Sails: The Source of Power, Part 2

by Rod Carr

Introduction

Technical discussions of model yacht sails seem to occur only occasionally but when gathered together form a body of knowledge valuable to every R/C skipper. This discussion is the second of a series that began in *Model Yachting* Issue 130, Winter 2003, page 18. This article is posted on the AMYA website <www.modelyacht.org> and can be downloaded from the *Model Yachting* magazine home page at the *Downloads* link, in the *Publication* pull-down menu. Additional material, pointed at the EC-12 class, but with application to any model yacht, will also be found in *Model Yachting* Issue 145. Back issues of these publications may be obtained from AMYA.

Your first step in developing an understanding of your sails is to learn the particular nomenclature that defines the sides, corners, and details of both jib and mainsail. Figure 1 is repeated here for your reference.

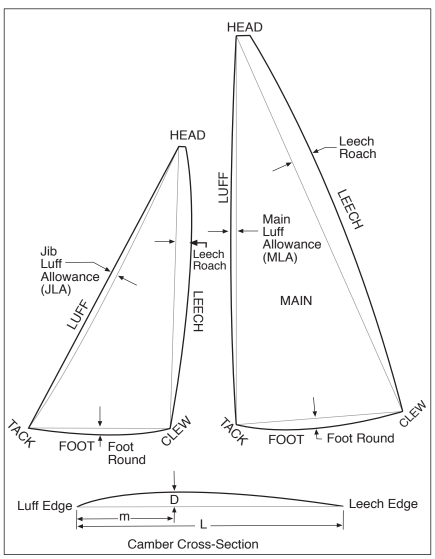

Figure 1

Your second step should be determining the amounts of Jib Luff Allowance (JLA) and main luff allowance (MLA) built into your sails by your sailmaker. If he does not volunteer the information, ask him—Point Blank! If he cannot produce the information, you'll have to measure it yourself or consider a different sail maker. Tape the head and tack of the sail down on a flat surface with the tape holding the sail so that it can "hinge" itself at the surface. Then raise the clew of the sail to the point where the sail sweeps down to the surface and just becomes tangent to the surface at the luff of the sail. The extra fullness built into the sail will show itself as camber, and the departure of the sail luff from a straight line will be a measure of the JLA or the MLA. You must know the MLA to know how much mast bend your mainsail can absorb before a mast "overbend" wrinkle forms between the mid-point of the mast and the clew of the sail. You must know the JLA to start developing a strategy for opposing jibstay sag with adjustable backstay tension.

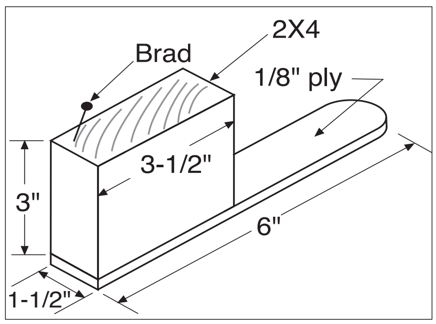

Figure 2

Camber and Draft in Paneled Sails

Your mainsail is the primary power-producing component of the sail plan. Mainsails are usually both the largest and tallest of the sails on a sloop, and thereby have the greatest opportunity to work in the fastest moving air aloft above the water. The shape built into the mainsail must be understood if sail set and sail trim are to be optimized.

So let us first consider the shape of the mainsail when configured for no twist, i.e., the legs of the measured triangle and the three corners of the sail all lie in the same reference plane.

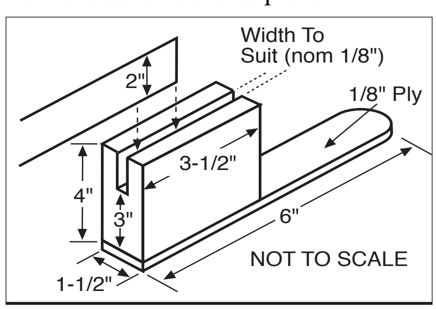

Figure 3

Make three corner-holders as shown in Figure 2. These will establish the reference plane as parallel to and offset 3" from your work surface. The tongue extensions provide places for weights to keep the holders in place while measuring. Make a pair of straight-edge holders as shown in Figure 3. These holders will allow a straight-edge to be held over the sail, perpendicular to the luff, and just touching the luff and leech, representing the chord of the sail at that height.

