will not contribute any lift at all to the sail combination. Similarly, it will not have any effect either on the topsail or the mainsail. You can see this situation aboard a boat when the staysail appears very "soft" in shape, and obviously does not seem to be carrying much load. In some cases the whole staysail may seem soft, but usually it is just a part of the sail that is affected.

Therefore, if the staysail is going to contribute any lift at all, it will have to be placed at an angle of attack to the local curved flow field created between the topsail and the main. In Figure 1, the line C-D fits this requirement. This sail is placed at an angle to the local curved flow and should, therefore, cause the flow field picture to change. As a result, it will have a pressure difference between the two sides of the sail and it will hold its shape and not luff. Finally, it may contribute to the total driving force of the sails. Note that I have said may, for, as we will see, the staysail has some strong effects on both the topsail and the mainsail.

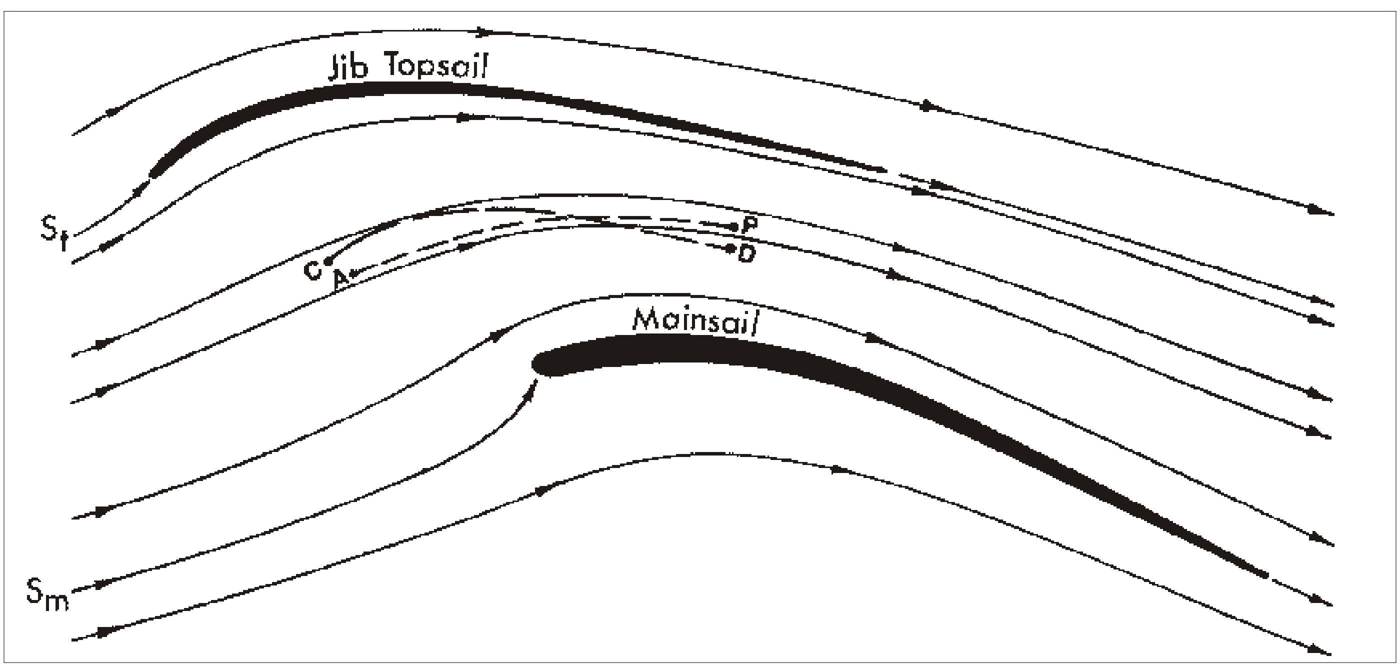

Figure 1

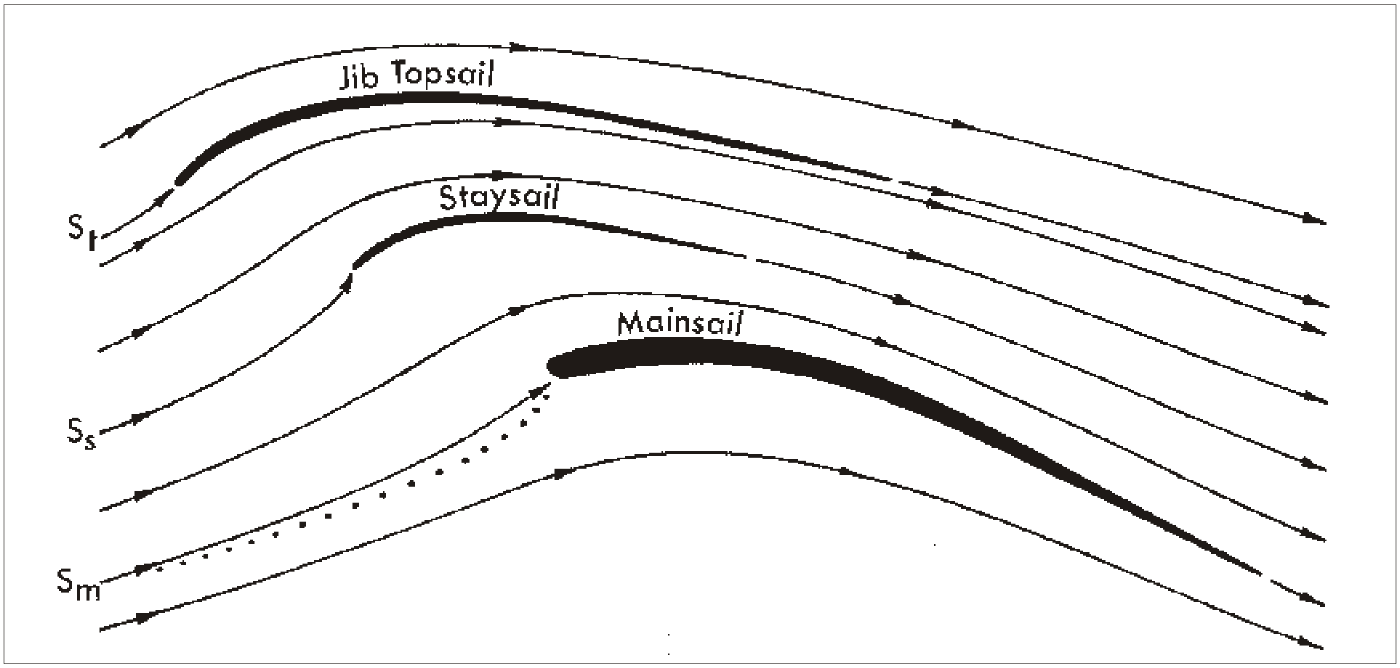

Figure 2

An accurate flow diagram for this three-sail combination is shown in Figure 2. If you compare Figures 1 and 2 very carefully, you will see some interesting things. First, the streamlines downstream of the leech of the topsail and the mainsail are almost exactly the same in both diagrams. Only the streamline passing right through the area of the staysail shows any change at all. Apparently, this staysail has not affected the downstream flow either of the topsail or mainsail.

