CRUISING PROA CONCEPTS

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Summary

This document is done to clarify and compare different type of proas. At the first stage the treated proa concepts are defined. Then there are comparison of righting moments and stability, possible sail areas, heeling moments, wetted surface, resistance and speed potential. The basic idea is to find out the fundamental characteristics of different proa concepts.

Introduction

Proa is a sailing vessel with low cost and high speed. Her construction costs are far more lower than trimaran or catamaran. When I first become inspired of proas, I sketched a pacific proa, but then I realised, there are lot of different concepts for proa: Pacific, Atlantic, then this Harry... Would there be others? What are the principal differences between them?

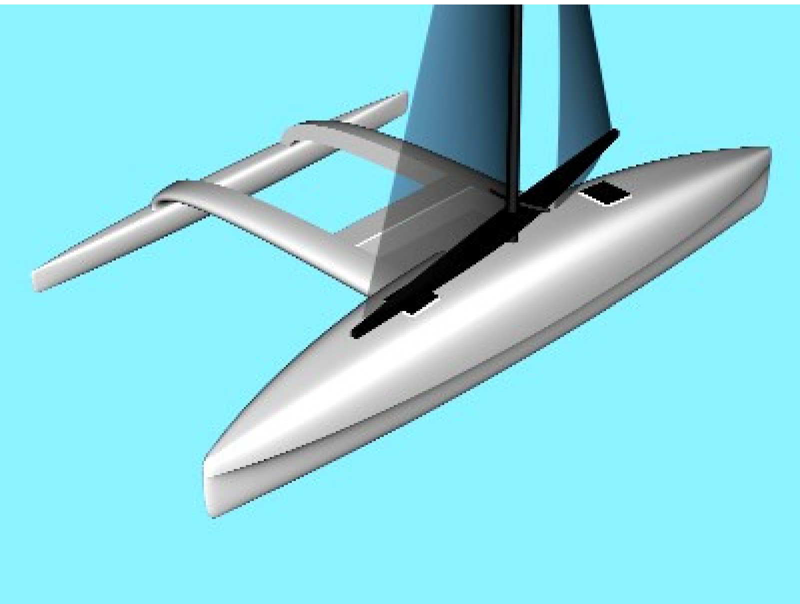
After I joined this proa group (Yahoo proa group) I realised quite a lot disagreements and debate in the previous messages. Aren't there objective facts available? I wanted to make some basic calculations to find out how these proa concepts really differ. Proa concepts dealt here are as follows:

- Pacific proa, original concept with light and short windward hull, accommodation and mast at large leeward hull.
- Atlantic proa, accommodation and mast at windward hull, smaller but as long leeward hull
- Harry proa, accommodation at short windward hull, mast at longer leeward hull
- Equal L proa, accommodation at long windward hull, mast at long leeward hull

There is no discussion of keels, rudders or rigging here, only the influence of the configuration. The next ones are examples with dimensions to make it possible to compare them with some calculations.

