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Anti

VORTEX

Panels

HOW DO THEY WORK ?

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ANTI-VORTEX PANELS

Since about 1980 successful experiments have been made to reduce leeway and improve the tacking ability of catamarans by anti vortex wings instead of keels or boards. These are often called vortex generators but this is misleading, because they should do precisely as is explained later. That is they reduce the generation of vortices (ref 1.) but more importantly they optimize the generation of hydrodynamic lift on hulls in the opposite direction to the wind pressure on the sails for better windward performance. This sounds all very mysterious and theoretical. Practically, such devices are used on the latest aircraft designs like the Boeing 747 and some very advanced corporate aircraft in the form of winglets on the wingtips. These are mainly used to reduce the tip vortex. The generated vortices are a part of the induced parasitic drag. By eliminating this drag a gain in speed of about 7 ^{0}. is accomplished and a reduction in fuel consumption. By using anti-vortex plates (end plates) on low aspect ratio rigid sails as it is done on the C-class catamarans, the driving force is increased by about 10 %. Therefore, the effect of these plates is twofold, namely to increase the efficiency of the lifting/driving devices and reduce the vortex at the same time.

Wing tip vortex

Anti vortex wings (or end plates) can be successfully used on very slender (L/B ratio better than 1 : 10) hulls (ref 2.) with "V", a-symmetrical and trapezoid cross sections, to improve their ability to sail to windward instead of keels or boards. U-cross section hulls by their nature cannot generate much dynamic lift. These depend always on keels or boards to reduce leeway.

THEORY

Modern multi hulls are capable of high speed. Therefore their windward performance becomes very important. When a boat moves it generates its own wind. The vector sum of the true wind and the induced wind can be such, that the boat sails from a wind behind the beam on the wind. A graphical solution to find the apparent wind VA in relation to the boat speed VH and the wind speed VT is shown in fig. 1. So it becomes clear that a good windward performance is important.

Every boat will settle to a leeway angle and speed depending on the wind speed, wind direction boat configuration, course and speed to the wind till all forces are in equilibrium (ref. 3). Assuming that the sails are perfectly cut and trimmed the windward ability depends (besides the parasitic drag of the boat it self and the rigging) on the hydrodynamic force generated by the underwater area of the boat which has to counteract the wind force on the sails. It is here that anti-vortex wings can play an active role to optimize the performance of the boat. To explain the working of anti-vortex devices we must understand how and which forces a hull generates to counteract the wind force. We can assume that "V", trapezoid and a-symmetrical hulls work like extreme short wings standing vertical in the water. These generate besides there normal lateral resistance (fig. 2a to 2d) of the projected area a hydrodynamic force in the opposite direction to the wind pressure.