Next, you will observe that the stagnation streamline for the mainsail (S_m) is a little straighter as it approaches the mainsail. In Figure 2, the dotted line is the mainsail stagnation streamline when the staysail is not present. The addition of a staysail seems to have reduced the upwash flow coming into the mainsail; however, it is important to note that the level of the mainsail stagnation streamline well out in front of the sail is about the same. In other words, the staysail apparently has not had a great effect on the total amount of air that is made to flow on the lee side of the mainsail (including the lee side of the topsail).

In other words, this means that the total lift obtained from the three airfoil combination is about the same as it is with just the topsail and mainsail! We have added sail area, but the lift does not increase.

This conclusion is also verified by a comparison of the stagnation streamline for the topsail in Figures 1 and 2. They are almost exactly the same. The staysail itself has not altered the upwash of the topsail stagnation streamline. But don't throwaway your staysail quite yet.

Despite the fact that the staysail has little effect on the flow in front of, and downstream of the sails, it does have a significant influence on the streamlines between the sails. The general effect is that the staysail just plays with the air that is flowing between the jib tip and mainsail but does not, in general, change the actual amount of air flowing between these two sails.

The primary thing a staysail does do is to cause a slight redistribution of the slot air by taking some of the air flowing near the lee side of the mainsail and shifting its flow path so that it is closer to the windward side of the jib topsail. The streamline on the forward-lee side of the mainsail becomes further away from the sail while the streamline on the windward side of the topsail becomes closer to the sail.

