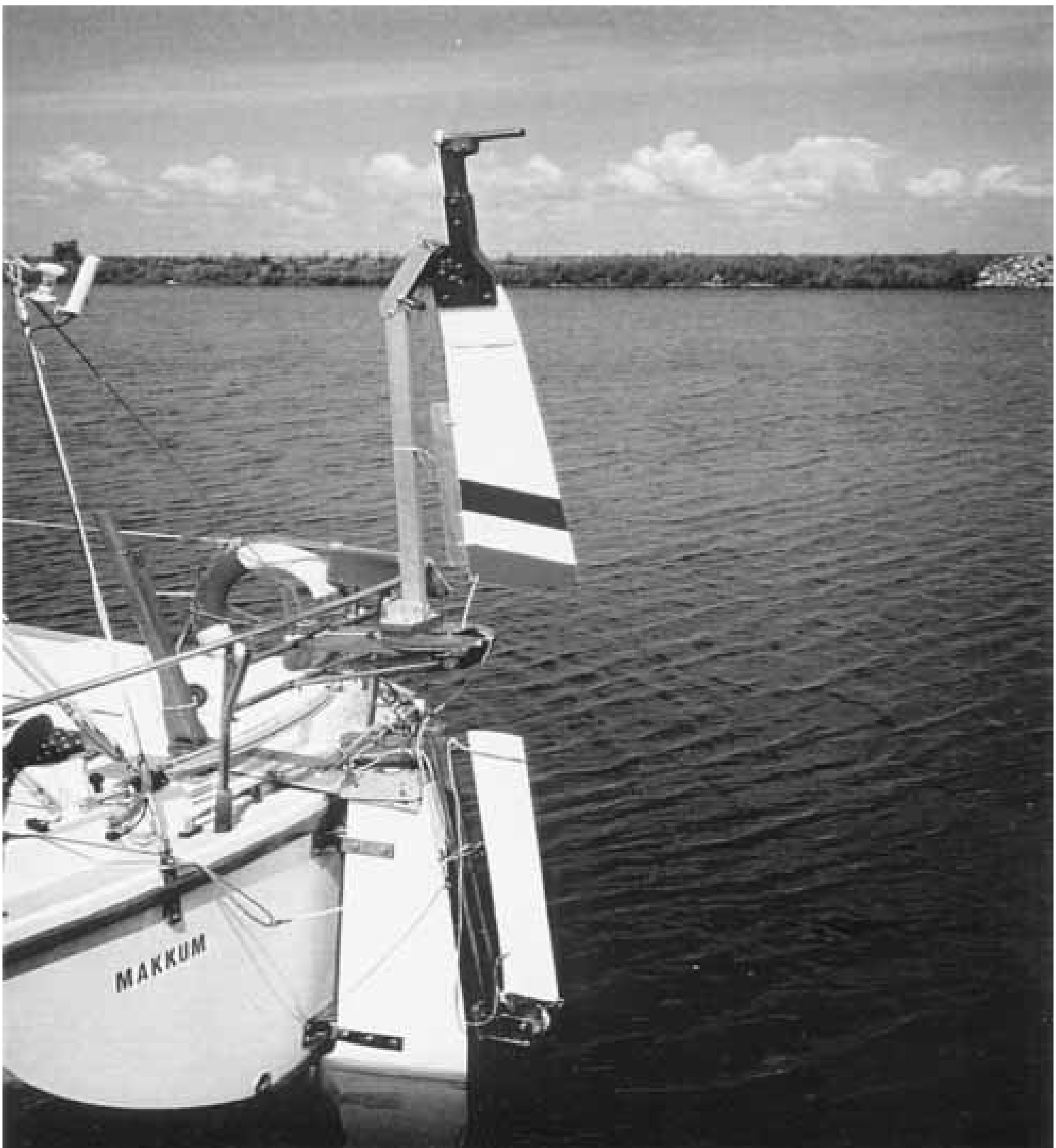
Catalyst

Journal of the Amateur Yacht Research Society

Number 23 January 2006



AMATEUR YACHT RESEARCH SOCIETY
2006 ANNUAL GENERAL MEETING

In accordance with the notice given in October's *Catalyst* Calendar, the 41st Annual General Meeting of the Amateur Yacht Research Society Ltd will be held on **Sunday 22nd January 2006** at the Village Hall, Thorpe, Surrey, after the All-Day AYRS meeting, so starting at or after 4.00pm. The AGM is open to all paid-up members and their guests.

AGENDA

1) Apologies for Absence.
2) Minutes of the 41st Meeting held on Sunday 23rd January 2005
3) Chairman's Report.
4) Treasurer's Report and Accounts
5) Confirmation of President and Vice-Presidents, Election of Officers and Committee Members.
6) To appoint a Reporting Accountant for the year.
7) Any Other Business
8) Vote of thanks to the helpers of the society.

Minutesof the 41st AGM: The draft minutes will be available at the meeting..

Chairman's Report: Centrepage pullout in *Catalyst*

Directors Report: Centrepage pullout in *Catalyst*, as is a Financial Commentary.

Officers and Committee Elections: Under our rules, the Chairman (Michael Ellison), Treasurer (Slade Penoyre), and Committee Members Dave Culp, and Robert Downhill have completed their current terms of office. Michael Ellison wishes to give up as Chairman, but is willing to continue on the Committee. The others are all willing to serve again. There is also a vacancy for someone to take over Catalyst. Any other nominations should be submitted, preferably in writing, to the Hon. Secretary, Sheila Fishwick, by or on 15th January 2006.

Reporting Accountant: The Committee propose that Robin Fautley be re-appointed.

Any Other Business: No matters have been submitted for this Item. Any items for formal consideration should be submitted by or on 15th January 2006.

A map of the locality is inside the back cover of this *Catalyst*.

Sheila Fishwick
Hon. Secretary
Fax: +44 (8700) 526657;
email: secretary@ayrs.org

Features

6 *Sailing Flying Foilers – a bar chart*
George Chapman

9 *Innovative self-steering systems*
Jan Alkema

20 *Stabilising foils and variable geometry for proas: lots of theory and a bit of practice*
Robert Biegler

Regulars

3 *News & Views - John Hogg Prize, George Chapman, DWFTTW success*

35 *Notes from Toad Hill*

36 *Calendar*

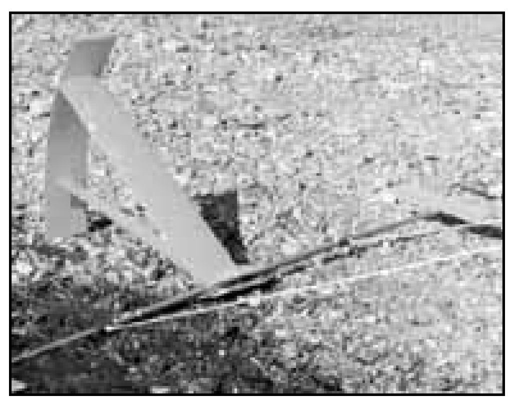
The AYRS Annual Report is in a pull-out centre section.

Cover Photo:

Jan Alkema's Upside-Down Vane self-steering gear

(Photo: Alkema)

George Chapman's Ceres



Catalyst

Journal of the
Amateur Yacht Research Society

Catalyst is a quarterly journal of yacht research, design, and technology published by the Amateur Yacht Research Society, BCM AYRS, London WC1N 3XX, UK. Opinions expressed are the author's, and not those of AYRS. AYRS also publishes related booklets.

Contributions are welcome from all. Email them to **Catalyst@ayrs.org**, or send (at your risk) disks or typed copy with illustrations to the Society's office. AYRS can take no responsibility for loss or damage in the mail.

AYRS subscribers receive both *Catalyst* and the booklets. Subscription is UK£20 or US$30 per annum for a Full Member, £10 or $15 for students and retired members. Subscription requests and all other queries to be sent to the AYRS Office, BCM AYRS, London WC1N 3XX UK, phone/fax +44 (1727) 862 268 or email: **office@ayrs.org**

AYRS is a UK Registered Educational Charity (No 234081) for the furthering of yacht science.

Website: http://www.ayrs.org

ISSN 1469-6754

John Hogg Prize

This issue of Catalyst presents the results of the 2005 John Hogg Prize for innovative yacht research and development. We congratulate the winner, who was presented with his prize on the first day of the London Boat Show (after this issue had gone to press). It is an interesting piece of work.

Mechanical self-steering systems have gone somewhat out of fashion in recent years, giving way to their electronic counterparts. However, they do have their advantages. I was interested to note recently that a certain circumnavigator considers it unsafe to continue with only a single electronic autopilot. She considers two to be the absolute minimum, because in the case that one breaks down, she cannot repair it. Maybe mechanical (repairable) systems have a future after all.

This year's judging was however tinged with sadness. George Chapman, who was a close friend of John Hogg himself, has chaired all the previous panels of judges. This year though he was ill, and declined the task. Then in the middle of judging, came the news that George had died. His last article for us, written during his illness, appears on page 6. We shall miss him.

Downwind Faster Than The Wind

In the last issue, I closed the correspondence on DWFTTW until such time as someone had some test results to report. I make no apologies for publishing Jack Goodman's letter on page 5 because indeed he *has* some results to report. However, they are only preliminary results, and I am not going to open the floodgates of correspondence until we have more information from Jack, or similar (or contrary) results from someone else.

His letter mentions a short (15 second) video. I have seen that video, and you will find a copy of it on the AYRS website http://www.ayrs.org. It shows his model on a treadmill, and while it will confirm the beliefs of those who already believe that it is possible for a wind-powered vehicle to travel directly down wind faster than the wind, it will not, I think, convince the doubters.

I am hoping that Jack will be able to send us further results and preferably a video of his model in the open air travelling downwind from rest with its flag gaily flying in the "wrong" direction. Until then we wait.

A happy New Year to you all,
Simon Fishwick

The AYRS JOHN HOGG PRIZE Competition 2005

Once again it has been an interesting task to judge the entries received from around the world. I am sure that for each one we received, several have been prepared but never posted, perhaps because time ran out, perhaps because it did not seem good enough, or perhaps it was felt the judges would never comprehend the idea nor the manner in which it should work.

John Morwood founded the AYRS to help and encourage anyone with an idea, he was always keen that membership should be open to all regardless of status or background. There were convincing arguments for making the Society exclusive with a substantial membership fee but these have been resisted. We do our best to judge contributions according to the published rules. Does the idea contribute to our understanding and development of sailing?

A void was left this year, as Cdr George Chapman, the previous chief judge, was unwell and unable to continue the task. We recruited David Chinery in his place.

A few of my personal notes and general observations on the seven entries follow, I am not the only judge and these are by no means the complete detailed judgement. We made three headings, Originality, Useful and Practical and gave marks to entries in each column. An entry could be useful but may not seem to be practical to produce as proposed. Under this system the winner was clear.

The Winner

The Judges were unanimous in awarding the John Hogg Prize for 2005 to Jan Alkema for his Upside-Down Vane self-steering system. The idea is original, it is a clear improvement on previous wind vanes, it works, and it is well made and tested.

Runners-Up

The two runners up were more difficult.

a) Robert Biegler's proa self steering by variable geometry: A lot of detailed and original thought on a subject that is still little understood. Good work on foils and hapa development that has applications to other boats than proas.

b) Jan Alkema's pendulum system for rudders clearly works, is well tested and useful on a transom rudder. It needs high freeboard aft (distance of lines to rudder head) and the conventional trim tab on the rudder blade has proved very reliable for ocean sailing.

Other Entries

Patrick Wheeler entered his "Stingray" shallow-water craft. There were some good ideas here; it would be useful as a "ground effect" craft; but as presented we felt it would be prone to capsize in a cross wind and would be difficult to control if the engine fails. In my experience of airscrew driven water craft (my father was a test pilot who often flew flying boats and seaplanes) excessive spray makes conventional engines unreliable. In spite of much research hovercraft still suffer.

Ken Coles' different approach to sail design seemed to us to be unlikely to be useful to an amateur, and not suitable for a professional sail loft most of whom already use computers to design their sail panels. It is an interesting proposal though, covering many of the tests carried out in early AYRS publications on wind gradient.

Robert Biegler's aerodynamic junk rigs carries on the proposals of Manners-Spencer in our 1960's and 1970's numbers, interesting reading but not, to me, a great advance in our knowledge.

Richard Tostevin's Romy Lateen Sail Rig: I built a similar rig with three sails on two 'A' frame masts for a Manners trimaran in 1969. The bow mast necessary for a monohull is likely to be hard to build and the tack of the yard needs to swing to windward when running. Other advantages are inexpensive second hand headsails readily available and an easy to control rig.

These are ideas from one of the judges. If you disagree, or have ideas for improvements, or can help with development or have a different idea of your own, then please put finger to keyboard and let our editor know. Do not be afraid to do something wrong - be happy with the knowledge that at least you did something!

R Michael Ellison
Chairman of the Judges

[Note from the Editor: Jan Alkema's papers are published in this issue of Catalyst*, as is Robert Biegler's work on proa self-steering. Patrick Wheeler's material and Ken Coles' paper will be published in the next issue. The Romy rig was published in Catalyst No 17 and Robert Biegler's junk-wingsail in No 8. Both these latter back-numbers are available from the AYRS Office]*

George C Chapman, 1926 -- 2005

George Chapman died in hospital on Tuesday 22nd November following a period of illness from the end of the summer.

George joined AYRS in about 1964. He was very interested in experimenting. One of his early reefable wingsails - a forerunner of the rigs now used on landyachts -- appears on the cover of AYRS booklet No 76. Later he started concentrating on speedsailing boats building a number for the Weymouth Speed trials . As a spin off he branched out into hydrofoils, building Bandersnatch, Calliope, Ceres and lastly Demeter. None of these were record breakers, but together they showed that controlled hydrofoil flight could be achieved under sail under a far wider range of conditions than anyone had previously suspected. He continued active researching up until his death. At his memorial service, he was quoted as saying that one of the greatest satisfactions of his life was assisting with the work on junk rigs that led to his son's PhD. In recent years he chaired the Judges Committee for the John Hogg Prize, and would have continued to do so this year but for his illness.

Professionally, he was a Royal Navy officer, working on submarine systems, and it is said he was one of the crew of the first British submarine to cross the Atlantic submerged.

He was also very interested in home power generation, was a leading light in the British Hydropower Association, and had a small waterwheel in his garden which not only produced electricity for his home, but also produced enough extra to feed into the National Grid.

He leaves a wife, Avril, and two children, Joddy and Moggie, to whom AYRS extends its deepest sympathy.

Down wind faster than the wind

With all the theories over DWFTTW, I decided to build a wind-powered car, see photo, and put an end to the debate. I have just finished building the car, and it does indeed go faster than the wind. It is a three-wheeled model about 6 feet long and 3 feet wide. The frame is made of wood and aluminum. The propeller is wood, forty inches in diameter, has a 16.5 inch pitch (theoretical distance per revolution) and is facing and blowing aft, up wind in this case. The wheels, one up front for steering and two in the rear, are inline skate wheels. The gearing is a single timing belt running from the rear wheels to the fan shaft, and twisted ninety degrees. All bearings are high-grade ball bearings. The current gearing for down wind produces a car to propeller speed of 1.75 to 1. For every 17.5 feet the wheels roll the propeller moves a theoretical distance of 10 feet. At 10 mph the fan is blowing the air towards the rear at 5.7 mph.

It is difficult finding a flat place with a steady wind, especially at ground level, to do a decent test. The first trial run showed that the car would easily accelerate to wind speed, and would need to have steering, brakes, and a method of determining apparent wind direction. A radio control was added, along with a mast and flag well off to one side and away from the influence of the propeller. Unfortunately we live in a heavily wooded area with few flat parking lots and variable wind, so the results on land are at this time are unreliable. The flag often flies rearward to indicate DWFTTW, however until I see it fly back steadily for a hundred yards or so, I will not be happy. Fortunately we found an excellent motorized treadmill to do our testing on. For those who missed the July issue, No. 21, a vehicle on a treadmill in still air, with the wheels going eight miles per hour is the same as a vehicle going eight mph down wind, in an eight mph following wind. If a car moves forward on a treadmill with no assistance, it is going faster than the wind.

After leveling the track, putting a backstop on to get the car up to speed, and tying the car to a tension gauge, we started the treadmill and increased the speed in one mile per hour increments. At four mph the car leaves the backstop and rolls forwards, but with no measurable force. At five miles per hour the car generates 25 grams of pull. At six mph 45 grams of pull, at seven mph 70 grams, at eight mph 100 grams, at nine mph 125 grams, and at the ten-mph top speed of our treadmill, it is pulling with 150 grams of force.

By reversing the fan direction and taking force measurements, the total lift to drag of the system can be calculated. Subtracting the forward pulling force from the reversed pulling force, and dividing the

The wind car in its' short and narrow 'treadmill' configuration. Note the radio control for steering and brakes. The mast with apparent wind flag is not shown.

remainder, results in the total force (drag) required to turn the propeller and overcome friction. Adding the forward pulling force to this gives the pulling force (lift) of the propeller.