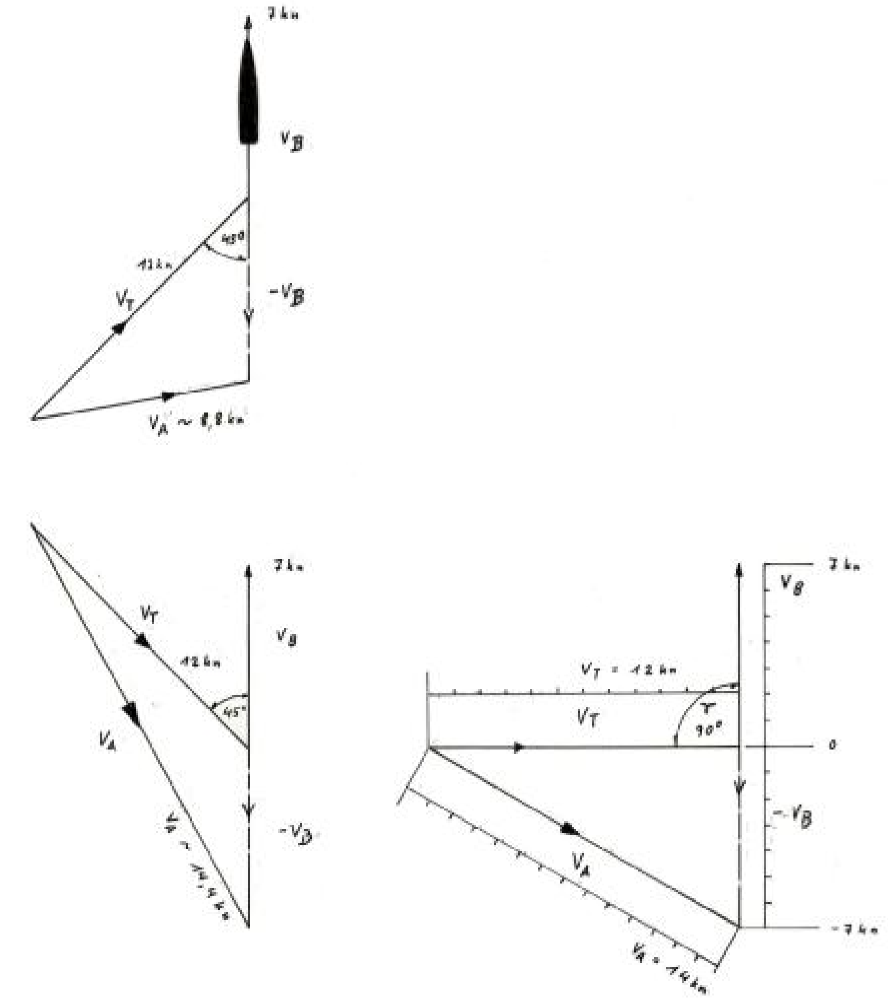


Figure 1 sailing triangle

The apparent wind VA is the vector sum of the true wind VT and induced wind – VB

The triangles show the graphical solution to find VA and the related apparent wind speed for three true wind directions

The forces on a hull, in general, are similar to those on an aircraft wing, but the are easier to explain on a wing. The following brief description of how lift is generated and drag is induced is simplified but sufficient for our purpose to understand the usefulness of anti-vortex wings and plates. For more scientific explanation see ref. 4 and 5).

When a wing (see fig. 3) moves through the air a low pressure area is induced on the upper surface and a high pressure on the lower surface. The sum of the suction power and the pushing power is known as lift. See profile on fig. 3a. On a wing (fig. 3b) the greatest lifting moment is in the center and vanishes to zero on the wing tips. The lift distribution is more or less elliptical, because the air will "leak" from the high to the low pressure region, thus reducing the lifting force. At the wingtip there is almost a "short circuit", so there is no lift left over at all. The fast movement of the air from the high to the low pressure region and the forwards movement of the wing results in a rotating air stream which starts at the wing tip, this is called the tip vortex. This represents a big part of the total induced drag. Through the flow of the air from the lower to the upper surface, the streamlines on the upper surface are deflected towards the center and on the lower surface towards the tip, which results in the trailing vortices. Again in the center region this disturbance is small and becomes more exacerbated towards the wing tips. The tip vortex and the trailing edge vortex form together the total trailing vortex. Thus the wing tips are the biggest cause the biggest loss of lift and induce the greatest part of the total drag.

To lessen the negative effects on aircraft wings many solutions or combinations of solutions are possible, high aspect ratio wings, elliptical wings, end plates on low aspect ratio wings and winglets on high aspect ratio wings.

Now we look again on the underwater sections of the hulls in figure 2. Look at them like wings standing vertically in the water. The sections a, b and c generate when moved through the water, high pressure on the leeward side and low pressure on the windward side. The resulting force acts against the wind pressure on the sails (and upper boat surface) and the boat moves to windward. The angle to the apparent wind which a boat can sail at depends on the force that the underwater ship can produce. This force depends on the underwater profile, speed through the water, angle of attack (leeway angle) and the counterproductive drag angle Rl. Like on the wing tip the water flows over the keel from the high pressure side (leeward side) to the low pressure side loosing a great part of its power and induces vortices at the same time. The power loss is exacerbated through the low aspect ratio of the underwater ship and, in the case of a U-cross section, almost vanishes through the large amount of generated vortex (fig 2d). This is the reason why U-shaped hulls need keels or boards for windward sailing. In the case of the other hull sections it becomes clear that through the installation of anti-vortex wings the hulls will generate a greater force and that the vortex can be partly eliminated. By its nature the anti-vortex wings can be small to be very effective, so that the increase of wetted are is not important. For the same effect keels or boards must be much bigger. By the way, slightly rounded cross sections do not work like wings any more. A typical example is the Pahi range of catamarans from

