REDUCING DRAFT ON LARGE SAILING YACHTS

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The accessibility of shallow harbours, and being able to anchor close to islands and beaches, is an important requirement in the design of large sailing yachts. We are often confronted by owners, and people representing owners of large cruising sailing yachts, during the first discussions about a new design, with harsh requirements of this nature. It has become standard practise in those instances to explain that it is important that a specific minimum keel and rudder span needs to be maintained for reasons associated with stability (safety) and windward performance. It is usually possible, together, to define what this minimum needs to be.

The desired span of fixed keels and rudders is dependent on hull length, sail area, and displacement. Desirable values, for a fixed planar type of keel (basically a trapezium-type of design), can be expressed as a function of waterline length as follows:

Waterline length in metres	Desired span (height) of conventional keel in metres	Typical associated draft in metres
10	1.51	2.21
20	2.64	3.86
30	3.65	5.34
40	4.59	6.71
50	5.49	8.03

These values approximately constitute a boundary in the sense that less span will tend to harm performance and stability, if measures are not taken.

So what then are the unwanted effects associated with not having a keel (and a rudder) with sufficient span. The most obvious of these is the inability to position the ballast housed in the keel sufficiently low down. As keel span is reduced, the ballast will need to be positioned higher, with detrimental effects on the value of the angle of vanishing stability (the heel angle at which the yacht will capsize). The second unwanted effect is that associated with the inability of the keel to develop sufficient hydrodynamic side force, required to minimize the leeway of the yacht. The third unwanted effect is the increase in so-called induced drag, with an important loss in speed. Finally, the inability of the keel to develop adequate side force levels will result in a greater contribution of the hull (also termed the canoe body) to the side force, which is usually accompanied by a large increase in the amount of weather helm as the yacht heels - sometimes even resulting in loss of directional control sailing upwind, with the yacht rounding into the wind. When the rudder is limited in span as well, insufficient directional control is often experienced sailing downwind in stern-quartering seas.

The loss of stability, when reducing draft, can be prevented when adequate design measures are taken. Stability can be greatly improved by housing the greatest part of the ballast in a torpedo-like appendage (also-called a bulb) at the bottom of the keel. Even when the span of the keel is reduced, this will normally result in sufficient compensation with respect to the safety of the yacht, in obtaining a high-enough angle of vanishing stability. It is important however that this bulb is well-designed and that a shape is employed that minimizes hydrodynamic resistance. A large increase in viscous resistance occurs if a bulb is too fat in relation to its length. When the bulb is relatively voluminous, the wave-making resistance of the yacht is adversely effected as well.

The loss of side force, and the associated loss in windward performance, can be compensated for to a large degree by ensuring that the keel has sufficient lateral area (requiring an increase of the average chord length of the keel), and the fitting of winglets. Winglets are wing-like appendages either fitted to the bottom of the keel (in absence of a bulb), or to the bulb, in the proximity of the trailing edge of the keel. Winglets were first developed for application to a keel on a sailing yacht for the winner of the America's Cup "Australia II", in 1983, by the author and his team. A computer rendering of a recent keel for an X-73, built by X-yachts, and designed by our office, is shown in Figure 1.

figure 1 New keel for X-73.

Winglets at the bottom of the keel or on the bulb increase the effective aspect ratio of the keel (i.e. the effective span), thereby increasing the side force per unit keel area, and diminishing induced drag. In this respect winglets fitted to keels work similarly to the winglets fitted to the wing-tips of modern aircraft such as the Boeing 747. As the relative span of wings (or keels) become smaller, the size of these winglets need to increase to obtain their full benefit. This is the reason why winglets fitted to keels are relatively larger in size than those fitted to aircraft. A beneficial attribute of large winglets is that they develop considerable side force themselves, when the yacht heels. This is the reason why winglets, fitted aft on the bulb, act very efficiently in avoiding excessive weather helm. As the yacht heels, and the disparity of the resultant force on the sails and the resultant force on the underwater hull and appendages requires an increase in weather helm to maintain a straight course, the increasing side force on the leeward winglet - when positioned relatively far aft - will tend to limit the increase in weather helm to acceptable limits. This feature is particularly important when, at larger leeway angles, a large contribution to the side force is made by the canoe body. By its nature, the canoe body will tend to develop side force at larger leeway angles in the vicinity of the bow, which - in turn - requires a considerable degree of compensating weather helm, unless some other appendage situated aft on the hull, such as the leeward winglet, is able to develop sufficient levels of side force at the same time.

There are off-course other solutions to the problem of how to obtain an efficient keel together with a shallow draft capability. The well-known Jongert yard have developed a foldable keel, a keel that actually folds into a horizontal type of appendage just below the hull. Others have developed various types of variable-draft keels or keels with centerboards which can be raised and lowered. In most of these cases, however, the amount of ballast that can be carried in these keels is limited, often resulting in a loss of stability. Then there is always the loss of interior space associated with having to haul the keel, or parts of the keel, into the hull in these cases.

When keel geometry has been optimised for a specific (reduced) draft, careful consideration needs to be given to the performance of the rudder. The draft to the bottom of the rudder is usually chosen to be at least about 0.3 metres less than the draft to the bottom of the keel, to avoid damage to the rudder when the vessel should run aground. When the draft is reduced considerably (as is invariably the case in the design of cruising yachts longer than 30 m) the span of the rudder will be too small, resulting in insufficient rudder force at normal helm angles. Sometimes a serious loss of control in stern-quartering seas occurs (when the demand for large rudder forces is greatest). Our office has developed various rudders fitted with sizable winglets to overcome this problem. Here, winglets on the rudder act in a similar way to winglets fitted to the keel in increasing effective span, increasing the side force per unit lateral area, and decreasing the induced drag. When winglets are placed aft along the bottom chord of the rudder, however, the required rudder torque is excessive, demanding large steering gear, unless the balance of the rudder is adjusted.

Our office, together with Guillaume Kruyskamp, recently developed a variable-span rudder, which has now been fitted to 2 large cruising yachts built by Jongert. Figure 2 shows a computer rendering of one of these designs. In this concept the bottom half of the rudder slides up and over the top half. This is realized by a hydraulic cylinder fitted inside the top half of the rudder. Both vessels to which these rudders have been fitted were also fitted with the Jongert foldable keel, yielding a true shallow-draft capability, with none of the short-comings associated with the long-chord, skeg-like keels that other yachts utilize to obtain the same (shallow) draft.

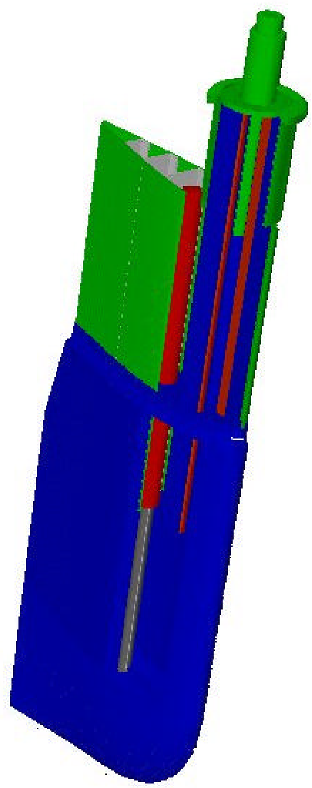

figure 2 Variable span rudder.