If we remember Bernoulli's principle, we realize that the forward-leeside pressures on the mainsail will be higher and the lee-side pressures on the topsail will be lower which means that the theoretical lift contributed by both the topsail and mainsail will go down. This is what we mean when we talk about sail interference.

All these effects are clearly shown in the pressure distribution plots shown in Figures 3, 4, and 5. In each plot the solid line shows the pressures with the staysail set, and the dashed line shows the pressures without the staysail.

In Figure 3, note that the lee-side suction pressures (negative pressures) have not been affected by the staysail but the jib topsail windward-side pressures have been strongly affected by the staysail. The lifting force on any part of the sail is represented by the difference between the lee-side and windward-side pressures and the total lift is represented by the area between the lee and windward pressure curves. This jib topsail suffers a large loss in lift because of the presence of the staysail.

Mainsail pressures are shown in Figure 4. The staysail has caused a significant reduction in suction pressures over the forward-lee part of the sail, and has slowed down the air in this area. This produces a loss in the mainsail's theoretical lift.

Pressures for the staysail are shown in Figure 5. Again, the lift of the staysail is determined by the area inside of the lee and windward side curves. In this example, the lift of the staysail is just enough to offset the lift losses from the

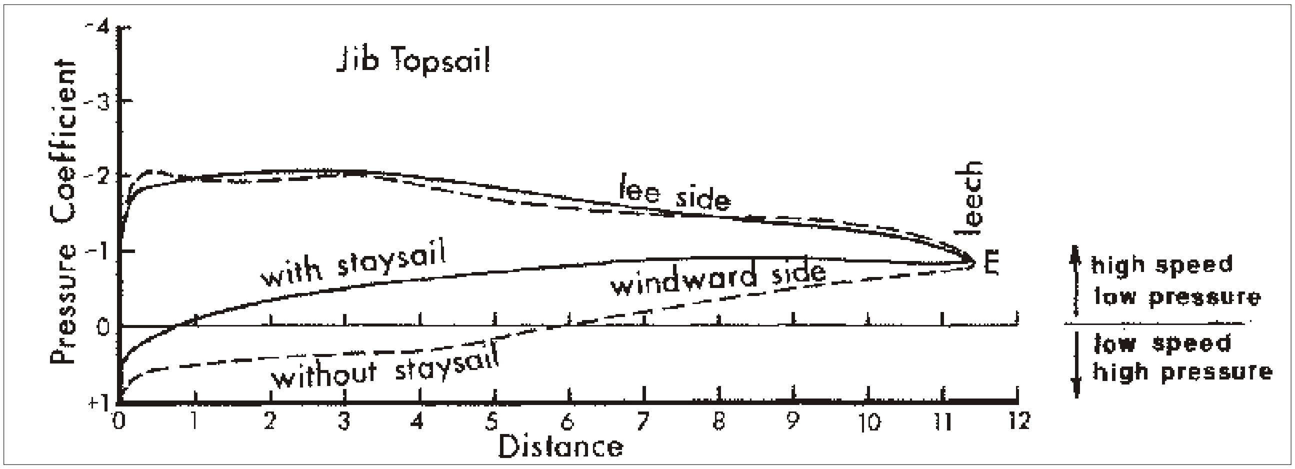

Figure 3

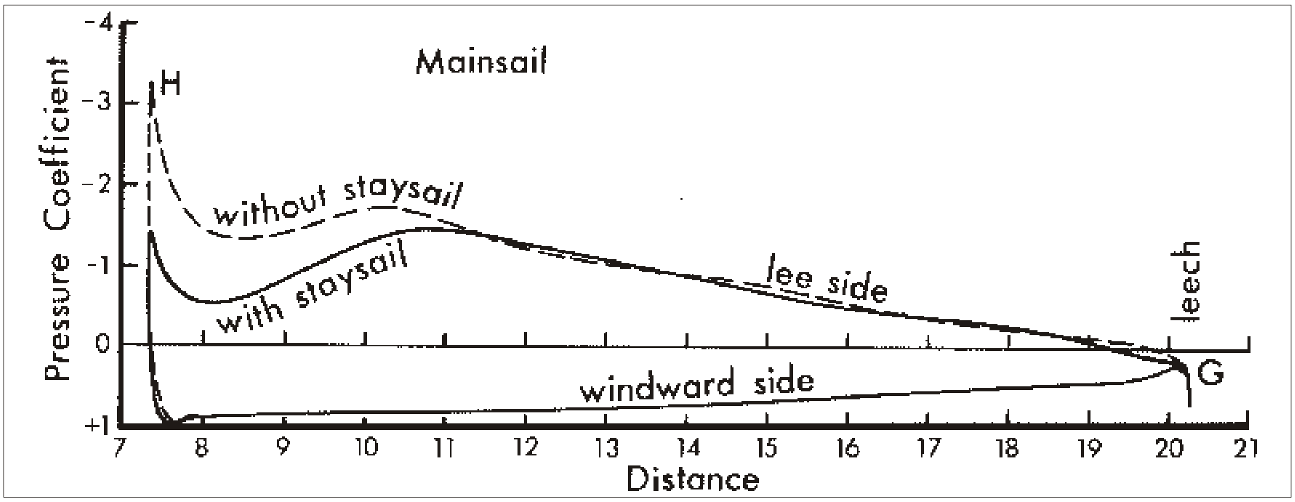

Figure 4

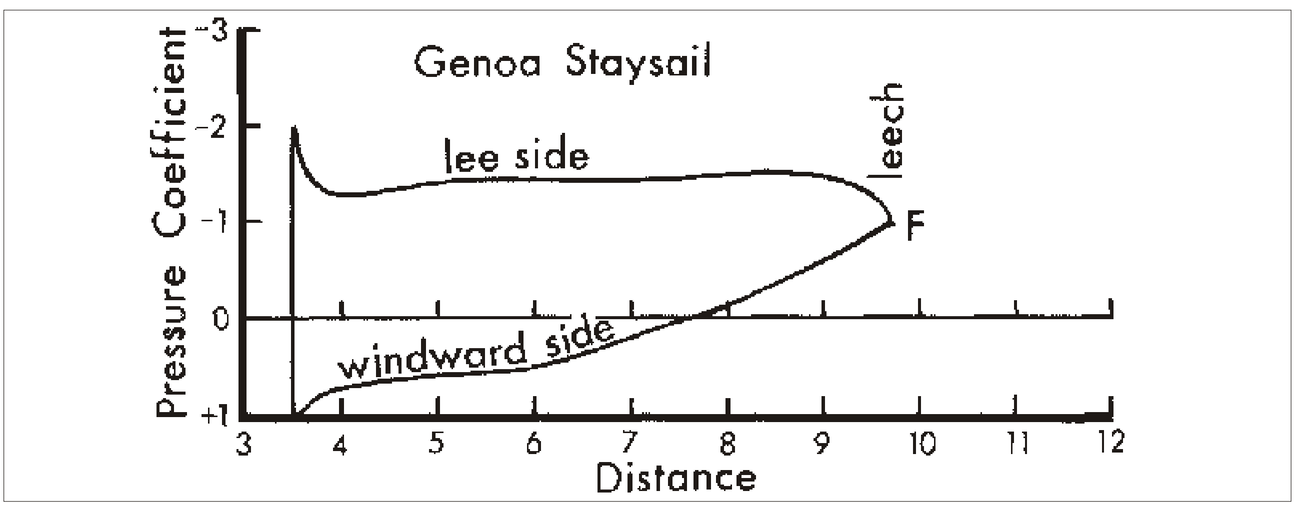

Figure 5

interference on the topsail and the main. However, there are some strong positive effects the staysail has as we will see later.

I do not mean to imply from this analysis that no staysail will contribute additional lift. The airfoil shapes I used for this study were rather arbitrary in shape, and were selected only to illustrate the types of effects that can occur between the three sails. Other airfoil shapes and positions would give differing amounts of interference but the types of effects that occur would probably not change much.

You might well ask the following question at this point. If a mainsail causes an increased upwash of the flow into the jib, then why doesn't the staysail do the same thing for the jib topsail instead of actually reducing it? The answer seems to lie in the fact that the staysail leech is ahead of the leech of the topsail and does not significantly affect the flow conditions at the topsail leech. If the staysail were going to affect the leeside velocities of the jib topsail, it would have to be through some change in the leech flow of the topsail. The staysail is not positioned to do this.