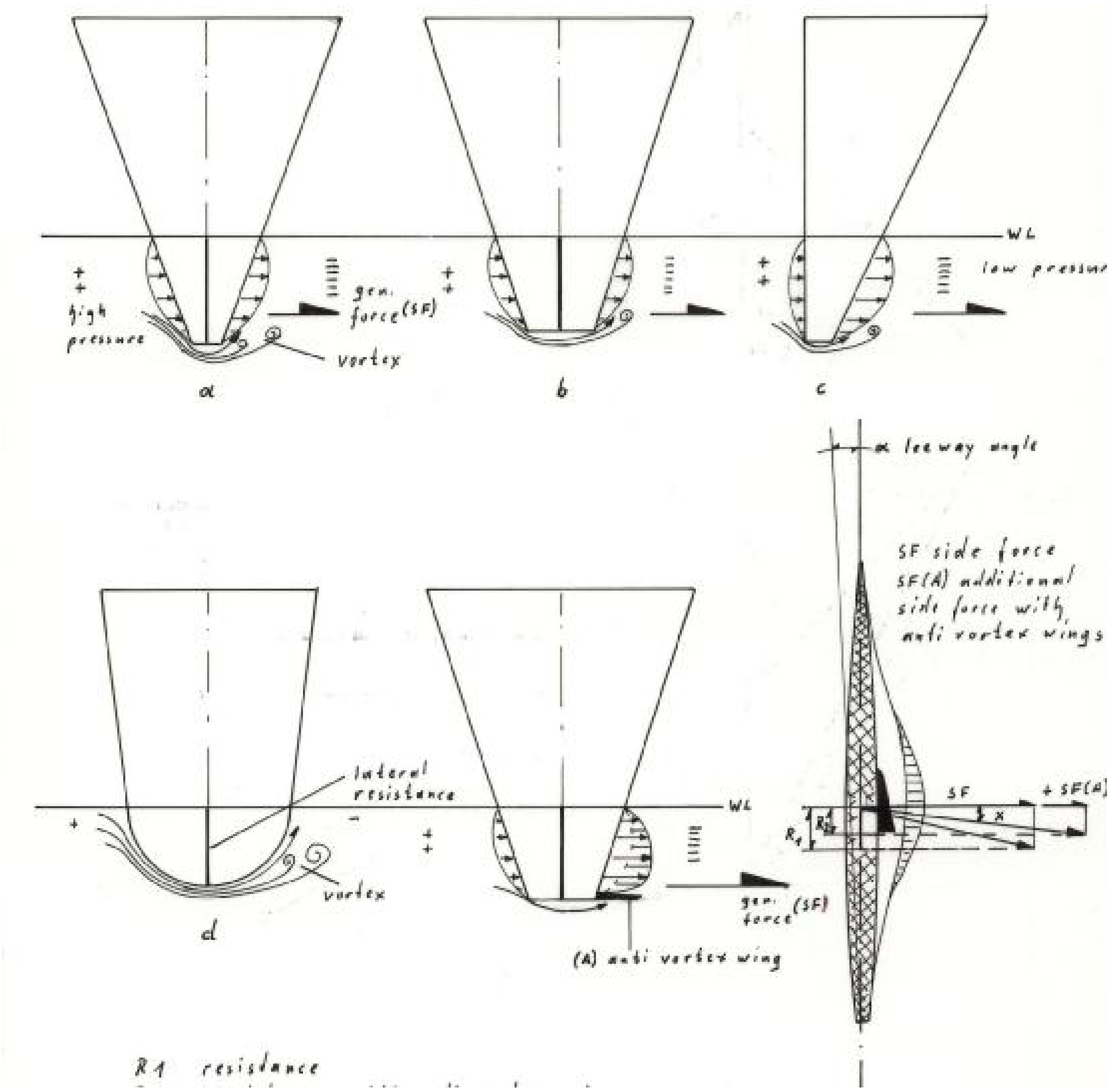


Figure 2

Warram designs. The hulls of these catamarans have a bent V-cross section. For good windward performance they need, and have, dagger boards. More recently, some keels of mono hulls also have wings. In principle, when they have small winglets on the aft part, this reduces the tip vortex and increase lift. The big wings which same boas have now work differently. When such a mono hull heels, the leeward wing increases the working area like a extra board. The bulb of the Scheel keel on the other side works like an end plate (or wingtip tank on aircraft's). In general anti-vortex wings and end plates are only useful on hulls which generate a large amount of force. A good example of how effective they can be is shown on Flettner rotors (ref. 6). By the way, do not use anti-vortex wings on extreme low a/r-keels. These keels do not create any side force but work like "anti short circuit panels". Anti vortex wings will increase the wetted surface only.