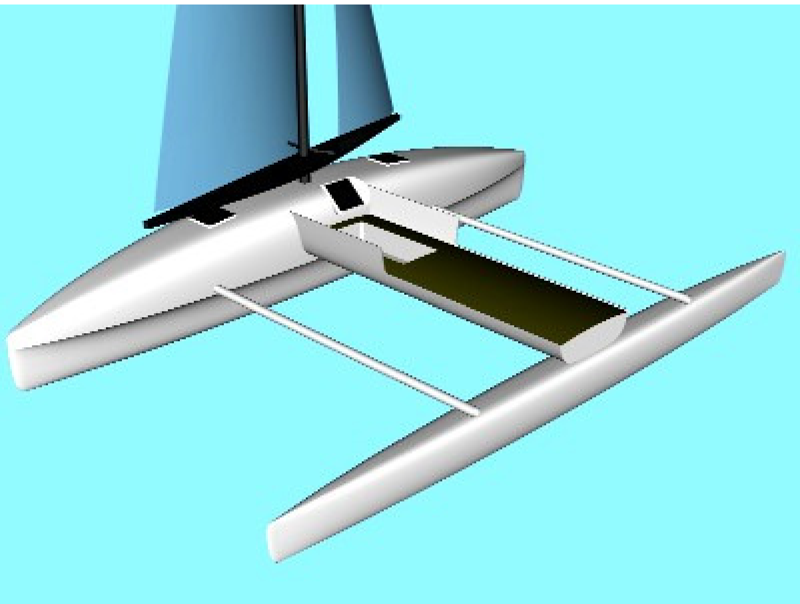
Proa Definitions

Pacific Proa



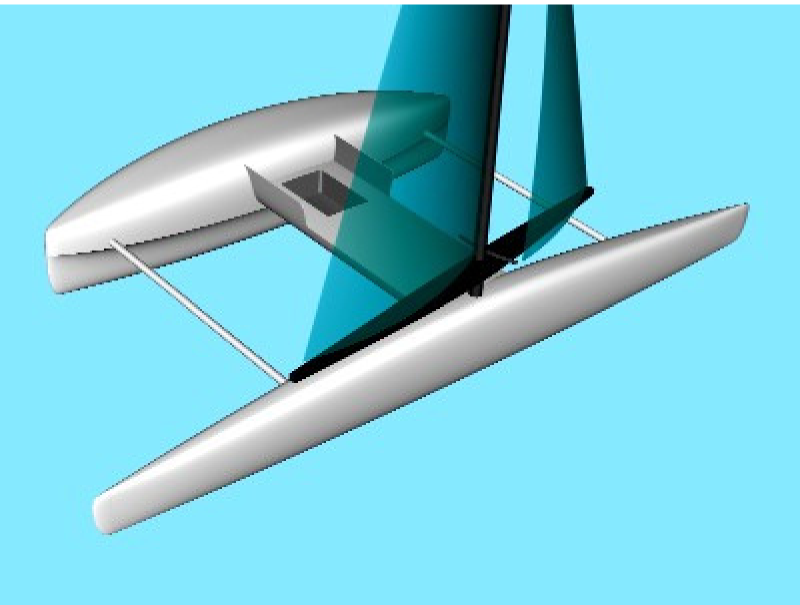
Windward hull: Length 8.0 m, Displacement 0,25 m3
Leeward hull: Length 12.0 m, Displacement 0,75 m3
Distance between hull centrelines 6.0 m
Rigging is on the leeward hull.
In "Pacific W" the water ballast is 250 kg.
While it is impossible to know, how much sailing with Pacific is with/without water ballast, the reader has to make some linear interpolation between Pacific and Pacific W curves.

Atlantic Proa



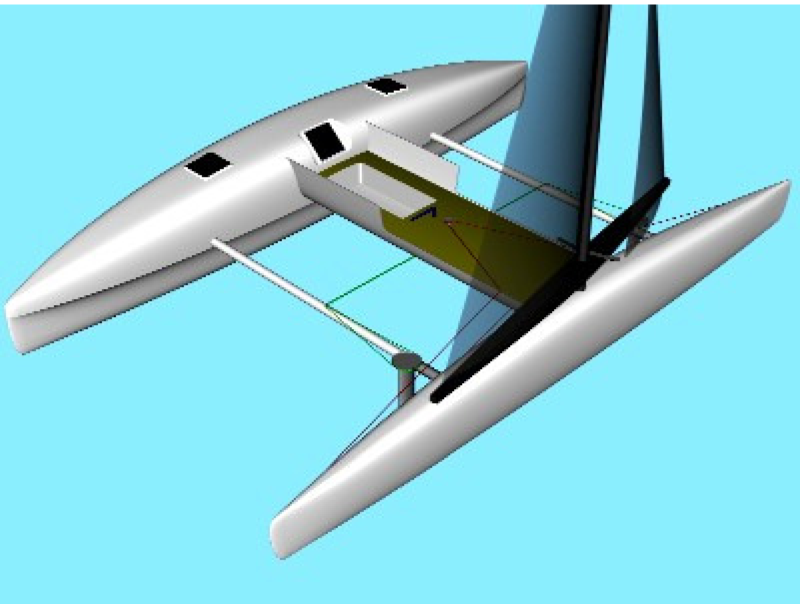
Windward hull: Length 12.0 m, Displacement 0,75 m3
Leeward hull: Length 12.0 m, Displacement 0,25 m3
Distance between hull centrelines 6.0 m
The Rigging is on the windward hull.

Harry Proa



Windward hull: Length 8.0 m, Displacement 0,60 m3
Leeward hull: Length 12.0 m, Displacement 0,40 m3
Distance between hull centrelines 6.0 m
The rigging is on the leeward hull.

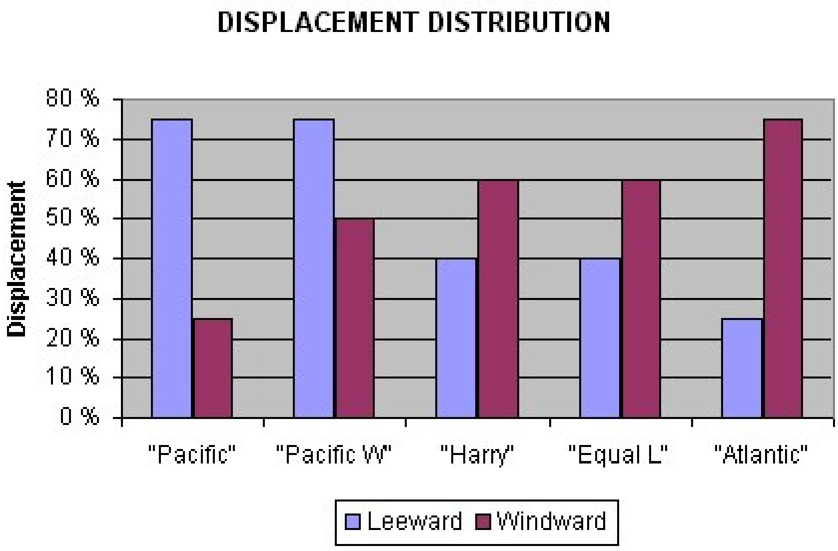
Equal L Proa



Windward hull: Length 12.0 m, Displacement 0,60 m3
Leeward hull: Length 12.0 m, Displacement 0,40 m3
Distance between hull centrelines 6.0 m
The rigging is on the leeward hull.

