Adapting Full Sized Sailmaking Design and Broad Seaming Techniques to Model Yacht Sails

by

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Current Technology

I started sailing model yachts about 8 years ago. One of my first observations was that model sails didn't fit the sail trimmer's eye I developed over many years of big boat trimming, some of that professional, on everything from one-designs, metre boats to ocean racers. The mains were oddly proportioned, but tolerable, but the jibs – not so much. I further noticed, however, that the boats leading the fleet, with sails identical to the followers, had better shapes. Hmmm..... interesting!

I soon learned, that model yacht sailmaking technology has changed little for decades. Simply due to the small size of model yacht sails, the design and broad seaming techniques used by full sized yacht sailmakers were impossible to duplicate. Instead, sail blocks and sail boards were developed to enable small model yacht panels to be seamed together in a way that produced a cambered shape. This practical technique overcame the shaping limitations of single flat paneled sails, which could only be cambered by making darts and or by cutting curved edges on the luff of the model yacht's sail. While sail blocks or boards, by bridging the ridge, can produce a cambered seam, the shape of the seam, and therefore the shape of the sail produced, is a circular arc. (See Figure 1). https://docs.google.com/document/d/1FRC5Dx1XmQhYcWkzISrC-d-Ec4N0H0qdrQnP9Kr651I/edit?usp=sharing

This shape is less than optimal for high performance racing sails. No full sized yacht racing sails are designed, seamed or shaped in this manner. Performance of arc sails becomes the result of trial and error and is usually class specific. Many model sailmakers of block made sails are focused primarily on making smooth cambered seams and finishing the sail. None are “designed” in the engineering sense and much of the final

sail shape is a result of default and the expertise of the sail trimmer.

Over time, some model sailmakers recognized that arc shapes are less than optimal for racing sails, primarily because circular arcs are a high drag shape. To mitigate this and improve the shape of block made sails, they are generally made quite flat. Stiff battens are often used, not to support the leech roach, but rather to help flatten the leech area and reduce some of the drag. Also, relatively high luff tensions, and in some cases mast prebend, are required to “pull” some of the arc shape more forward to improve the entry angle and to also help flatten the leech. Setting more twist in block made sails is also used by expert sail trimmers to further mitigate the arc shape. All this combines and explains why model yacht sails are so hard for many to trim. The sail first requires appropriate shaping by the skipper (the fleet leaders) and then trimming to the conditions.

New Technology Development

About six years ago, I set out to change all this by bringing full sized design and seaming techniques to our hobby. The first step I took to develop new model yacht sailmaking technology was to search for sailmaking design software. It quickly became apparent that while programs were available, the cost was prohibitive. Further, they were loaded with structural analysis features that had no utility on model size sails. My solution to this fact was to find an open source CAD program and then customize it to become a proprietary 3D model yacht sail design program.

Applying Full Sized Design Techniques

Full sized sailmakers design sails so that the entire sail plan (main and jib) ideally achieves elliptical wind loading. This combined with a true airfoil shape, produces the lowest form drag (drag from the sail shape) and helps to minimize induced drag (top and bottom air leakage). While this is often not possible given that most class rules limit sail sizes and shapes, still, the camber locations can be distributed (fore and aft) and the amount of camber determined to achieve the best fit elliptical load pattern. (See

Figure 2).
https://docs.google.com/document/d/1ITxOLYQ9efYprrg6FPEEmT9jxcZABR28HespA1fbGmw/edit?usp=sharing

Once the camber distribution is determined, the next design step is to focus on the mid section of the sail and determine the design from the middle up and the middle down. This is done for two reasons. First, the shape of the sail at the mid-quarter point has an effect on the shape of the upper and lower quarter points. Second, the middle of the sail is the so called “sweet spot” designed to match the physical parameters of the boat and maximize performance. To design the sail, the first step is to determine the appropriate camber amount (we have already determined the location) at the mid point, then follow that with the designed of the entry angle, exit angle and twist. This is then repeated by design coordination of the upper quarter point to the middle and the lower quarter point to the middle. Vertical shape (partitioning), which cannot be achieved without a graphical design, is also considered at this point. On a main, this results in a sail with lower camber amounts located more aft at the lower quarter point and increasing camber, which moves more forward proceeding to the upper quarter point. (See Figure 3).
https://docs.google.com/document/d/1j9dm_iGWGZSVaTxqVL698UJPUy2MAoRxb_HRW8Um5tk/edit?usp=sharing

On a jib, camber also increases from bottom to top, but the distribution is opposite of the main. All this is identical to designing full sized sails.