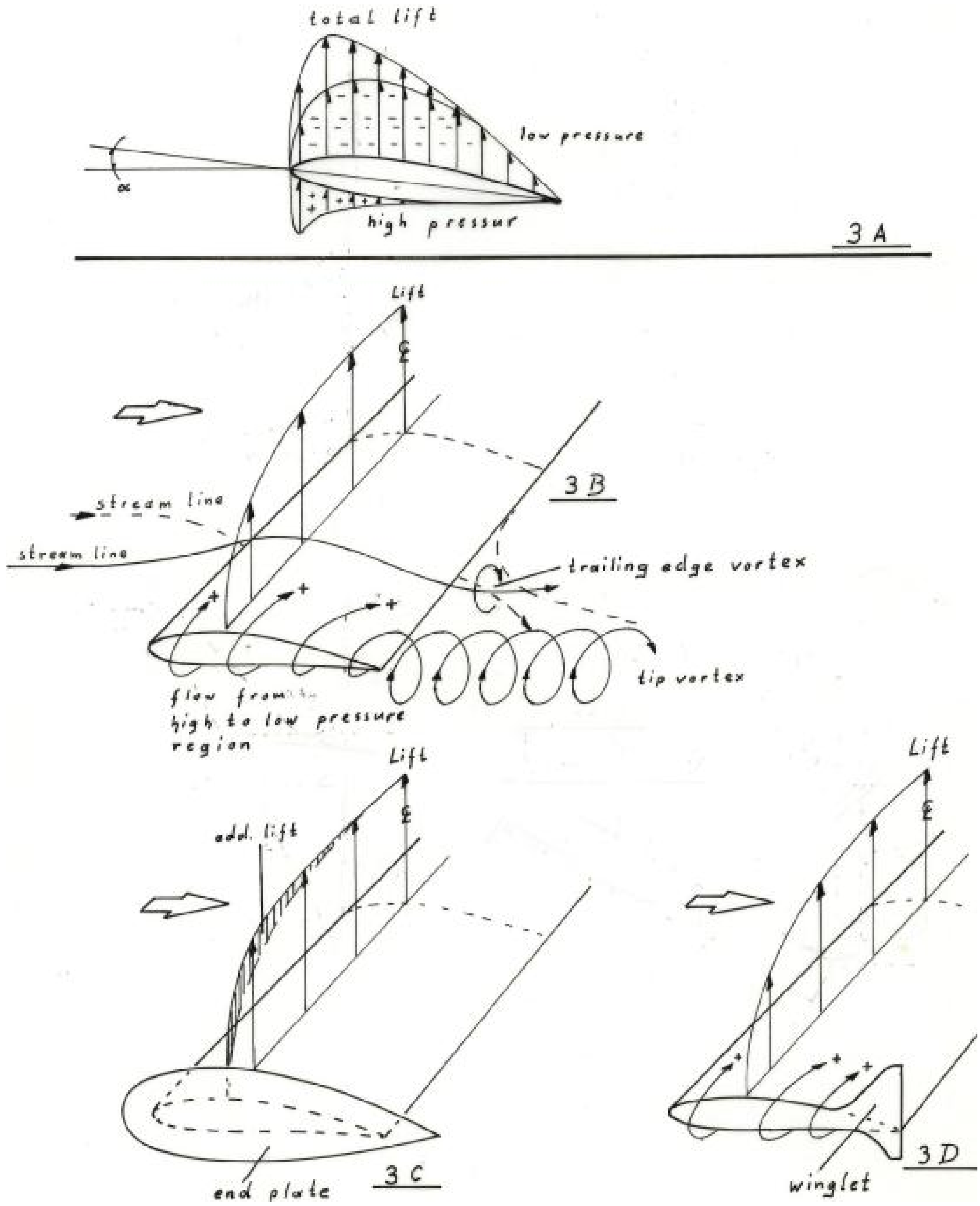
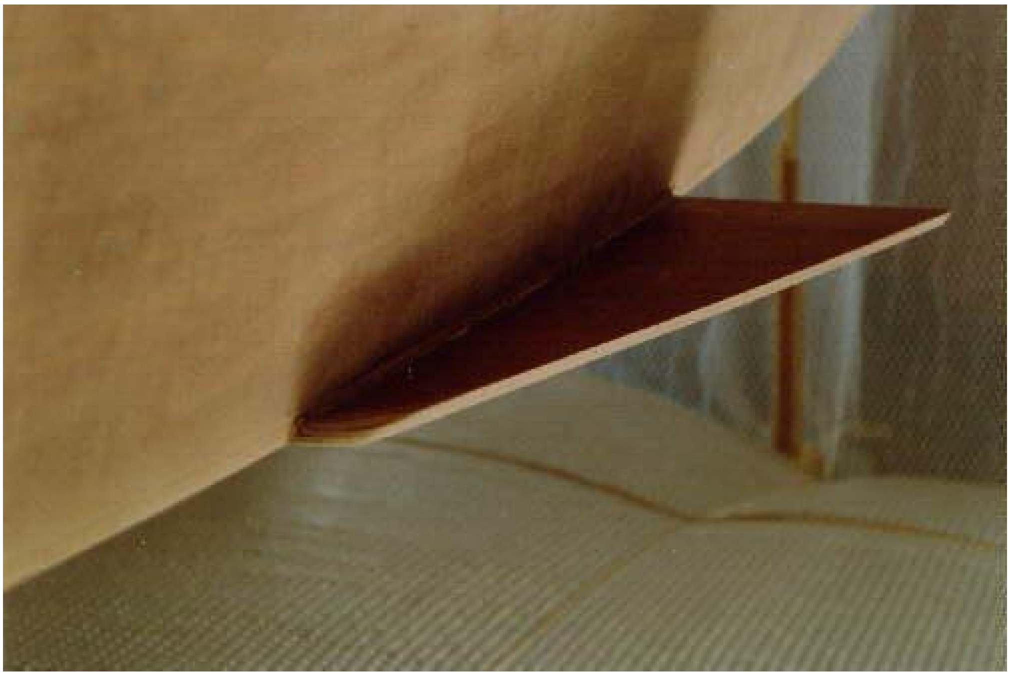


Figure 3

PRAXIS

Our own experience over the past four years with anti-vortex wings on our own catamaran PELICAN (Pelican design) and two more designs from my drawing board (an other Pelican and a KD 135) show clearly that these devices work. Till now no good mono hull of the same waterline length we encountered could clopper us to windward. The owners of catamarans which fitted our anti-vortex wing designs report all very favorable of them. Even a owner who fitted anti-vortex wings on his multi chine catamaran ! So there is more to them as I was expecting.



A anti-vortex panel on a PELICAN hull. The panels are mounted to the inside of the hull. The Delta shape is the most logical for the purpose. The are designed for minimum running resistance. But I do not say that this shape is the best solution. To find this out tests are necessary.

Some practical tips:

Anti vortex wings must run parallel to the water line.