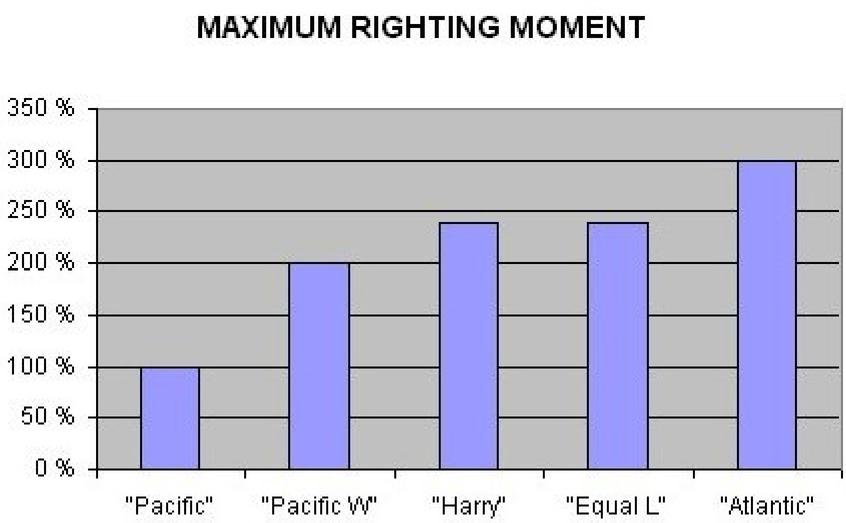
Displacement Distribution

This is the principle displacement distribution of example proas. For Pacific proa the sum is 125% because of the extra water in the windward hull. There can also arise a question if Atlantic and Equal L are as light as the others. Here the assumption is, yes they are.



Righting Moment

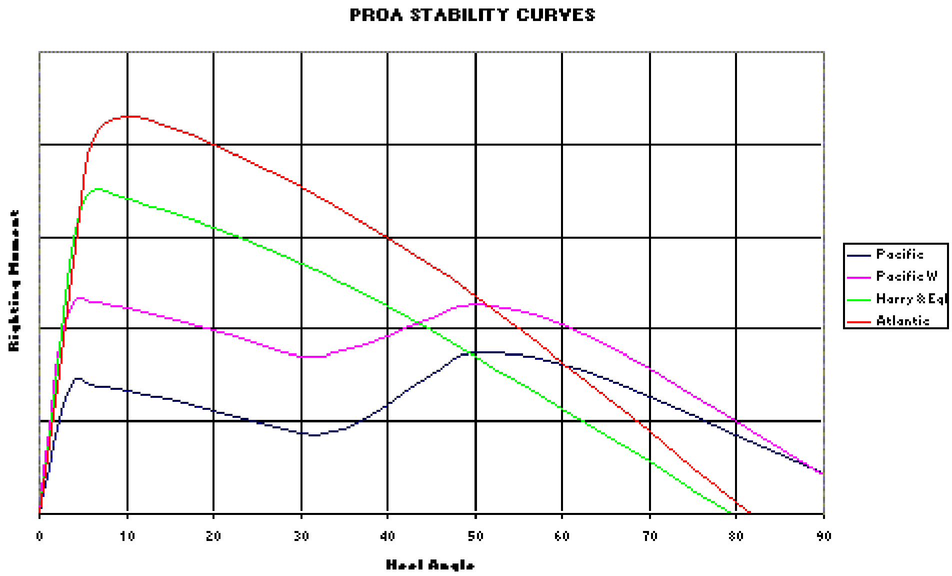
Righting moments are calculated simple: RM = Displacement of windward hull * Distance between hull centrelines. Pacific proa as a "basic proa" is selected to 100%.



Atlantic proa has the highest righting moment and Pacific proa the lowest.

Stability Curves

Stability curves are calculated by Nautilus software.