At 4 mph the measured lift of the propeller is 92 grams and the force required to turn the wheels at that speed is 92 grams, for a L/D of 1 to 1. By ten mph the lift of the propeller is 552 grams and the force to turn the wheels at that speed is 402 grams, for a L/D of 1.37 to 1. With a steady wind over 4-mph, the car will exceed wind speed down wind.

The key to understanding DWFTTW, is that the wheels are turning the propeller and that the propeller need only produce enough lift in still air to overcome the forces required to turn it.

A few notes on car performance on a parking lot;

It is self-starting down wind, and once moving, accelerates rapidly.

It prefers to go straight down wind, not at an angle as on a broad reach.

When the gear ratio is reversed to allow the propeller to act as a windmill and turn the wheels, it goes up wind very well, even though the fan is being used in reverse and not shaped properly.

With the proper ratio, and good conditions, I believe the car will go close to wind speed up wind, and 1.5 times wind speed down wind. At this point I have not tried any other ratios either up or down wind, so further improvements are possible.

For a short video of the car on the treadmill or more information regarding the car or to make suggestions, especially regarding testing, or if anyone wants to come to sunny Florida to watch first hand this winter, let me know via EMAIL.

Jack Goodman,
imaginationltd@aol.com

Sailing Flying Foilers – a bar chart

By G.C.Chapman

9 September 2005

1. This time-based bar chart aims to show the timescales involved in the development of successful sailing flying foilers since 1977. It is the inverted-T lifters with trailing sensors which have proven successful in providing stable flying, avoiding the porpoising and crashing typical of inclined surface piercing foils. The chart concentrates therefore on inverted-T craft. The key at top right shows the conventions used in the bars. Speeds shown are over 500 metres, mostly at Weymouth Speed Weeks, except where stated otherwise. GPS is unreliable as a spot speed indicator.

2. The entries are grouped, the English eight at the top, then the seven US, then the Australian Moths and finally, as a lesson in perseverance against an obviously unrewarding idea, the French campaign initiated by the late Eric Tabarly who was lost at sea in 1998.

3. Mark Simmonds' 1976 RAMPAGE was a standard Unicorn, with manual control of the flapped port (first ever) daggerboard-lifter, a starboard fixed incidence ditto and an inverted T port rudder. Aimed to sail at speed only on starboard tack. In 1978 and '79 he had a feeler from the bow controlling the port flap; fixed starboard T lifter and the port T rudder. 16.2 knots in 1977. 8.7/16.6/16.7 knots in '78/79/80. Arguably the first bi-foiler ?

4. Philip Hansford's PHILFLY, a centre-cockpit trimaran tri-foiler, first appeared at Weymouth in 1984 but did not sail for lack of wind. She first sailed in 1985, and her best speed was 17.49 knots in 1988. She was the first to successfully demonstrate flight on two inverted-T main and one rudder lifter with trailing feelers controlling flaps on the main lifters: and with only 10 sq.m. of sail.

5. FORCE 8, a centre-cockpit trimaran tri-foiler, had fully-moving (but not balanced) main foils controlled by forward-reaching feelers, the crew with foil-over-ride controls and foot steeering. The boat had an A Class semi-wingsail which was self tacking. Flight was not as assured as that of PHILFLY. The designers and builders were the Pattison brothers of whom the elder, Doug, became the chief of the Royal Navy's Royal Corps of Naval Constructors. After sailing the 500 metre course at 17.5 knots in 1980, FORCE 8 was wrecked trying to sail off a lee shore.

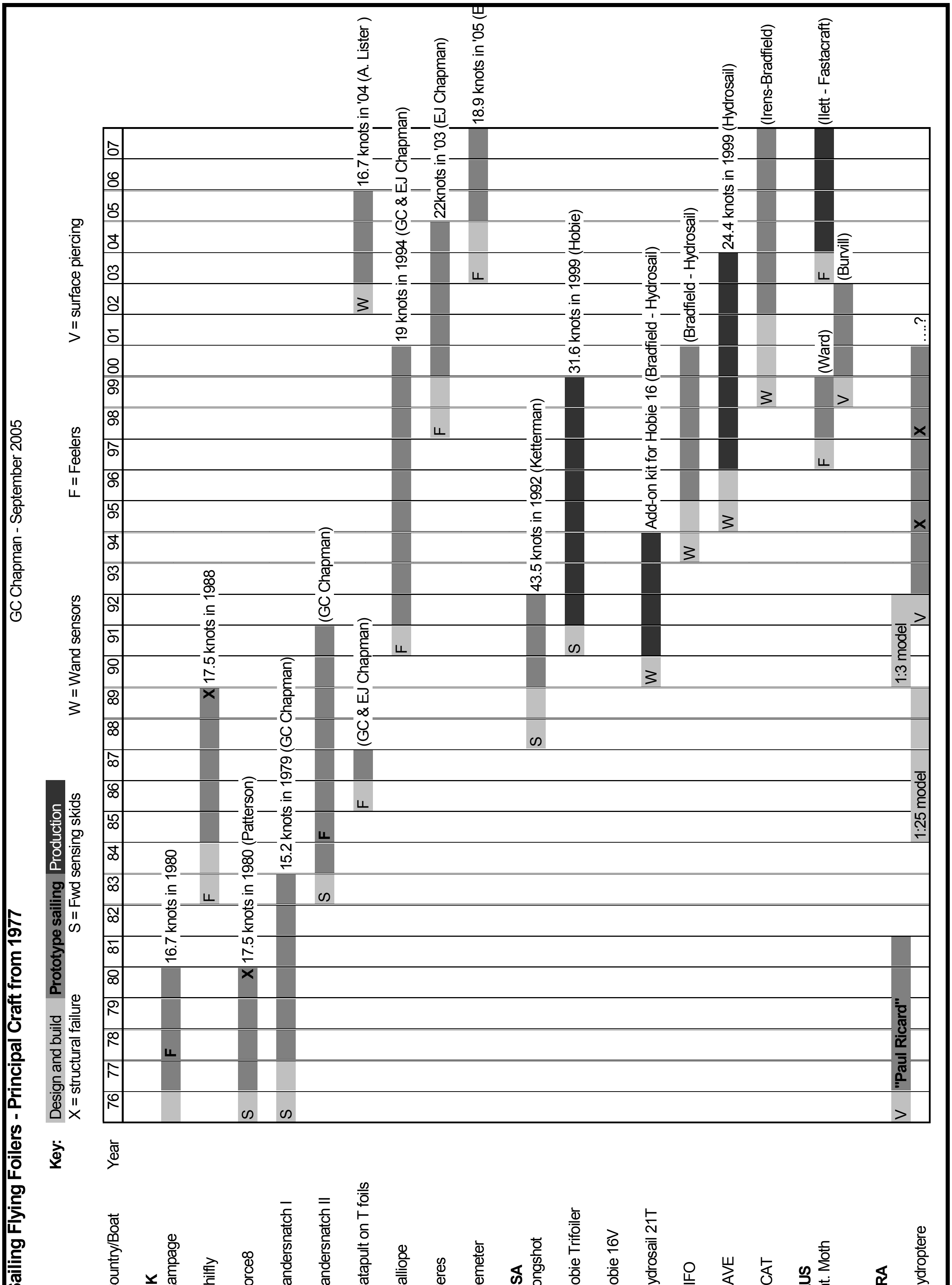
6. The first version of George Chapman's 10 sq.m. catamaran BANDERSNATCH sailed on surface piercing foils in 1977. From 1978 she had inclined inverted-T (fixed) lifters the whole assembly controlled via cords by small foils whose struts slid up and down in slots at the bows; 15.2 knots in 1979.

7. The second version with new hulls continued the system briefly with improved lifters, but these were unwieldy and the concept was dropped. She sailed with flapped inverted-T lifters with feelers from 1987. In the same year George and Joddy Chapman borrowed a stock CATAPULT from the makers and fitted similar inverted-T lifters. It was difficult to sail due to poor sails and too small lifters, but on one occasion managed 14 knots for maybe half a minute, according to 8mm cine film.

8. In 2003 Arthur Lister, on the Chapmans' advice, fitted a set of RAVE flapped foils, wand controlled, to his CATAPULT and worked up to stable flight at 16.66 knots in 2004.

9. CALLIOPE, the next Chapman catamaran tri-foiler, started with flapped lifters on daggerboards. Many lessons were learned during 1992/3, not least (from Bethwaite's High Performance Sailing, 1993) how to avoid ventilation of struts. For 1994 new balanced lifters were fitted, and Frank Bethwaite enjoyed a flight during a side visit to Plymouth UK from the Tasar Worlds. Her best Weymouth 500m speed was 19.01 knots in 1995.

10. CERES is a $1^1/_8$ times (in length) clone of CALLIOPE, intended for two people. She has performed consistently at Weymouth, with a best speed of 22 knots in 2003. Several guest crews have come away with the tankard awarded for the best speed of the day; this success being very much a function of the wind and the ability of other contesting craft to compete in that wind strength. Full details of these two craft are at:- http://homepages.rya-online.net/ejcchapman/



Sailing Flying Foilers - Principal Craft from 1977
Key:
Design and build
Prototype sailing
Production
X = structural failure
S = Fwd sensing skids
W = Wand sensors
F = Feelers
V = surface piercing
GC Chapman - September 2005
Year
76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07
Country/Boat
UK
Rampage
F
16.7 knots in 1980
Philfly
F
X
17.5 knots in 1988
Force8
S
X
17.5 knots in 1980 (Patterson)
Bandersnatch I
S
15.2 knots in 1979 (GC Chapman)
Bandersnatch II
S
F
(GC Chapman)
Catapult on T foils
F
(GC & EJ Chapman)
W
16.7 knots in '04 (A. Lister)
Calliope
F
19 knots in 1994 (GC & EJ Chapman)
Ceres
F
22knots in '03 (EJ Chapman)
Demeter
F
18.9 knots in '05 (E
USA
Longshot
S
43.5 knots in 1992 (Ketterman)
Hobie Trifoiler
S
31.6 knots in 1999 (Hobie)
Hobie 16V
Hydrosail 21T
W
Add-on kit for Hobie 16 (Bradfield - Hydrosail)
EIFO
W
(Bradfield - Hydrosail)
RAVE
W
24.4 knots in 1999 (Hydrosail)
SCAT
W
(Irens-Bradfield)
AUS
Int. Moth
F
(Ward)
V
(Burvill)
F
(Ilett - Fastacraft)
FRA
Hydroptere
V
"Paul Ricard"
1:25 model
1:3 model
V
X
X
...?

11. LONGSHOT, a centre-cockpit trimaran designed by Greg Ketterman for Russell Long as a world sailing speed record contender able to look for 'perfect' conditions, used a similar lifter control system to BANDERSNATCH I, but with the forward ski-sensors each moving the whole ama and rigidly attached J-lifter. Biplane rig ensured low heeling moment. Best speed was 43.55 knots in 1992 on the French trench; wind speed 30+ knots..

12. Hobie TRIFOILER, available to purchase since 1992, is based on LONGSHOT, seats two, is slightly longer and heavier and has more sail area.

13. Dr Sam Bradfield's Hydrosail company in Florida has developed the following five craft. He had built a number of earlier foilers with surface-piercing foils. With the Hobie 16 add-on foil kit, making the catamaran a tri-foiler, he pioneered the wand sensor which is pivotted at the top of the strut. This offers some advantages over the trailing feeler but is not universally applicable. The HS21T, EIFO (Easily Identified Flying Object) and SCAT (Sam's Crazy Arsed Trimaran) trimaran tri-foilers are a logical progression towards the goal - which has been largely achieved in SCAT - of producing an ocean-going flying foiler. EIFO was sold to a Dutch sailor, SCAT has shown in two Miami-Nassau races (2004 and '05) that on broad reaches she can outpace larger multihulls despite the weight penalty of ocean racing crew and kit.

14. Dr Bradfield's RAVE design, manufactured by Windrider, is a centre cockpit 2 seat trimaran in a similar vein to the TRIFOILER but with a single sail and inverted-T flapped lifters. This boat has proved popular in the US where there is much suitable sheltered water for racing.

15. Australia seems to have become aware of lifting foils rather later, but in the few years since Dr Ian Ward started experimenting with bi-foilers strenuous efforts by keen Moth sailors have enabled them to learn and accept what took the Europeans so long (and see next paragraph!). Within six or seven years they have revolutionised the Moth and brought John Ilett's production PROWLER to the state where it can so convincingly win the World Championship under Rohan Veal.

16. The data is all available (including in VPPs) for other Classes to adopt and for designers to create more excitingly fast sailing boats. At the same time we have the knowledge to design and build flying foilers which sail smoothly, upright, without the need for trapezing, but quicker than their non-flying siblings, often with less sail area. They do not look fast so photographers do not often snap them. Ideal craft for older sailors who still like speed but in comfort.

17. HYDROPTERE is an example of perseverance against impossible odds. Stemming from Eric Tabarly's realisation even before 1976 that foils can lift vertically, he progressed cautiously through two models of his design before the heavily sponsored (and Government backed) full size monster HYDROPTERE was launched. A tri-foiler 69 ft long by 75 ft beam and weighing 4.8 tons she has enormous inclined surface-piercing main foils and 250 sq.m of sail. High speeds - in the 30s - have been achieved in smooth water but as the chart shows, she has crashed and suffered major damage on at least two occasions.

This is the last article written by George Chapman just a few weeks before his death. The photograph shows him at ease with modern boatbuilding technology constructing a foiler hull with a resin infusion jig (in his drawing room!). George died on 22nd November 2005. Yacht research in general and AYRS in particular will be the poorer by his death.

Innovative self-steering systems

Jan Alkema

I became interested in selfsteering in 1972 and I bought the AYRS book Self Steering in 1973. That was the start of studying this subject and building self steering systems myself.

I used the idea of QME when I started building my own selfsteering system. I improved it by making the vane rotation axis adjustable.

Later on I built a pendulum system, specialized for an outboard rudder.

After many observations and also calculations I found that the commonly accepted windvane with the near horizontal vane axis is not fully adapted to the sailing circumstances. The influence of heel seems to be completely overlooked by all manufacturers of windvane systems and also in books regarding selfsteering. Adjusting the vane axis to compensate the heel angle was a good step forward. Only one or two manufacturers are using this idea.

A few years ago I invented the upside down vane. This vane takes into account the effect of heel and adapts its action more or less according to what is needed on various courses. I built the vane and it proved to work. Since then I am sailing with this vane.

This contribution describes in short the characteristics of a windvane and also what action is needed when sailing on different courses. It is shown that the normal windvane is not really well adapted. Calculations indicate the possiblities of the upside down windvane. Tests proved that this windvane is performing better.

This contribution also describes the problems for a windvane system for sailing boats with an outboard rudder. A comparison is made between a trim tab and a pendulum solution. Both systems have advantages and drawbacks. After some design and think work I came up with a synthesis between trim tab and pendulum, the rudder head mounted pendulum or oar. Its merits are discussed in this contribution. I use the RHM pendulum already for more then 20 years, so it is well proven technology. It is a simple construction, very suitable for selfbuilding. The idea is still quite new for most sailing people.

Although these ideas have been published in Practical Boat Owner and via the internet forum www.cruisenews.net, I have the idea that the AYRS is the right forum to absorb these ideas and to spread it via books and publications to its interested members. In a way I feel obliged to send ideas back, as I was really inspired by your book in 1973.

I like to submit this work for the AYRS John Hogg Memorial Prize Award 2005. It is a contribution to the development of selfsteering systems, based on my own observations, research, tests and practical solutions.

An innovative windvane system

Jan Alkema

Preface

This article deals with a new type of windvane. It is invented by the author, tried and tested and in use for years now.

Existing windvanes.

Windvane systems exist already for some 50 years. There has been a lot of development during the years, but the last 20 years the development seems only to be cosmetic. The present systems, mostly pendulum systems, are nicely shaped and also much lighter in weight than the older types, but its working principle remained the same.

The windvane can have a vertical (V-vane) rotation axis or a nearly horizontal rotation axis (H-vane). Windvanes with a nearly horizontal rotation axis are mostly used on present systems.

The windvane rotation can be calculated with the (simplified) formula:

$$\tan(b) = \tan(c) \, I \, \sin(a)$$

where b = vane rotation angle
c = wind course error
a = vane axis tilt angle

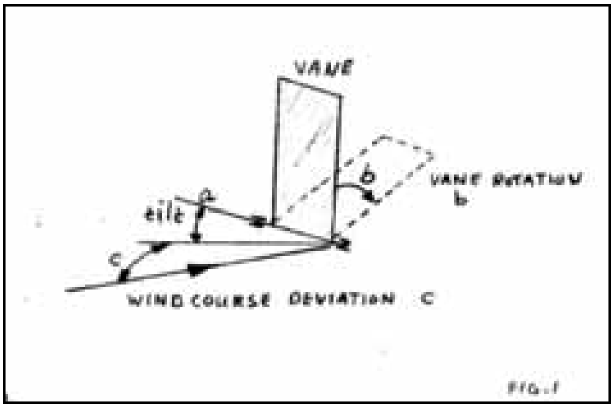
See figure l.