It is sufficient to mount them only on the inside of the hulls. They should be mounted 5 to 6 % before the center of effort of the sail area.

Delta shape for practical reasons but see above remark. Length about 15 % of the waterline length. Span on the trailing edge about 1/4 of the length.
Slender profile of the wing section. I use a combination profile, forwards rounded and on the edges resembling a Kaspar profile.

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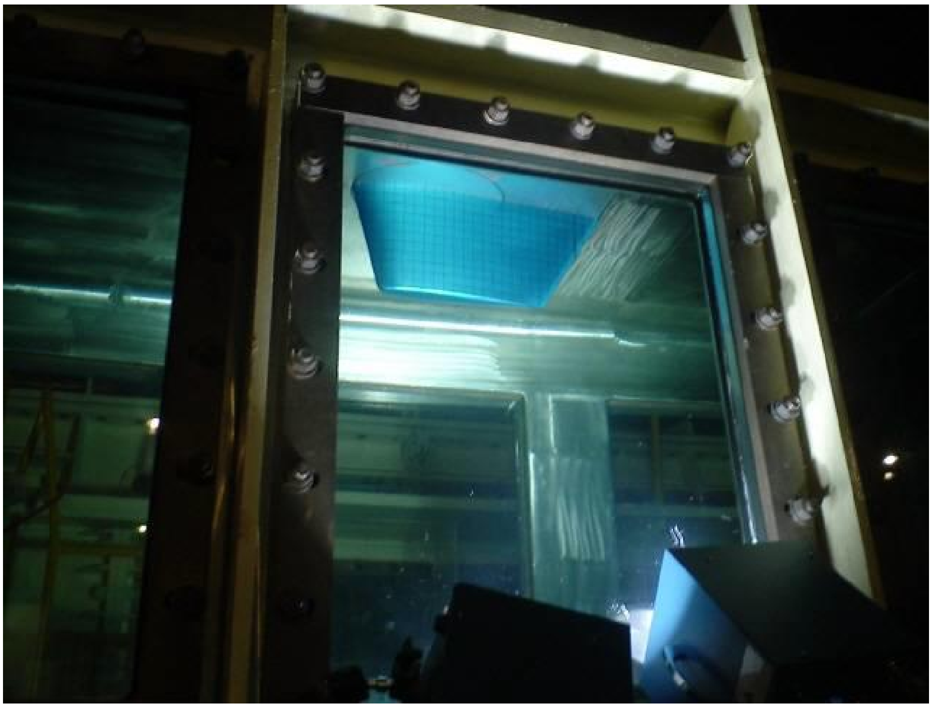
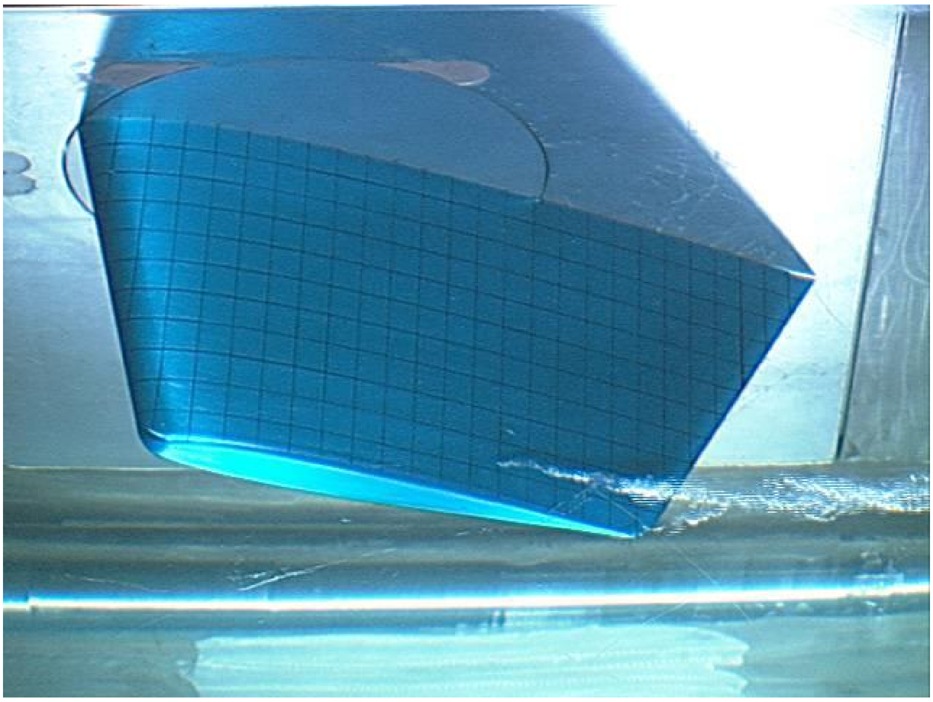
TESTS, RUDDERS WITH AND WITHOUT ENDPLATES