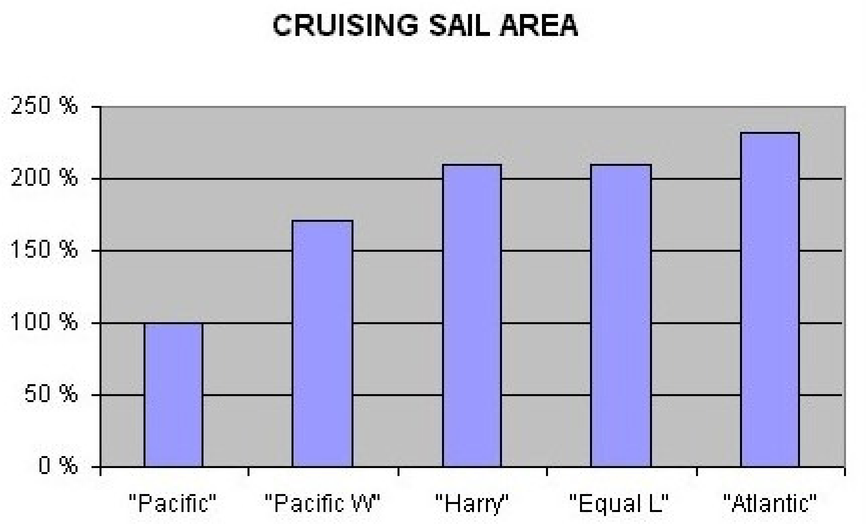


Atlantic proa has the biggest righting moment due to her heaviest windward hull. These pacific proas, unlike in the pictures above, have a leeward pod, which produces the rise of stability curve above 30 degrees. The heeling moment flying windward hull of pacific proa and producing heeling angle up to 30 degrees heels the other proas only for few degrees.

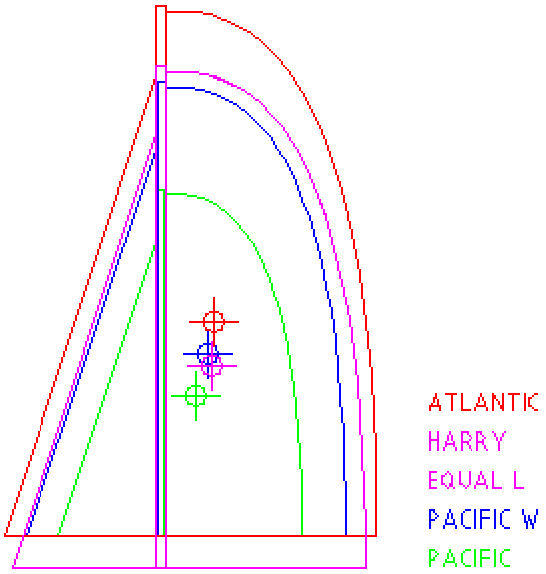
The energy needed to capsize the boat is the area of righting arm curve above x-axis times the displacement of the boat. Pacific proa with pod has bigger capsizing energy than without pod. The drawback with pod is slightly smaller righting moment.

Sail Areas

Calculated sail areas depends on maximum righting moment. The sail area is calculated so, that the maximum righting moment is equal to the heeling moment at the same wind speed. In other words they all are flying their windward hull at he same wind speed. This must be the principle with cruising proas.



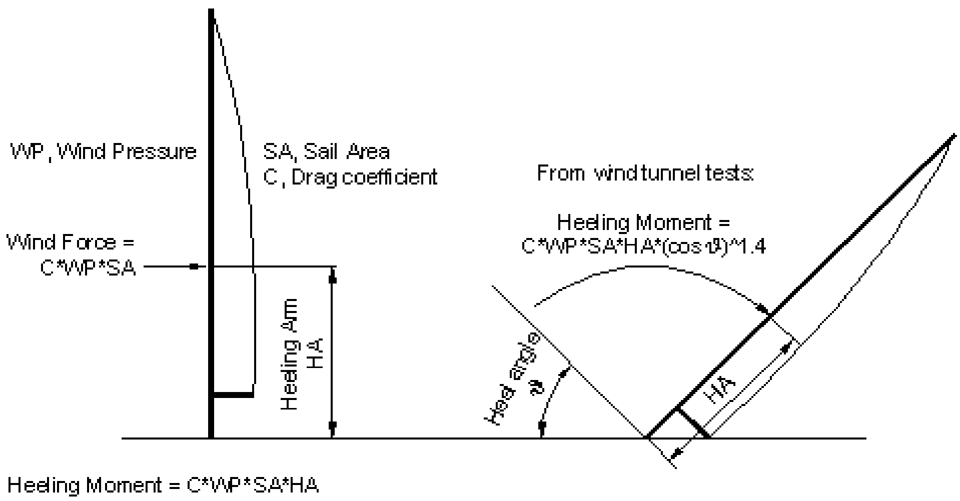
Atlantic proa can carry the biggest sail area and the Pacific proa the smallest. This is as result of their righting moments. When the Pacific is water ballasted, her sail area is bigger, but so is her displacement. Harry proa and Equal L have the sail area slightly bigger than just direct estimated from righting moment, cause their base leech is about 0.5 meter lower than on other proas and hence is their centre of effort.



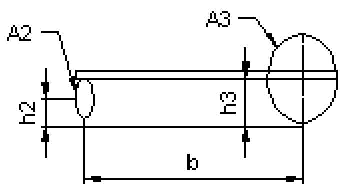
Heeling Moments

Here are lot of pictures which made me to realise, that there really isn't any difference of heeling moment produced by the sails whether the mast is on the leeward hull or on the windward hull. The only differences seems to be from projected areas of hulls.