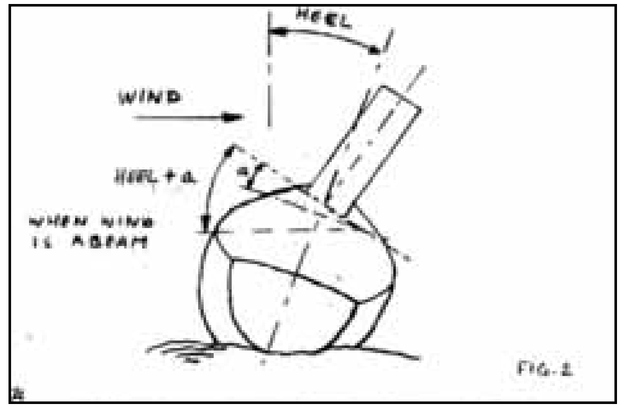
The relation between course error and vane rotation appears to be highly depending on the vane axis tilt angle.

The H-vane is magnifying the wind error signal, depending on the tilt angle of the axis. Therefore the H-vane is more powerful and can have smaller dimensions than the V-vane. Most systems now use a tilt angle of 20 degrees.

Influence of heel.

During sailing the yacht is normally heeled, depending on the wind strength and course angle to the wind. The heeling angle of the yacht has a remarkable influence on the effective tilt angle of the vane axis to the wind direction. The maximum effect is when the apparent wind direction is just perpendicular to the yacht. In that situation the heel angle and the tilt angle have to be added before using the formula. See figure 2.





When the heel is taken into account then the formula has to be extended to:

$\tan(b) = \tan(c)\ I\ (\sin(a + heel * \sin(course))$

where heel = the heeling angle of the yacht

course = the adjusted course angle between vane and yacht

We now can calculate the vane rotation depending on the heel angle.

Suppose a tilt angle a =20 deg.

Sailing before the wind, the heel = 0 and the course = 180 deg.

Then the relation between vane rotation and wind course error is:

$$\tan(b) = \tan(c) / \sin(20)$$

$$\text{so } \tan(b) = 2.9 \tan(c)$$

When the yacht is heeled 20 degrees and the vane is adjusted to the apparent wind at 90 degrees with the boat axis, then $\tan(b) = 1.55 \tan(c)$

In that situation the vane action is reduced to approx. 50% compared with the unheeled situation. As the vane is connected with the rudder via the pendulum the rudder action is also reduced by heel.

We now analyse what is necessary for steering the yacht.

It is known that downwind sailing is a difficult course for most windvane systems, because most yachts are less balanced on that course and are prone to yawing. When the vane action is too high then the system induces oversteering and the yacht starts yawing.

Reduced rudder corrections are necessary, but the windvane action is unfortunately at its maximum then. The vane action on the rudder can be influenced by varying the positions of the steering lines on the tiller. On most yachts this correction method is very limited and not always successful for reducing yawing on running courses.

On windward courses most yachts built up some weather helm when heeled. To remain on course more rudder action is needed. But according to the formula the action of the H-vane is reduced due to heel, just when more action is needed to stay on course. The result is a substantial course deviation, before the rudder angle is sufficient to counteract the weather helm.

When the wind force is varying, the heel and amount of weatherhelm is also varying. Due to the reduced vane action there will be an oscillating course with the risk of rounding into the wind.

Note that V-vanes are hardly influenced by heel. In fact the vane action is slightly increased by heeling.

The conclusion for the mostly used type of windvane, is that, when the vane action is maximum, we don't need it and when it is needed, the vane will not give it.

The adjustable vane axis tilt angle.

A solution to the unwanted behaviour of the H-vane is to have the possibility to adjust the tilt angle of the vane. When heeled the vane axis is simply adjusted in the opposite direction to compensate for heel. For instance, for a 20 degrees of heel and the apparent wind abeam, just compensate with -20 degrees. Now the effective tilt angle remains 20 degrees and there is no loss of steering action due to heel. For the running courses just increase the tilt angle of the vane axis to 30 degrees to reduce the vane action. This will dampen the yawing course.

I have sailed with a windvane with adjustable axis since 1976. I reduced the tilt angle for windward courses to get action and accuracy and I increased the tilt angle for the running courses for reduced action, to prevent yawing. It worked very well.

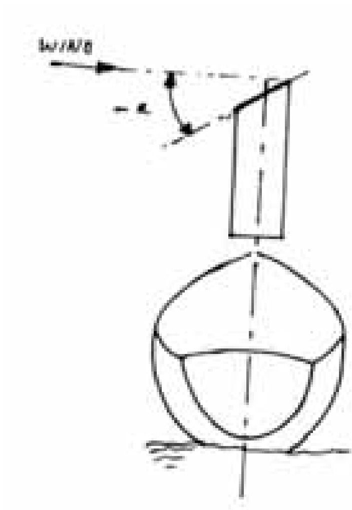


FIG. 3

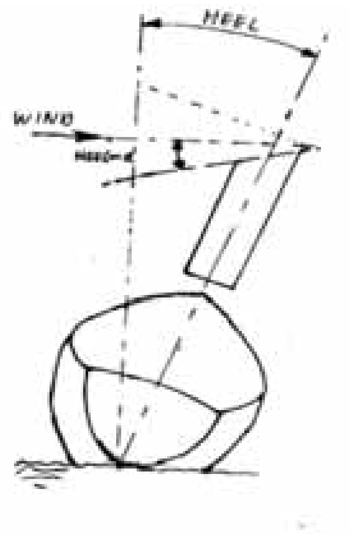


FIG. 4

The upside down vane.

An automatic compensation for the vane axis tilt angle is theoretical possible when the vane is positioned upside down, with a vane axis tilt angle of say –30 degrees. (In the formula a = -30) See figure 3 and 4 and a picture of the real vane in figure 5.

The unheeled vane action is less compared with the known systems as a bigger effective tilt angle is applied. On courses with heel, the effective tilt angle of the vane axis is decreased and consequently the windvane action is increased. This is desirable to cope with weather helm and to keep the course more accurate.

Theory

To show the differences between the normal vane and the upside down vane I calculated the rudder rotation as a result of a windcourse error of 5 degrees. I assume that via the linkage, pendulum and steering lines the rudder rotation is half of the vane rotation. For this comparison the normal vane has an axis tilt angle of 30 degrees (existing systems use 20 degrees on average) and the upside vane -30 degrees.

	normal vane	upside down vane
down wind no heel	5 deg.	5 deg.
wind 90 deg. 10 deg. heel	3.9	7.3
wind 50 deg. 20 deg. heel	3.5	10

These calculations show indeed that the vane and consequently the rudder action are increasing with heel, which seems to be more in line with the actual need on various courses.

Practice

I built a prototype of the upside down vane to my existing pendulum system to find out how it should work in practise. The first tests were in Nov. 1998 and I compared the output of the upside down windvane with the normal (but adjustable) windvane.

It worked as expected and the observation was that the boat was steered more precisely on close hauled and close reaching courses, without yawing on running courses. See figures 6 and 7. Note the straight track in figure 6. The behaviour in variable windstrength was also good. In a puff the boat heels a little more and the vane builds up more action and steers more accurate.

After the prototype I built the mark two version of the upside down windvane, (shortly named USD vane) and I am still sailing with it.

Conclusion.

The upside down vane coupled to a pendulum system works very well and steers the boat in a more natural way as it adjust itself to the sailing circumstances.

This new windvane principle can be used on all kinds of windvane pendulum or trim tab systems.

The upside down or USD windvane has also been described in "Which windvanes work best" (Practical Boat Owner nr. 414 , June 2001).

Fig 6: A straight track on a downwind course, and ...

Fig 7: Accurate sailing close to the wind

An innovative windvane pendulum system for sailing boats with outboard rudders.

Jan Alkema

Preface

On boats with outboard rudders, it can be troublesome to install a pendulum windvane system. The pendulum has to be free of the rudder and should not limit the rudder movements from full port to full starboard. That means that the windvane system has to be mounted further aft of the boat on an extended support frame, which makes it more vulnerable in harbours and crowded marina's. It will also put extra weight on the transom.

A lot of sailing boats with an outboard rudder and wind vane system make use of a trim tab, directly mounted at the rudder. The trim tab works as a servo system to generate enough force to turn the rudder. It is unquestionable that a trim tab with the right dimensions works, but on some points its performance is less than that of the pendulum system.

Pendulum or trim tab?

Let's compare the characteristics of a trim tab and a pendulum system and focus on the following aspects:

- Steering torque
- Steering efficiency
- Yaw damping
- Support and vulnerability
- Obstructions in the cockpit

Steering torque.

The trim tab can be situated just at the trailing edge of the rudder or at some distance of it. This choice is mostly depending on the shape of the rudder. In figure 1. the trim tab is directedly mounted after the trailing edge of the rudder. In figure 2. the trim tab is mounted at some distance behind the rudder. In both cases the trim tab is working in the wake of the rudder. The solution of figure 2. has the advantage of giving a bigger torque, due to the increased distance between trim tab and rudder hinge.

The pendulum has normally a larger power arm as can be seen in figure 3. So the pendulum with the same dimensions of the underwater part as the trim tab, delivers more torque. This can be advantageous for heavy or unbalanced rudders. Pendulums can operate these rudders without problems, but trim tabs can be limited in their steering torque.

Steering efficiency.

A trim tab develops a force which direction is opposite to the rudder force. The trim tab is decreasing to some extend the effect of the rudder. With normal dimensions the loss of rudder force is approx. 10 %. So the trim tab makes the rudder less effective. The pendulum force works in the same direction as the rudder, so it assists the rudder and increases the total rudder action and hence the steering efficiency.

Yaw damping.

Yaw damping is the ability to prevent or reduce oscillations in the course. Lack of this ability gives a zig-zag course, so it is an important characteristic of a course controller.

Yaw damping is not easy to explain, but the following example may help to get an idea of it. In this example we are only considering the influence on the rudder and we suppose that the vane is not turning during the yawing motion of the boat.

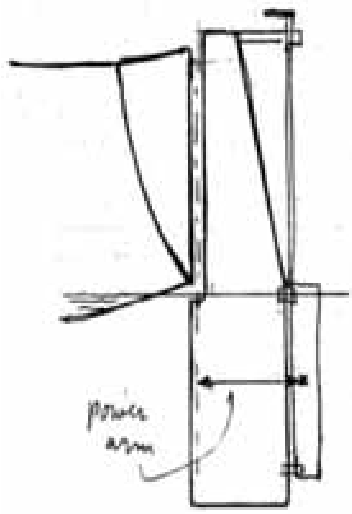


Fig 1: Trimtab close to the rudder

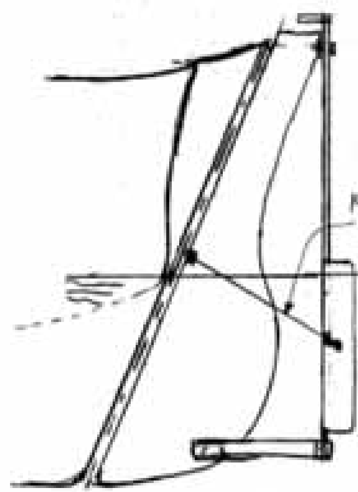


Fig 2: Trimtab some distance behind the rudder

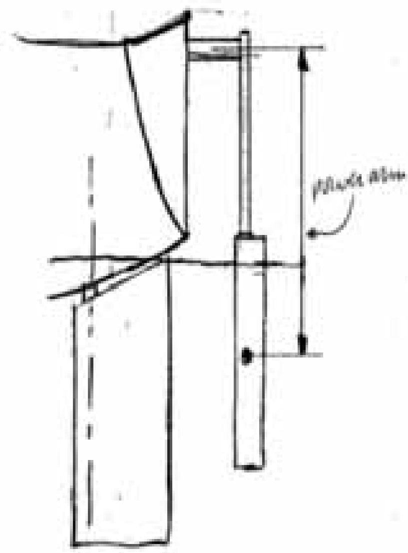


Fig 3: Pendulum system with a big power arm

When wave and/or sail forces are turning the boat (yawing), then there will be pressure on the rudder from the water flow. When the rudder is fixed a force is developed on the rudder which counteracts the yawing motion.

When the rudder is free, then it will line up with the water flow and does not give any counter-force to the yawing motion.

A rudder with a trim tab is not fixed or free but controlled by the trim tab. When the boat yaws the water flow creates a force on the rudder+trimtab and initially the rudder tends to line up with the water flow and rotates a bit. But the trim tab gets a greater rotation (in the same direction) due to the linkage between trim tab and wind vane. The water flow on the deflected trim tab creates a force which prevents the rudder from lining up with the water flow. As a result of it the rudder gives some counter force, which damps the yawing motion. This counter force and so the yaw damping, is however smaller compared with a rudder alone, had that been fixed.

A pendulum system, connected to the rudder can give more yaw damping and most when the pendulum is far aft of the rudder and out of its wake. When the boat yaws the rudder and the pendulum get pressure from the incoming water flow. The pendulum wants to swing out and the rudder wants to line up with the water flow. But because the pendulum is much more powerful than the rudder, it swings out and turns the rudder in the opposite direction. So instead of limiting the rudder angle from giving in (which is what the trimtab does), it increases the rudder angle to create an increased counter force. So the pendulum system gives a powerful and active yaw damping. The counter force and so the yaw damping of a rudder+pendulum system is bigger than for a fixed rudder alone.

This is true when the pendulum is out of the wake of the rudder. When the pendulum is close to the rudder then the active yaw damping effect is less. But it is always more than from the trim tab, because when the pendulum swings out, it brings the blade far more out of the wake of the rudder compared with the trim tab.

Support and vulnerability

An advantage of a trim tab system is that no heavy support is necessary. The trim tab is directly mounted on the rudder.

The trim tab is well protected by the rudder which is an advantage compared with a pendulum, which swings out and can pick up weed, ropes and floating debris As already mentioned an extended support frame is inevitable for the normal pendulum system for an outboard rudder.

Obstructions in the cockpit.

The trim tab system has no steering lines and blocks to the tiller or wheel. The trim tab directly controls the rudder blade.

For normal pendulum systems steering lines with several guiding blocks are running through the cockpit to operate the helm or the steering wheel. This is mostly a nuisance in the cockpit

Combining the advantages.

When I started to design a windvane system for my boat with an outboard rudder I wanted to have the best of both worlds. So the advantages of a pendulum system should preferably be combined with the advantages of a trim tab system. Would that be possible?

After many sketches and a lot of thinking I came up with a system which I later named the *Rudder Head Mounted* (RHM) pendulum or oar system. See the sketch in figure 4.

The pendulum has the horizontal hinge mounted on the rudder head. Essential are the two restraint lines from the transom side to the oar carrier or pendulum tube. When these lines are loose, the pendulum can swing to each side, but it can not turn the rudder. The system is disconnected. When these restraint lines are tight, then they form a fixed point on the tube which will be a pivot point. (point P) When the pendulum swings out then the rudder is forced to turn.

Figure 5 shows how the swing out movement of the pendulum gives a rudder movement, when the restraint lines are tight.

For stretching or adjusting the restraint lines I use clam cleats on the aft cockpit sole. To release the lines, simply pull them out of the cleats.