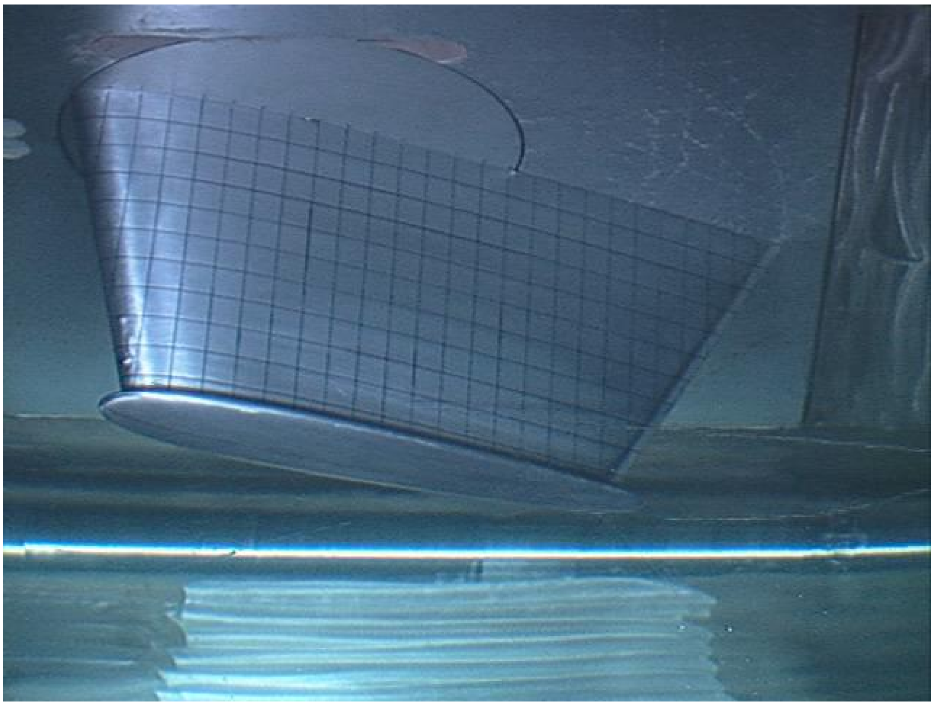
The following pictures are made in a test tank in South Korea. Here rudders with different endplates where tested. It is not important if end plates (anti vortex plates) are used on a hull or on a rudder. The function is the same, to diminish vortexes and increase by these the efficiency. The pictures show clearly the diminishing of the vortexes. I am not allowed to show the measured results. I can tell you that the increase of efficiency is in the order of 20 %.
The rudder section is a NACA 0012 section, speed15knots, Angle of attack 26 degree. 0012 means that the thickness of this section is 12 % of its corde. Comparative to the length to beam (L/B) ratio of a hull. For example our Pelican design has a L/B of 1 : 14 or 14% of its waterline length.



Test set up



Rudder without end plate. Observe the trailing vortexes. For comparison see figure 3B. The drawing compares very well to reality.



Rudder with end plate.

It would be interesting to conduct tests with anti vortex panels on hulls in this way. But these tests are to costly for a small company like mine

Maisons December, 2008

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