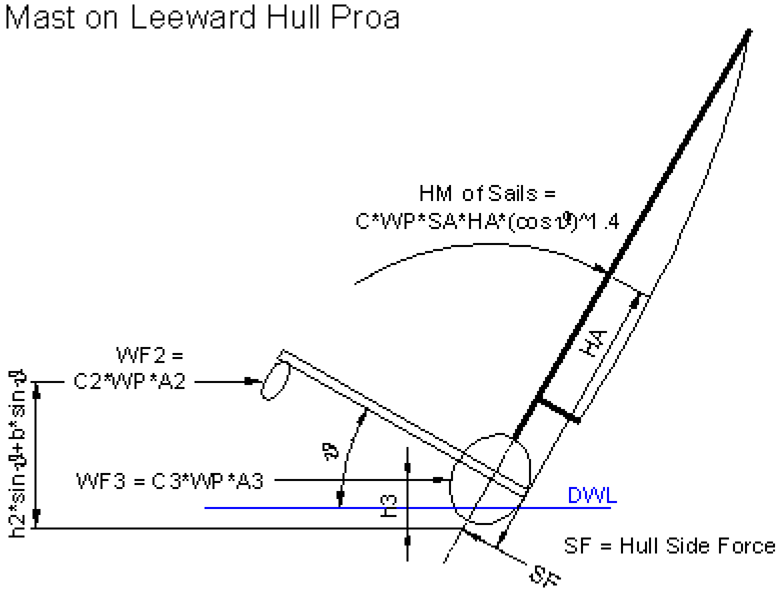
Heeling Moment of Sails



Proa hull dimensions



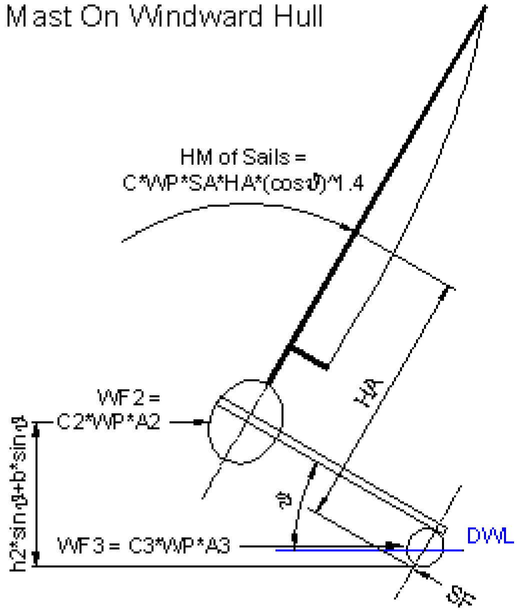
Mast on Leeward Hull Proa



Heeling Moment:

$$HM = C*WP*SA*HA*(\cos\vartheta)^{1.4} + C2*WP*A2*(h2*\sin\vartheta+b*\sin\vartheta) + C3*WP*A3*h3$$

Mast On Windward Hull



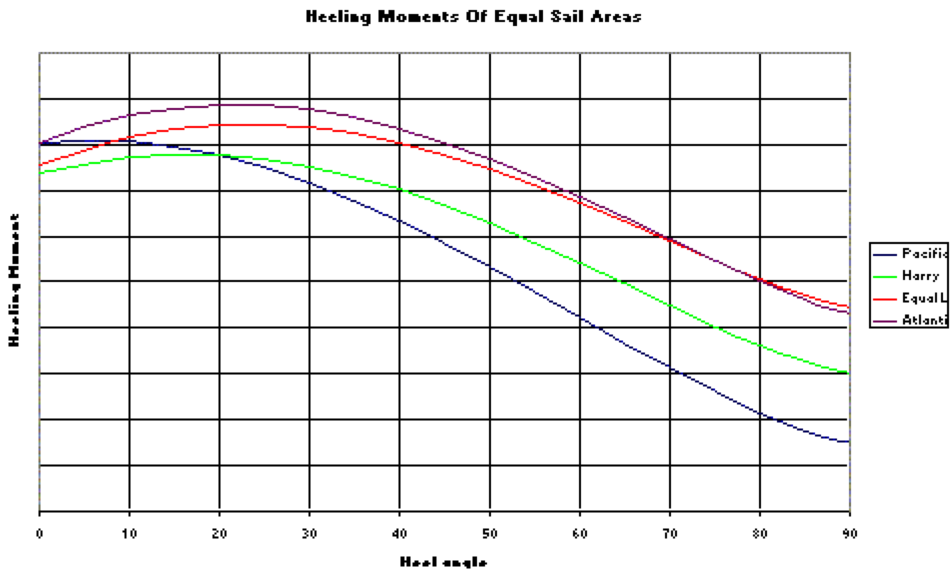
Heeling Moment:

$$HM = C*WP*SA*HA*(\cos\vartheta)^{1.4} + C2*WP*A2*(h2*\sin\vartheta+b*\sin\vartheta) + C3*WP*A3*h3$$