This Rudder Head Mounted (RHM) pendulum combines all the advantages of both the pendulum and trim tab:

- It is a true pendulum with the power of normal pendulums.
- It increases the rudder action.
- Yaw damping is better than with a trim tab
- No heavy support frame is necessary.
- There are no steering lines in the cockpit

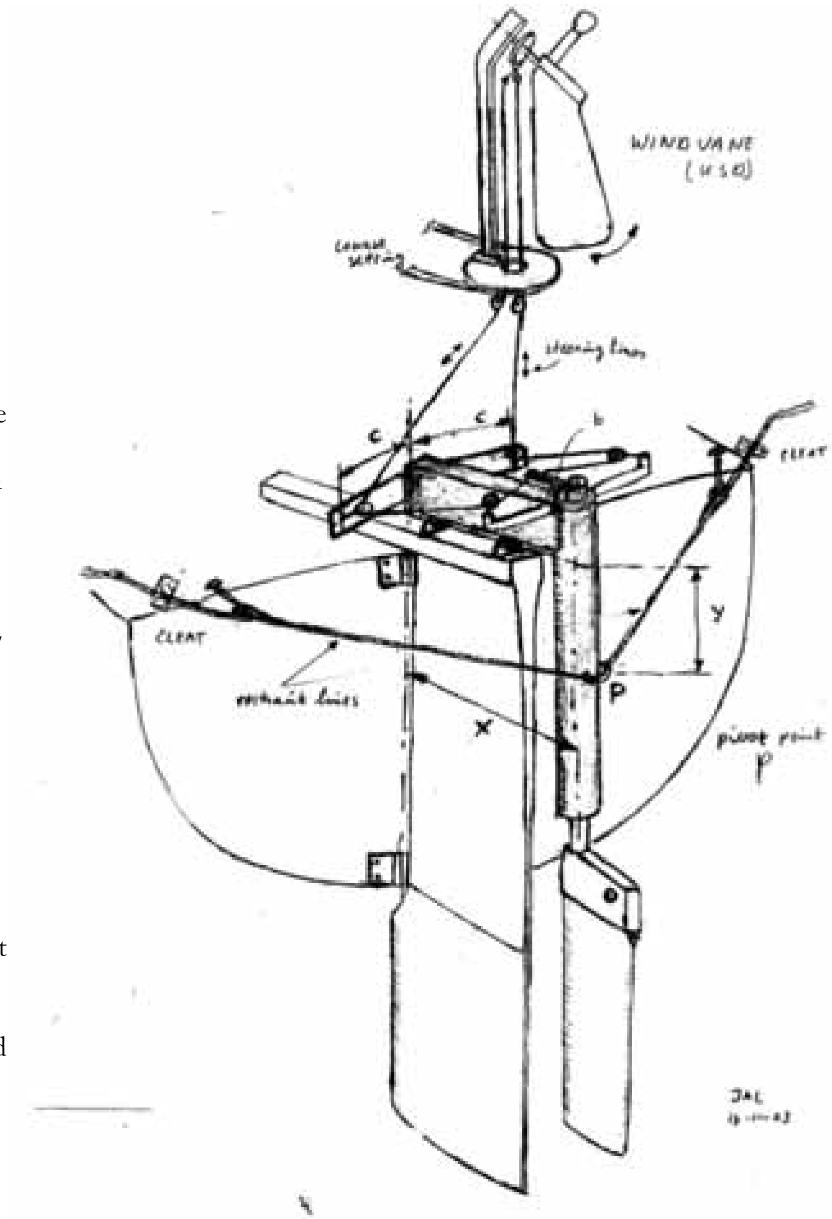


Fig 4: The Rudder Head Mounted Oar

One minus point of the pendulum remains. The pendulum is not so well protected by the rudder as is the trim tab.

Prototype

I made the prototype of the oar carrier and the oar from plywood. I used SS hinges which are normally used for the rudders of small dinghy's. The first sailing tests were carried out in 1981 and it worked from the start. Figure 6 shows the prototype of the oar carrier and oar, which fitted very well with the shape of the rudder.

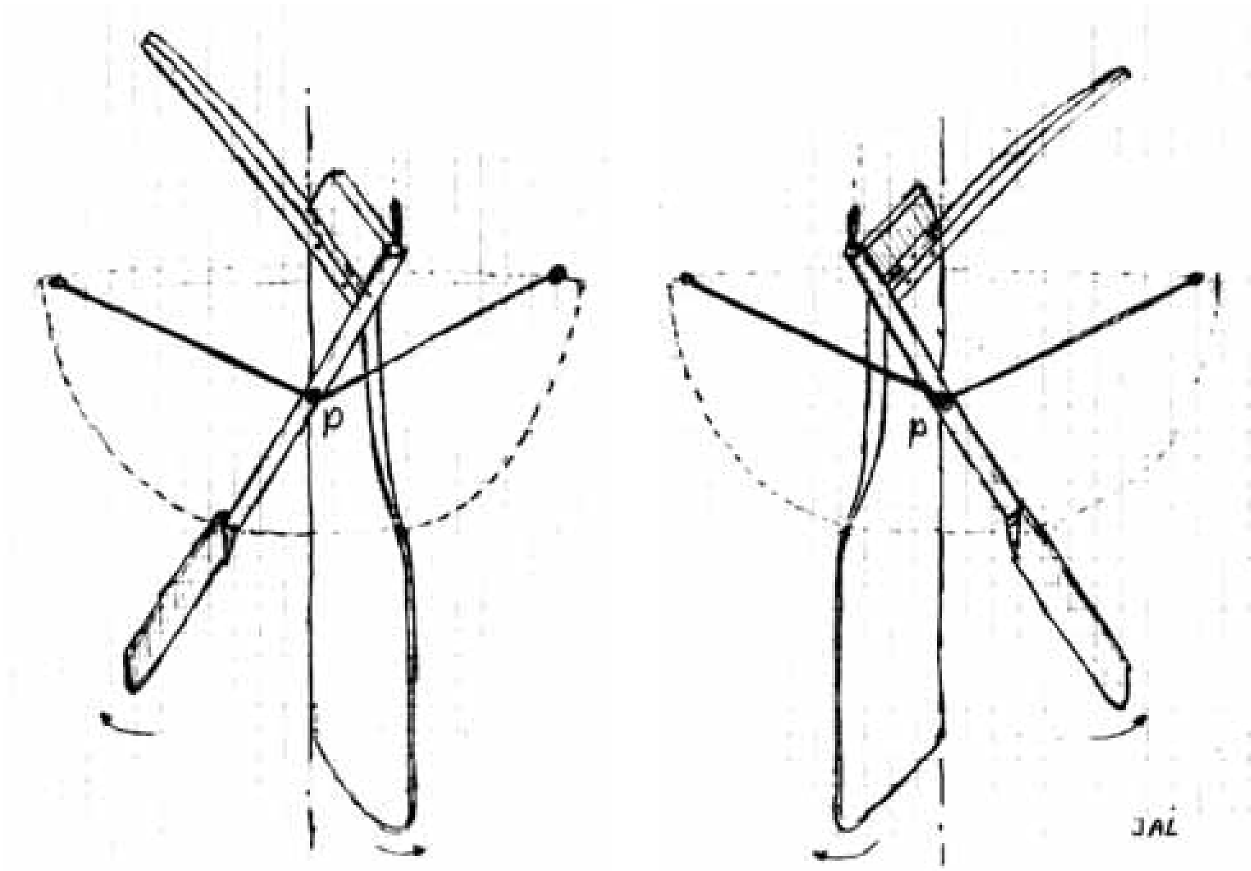


Fig 5: How the oar turns the rudder

This RHM pendulum system is combined with a seperate wind vane which is mounted on the pushpit. Via thin stainless steel cables the rotation of the vane is transmitted to the little tiller on the oar.

Figure 4 shows how the cables run from the windvane to the small tiller arm on the oar.

I used the prototype of the RHM pendulum for some 5 years. After that I rebuilt the system, using stainless steel tubes. Ball bearings are used for the oar rotation and in all blocks to get as low friction as possible. I also made the blade retractable. It is still in use, after 20 years, with only small modifications up to now. Figure 7 and 8 show the pendulum system, including the wind vane. The windvane part will be discussed later.

Position of the cleats for the restraint lines.

The position of the cleats should be close to the sides, using the full width of the transom. The restraint lines have to remain reasonable tight without slack or overtension for rudder angles of +/-20 degrees, which is the max. range for rudder corrections during sailing.

On my boat it appeared that the cleats should be positioned higher than the connection point P on the oar corner or pendulum tube. On my system the vertical distance between P and the cleats is about 0.3 m (1foot).

In general it may need some trial and error to find the best positions of the cleats.

Well mannered behaviour.

On every pendulum system the oar needs feedback, otherwise the system will oversteer. When the oar is initially turned by. the vane, it will swing out, but during that swing the oar is rotated back, to arrive at a certain swing angle and so at a certain rudder angle. The information of the swing angle is

Fig 6: The prototype oar and oar carrier made from plywood

fed back in the turning of the oar through the linkage between vane and oar.

The RHM pendulum system needs more feedback than a normal pendulum, because the pendulum rotates together with the rudder, so that rotation must also be compensated as an extra.

The geometry of the cross beam and wires and blocks however ensures that there is more then enough feedback in the system, to get a well mannered behaviour of the pendulum without any sign of oversteering.

The system gives a good yaw damping in downwind and broad reaching courses on a lively boat like the Westerly Konsort. Note the straight track on figure 9 during a running course in force 5. On windward courses the system works also very well.

Note the oar at work, most of the time it is out of the wake of the rudder, as in figure 10.

How to operate the RHM /USD system.

The windvane was developed separately from the pendulum. Before starting with the RHM pendulum I used a big wind vane, directly coupled to the rudder. I had taken that windvane from my previous boat. It had an adjust-able vane axis tilt angle. After building the RHM pendulum I combined it with the existing wind vane. The combination worked very well, although the vane was a bit oversized for operating the small oar.

Some 6 years ago I designed a new type of wind vane, the *Up Side Down* (USD) windvane, which could easily be connected to the existing RHM pendulum via the thin stainless steel wires.

At the start the vane is locked is a vertical position and the restraint lines are slack, the blade is put into the water. With slack restraint lines no forces are excerted on the rudder. It appears that the oar is following the rudder without swinging out, also when the boat is steered manually.

When the restraint lines are tightened and the vane is set on the desired wind course and released, then the system is taking over and will steer the boat. Normally I put the tiller in the upright position to get a free and uncluttered cockpit.

To disconnect the system I first lock the vane in a vertical position and then pull the restraint lines out of the cleats. Then the boat is ready for manual steering again.

Conclusion.

The described construction principle of the Rudder Head Mounted pendulum has been used for 25 years now. I made many sailing trips with the system to Denmark, UK and France. Up till now I have not experienced any shortcomings in the system.

RHM and USD are working together perfectly, steering the boat accurately without yawing and making sailing trips even more enjoyable.

In my opinion it is a feasible and satisfying solution for boats with outboard rudders and a not too difficult do-it-yourself job to build.

Fig 7: The oar blade in the water

Fig 8: The oar blade retracted

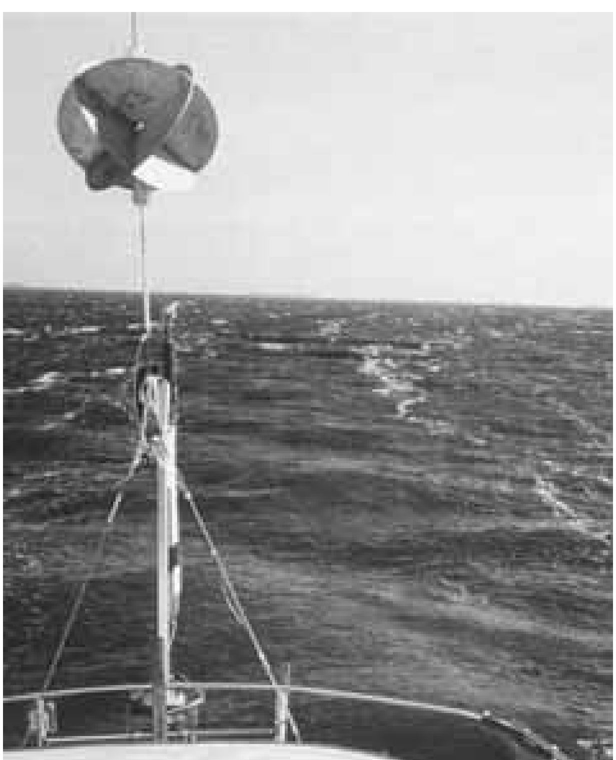


Fig 9: Downwind, straight track, no yawing

Fig 10: the oar working out of the rudder wake

Stabilising foils and variable geometry for proas: lots of theory and a bit of practice

Robert Biegler

My interest in stabilising foils and variable geometry proas stems from a wish to have a fast cruising boat that looks after itself, i.e. that is stable around the pitch axis (it does not pitchpole) the roll axis (it does not capsize) and the yaw axis (it steers itself). It needs to be cheap as well. One option is to use a rig that develops no heeling moment, either sideways or forward. Kites exactly fit that specification, but at the current stage of development they have a few practical drawbacks. Another option is to have a long lever arm between weight and buoyancy. A variable geometry proa achieves just that, on a relatively lightly loaded structure. The first part of the article will describe that idea. But even multihulls are fastest when sailing on only one hull, and when relying on weight to weather of that one hull to keep the boat upright, the balance is precarious. Maximum stability is achieved when the weather hull just clears the water, and decreases thereafter. Stabilising foils can be designed so that they pull down just enough and no more, offering a more benign stability curve or even non-heeling. The bulk of this article deals with the design of such stabilising foils for proas.

Variable geometry.

Proas offer a number of specific design challenges. The most important for safety is how to make a proa self steer so that it does not get caught aback. A second challenge is how to prevent the bow from digging in. Catamarans and Trimarans can be designed so that the centre of buoyancy moves forward as they heel while still maintaining level trim or even a bow-up trim. The fore and aft symmetry of a proa makes that difficult. Finally, there is the issue of manoeuvrability. Moving a sail actively through 160° or so when shunting takes some time. All three problems can be solved, at least in theory, by connecting the hulls with a pantograph cross beam arrangement, so that they can move relative to each other in parallelogram fashion, and combining that with a tailplane-controlled sail on the lee hull.

First, self steering.

In the diagram the cross beams that allow the hulls to move relative to each other are not shown, for simplicity. There are only two hulls, a lee board on the weather hull and a sail on the lee hull. The angle of attack of the sail is controlled by a tailplane. The sail is self-adjusting: its angle of attack will stay the same, no matter where the apparent wind comes from. Diagram A shows the boat hard on the wind, the hulls offset so that all forces balance out and the boat is stable. I have assumed that the lee board has the same drag as a hull and a lift to drag ratio three times as high. Diagram B shows what happens if the wind shifts suddenly by 30° so that it comes from what is normally the lee side. If the sail were fixed relative to the boat, it would develop thrust towards the weather hull, and given enough wind the boat would capsize. The thrust of the tailplane rig is still towards the lee hull and somewhat aft. The result is a large turning moment that will put the boat back on the same course relative to the apparent wind. Diagram C shows that if the wind shifts 30° the other way there is an equivalent turning moment in the opposite direction, which will again put the boat on course.

It is clear from the diagrams that the magnitude of the turning moment is greater the more lateral resistance is in the weather hull and the less there is in the lee hull, because only the weather hull is on a lever arm that can provide a turning moment.

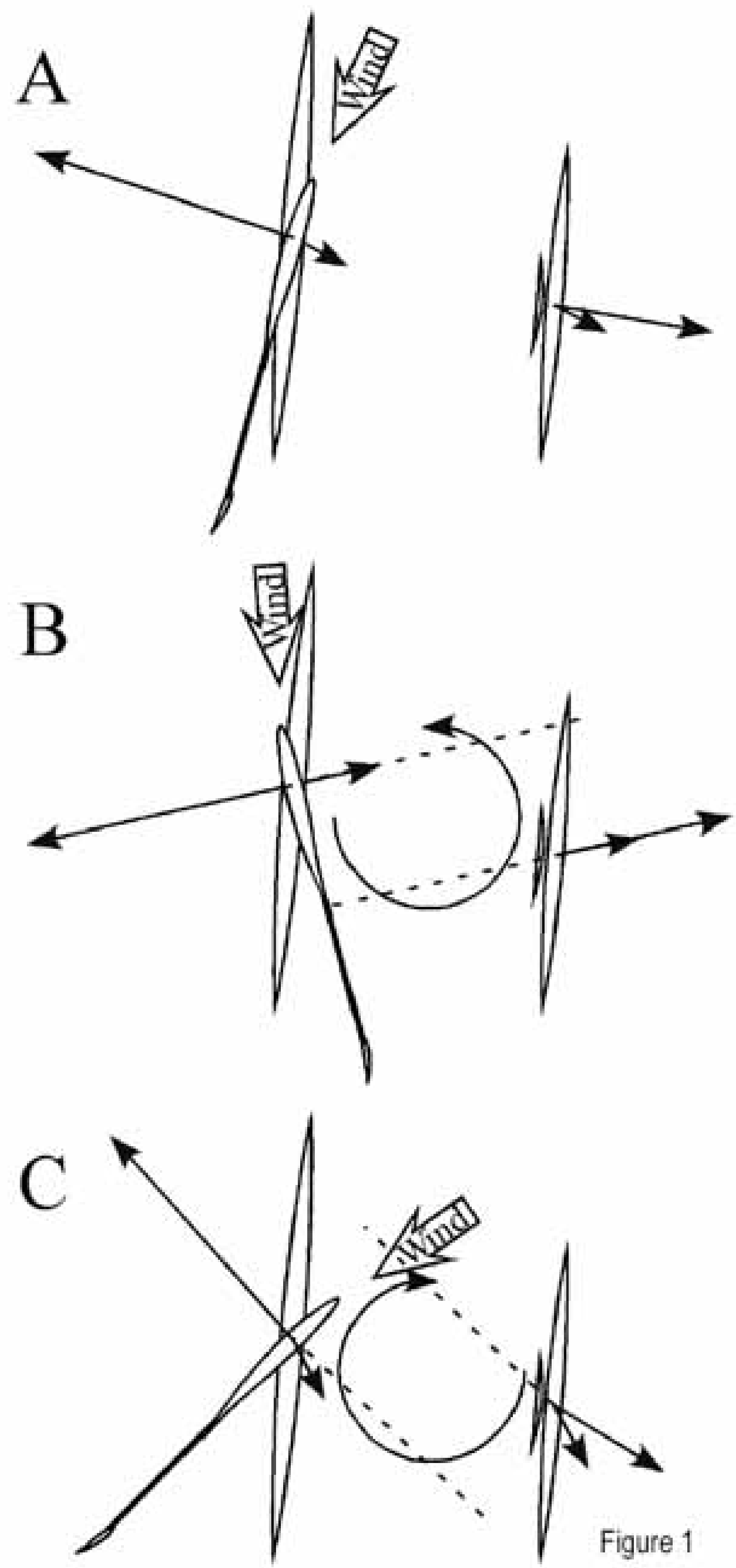


Figure 1

All the forces from the lee hull are right under the rig. For courses other than shown here different offset angles between the hulls are needed. In principle, the boat can be steered without rudders, exactly like Dave Culp's kite-propelled proas.