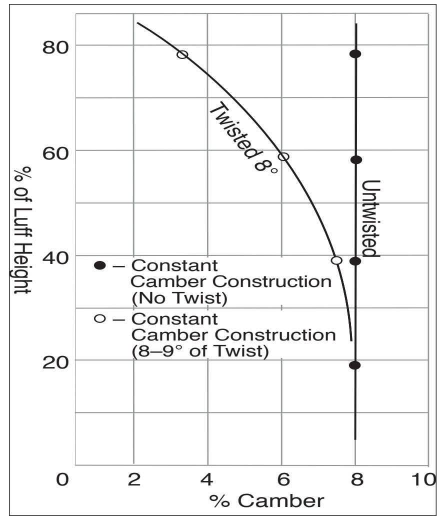

Figure 4

Now with the three corners of the sail held in the same plane, and the straight-edge holders in place, one can measure the chord (L), the depth of draft (D), and the point of maximum draft (m) anywhere along the sail. For convenience, measurements taken at 20%, 40%, 60%, and 80% of the luff height produce sufficient data to describe the sail.

Follow the directions in the first article for calculating percent-camber. Plot the data as shown in Figures 4 and 5. This data will be for an untwisted sail.

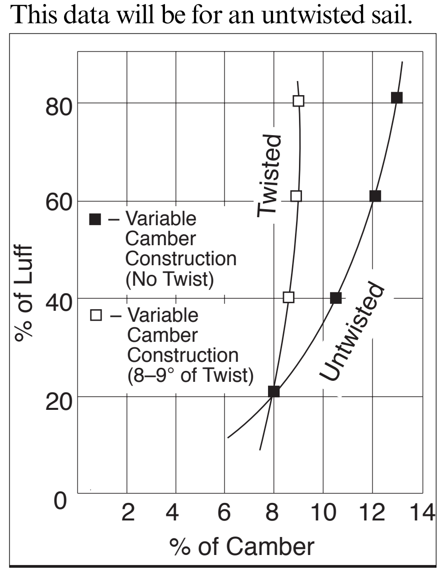

Figure 5

Mainsail Twist

To induce twist into the sail, move the clew holder parallel to the luff, toward the head of the sail. The leech will sag below the reference plane, and the straight edge in the straight-edge holder will no longer touch the leech. This is why we will measure the sail in its untwisted configuration and use that data to assess the cambered shape. One can make an adjustable straight-edge holder to measure cambers in twisted sails, but it is a laborious process. We've done it and will simply present the results later in our discussion of camber as a function of twist.

At the same time twist induces a change in the direction of the sail chord at each station, it also causes the entry angle at the leading edge of the sail to increase from foot to head. Maximum efficiency would seem to demand that the wind seen by the sail should therefore to come from farther aft as one ascends the mast. But more on that later.

There are two kinds of sails being produced today: 1) Constant camber sails that have the broad-seaming in each panel joint the same, producing an untwisted sail in which the camber is constant with height (Figure 4, "Untwisted") and 2) Variable camber sails in which different broad seam configurations in each panel joint make a sail in which camber varies with height (Figure 5, "Untwisted"). Some commercial varieties of this second configuration are labeled High Twist (HT) sails.