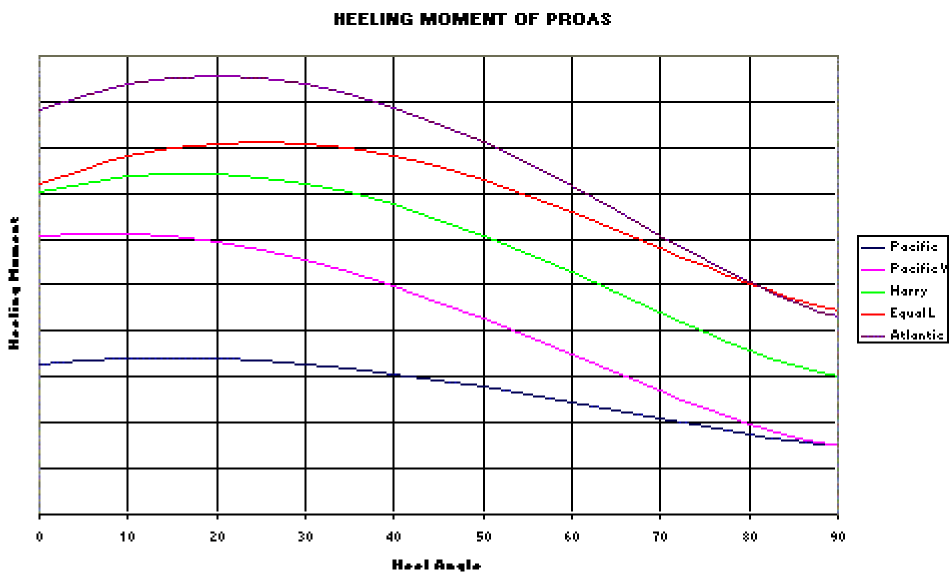
The equations for Heeling moment are similar regardless of the transverse place of the rigging.

Heeling Moment curves

These curves are calculated by heeling moment equation above. The drag coefficients are assumed to be 1.0 for simplicity. These sail areas are equal at the first plot to compare principle differences.



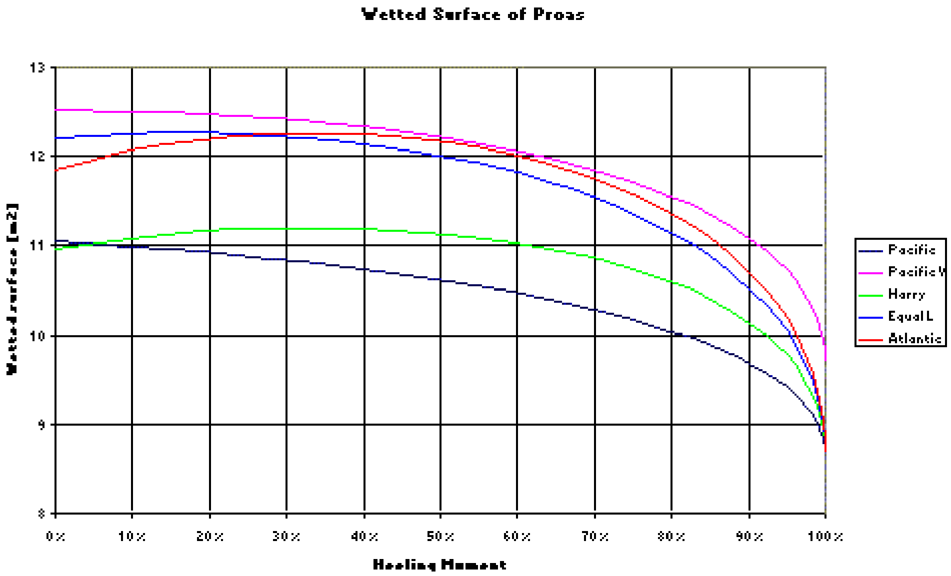
The higher heeling moment of Atlantic or Equal L proas are cause of their bigger projected area of their windward hull. The heeling moment at zero angle of Harry and Equal L is lower than Atlantic or Pacific because their centre of effort is lower. The heeling moment of Pacific proa decreases more rapidly than other proas. So flying her windward hull is safer than the with other proas.



When use calculated sail areas the differences get bigger. Look at these curves simultaneous with stability curves.