To steer the boat further and further off the wind, the weather hull must be positioned more and more aft. That necessarily reduces bow burying. If the lee hull and weather hull (including any boards and rudders that may be present) have the same lift to drag ratio, then the sail's thrust and the weather hull's weight will be exactly in line, and in the absence of dynamic effects the boat will maintain level trim. If the weather hull has a higher lift to drag ratio then there will be some turning moment pushing the bow down, because the drag of the lee hull will pull that hull and its buoyancy a bit aft, but that pitchpoling moment will be far less than on a conventional proa with fixed geometry.

There is a limit to the possible offset angles. If the weather hull was directly behind the lee hull, transverse stability would obviously be nil. If no offset (cross beams perpendicular to the hull) is defined as 0°, then stability around an axis parallel to the cross beam is proportional to the cosine of the offset angle. At 30° it would be 86% of the fore-and-aft stability at 0°, at 45° it would be 71% and at 60° 50%. A stop would be needed to prevent the hulls from moving beyond the maximum offset angle judged to be safe. A rudder or an additional sail on the weather hull or on a stay between mast and weather hull would be needed to steer further downwind than the course achieved with the maximum safe offset angle.

The variable geometry could be a safety feature in yet another way. If the boat ever did capsize, then removing the stop and folding up the boat until the hulls are in line would at least turn it on its side if there is any buoyancy in the mast. It should be possible to distribute buoyancy so that, at least in calm water, the boat rights itself when being unfolded again. It is possible, though, that the unfolding would require too large a force and/or put too much stress on the structure to be a practical proposition.

Turning a lightly loaded tailplane through something like 30° is obviously less work than pulling the whole sail around. With a tailplane-controlled rig the wind will do that, and it will happen faster the more wind there is. That would not improve manoeuvrability if the crew then has to haul the hulls to their new offset angle. Fortunately, there is an easier way. If a rudder is used to set a course while leaving the weather hull free to rotate to any offset angle, it will automatically settle at the offset angle that will keep the boat on course if crossbeams and rudder are locked. Both this automatic adjustment and self steering will only happen if the weather hull has some lateral resistance. If there is none then, having only drag and no lift, the weather hull will always make the boat luff if it is kept on the weather side. Left to find its own position, it will trail behind the lee hull, on all courses. That is exactly what happened to one the very few variable-geometry proas ever built. Rosiére's small weather hull pivoted freely around a vertical axis, independently from the lee hull. A fixed skeg in the stern kept the hull aligned with the water flow, so it only ever produced drag, never any lift. At the start of a transatlantic race the skipper wanted to reduce pressure on the bow by winching the weather hull to a position further aft. The line slipped off the winch, there was no backup or stop and the boat folded up and capsized. The weather hull must have lateral resistance, the more the better.

A variable-geometry proa with most lateral resistance in the weather hull and with a self-adjusting sail should be more manouevrable than more conventional designs, it should be far less prone to pitchpole and it should look after itself when left to its own devices, without getting caught aback and capsizing. The greatest practical problem is likely to be building the pantograph cross beam arrangement so that it never seizes up and is still light enough.

To some extent this self-steering scheme can also work with a sail that is sheeted, and keeps a fixed angle relative to the boat, rather than relative to the wind. However, I found that a sheeted sail makes for far worse self-steering than a self-adjusting sail. When I sailed my canoe as a kite proa (the kite being another form of sail with a constant angle of attack) it self-steered very nicely, as described above. The boat self-steered even though the lateral separation between the board and the kite attachment was only about 80 cm. When I rigged the boat with a hapa, an Ashford-designed anchor dog (basically a Bruce foil on a string deployed on the weather side; see AYRS 114 and descriptions below) and a junk sail, self-steering was much less stable. That despite the fact that the effective lever arm for self-steering of the hapa was more than twice as long as for the kite set-up. Having a self-adjusting sail makes a big difference.

Another self-steering rig.

It is not necessary to use a single self-adjusting sail to achieve good self-steering. A self-adjusting jib will do the job, and does not even depend on having the lateral resistance in the weather hull, though that would help. I have drawn figure 2 as if there is some lateral resistance is in the weather hull. The important feature of the rig is that it has jibs set on balanced booms. The forward 'acting jib' is controlled by a tailplane, the aft 'acting mizzen' is sheeted to a fixed angle relative to the hull (the mizzen's tailplane should be free to rotate, to reduce sheeting loads), with a smaller angle of attack than the mainsail (figure 2b). The self-adjusting jib will always pull the bow to what should be leewards, with a constant force, independent of heading. So if the boat turns too far into the wind, the mizzen and then the main lose drive, while the jib keeps pulling, setting the boat back on course. The jib also gains a larger lever arm relative to lateral resistance in the weather hull (see stippled line). If the wind has shifted a lot very quickly, eventually the mizzen fills from the other side pushes the stern to what should be windwards, adding more turning moment (figure 2c). At that point, the heeling moments of mizzen and jib will at least partly balance each other, making a capsize unlikely, so long as the main (not shown in figure 2a) can rotate all the way round the mast. If the boat has fallen off too far, the lightly sheeted mizzen gains drive faster than the other sails and makes the boat luff again (figure 2e). If there is some lateral resistance and some drag to weather, the jib will lose some leverage relative to that and will be less effective pushing the bow leewards (stippled line). If the overall hydrodynamic centre of effort is not to weather of the jib, then that effect cannot make any contribution, and the mizzen has to do all the work.. This self-steering scheme should work on any course with the wind ahead of abeam, and the boat could even be steered with sails alone. To increase sail area a bit more, and to make downwind steering easier, it would be possible to set a (sheeted) staysail on the shroud, as Fritz Roth does on his proas.

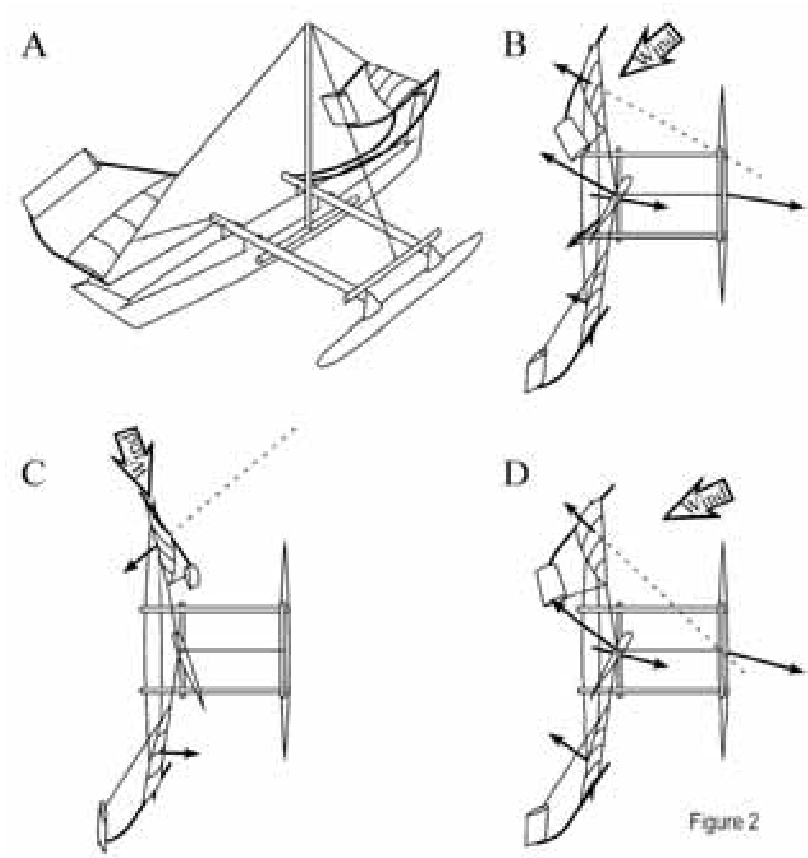


Figure 2

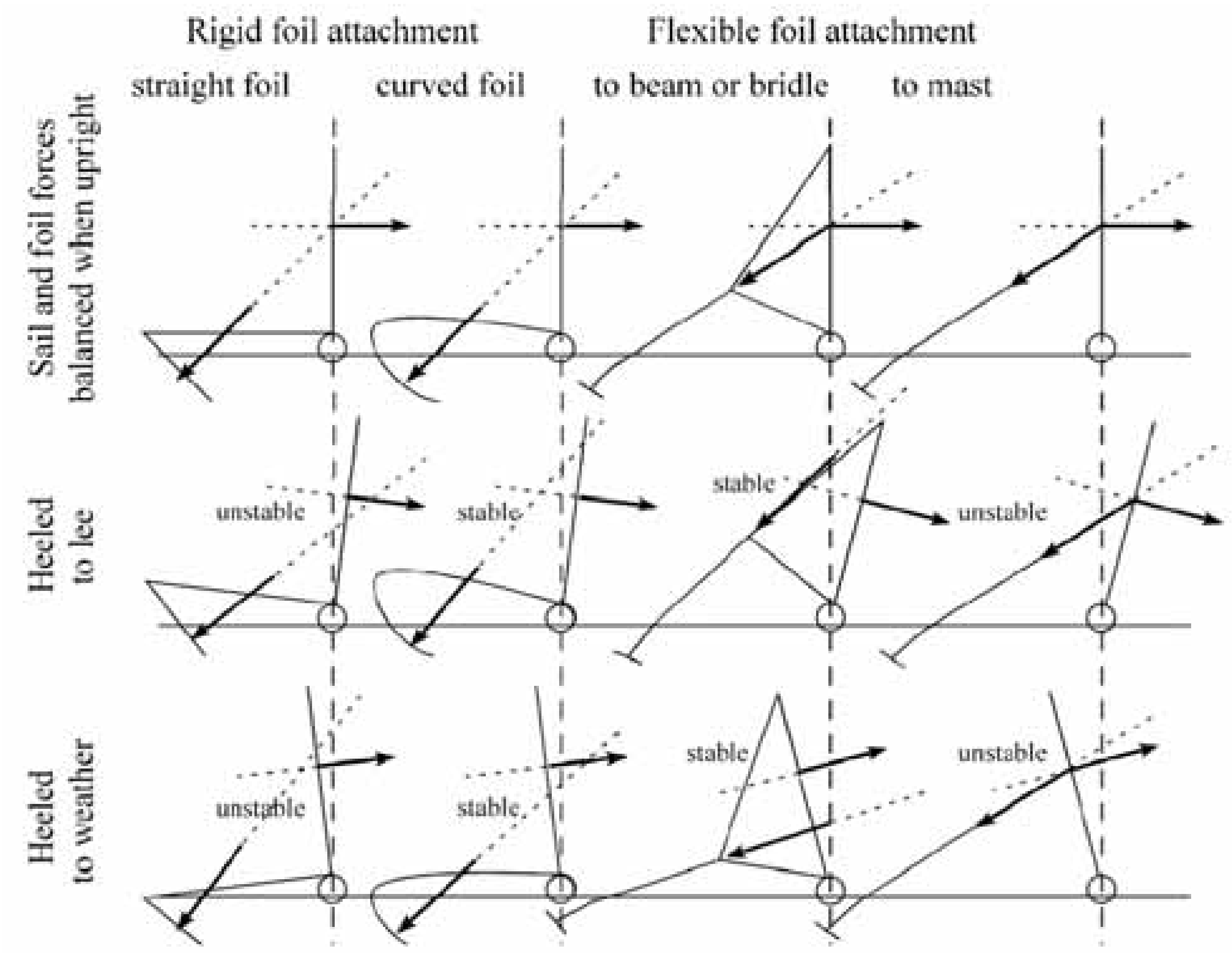
The inclination of the jib and mizzen lifts the bow and pushes down the stern, counteracting pitchpoling. Because this effect relies on the inclination of the sails, the attachment of the stays to the mast should be as low as possible, while the attachment to the hull should be fairly high and as far out as possible. For this reason, the boat in figure 2 has something like inclined bowsprits.

This design meets the criteria of good stability around pitch and roll axes without needing bearings in the crossbeams. Reducing the number of moving parts seems like a good thing, both for increased reliability and lower cost. However, such a boat still can't fly the weather hull without someone paying careful attention to prevent capsize, because maximum stability is reached just when the ama comes out of the water and decreases from there on. A better stability curve, or even non-heeling, can be achieved by using a stabilising foil.

Stabilising foils.

These come in two basic flavours: the familiar one of lifting up the lee side, and the less familiar one of pulling down on the weather side. The lifting lee foils behave much like a lee hull, they don't give the kind of stability curve I would like to see, and they don't lend themselves to stable self-steering as well as foils to weather do. So I will discuss foils that pull down.

Prof. Hagedoorn pointed out that a fixed, straight Bruce foil pulling down on the weather side is unstable (AYRS Airs 2). If it comes out of the water a bit in a wave, the foil's centre of effort must move down a bit. Because of the foil's inclination, that means the centre of effort also moves in a bit, there is less leverage, and the boat will heel more until the foil comes out entirely. Another way of looking at this generalises to other foil configurations. Imagine a vertical plane through the centre of buoyancy. A boat achieves non-heeling if the force from the foil intersects that buoyancy plane at the same height as the force from the sail. In figure 3 these buoyancy planes are shown as vertical stippled lines. The straight Bruce foil coming out of the water moves the intersection of foil force with the buoyancy plane down. On the other hand, if a straight Bruce foil goes into a wave, the centre of effort moves up and out, that moves the intersection of foil force with the buoyancy plane up, the boat heels to weather and the foil digs in even more.



One solution is to curve the foil tip towards the boat. Then if the foil comes partly out of the water, the remaining part is inclined more, the intersection of foil force with the buoyancy plane moves up, and the boat levels out again (this assumes the foil still takes the same lateral load). If the curved foil goes into a wave, portions that are less inclined start to work, the overall foil force vector flattens out. As the intersection of foil force with the buoyancy plane moves down, the sail can pull the foil up a bit. Fritz Roth has used this configuration on proas and claims a perfect safety record so far.

In figure 3 the two Bruce foilers were heeled only 7° either way. More than that, and either the foil is in danger of stalling, or the crossbeam digs in. The boats with flexible foil attachments are shown heeling 15° either way, because they can cope. That suggests the flexible attachment should run less risk of a foil popping out in a seaway.

Another important point is that when a boat has a rigid foil attachment, the whole boat must roll immediately in order to allow the foil to track the water surface. The higher the roll moment of inertia, the greater the force the foil must provide to overcome that rotational inertia. Putting ballast to weather increases rotational inertia and so may prevent the foil from rolling the boat quickly enough and may cause capsize. Conventional multihulls rely on high rotational inertia to prevent wave-induced capsize. As far as I can work out, a boat with a rigidly attached foil pulling down the weather side must follow different design principles, keep rotational inertia low, and always rely entirely on the foil. If the foil is flexibly attached, there is no such conflict, because the foil is decoupled from the rolling of the boat. It can follow a wave trough immediately, and make the rest of the boat follow later.

Fig 4: Close-up of a two-way hapa

The two right-hand columns of figure 3 demonstrate that the hinge point of a flexibly attached foil must be to weather and relatively low. If the foil is attached directly to the mast and the boat heels, the foil will pull down the attachment point and increase heel further.

A foil that is stable in pitch can be attached to the boat with string. In Catalyst Vol. 1 No. 3 I reported on my tests of the Ashford-designed anchor dog (see AYRS 114). It is quite stable in pitch and because it puts low loads on its components it lends itself to low-tech construction. On my sailing canoe, the Ashford anchor dog worked wonderfully as long as I stayed on one tack. But if I wanted to come about, the boat tended to swing around the hapa and did not have enough momentum to get onto the other tack. Once I had paddled the boat around, I had to deploy one hapa on the new weather side, and retrieve the hapa on the lee side. Paul Ashford has suggested possible solutions to these problems, but rather than attack them head on, I decided to sidestep them by putting a hapa on a proa. Then I don't need to tack or gybe, and I never need to retrieve a foil that suddenly finds itself on the lee side.