It is interesting to note that many model yacht sails are actually built upside down, which explains the odd proportions I first noticed years ago. For example, if the same sail board or block is used to assemble each seam, the camber built in will decrease from the bottom of the sail to the top due to the shorter arc section of each seam. No full sized sail is built that way. The camber should always decrease from top to bottom as a function of the local area. More area needs less camber and less area needs more camber to equalize the loading. It explains why arc sails with only upper seams and no lower seams perform better than arc sails with seams

equally spaced. It also explains why many jibs, supplied with seams, are simply flat panels with no built in camber. They actually can be shaped/trimmed easier and perform better than a jib with inverse camber orientation.

New Broad Seaming Technology

Once the sails are graphically designed using the proprietary design software, offsets are needed to describe the broadseam, entry angle and luff allowances that will reproduce the designed shape in a suitable sail material. (See Figure 4).
https://docs.google.com/document/d/12YcH3GO0mWyK3WQy313hMKEm5pChTQlq2ChcyN_JUbA/edit?usp=sharing

Further, since even the largest models have sail sizes that are so small, compared to even the smallest full sized sails, very tight tolerances (.05 millimeter) are required. To achieve true fidelity to the design, algorithms had to be developed to apply to the offsets to model the effect of seam length, sail proportion (high aspect or low aspect ratios) and material elasticity. All done in the proprietary software, the final output are sets of X-Y coordinates needed to describe the sails. The next challenge was to develop tools to actually perform the seaming and construct the sails.

The first tool developed was a lofting/offset board, which is basically a copy (on a very small scale) of the layout of the sail that full sized sailmakers simply draw on the loft floor. (Currently, the most high-tech sails substitute a full sized mold for the floor). After the panels are seamed, this is used to orient the camber points, build the entry angle (luff allowance), then the allowance for mast bend or forestay sag, cutting to final size, finishing the corners and attachments. Like full sized sails, a specific board must be made for each sail design.

As a side note, full sized sails are always lofted from the starboard side (starboard side up). This is a tradition that dates back centuries. I have noticed that most, if not all, model yacht sails are lofted from the port side. This interesting departure from full sized sails must have originated with the early pioneers of model yacht sailmaking. To honor that, and since it

makes no performance difference, I too loft from the port side.

The most formidable challenge was designing a practical broadseaming tool. Early efforts and failures spanned a period of almost two years. Occasionally, seams could be made that would faithfully reproduce the graphical design shape, but certainly not in a practical or repeatable way. I actually gave up three separate times, but the engineering all came together on the fourth attempt. Sirius Sails (www.siriussails.com) was then formed to provide a high performance sailmaking alternative to existing model yacht sails.

Summary and Practical Implications

Model yacht sails designed and shaped like full sized sails are not a magic bullet. While it was an interesting engineering exercise to develop the necessary technology, even next generation sails don't trim themselves, get a good start, tack the boat when appropriate, stay out of penalty situations or round marks efficiently. They do, however, offer very noticeable performance advantages in light air and also in heavy air when better shapes significantly matter. Mid-range, noticing better performance is somewhat limited, since most any sail, even flat panels, can be made to drive the boat at hull speed. Better acceleration out of the tacks and at mark roundings, plus superior pointing, however, are obvious in all conditions. The need to first shape the sail, then trim to the conditions has been eliminated. Since the sail is designed shaped like a full sized sail, trim techniques learned and used on full sized sails are directly transferable. Sirius Sails, with Distributed Camber(TM), are the next generation in sailmaking for model yachts. They are the only model sails made that can duplicate the design, the broad seaming techniques and airfoil shapes used on full sized racing sails. (See Figures 5 & 6).
https://docs.google.com/document/d/1RhTJKH1NZE84lXotIRwqfJUSv6NWNrC-CC-3Aj_WQQo/edit?usp=sharing

https://docs.google.com/document/d/19PrF1xre7oYqStr35YRh_0iLvj2nSvp2euvpivhYljo/edit?usp=sharing

This is accomplished by designing the sails, using custom 3D sail CAD

software, and then using proprietary tools to broad seam the panels to produce the design shape. This exactly replicates full sized sailmaker techniques. Precise control of maximum camber, it's location, luff entry, leech exit angles and twist, are possible using the proprietary software and seaming tools developed by Sirius Sails.