Wetted Surface

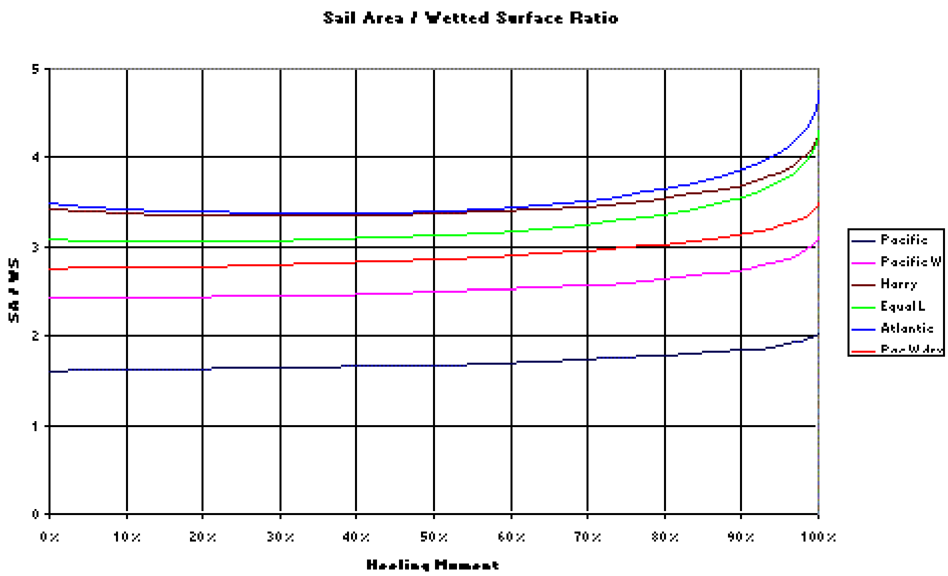
The next curve displays the wetted surface against the heeling moment. 0 % of heeling moment means level sailing and 100 % of heeling moment means flying the windward hull.



The all proas have nearly equal wetted surface when flying windward hull, but as mentioned earlier, only with Pacific proa with pod it is somehow safe way to do. The wetted surface of pacific proa is the smallest except for zero angle where Harry has the smallest wetted surface.

Sail Area / Wetted Surface Ratio

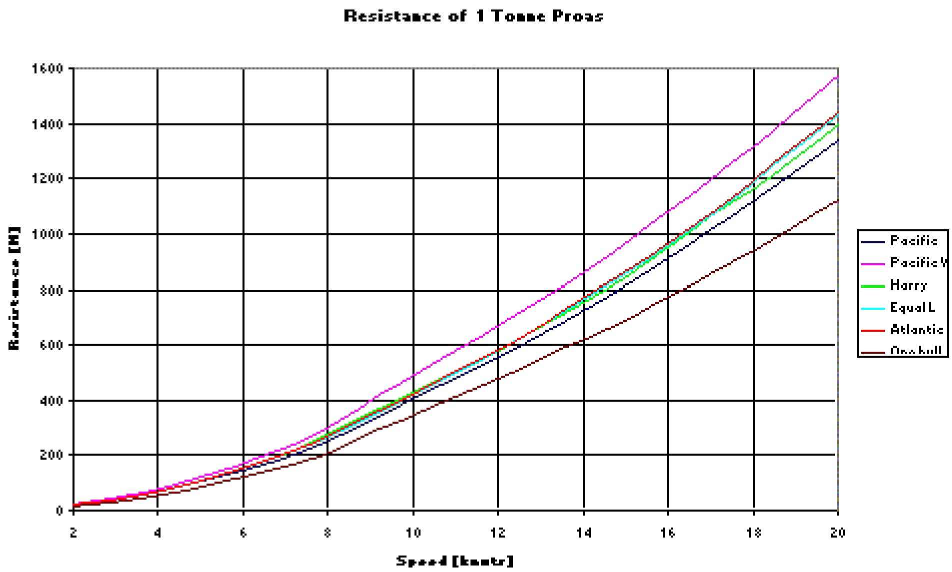
This tells the performance of proa at light wind conditions. The higher the SA/WS ratio the better the speed at light wind. Here the red curve is Pacific W without water.



Atlantic and Harry proas are fastest at light wind conditions when the sail areas are calculated on the basis of righting moment. (As should do with the cruising proas.)

Resistance of One Tonne Proas

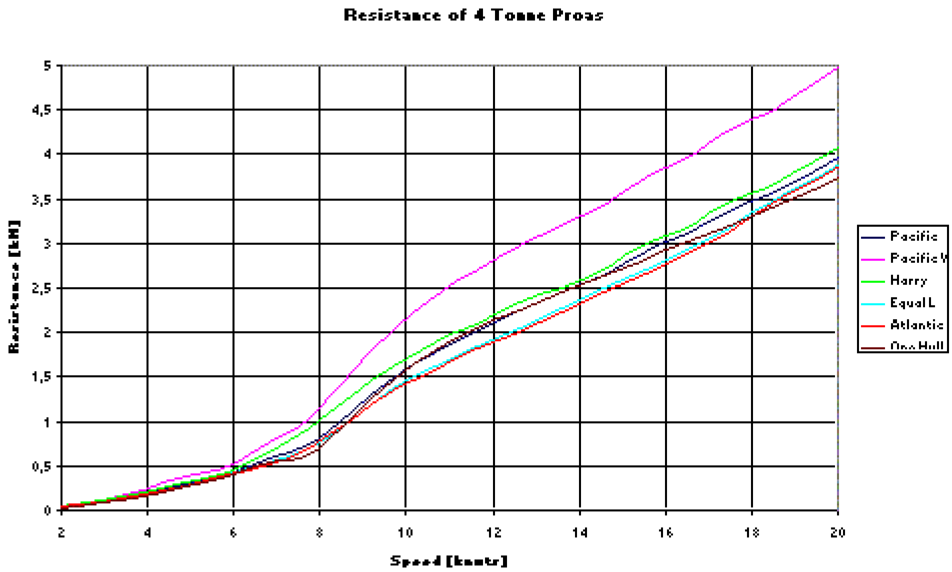
The lower the curve the smaller power is needed to reach the speed. These curves take account friction and residual (wave) resistance's.