If, however, each sail is adjusted so that there is an 8–9 degree twist between the 20% chord and the 80% chord, the plot of camber versus luff height becomes as shown in the "Twisted" plots in Figures 4 and 5. Both sails respond

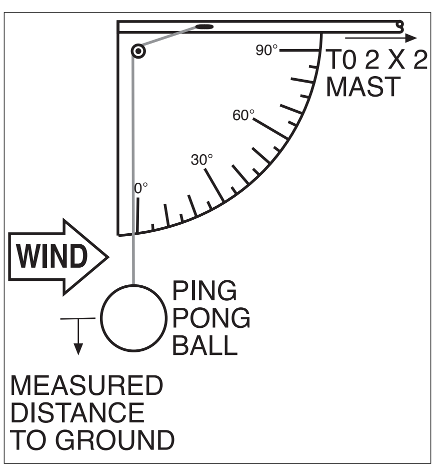

Figure 6

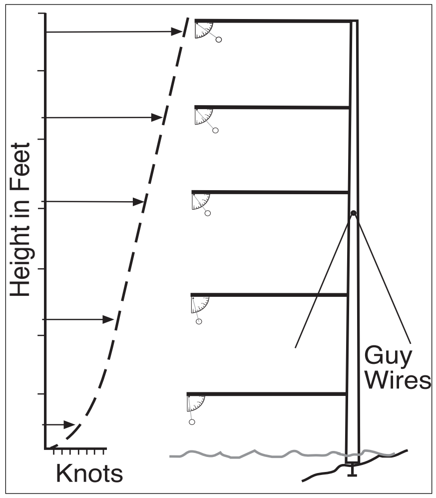

Figure 7

to twist by reducing the camber as one moves up the sail. The constant camber sail sees its head camber reduced almost in half, with the upper seam showing only 5% camber, not a very powerful airfoil to be asked to work in the faster moving air aloft. The HT sail also reduces its head camber, but only down to a 10 – 11% camber, very appropriate for light to medium wind speeds.

So which kind of sail to choose, and why? We need more information about the vertical speed and direction of the wind in which we sail before we can make an informed selection.

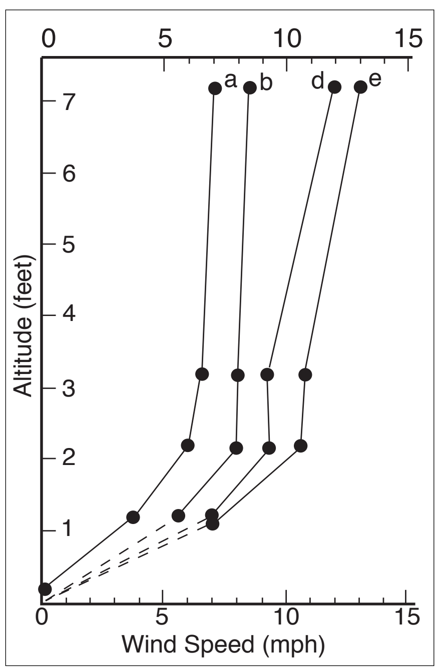

Figure 8

Wind Velocity Gradient

Common sense suggests that immediately next to the water there is an air molecule that is moving, but little. But above the water, say 30' up where the Weather Service or the local TV station has an anemometer whirling away, the free-stream wind speed reported on the evening news occurs. Between these two points there must be a continually changing wind speed, starting at 0 mph at the water surface and increasing to the local wind at height. Model yacht sails are asked to function in the lower 10' of this changeable realm, and the change that close to the water has really been of interest only to R/C skippers and a handful of scientists who study how materials exchange across the air-sea interface.

In the early 1970s, the only published measurements of this change in velocity with height (a velocity gradient) covered an altitude from 6' to about 38'. Model yachtsmen needed to do their own research.