The challenge then was to design a hapa or sea dog that works both ways. Figure 4 shows a design that I tested on a 4.8 m long proa with just under 4 sqm of sail. I could have used a T-foil with an angled cross piece, like in the anchor dog, but I opted for a curved foil and two struts. Because of the curve, the foil can be shorter and angled less relative to the strut, yet still reliably hook in (if only the lower tip of the foil were in the water, the foil will hook in only if the resultant force from the foil tip passes above the hapa spine). I chose two struts, because I was sure that sooner or later the hapa would ground when sailing onto or off a beach, and it would be difficult to make a single joint strong enough to resist the resulting bending loads. The curved hold-down foil pivots on the central spine. The pivot axis is inclined so that it passes well above the foil. Drag then always pivots the foil backwards, so that it pulls down. It has the same relationship relative to the (currently) forward control foil as in the Ashford anchor dog. The struts leading to the hold-down foil, on the other hand, can't push up to pitch the whole thing forward and down, as the single strut does in the Ashford anchor dog, because they are not aft of the T-foil, and they don't have a suitable angle of attack anyway. The aft control foil has to take over that job. It does so once it has been pulled down far enough. Paul Ashford has done a theoretical analysis of the most desirable orientation of the pivot axis and the angle through which the central foil should pivot. Not having precise control over the pivot angle in my rather improvised design anyway, I just guessed.

The two control foils are angled up at the outer ends, so that the forward foil functions as a canard.

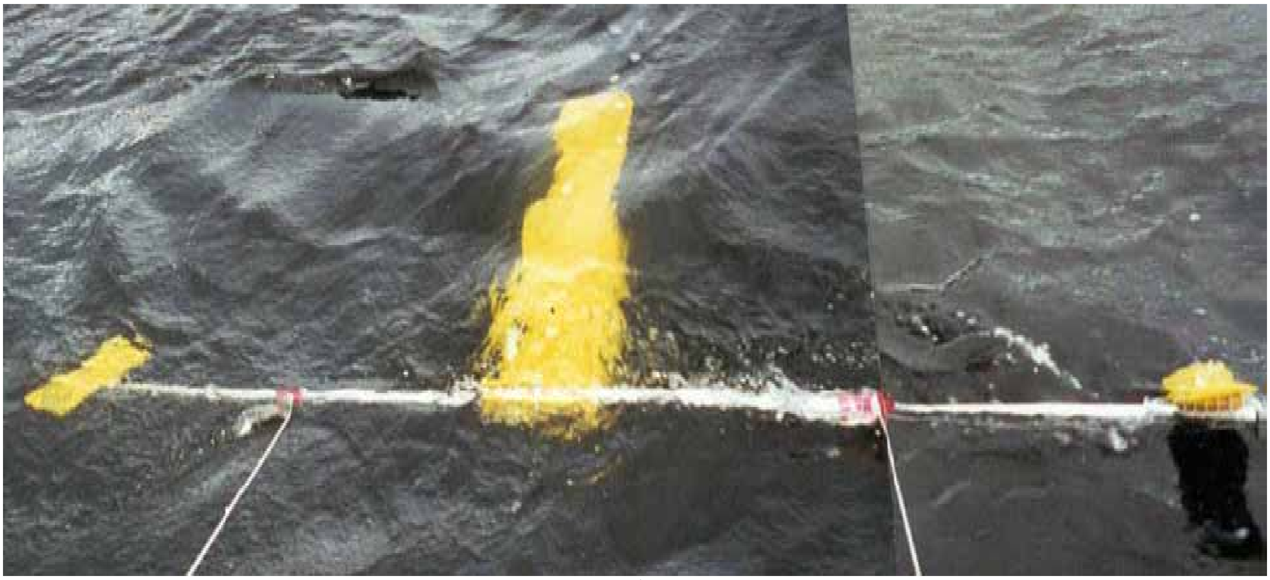


Fig 5: 2-way hapa in action

The central foil pulls down until the aft foil has a positive angle of attack and starts lifting. At that point, the 2-way hapa has similar pitch stability to the anchor dog: if the forward foil comes out of the water, the central foil pulling down and the aft foil pushing up will restore pitch. If the forward foil dives into a wave, it's greater angle of attack will lift the front.

The design follows the water surface exactly as predicted, as can be seen in Figure 5 (assembled from two photos taken seconds apart, because the whole hapa would not fit into the frame). The forward control foil is less than half immersed, but from about a quarter of the length back the hapa is fully immersed. The aft control foil is entirely below the surface (in the photo it is also a bit twisted, but the hapa still worked equally well either way). In the fairly flat water on Loch Lomond this design was stable. In its current form, I expect it would pitchpole in a following sea if the concavity of the water surface were enough that the forward control foil experienced a negative angle of attack.

A possible solution is to replace the fixed control foils by ones that pivot around an inclined axis. Figure 6 shows such control foils on the ends of a hapa, seen from the weather side (the centre of the hapa has been cut away for simplicity). The foils are swept towards the centre of the hapa and are set well above the pivot axis. The drag above the axis will give the foils a positive angle of attack. The forward foil is swept back, so its angle of

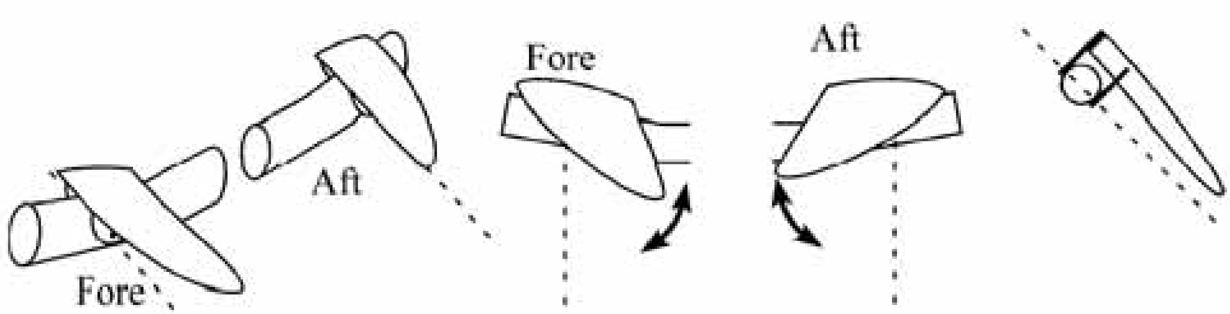


Fig 6: This control design should be less likely to pitchpole. The forward foil is self-adjusting, similar to a hangglider, except that due to the sweepback, the angle of attack increases with immersion of the foil. The aft foil comes top rest against a stop.

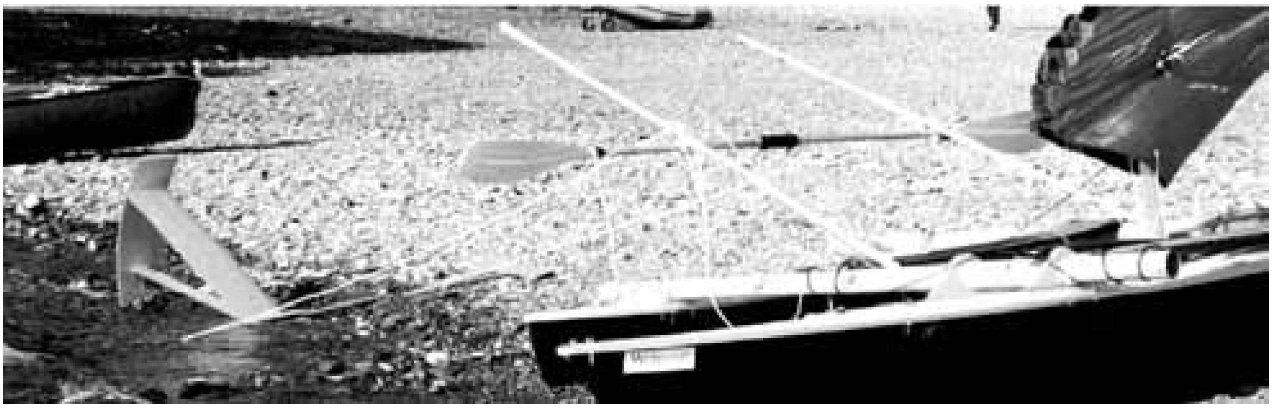


Fig 7: The attachment of hapa to boat was rather improvised, but allowed me to shift the hapa by grabbing any of the three spars.

attack is initially small when only the foil tip is immersed, but as the foil immerses more and the centre of pressure moves forward, the angle of attack increases. Even if the hapa stuffs the forward foil deeply into the back of a wave when going downwind, the foil will retain a positive angle of attack and pull up. A rotation range of 20° or so should be enough. The aft foil is swept forward and would keep increasing its angle of attack if it did not come against a stop that keeps it aligned with the longitudinal axis of the hapa. So the aft foil ends up with a small fixed angle of attack, lifting the aft end of the hapa. That way it should be possible to keep the spine and control lines out of the water much of the time, reducing drag. Leeway and dihedral angle should prevent the aft foil from experiencing a negative angle of attack, but if that ever does happen, the stern of the hapa would only be pulled down until the aft foil has a positive angle of attack again.

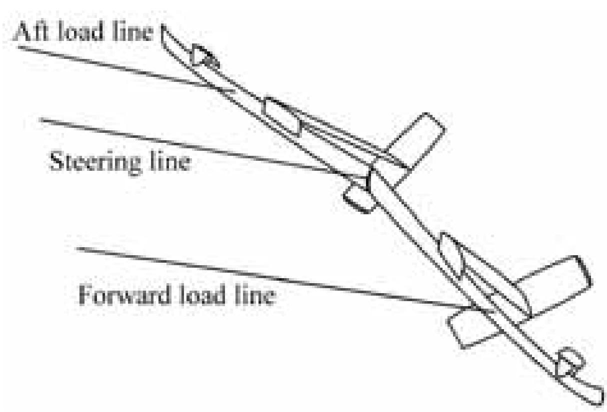


Fig 8: Design for a steerable two way hapa. The steeper angle of attack of the forward T-foil has nothing to do with steering -- it makes it easier for the hapa to pitch down after going through a wave

The Ashford anchor dog steered my sailing canoe well enough. The canoe has a hull that turns fairly easily. The proa I used to test the 2-way hapa has a deep-V hull that does not turn easily. A single hapa did not steer that boat well. On the other hand, the way I attached the hapa to the boat made shifting it fore and aft quite easy, even though the attachment was heavily improvised. That part of the design seems quite useful. As shown in figure 7, two inclined spars were attached to the lee hull and lines to the mast so that the spars could rotate around more or less vertical axes. At their outer ends these spars were connected by a longitudinal spar (a paddle I had lying around), that kept the transverse spars parallel. The hapa was attached to the joints between longitudinal and transverse spars. Pushing or pulling on either transverse spar moved the hapa fore or aft. For cruising I would want some lines that let me fix these spars at any offset angle I choose.

On the small boats I used, the force needed to shift hapa and boat relative to each other was not large, but I don't know how that would scale up. Also, I don't know how good fine control would be. For those reasons, I have thought about the design of an articulated hapa that should improve steering.

The basic idea is to take two of the 2-way hapas, cut about one quarter off each, and join them there with a hinge (Figure 8). A steering line is attached at the central hinge, and the two load lines are positioned so that there is always some

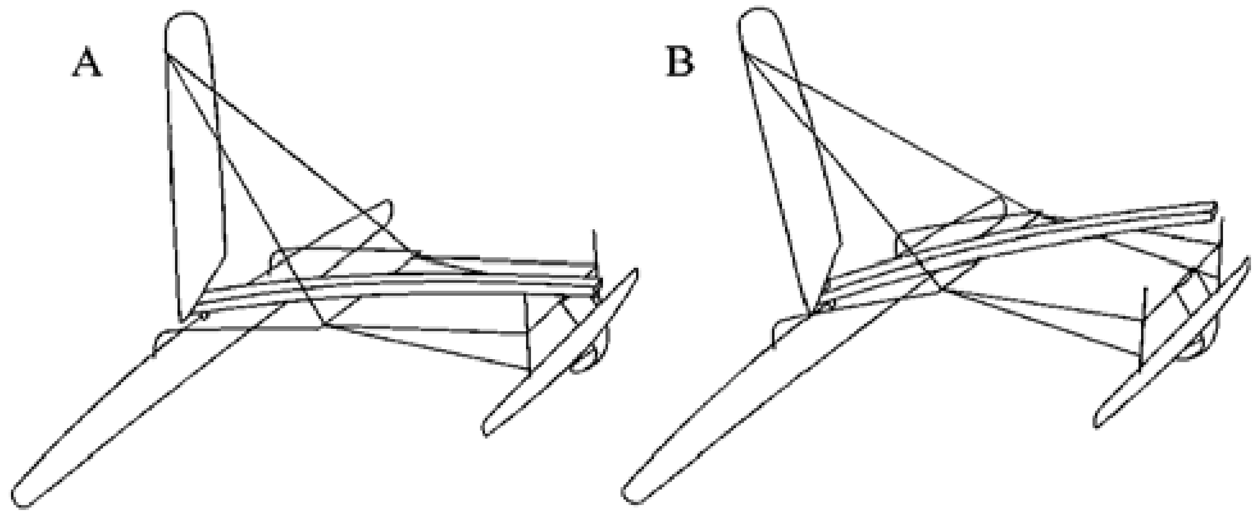


Fig 9: Design for a variable geometry proa with stabilising foil

tension on the steering line. The control foils partly balance the lateral pull from the hold-down foils. The hinge should limit movement to about 10° either side. Pulling on the steering line would make the boat head up, letting out the steering line would make the boat fall off. As far as I can work out, there should be no vertical (pitching) movement at the hinge. The two parts could be allowed to twist relative to each other, though I haven't been able to think of any advantage that would have. The pivot angles of the two hold-down foils should be such that the forward foil pulls down a bit more. That should improve surface tracking when going upwind. This principle could also be applied to one-way hapas. Cut off the tail just behind the second hold-down foil, fix the two hold-down foils, and you have a steerable anchor dog. The ratio of load on a line to its elasticity would have to be same for all three lines, though. If the steering line stretched less, then additional force on the load lines in a gust would make the boat head into the wind. The opposite would happen if the steering line stretched more than the load lines. Careful tuning might produce whatever reaction to gusts is desired, but there is the potential for unpleasant surprises here.

If my previous experience is anything to go by, a hapa should be a cheap way of making a canoe stable around all three axes, once the hapa is loaded up by wind pressure on the sails. What I don't know is whether the hapa will reliably stay loaded, even in heavy weather, when the boat gets pushed around by cross seas and when the sail may be partly becalmed in wave troughs. That may not be such a concern for a canoe that shouldn't be out in heavy weather anyway (though it would be reassuring if it could cope), but it becomes important if hapas are ever to be used on larger boats. Is it absolutely certain that the hapa would never bang into the boat and damage the hull? If not, can it be reliably retrieved in any sea state?

Another issue is the drag of the many foils needed to make the 2-way hapa stable in pitch. They could be done away with by coupling the pitch angle of the hapa to that of the boat. To achieve that, the stabilising foil must be connected to the boat by crossbeams rather than by lines. That could also deal with the problem of keeping the foil away from the hull at all times. One drawback is that these crossbeams must be connected to the foil by bearings if the foil is to be moved fore and aft. Bearings are difficult to streamline, but if they are kept out of the water, bending loads are necessarily introduced, where the hapa on a string had loads in tension. Nevertheless, I will next look at a variable-geometry, foil-stabilised racing proa that throws high-tech at structural problems, then I will consider ways of simplifying the design.

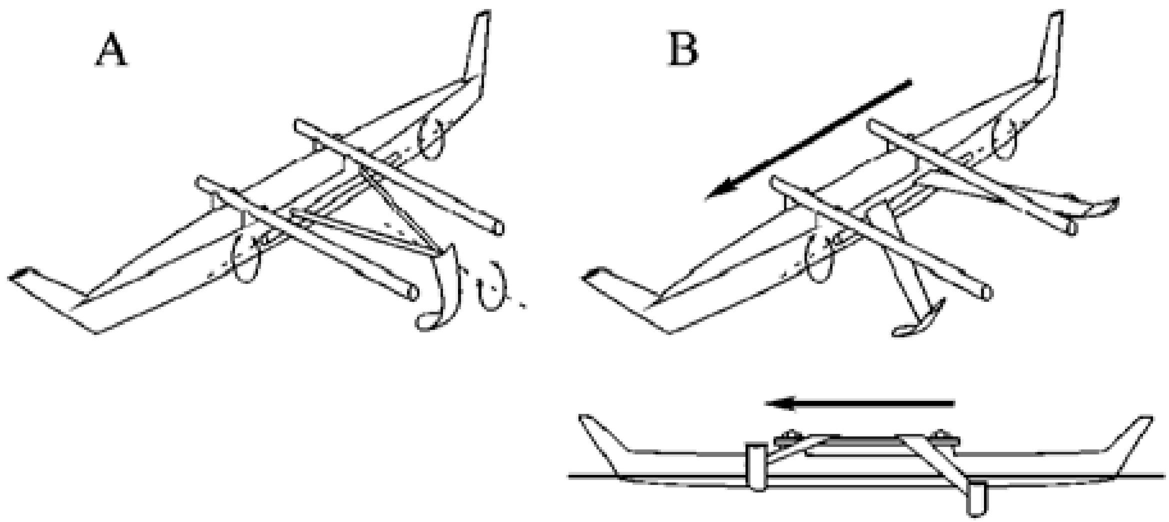


Fig 10: Designs for stabilising foils without variable-geometry and with far fewer bearings

The basic design is shown in Figure 9. The foil is attached like a leeboard, with a pivot at the top, and with the ama serving as a rail. In light winds, the cross beam rests on the foil and ama arrangement, as shown in Figure 9a. When the wind picks up, the boat heels a bit, the beam rises off the foil attachment, and the foil keeps tracking the surface, as shown in Figure 9b. The balance of foil forces should be such that the ama is then just above the water. In heavy weather, the boat could be left to drift with a drogue or sea anchor off the weather end of the beam. An accommodation pod, detachable to serve as lifeboat, could also be fitted there. This design marries the self-steering and level trim of a variable-geometry proa to the stability provided by a reliably surface-tracking foil. A major drawback is that the variable geometry and the foil pivot need a total of 13 bearings, many of them highly loaded.