These curves are calculated by Michlet 6.06 of Leo Lazauskas. The hulls are supposed to be elliptical and B/T ratio is 2. Every proa is calculated at situation, where they are heeled by half of their righting moment. In other words the windward hull has lighten 50 %. When the weight of proa is low (low displacement/length ratio) there is some benefit (10-20 %) to fly the windward hull. One tonne proa has D/L ratio 16.

Resistance of Four Tonne Proas

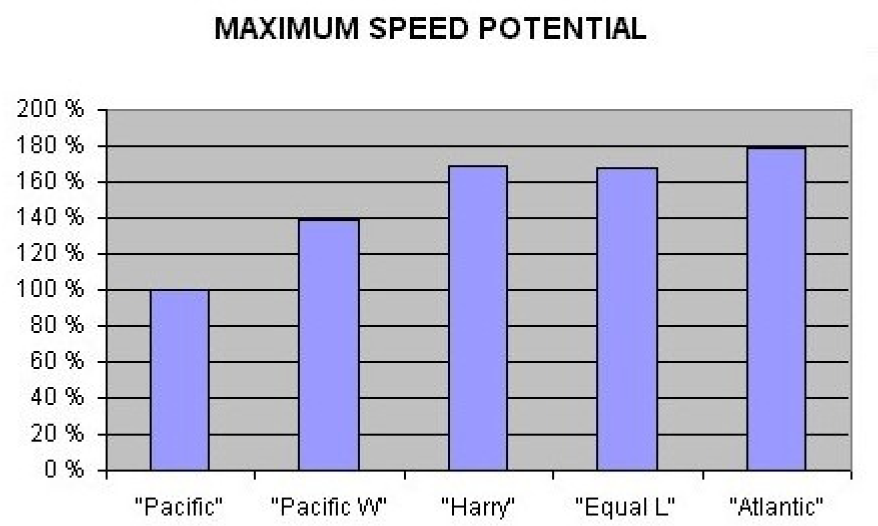
These curves are for "heavy" long distance proa cruisers. All displacements are four times bigger than at the definitions.



When the displacement/length ratio is higher (65 for four tonne proa), the wave resistance will have more influence. Now there is no more benefit from flying the hull, but the more equally distributed displacement (like Equal L and Atlantic) have in fact smaller resistance between 8.5 to 18 knots.

Speed potential

The maximum speed potential is found using formula of Malcolm Smith: "Maximum speed would then be a function of (Sail Area x Righting Moment) / (Heeling Arm x Resistance)." The heeling arm is individual for every proa, depending of the sail area. The resistance used is from polynomial equation of the one tonne resistance curve at each proa.



Atlantic proa has the highest speed potential. Harry and Equal L are very near. For Pacific proa, the small righting moment inevitably leads to smaller speed potential.

Discussion of Cruising Proa

For a cruising vessel there are some fundamental characters which can't be evaded. When you go out there for cruising, you surely want to come back alive and healthy. So the first thing is safety. Your cruising vessel is your home, though small, and you don't want to mix it up. So capsizing and high heeling angles are out of order. Flying a hull with family crew is very near capsize, and out of cruising too. To avoid capsizing, you need as much righting moment area as possible. The structure of boat and the possibility of pitch pooling limit the lateral distance of hulls. The longer the hulls the smaller the possibility for pitch pooling.

To maximise the speed of pacific proa by flying windward hull, larger sail areas than suitable for a cruising boat can be used. That leads to design of a pod for the leeward hull to prevent capsizing. For the other types of proa, no pods are needed cause their higher righting moment. They can carry enough sail area to be fast with safe.

Conclusion

If a moderate speed potential (much better than similar size monohull, though) and better ability to avoid capsizing (with a pod) is the issue, Pacific Proa is the right choice. She also has some traditional values, which people like.

For the fast cruising proa the best concepts are Harry, Atlantic or Equal L. The final choice is more a question of liking. Atlantic and Equal L are the best cruising proa configurations for bigger D/L ratios and Harry for smaller D/L ratios.

More weight on the windward hull and less weight on the leeward hull means higher speed potential due to ability to carry more sails. If overdone, this can lead to troubles at caught aback situations.