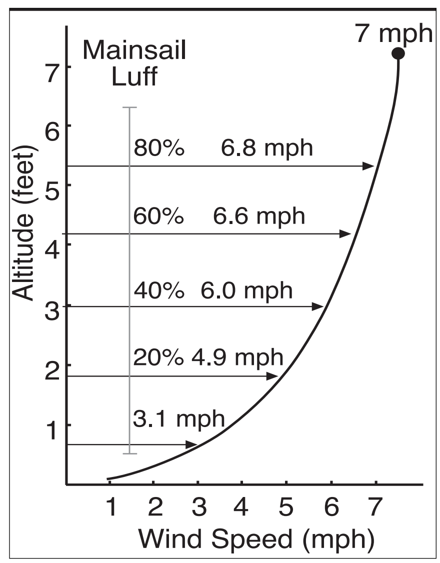

Figure 9

An article I published in the March 1977 issue of *Model Builder* magazine, reports actual measurements taken between the surface and 7' altitude of a Virginia lake. A 7' pole with ping pong ball anemometers mounted at intervals was placed in the lake (Figure 6 and 7). Photographs of the instrument were taken from a distance away that allowed the displacement of the ping pong balls and, hence, the wind speed to be measured. The data clearly showed a transition from the water surface to free-stream wind speed occurring and being generally complete by the time an altitude of 7' was reached for a 2–3 mph wind and by about 4' for a 10 mph wind (Figure 8). In other words, the change in wind speed with height is more rapid when the free-stream wind is faster, certainly logical. Figure 9 shows an idealized plot of velocity gradients for a free-stream wind speed of 7 mph. Data for an EC-12 mainsail luff are shown with wind speeds indicated at various heights.

Apparent Wind: Definition and Distribution with Height

Our sails see not only the wind that blows over the water, but we must account also for the apparent wind that is caused by the boat's movement through the water. If a yacht were given a 1.5 mph shove in still water and still air, a sensor on the boat would register a head wind of 1.5 mph. The boat speed wind must be added to the true wind to give us a direction and speed for the apparent wind, the wind the sails actually feel. Figure 10 shows how to graphically add the two winds together to get the apparent wind vector. "Vector" is a useful term that contains both speed and direction, and is shown as an arrow.

In Figure 10 we see that the apparent wind at the foot of the sail (0% luff height) is 4.2 mph and is felt to be coming from 31 degrees off the starboard bow of the boat. But at the 80% luff height, the wind is stronger, at 8.0 mph, and the direction has come aft by 7 degrees to 38 degrees off the bow. The inescapable conclusion is that the top of the sail must be trimmed farther off the centerline of the boat to avoid being stalled. If the sail is not twisted off, the head will be trimmed too tight, drive will be lost, and additional heeling will result.

So in a nutshell, the increasing wind speed with height produces a progressive change in both the speed and direction of the apparent wind, and an optimized sail must match the direction change, hence the importance of twisting model yacht sails, and maintaining power-producing camber in the upper half of the sails for good performance.

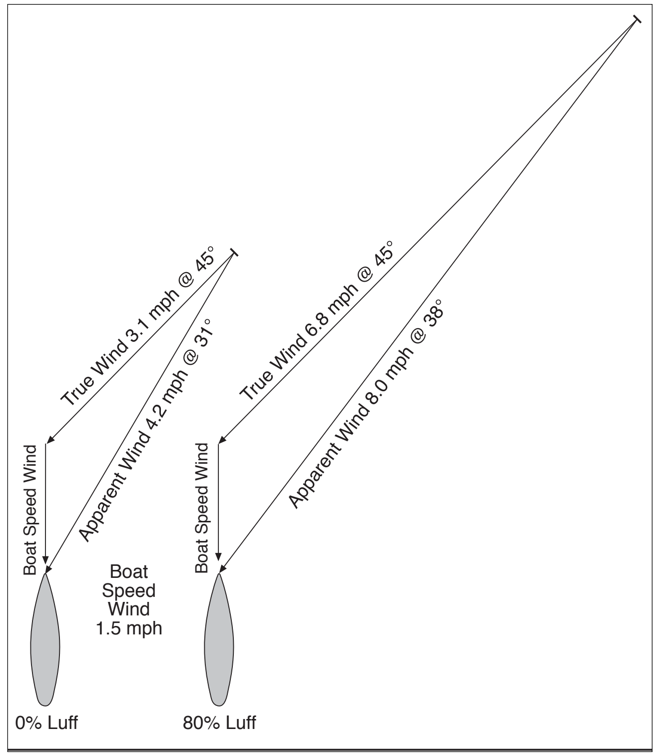

Figure 10