Most of those bearings have to do with the variable geometry. Is it possible to abandon that? The answer is yes, but at a price. A boat with a flexibly attached foil must be quite wide to achieve complete foil stabilisation. Without variable geometry, a foil far to weather that does not swing aft will cause massive weather helm. Just look at figure 1c again and imagine the foil fixed at midship, which is even further forward. If the foil cannot be swung aft, it must be a lot closer to the lee hull, abandoning complete foil stabilisation and using the foil only to reduce heeling moment and change the shape of the stability curve (more about that later). The simplest design has the foil pivoting up and down around a single longitudinal axis. Unless the foil is so lightly loaded that it works at zero angle of attack (with an asymmetric profile), it is probably a good idea to have the foil also pivoting around a transverse axis, so that the lower tip of the foil always trails behind a bit (figure 10a; the ama is not shown to give a better view of the foil arrangement). The reason is that the effective angle of attack experienced by an inclined foil is less than that of a vertical foil (just imagine inclining the foil more and more until it approaches the horizontal). The rudders will normally be vertical, but the foil is supposed to provide most of the lateral resistance, despite its smaller angle of attack. Letting the foil pivot around a transverse axis will increase the angle of attack.. In a curved foil, that effect will be strongest for the lower, more horizontal portion of the foil that provides most of the downward component, and that would have a smaller effective angle of attack if the foil were fixed. The pivoting works as in the two-way hapa in figures 4 and 5, because drag acts on the foil well below the pivot axis.

As the boat heels and the foil's attachment to the boat rises, the foil heels the other way. There is a risk that the foil will become ineffective. In order to reduce this foil heeling, the distance from lee hull to attachment point should be less than the distance from attachment point to foil. As a consequence, the longitudinal hinge is fairly close to the lee hull, making sure that the foil is still inboard of the weather hull. That way, the foil can easily be pulled up in shallow water, at anchor, or when lying to a sea anchor.

There is an alternative to the single foil midships, with two perpendicular hinges: have two foils in tandem, each optimised for one tack (figure 10b). The foil that is currently aft is inclined so that the lower part of the hook pulls down. On the other tack, that same portion of the foil would push up. Therefore the centre of lateral resistance always ends up aft of midships, even before the crew pulls the forward foil the rest of the way up. This arrangement has the same number of bearings as the previous one. It trades the transverse hinge for another longitudinal hinge. It has the advantages that the foil profiles can be optimised for one tack, and that the foil's centre of effort can be as far aft of midships as desired. Therefore this design can be made a bit wider and come closer to the non-heeling condition. Also, if the hinge axis of each foil is toed in, the foil will pitch down and hook itself more firmly in the water as the boat heels. The design has the drawbacks that the currently forward foil eventually has to be pulled up all the way, and that the boat will not quietly lie ahull without sails: one foil or the other will go down a bit further, the other end of the boat will turn downwind, and as the boat gathers way the forward foil will come up a bit more. The boat needs either a sail sheeted to stop that, or both foils must be pulled up. This tendency to go off on a reach with sails down or slack could be especially problematic in a man overboard manoeuvre.

I tried out a design along those lines, but unfortunately I can't say anything about how well the foil would stabilise the boat. I sailed it only twice before giving it away, because it was so heavy that I could not pull it out of the water on my own. At that point, the boat became useless to me (I should have checked the weight of the second hand hull before I bought it). The foil was a pantographing design as in Figure 9, with inboard attachment as in Figure 10. I could assess the foil's effect on steering. I had hoped to be able to sail without rudder on courses from hard on the wind to a broad reach. When pulled all the way aft,,the foil ended up in the same position as the aft foil in figure 10B. That turned out to be enough to balance the boat on a very close reach, but for any course further off the wind I still needed a rudder.

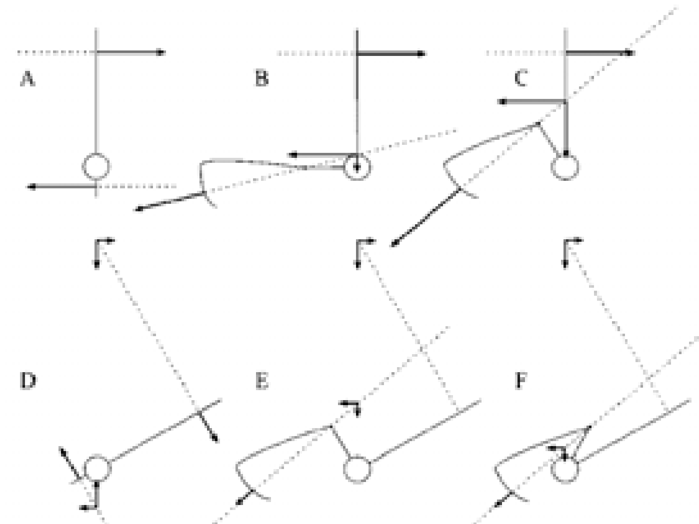


Fig 12: Additional stability provided by a hinged foil to weather, compared to a conventional daggerboard. A, B and C show the upright boats with board and low and high attachments for the hinged foil. In D, it may look as if the calculation of heeling moment through intersection of force vectors with the buoyancy plane is wrong, because lever arms increase with heel angle. However, for this way of calculating heeling moment only the intersections with the buoyancy plane of the horizontal components of the force vectors matter, and those decrease exactly as quickly as lever arms increase; so the two effects exactly cancel. The horizontal components of the forces are the same for all boats. B, C, E and F show the shorter lever arns of the horizontal force components and corresponding lower heeling moments when using the hinged foils. The low hinge provides less initial stability, but more final stability, than the high hinge.

How much benefit can an inboard stabilising foil be expected to give? If it is not possible to move the hinge out, should it be moved up? Figure 12 shows the stability derived from a foil only (ignoring all other sources of stability), compared to a board or keel of the same depth. For simplicity, I have assumed a cylindrical hull, and attachment points that differ from each other only in their initial angle to the horizontal. I have also made the simplifying assumption that sail force decreases with the cosine of heel angle. Since doing

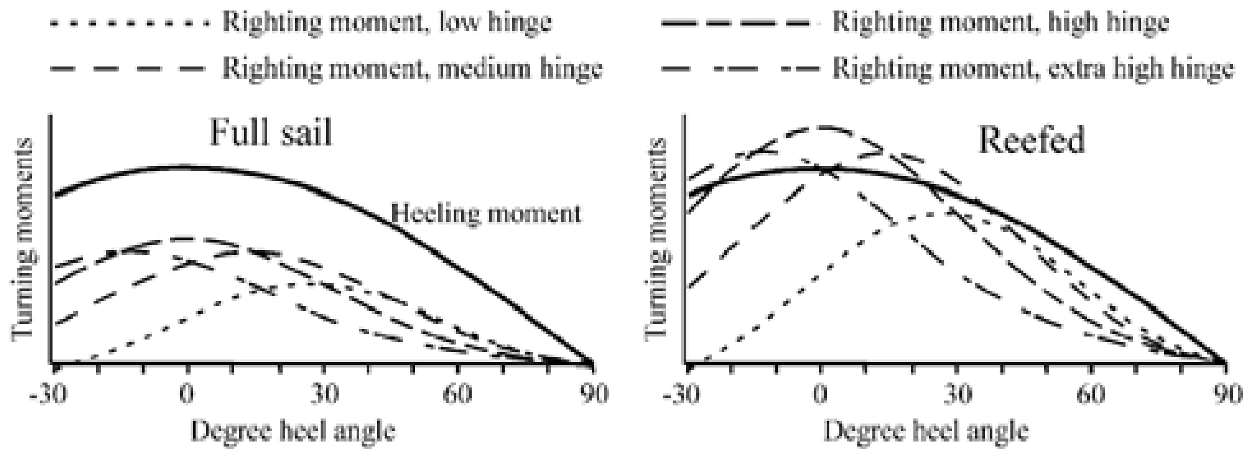


Figure 13. Heeling and righting moments for the boats of figure 11 with full sail (left), and when deeply reefed (right) with wind speed increased to produce the same heeling moment.

The heeling moment is calculated for the boat with a daggerboard, and is shown by the continuous curve. The reduction in heeling moment offered by the hinged foils has been plotted as a righting moment, and is shown by the various stippled lines. The foils generate righting moment from lateral force. That force decreases as the boat heels, and so the righting moment provided by the foils decreases accordingly. (I ignored windage of the hull, which would make the hinged foils look better.) The low hinge corresponds to the one shown in figure 11b and 11 e, with the arm that holds the hinge at an angle of 0º to the horizontal when the boat is upright. The medium hinge corresponds to an initial angle of 30º, the high hinge to 60º (same as shown in figure 11c and 11 f), and the extra high hinge has an initial angle of 90º, i.e. it is attached to the mast.

the calculations, I have read that hard on the wind, sail force decreases somewhat faster than that as the boat heels, on a broad reach slower.

It is already clear from figure 12 that the low hinge gives less initial stability, but more final stability. Multihulls have plenty of initial stability, and if stable hull flying is desired, it is necessary to increase stability once the hull does fly. Therefore a multihull may benefit more from a low hinge.

Figure 13 shows a simple quantitative analysis of the boats in figure 12, with two more hinge positions. As the hinge position goes up, maximum stability is reached at lower heel angles, at the expense of final stability. I calculated righting moments when deeply reefed, with enough wind to produce the same heeling moment again. The relative sizes of lever arms change, so the righting moment curves are higher, but their shape stays the same. Where a righting moment curve intersects heeling moment, there is a point of equilibrium, and the foil alone can keep the boat upright, without other sources of stability. An equilibrium is stable if the righting moment curve grows higher than the heeling moment curve at larger angles of heel. Looking at the reefed boat, where there are such intersections, it turns out that for the extra high hinge, there is no stable equilibrium at all (see also figure 3). The high hinge has a stable equilibrium when the boat heels 23º to weather, but the boat will capsize to lee if heeled more than 24º. The medium high hinge has its stable equilibrium at 1º of heel, and becomes unstable beyond 38º. The low hinge never quite manages to counter heeling moment on its own, and always depends on the boat having other sources of stability.

I have done similar calculations taking into account the stability of a hypothetical proa. Without hinged foil the boat becomes unstable as soon as it flies the weather hull. With a low hinge foil, the boat can fly the hull in a stable equilibrium, and the stable range extends over another 30º or so. With a high hinge foil, the equilibrium is at lower heel angles, the stability range is narrower, but the maximum stability is quite a bit higher. All this can be seen in figure 14. Even stabilising foils between the hulls can make a substantial contribution to stability.

I have concentrated on proas, because stabilising foils can easily be mounted so that they pitch with

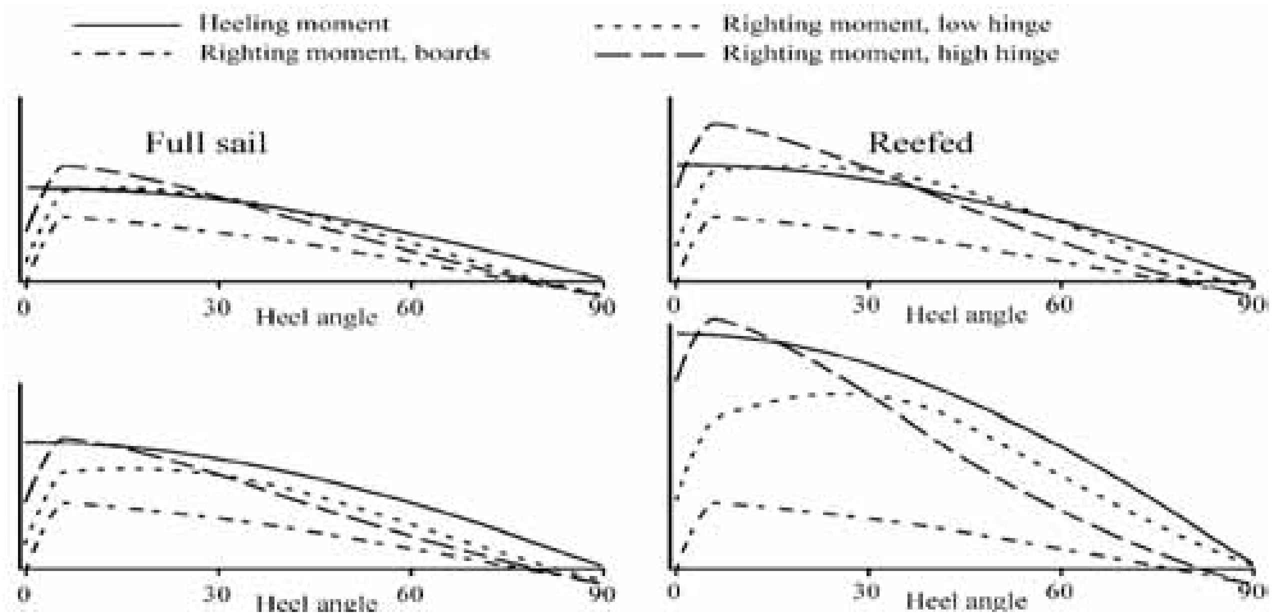


Figure 14. Combined stability from buoyancy, weight and stabilising foils in a hypothetical proa. The foils are mounted as in figure 10, with crossbeams going over the foil attachment and the weather hull just beyond the foil. The low and high hinges are as in figure 11. On the left are heeling and righting moments with full sail, at two different wind speeds. On the right is the same when reefed. The righting moments of the boats with stabilising foils depends on lateral force, so it changes with wind speed. The foils substantially increase stability and make flying the weather hull dynamically stable.

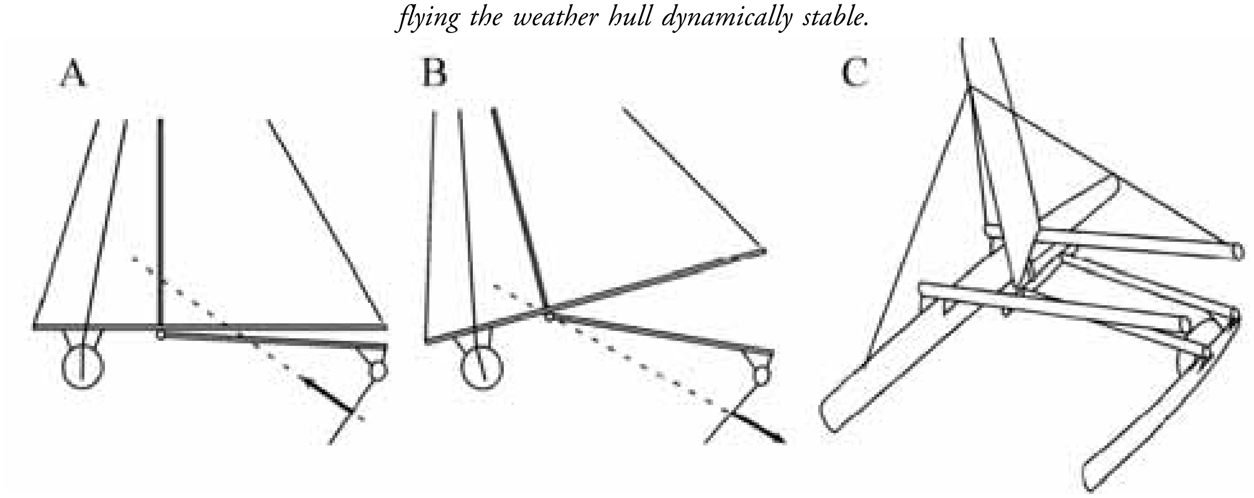


Figure 15. Hinged Bruce foiler. A) With the foil to lee, the upper beams rest on the lower beams. Putting a fender there to absorb shocks would probably be a good idea. The Bruce foil must have a steeper dihedral angle than usual, to allow for heeling of the foil when it is to weather. The boat would have to be quite wide to get non-heeling from the foil alone, and it would be easier to let an ama take some of the load. B) For reliable surface tracking with the foil to weather, the force from the foil alone when only the tip is in the water must pass above the hinge. Using a straight foil as shown here, the ama is pulled down until the combined force vector goes exactly through the hinge. If it is pulled down too much, a curved foil can take the foil force vector closer to the hinge without losing surface tracking, but then more buoyancy is needed with foil and ama to lee. With the hinge position shown, stabilisation is only moderate, but the hinge does not have to be under the mast. That merely seems structurally convenient. C) The length of the ama is excessive for the beam arrangement shown, but I could not get the perspective to look right for a more sensible beam arrangement. The length and buoyancy distribution of the ama is as intended: it will be pushed or pulled down on both tacks, lifting the bow. A vice, the need for buoyancy as well as a foil, is turned into a virtue.