In a previous article, (*SAIL*, Aug. 1973), I explained how the leech of a jib was in a high speed flow region created by the mainsail and how this creates increased velocities, reduced pressures and more lift all along the lee side of the jib. I call this the "bootstrap" effect, and its effect is present in both a two-sail and a three-sail combination.

Look at the leech pressure in Figure 4 (point G). This pressure level (near zero pressure coefficient) represents a mainsail leech velocity that is near freestream as is required by the Kutta condition (by which air leaves the airfoil at the leech smoothly with the same speed and pressures on both sides). The leech pressure of the topsail (point E in Fig. 3) is negative, about -1, which means the velocity of air coming off the topsail leech is much higher than freestream. This is beneficial because the velocities all along the lee side of the topsail will also be higher.

Note in Figure 5 that the staysail also has a high leech velocity (point F) about the same level as for the topsail. This occurs because the leeches of both sails are in the same high speed region of flow created by the mainsail. However, if the topsail were much smaller, and positioned so that its leech was located at about the maximum camber point of the staysail, as with a cutter rig, then we would get a double bootstrap effect. The mainsail would help the staysail, and the staysail in turn would help the topsail instead of hindering it. This combination would have less sail area, but I wonder what its resulting performance would be.

Before you cut up your staysail for a duffel bag, I should tell you of some of the positive benefits of the staysail. After all, we do know the double head rig can be an effective sail combination. First, in these illustrations the mainsail was sheeted in rather tightly. In this position it gave a strong upwash flow field for the topsail and created large increases in the topsail lee-side suction pressures. But this meant the leeside pressures at the leading edge of the mainsail had very high negative values (about -3 in Fig. 4, point H). This suction peak was followed by a rapid increase in pressure to the positive side. The boundary layer probably would not like this rapid increase in pressure; it would separate and the mainsail would be stalled.

However, with the staysail present, the suction peak is not so high, the pressure rise not so steep, and the boundary layer is able to withstand this change. Accordingly, it remains attached and does not stall. The staysail has suppressed the high velocities around the mast which allows the main to be trimmed tighter without stalling. The flow field created by this unstalled mainsail gives an increased upwash into the topsail and furnishes a higher velocity flow region that favorably influences the leech and lee-side velocities of the topsail. It is the staysail that permits the main to do all of this!

From practical experience we also know there are other beneficial effects that help compensate for the staysail's possible interference with the windward-side pressures of the topsail. The jib topsail is cut with a high clew which increases its overlap on the mainsail. This helps the mainsail lee-side flow in the upper part of the sail.

However, with the high clew, the foot of the topsail loses the end plate benefits earned by a low deck sweeper genoa. This is where the genoa staysail apparently fits in again. Because it is tacked low with a low clew, it makes use of some of this air. Additionally, the foot of the staysail does not have much topsail area to interfere with, for the topsail is high cut in this area.

In this discussion I have not distinguished between the different types of staysails that could be used. It is obvious that when a short hoist genoa staysail is used, it will have its maximum interference with the topsail and its suppression of peak velocities on the mainsail will be only in the lower portion of this sail.

Up high, above the staysail, we will have to rely on the large overlap and close proximity of the topsail leech to help the mainsail lee-side flow remain attached.

When bearing off from close hauled to a reaching course, the topsail is let way out and it is no longer able to keep the tightly trimmed upper part of the main from stalling. To remedy this, you must let out the mainsail and allow the upper section to twist off more. Another approach would be to change to a tallboy type of staysail. If the tall staysail goes near the top of the main, it will help suppress the peak velocities on the mainsail and keep the upper part from separating. All these arguments, of course, assume the wind is not high enough to create either excessive heel angle or weather helm.

A close-reaching condition is where the three-sail combination really comes into its own. The staysail helps control the separation on the mast and mainsail, it also carries a high lift because of the bootstrap effect, and the topsail now is sheeted out so far that staysail interference with it is at a minimum.

This all leads me to one important conclusion. The staysail is a very tricky sail to handle. If the mainsail is not trimmed so that it can benefit from the interaction effects created by the staysail, then the staysail may not increase the total driving force of the sail combination at all, even though considerable sail area is added.

The staysail does reduce the efficiency of the topsail if they are too close together. However, the side benefits of the staysail I have already mentioned do make it a useful sail; but it must be used with great care.