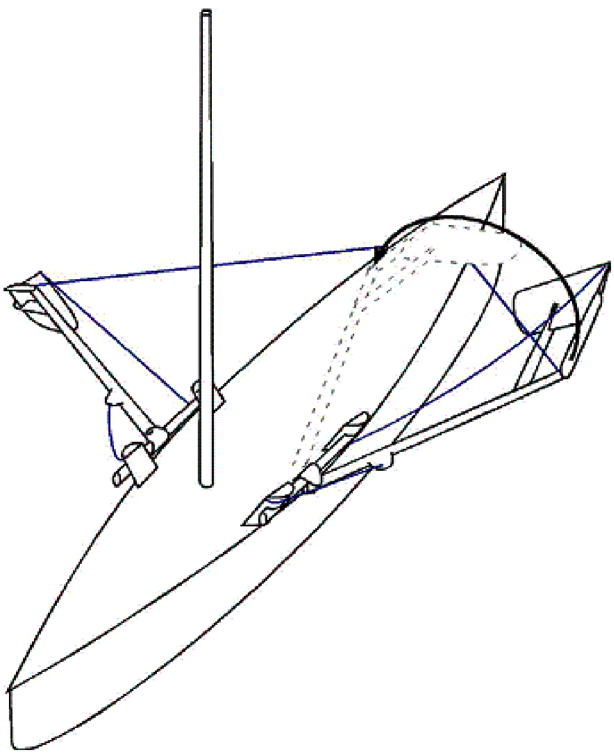


Fig 16.

the boat and they cannot swing about and hit the hull, yet they can be used either without having to retrieve foils at all, or with a very simple retrieval mechanism. These features can also be designed into a hinged Bruce foiler. Another look at figure 3 will show why a rigidly attached foil does not quite do the job of stabilising a boat in a seaway. The straight foil is not dynamically stable when to weather. But now imagine the two Bruce foilers sailing with the foil to lee. Reverse all arrows. Now it is the boat with the curved foil that is unstable. For any rigidly attached Bruce foil, if the foil is curved enough to give dynamically stable roll control when the foil is to weather, it is also curved enough to be unstable when to lee, and vice versa. It is possible to curve the foil just enough that it is indifferent to immersion depth, but dynamic stability is what's needed, not indifference.

Dynamic stability can be achieved through using a hinged, straight foil, that has a limited range of rotation upwards (figure 15). Then the foil must be angled so that the resultant force vector still passes just above the hinge when only the foil tip is in the water. When the whole foil is in the water, the resultant force vector is a bit higher still. A small ama can balance this turning moment that otherwise would pull the foil underwater. Having some buoyancy there is a good idea anyway, because unless the boat is very wide or the hinge quite high, the foil will not balance the whole heeling moment of the rig when to lee. The ama can be mounted well forwards, so that its immersion will counteract nosediving. The boat would need hiking out with the foil to weather, but would have a quite benign heeling response. In contrast to most Bruce foilers, the foil should stay hooked in even when to weather in a seaway. And no foil needs to be retrieved when tacking or gybing.

It is also possible to have a conventional lifting foil or hull forward and a hinged foil aft. The boat would look like the proa in figure 10 with the forward hinged foil removed and a lifting foil under the ama. Retrieval of the hinged foil is by pulling a string. Then the boat could be completely foil-stabilised on both tacks. These styles of hinged foil require rather specialised designs, in the case of the tacking Bruce foiler one specifically dedicated to foil stabilisation. Few people will build a boat just to try out a largely untested idea, so more widespread experimentation will depend on foil designs that can be used on existing boats. Figure 16 shows a suggestion for a sailing canoe. The idea is again that the foil pantographs, though here the second part of the pantograph arrangement is simply a line. The pivot is attached just far enough forward that the boat would turn into the wind and stop if the foil is not pulled aft by a second line. A third line attaches to the beam from the front and above. When the foil is to lee and starts to trail behind, that line limits how far the foil and beam can drop down. The foil could be retrieved by flipping it up onto deck, but there it would take up rather a lot of space. Possibly the space problem could be addressed, at the cost of rather greater complexity, by introducing an elbow joint into the beam. A simple alternative would be not to retrieve the lee foil at all, using a more rigid, non-pantographing beam arrangement. I hope to try that out on a model boat.

Dave Culp has pointed out that, in a steady state, ballast is more efficient than a hold-down foil because it can provide the same stability without the added induced drag. Conditions at sea are rarely all that steady, so in the absence of active control, ballast would need to be enough for the worst case, while the foils adapt to conditions. Therefore foils could work out faster on average.

Rob Denney pointed out a potentially rather more serious problem. If the foil picks up a plastic bag, or if the boat hits anything that slows it down enough, the foil will lose its grip. In the case of a multihull, there would only be any point in using a foil when there is enough wind to capsize the boat without foil. Loss of the foil's righting moment therefore would be quite likely to lead to a capsize.

Until more is known about how probable this scenario is, I would only use these hold-down foils on a boat that either self-rights, or that can be righted by the crew.

I have explored the potential of hinged, but otherwise rigidly attached foils because I worry about retrieval in heavy weather, and collision with the boat of hapas attached by string. That should not detract from the fact that string-controlled hapas are much easier to build and to attach to existing boats. At the present state of development, they can be used to provide stability, lateral resistance and self-steering for a variety of boats. They look especially interesting for cruising dinghies and sailing canoes, but even offshore cruisers may get some benefit from using hapas as mobile flopperstoppers, to reduce rolling. I can't think of anything in AYRS publications easier to build and to experiment with. I hope the exploration, in this article, of the possible benefits of a variety of stabilising foil arrangements will inspire others to try them out.

Robert Biegler
Trondheim, Norway
First written in 2001, updated April 2005

Related work well worth reading:

Paul Ashford described his hapa developments in AYRS 108 and AYRS 114. He designed the anchor dog.

Edmond Bruce came up with the idea of using a single stabilising foil that pushes up when to lee and pulls down when on the weather side. Information on Bruce foilers is in 'Design for Fast Sailing' and many other AYRS publications.

Didier Costes has developed sea dogs or hapas since the 60s. Some of them are described in AYRS 118.

Prof. Hagedoorn analysed the stability of straight, curved and hinged Bruce foils (AYRS Airs 2) and came up with the idea that a sailor could just be suspended between a stabilising foil and the sail ('Ultimate Sailing', reprinted in AYRS 114). Fritz Roth has used rigidly attached curved Bruce foils on proas for many years. The rig he uses inspired the one shown in figure 2. His designs are described on http://www.proagenesis.org

Sid Shutt described in AYRS Airs 8 a hydrofoil trimaran stabilised by a single foil to weather. A surface sensor adjusted the angle of attack of the stabilising foil and so regulated the amount of force. The stabilising foils described in this article work by changing the direction of force instead.

Giles Whittaker is developing stabilising foils for one-way craft that tack and gybe. The racing proa was inspired by his work. He described his designs in AYRS Catalyst 13.

A Letter to the Readership of the *Catalyst*

A recent telephone conversation with Mr. Richard Boehmer, of the Sail Performance Center in Massachusetts elicited the following information (Mr Boehmer is a valued contributor to the *Catalyst*).

Mr Boehmer has been following of late, among other things, the "Coffee" race, the proper name being Transat Jacques Vabre. This is a race from Le Havre, France to Salvador (Bahia), Brazil. The race fleet is composed of 50 foot and 60 foot catamarans and trimarans and monohulls. The longer multihulls, because of their supposedly superior speed, have to circle around Ascension Island, thus making their route longer. Rich informs me that the winner of the race was a 50 foot tri, *Crepes Whaou* [II]. He mentioned that there appeared to be an inordinate amount of structural failure among the 60 foot ORMA trimarans. The basic question is: Is bigger better?

The smaller boats may be easier to get to their ultimate speed crew ability-wise than the larger boats. The extra ten feet may add an disproportionate amount of physical stress and structural stress and breakage. Rich also has some data on cost differences between 50 footers and 60 footers. Some cost data wrung from Rich shows the following. The extra 10 feet on a tri may cost as much as three times the cost of a 50 footer, and easily double the cost of a 50 foot mono versus a 60 foot mono. An analysis of what broke and under what circumstances, would be interesting if we could get some handle on safety factors involved in the various designs, but that is extremely unlikely I suppose. It would not be too difficult to get the breakage data I hope for further analysis. Was it mast, shrouds, the cross beams, hull splitting, etc.

As I remember vaguely from the dark ages, Sir Francis Chichester, made the comment that he wished his boat, the Gypsy Moth IV was a bit smaller. Rich says it was 54 feet in length. So I again suppose we will not know if bigger is better until some future time. The germ of an idea may be here but I am not sure exactly what it is. In this same conversation, Rich touched upon trends in monohull design which permit hulls to go considerably faster than the previously suggested parameters limiting that speed. So we might have hull design associated intimately with statistical analysis of races, if it is not already being done. Rich could have all the data! So much to do, so little time.

Sincerely,
Frank Bailey
Toad Hill Boat Shop

Letters (continued from Page 5)

J S Taylor

I currently am trying to locate J. S. Taylor or his heirs in Australia, his home country.

The only info I have came from an article written for Sea Spray magazine in June 1968 where it shows some complete designs he did for the Singapore government. The 26' cruising pac proa "Drua" and a 60' racing proa called "Fiji". In this same article, info about Botje III is included also.

Hopefully I can locate the plans for these vessels.

If Mr. Taylor is still living, he will be very elderly.

If anybody has any information, could they please get in touch.

Regards,
Doug Derbes
dougderbes@yahoo.com

Catalyst Calendar

This is a free listing of events organised by AYRS and others. Please send details of events for possible inclusion by post to Catalyst, BCM AYRS, London WC1N 3XX, UK, or email to **Catalyst@ayrs.org**

January 2006

6th - 15th London International Boat Show
EXCEL Exhibition Centre, London Docklands. Those who can give a day or two, from 28th December onwards, to help build/staff the AYRS stand (reward - free entry!) should contact Sheila Fishwick tel: +44 (1727) 862 268; email: office@ayrs.org

22nd All-Day AYRS Meeting
9.30am-4pm, Thorpe Village Hall, Coldharbour Lane, Thorpe, Surrey (off A320 between Staines and Chertsey – follow signs to Thorpe Park, then to the village). Details from Fred Ball, tel: +44 1344 843690; email frederick.ball@tesco.net

22nd AYRS Annual General Meeting
4pm, Thorpe Village Hall, Coldharbour Lane, Thorpe, Surrey (as above). Details from the AYRS Hon. Secretary tel: +44 (1727) 862 268; email: secretary@ayrs.org

February

1st AYRS London meeting
Subject to be confirmed. 19.30 for 20.00hrs at the London Corinthian Sailing Club, Upper Mall, London W6 9TA. Location Map: www.linden-house.org. Contact: AYRS Secretary, BCM AYRS, London WC1N 3XX, UK; tel: +44 (1727) 862 268; email: office@ayrs.org

March

1st AYRS London meeting
Subject to be confirmed. 19.30 for 20.00hrs at the London Corinthian Sailing Club, Upper Mall, London W6 9TA. Location Map: www.linden-house.org. Contact: AYRS Secretary, BCM AYRS, London WC1N 3XX, UK; email: office@ayrs.org

April

5th AYRS London meeting *to be confirmed*
19.30 for 20.00hrs at the London Corinthian Sailing Club, Upper Mall, London W6. Contact: AYRS Secretary, BCM AYRS, London WC1N 3XX; email: office@ayrs.org

7th-9th (Dates to be confirmed)
***Broad Horizons* – AYRS Sailing Meeting**
Barton Turf Adventure Centre, Norfolk UK, NR12 8AZ. Contact AYRS Secretary , BCM AYRS, London WC1N 3XX, UK; email: office@ayrs.org. Note: All boats limited to 1.2 metre max draft!

23rd Beaulieu Boat Jumble
AYRS will be there !

29th-5th May AYRS boat speed tests
To be confirmed. Portland Harbour, Dorset, UK. Shore location to be confirmed. Contact: Bob Downhill; tel: +44 (1323) 644 879

October

14th-20th Weymouth Speedweek
Portland Sailing Academy, Portland Harbour, Dorset UK.

18th AYRS Weymouth meeting
Speedsailing. 19.30 for 20.00hrs at the Royal Dorset Yacht Club, 11 Custom House Quay, Weymouth. Location Map: www.rdyc.freeuk.com. Contact: AYRS Secretary, BCM AYRS, London WC1N 3XX; email: office@ayrs.org

November

1st AYRS London meeting
Subject to be confirmed. 19.30 for 20.00hrs at the London Corinthian Sailing Club, Upper Mall, London W6 9TA. Location Map: www.linden-house.org. Contact: AYRS Secretary, BCM AYRS, London WC1N 3XX; email: office@ayrs.org

December

6th AYRS London meeting
Subject to be confirmed. 19.30 for 20.00hrs at the London Corinthian Sailing Club, Upper Mall, London W6 9TA. Location Map: www.linden-house.org. Contact: AYRS Secretary, BCM AYRS, London WC1N 3XX; email: office@ayrs.org

AYRS MEETING - Sunday 22nd January 2006, 0930 - c.1600 hrs
Thorpe Village Hall, Coldharbour Lane, Thorpe, Surrey

Projects, Progress and Theories

Be prepared to talk about your own projects, and/or to comment upon other people's! There is space to display small boats.

An OHP and video/DVD/PC+projector will be available.
Tea and coffee provided, but bring your own lunch.
No charge, but donations will be invited to defray the costs.

More details from Fred Ball, tel: +44 (1344) 843690;
email: frederick.ball@tesco.net

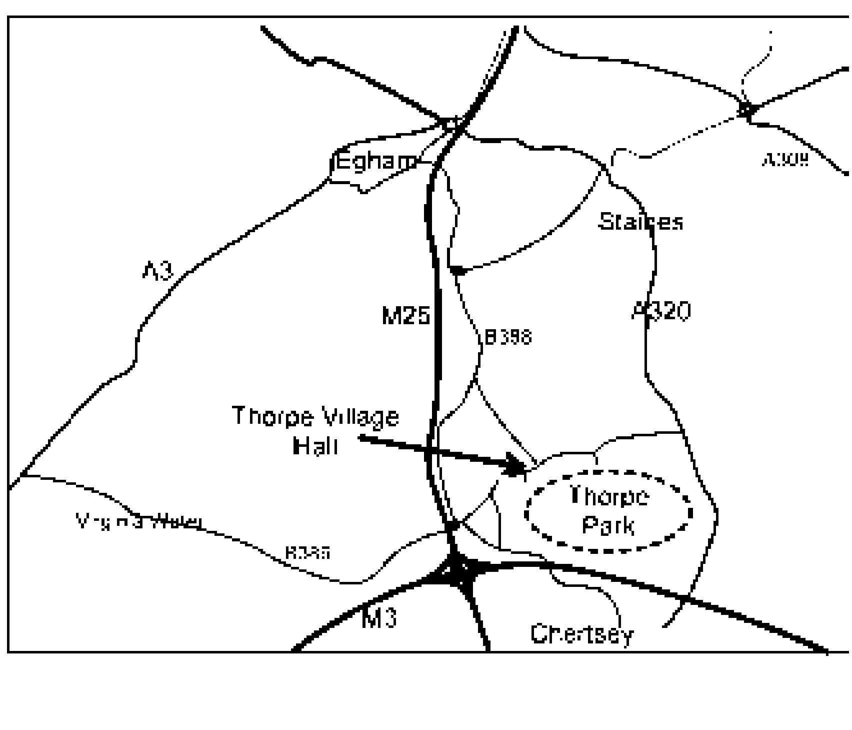
The day will end with the AYRS Annual General Meeting.

How to get there

Thorpe Village Hall is in Coldharbour Lane, off the A320 between Staines and Chertsey, close to Heathrow Airport, and to Junctions 13 (Staines/Egham) and 11 (Chertsey) of the M25.

From the North, leave M25 at Jn 13, go into Staines, follow the signs for Thorpe Park and turn right opposite Penton Hook Marina (signposted Thorpe Village). From the South/West exit at M25 Jn 11, and also follow the signs to Thorpe Park, but drive past it on the A320, and turn left to Thorpe Village.

Note: There is a car park st the rear of the hall, but space is limited, and the street parking regulations limit local parking. It may be necessary to park outside the village and walk in a few hundred yards.



Catalyst — *a person or thing acting as a stimulus in bringing about or hastening a result*

On the Horizon . . .

A different approach to Sail Design & Construction — Ken Coles

Stingray - Patrick Wheeler

Tri-foiler project update — Peter Jefferson

Rotorboat — Stephen Thorne

....

Amateur Yacht Research Society
BCM AYRS, London WC1N 3XX, UK

Printed by HenDi Systems & Communications, London N1 6DL.