Catalyst

Journal of the Amateur Yacht Research Society

Number 33 January 2009

SUNDAY 3rd MAY 2009.

Get yourself sponsored and come and join many hundreds of other windsurfers on the water (at their own local location or at Hayling Island).

At Hayling you can join some of the top windsurfers (Dave White and others) on the water. Many will be on the water at "Sunrise". However you do not have to sail ALL the day, just get sponsored and on the water.

Join the many windsurfers who will take to the water that day. They will become part of a new national record for the "most number of windsurfers recorded in a single event on the water on one day".

However this event is not just about setting a record because it is all about promoting Cancer Awareness amongst fellow windsurfers and, through specific projects, (SunriseSunset is the first such event) to raise funds in aid of Cancer Research UK.

Please get sponsorsed and get on the water. If you can make it to Hayling Island that will be great but you can also do "your own thing" at your local venue.

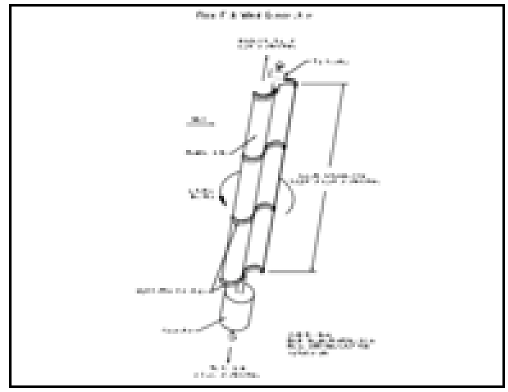
The Weymouth Speed Week team is pleased to offer its support and help launch this event. If you would like to contribute in any way please email support@sunrisesunset.ws and we will include you in the plans.

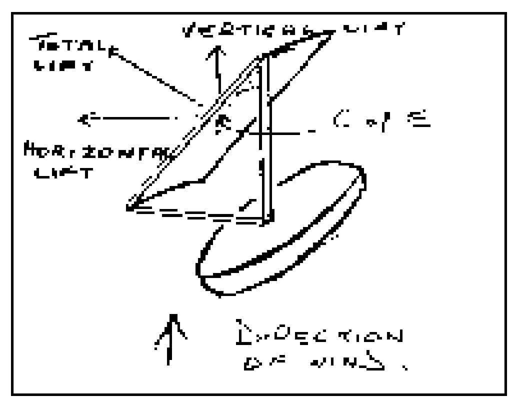
Features

Regulars

Cover Picture
Jack Goodman's Flex Foil Wind Generator in its operating position

(Photo: Goodman)





Catalyst

Journal of the
Amateur Yacht Research Society

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This issue of Catalyst was started, as the cover date implies, in January 2009. Business commitments however got in the way, so it's completion has taken about nine months.

That means I'm at least two Catalyst issues behind my target of four issues a year.

I will try to catch up, but I do need your help.

I think I have enough articles to do the next two issues. But after that there is very little. So, I need some good articles to fill future issues.

So what makes a good article?

Well, first it needs to be interesting. It needs to be something to which AYRS members, either in actuality or in their imagination, can relate. It needs to get its message across, without an excessive amount of mathematics in about four to six pages of typescript plus a similar number of pictures or graphs, making about an eight-page article in all. Ideally longer articles should be breakable into parts, each meeting the above criteria.

In writing that, I am running the risk of being accused of "dumbing down" Catalyst. My defence is that if the essence of an idea or a project cannot be got across in that sort of length then it is probably too obscure for Catalyst, and maybe should be worked up into a monograph. Complex mathematics may have its place, but that place is in an appended sidebar. Only the results belong in the main text, and those are best presented, if possible, in graphical form. Think of a Catalyst article as a presentation – pictures plus words – and you'll get the general idea.

Contrary to popular belief, we do submit articles to a level of peer-review. The primary reviewer is me. I am a university-trained professional engineer, and I've been messing around with odd boating ideas since the 1960s. If I cannot understand an article then it's probably out of scope. If the field is not one I am familiar with then there are other people I can call on. I also filter out articles on things that turn out to be perpetual motion machines, where there is no obvious energy source matching the energy expended. (We do get a few of these; and no, DDFTTW was not one of them!)

The second stage of review is the AYRS Secretary, who is also a graduate scientist, with a flair for design. She checks for readability, comprehension and presentation. If she cannot follow the thread of an article then it probably needs editing. She also does the proof-reading and is critical of my layouts.

The final stage of review is you, the Catalyst reader. The letters pages are for your feedback, and for critical discussion of ideas.

So please, put pen to paper, or better, finger to keyboard, and send me your articles. Technical guidelines are inside the back cover, but the important bits are the words and pictures we need to get your message across.

Simon Fishwick

Macquarie Innovation takes a record at 48.15 knots

On the 13th October, MI made four runs along the Sandy Point speed sailing course, the best of these reaching 45.32 knots as an average speed and included a peak recorded speed of 48.40 knots. While this effort was unremarkable in the context of the world record chase, the fact that it was achieved in only an average of 15.4 knots of wind was in itself a new milestone for our sailing performance. This effort signalled not only that the developments made to MI had again further improved its efficiency, but more importantly, it clearly identified that the team were now well within range of the world record in winds under 20 knots.

Unfortunately, they had to wait a further 2 months before they had appropriate weather to make a serious attempt at the record. But the perseverance finally paid off and on 19th December, they were able to run MI in clear winds on a part of the Sandy Point course that was not affected by the growing sand hills. MI completed six runs on this day, the best of which was timed at 48.57 knots over the 500m course with a peak speed of 51.47 kts. Due to the tidal variances on the course, this figure will be revised to 48.15 kts but it still allows them to claim a new world record in our sail area division of C class as well as the title of the fastest sailing boat in the world. Furthermore, this world class effort was achieved in an average wind speed of only 17.2 knots making this not only the fastest sailing boat, but also the most efficient sailing craft to have ever held a World Sailing Speed Record.

"It was a great day for the team and just reward for their perseverance and dedication to a goal that has been within reach for so long. Since first exceeding 50 knots in 1993 with our original craft Yellow Pages Endeavour, the team have been very confident that this design could sustain these speeds for the required 500m. We remain keen to be the first sailing boat in the world to produce a 50 knot run and are currently evaluating options to further improve the chances of achieving this goal.

We would again like to take this opportunity to thank all those who have provided such tremendous support over the years. We are proud to be presenting an all Australian designed, built and campaigned craft and having it perform at such a world class level. The support provided to the team by all its well wishers has been overwhelming and is pivotal to our quest for 50 knots!"

Macquarie Innovation at 48 knots. Photo: Steb Fisher

... but l'Hydroptère capsizes at 61 knots

On 21st December, l'Hydroptère attained a spectacular speed peak of 61 knots during her first run.

The wind conditions were very strong, with winds established at 35-38 knots and gusts of over 45 knots. The water surface was rough, which made sailing difficult. (See video at www.hydroptere.com).The gust that permitted l'Hydroptère to attain this extraordinary speed, unfortunately also caused her to capsize.

"The gust of wind was very violent, l'Hydroptère *was in full acceleration at over 61 knots, when she stopped and capsized,"* tells Alain Thébault briefly as he organizes the towing of the boat with his crew members, all who have come away with only slight injuries.

Now, l'Hydroptère team is motivated by a double objective: the absolute speed record (an average of 50.57 knots over 500 meters), as well as an open-sea record, the longest distance travelled in 24 hours. For that reason, the lower part of the foils, having demonstrated proper functioning at the target speed of 55 knots, will be preserved. The upper part, not sturdy enough for sailing in waves, will be modified.

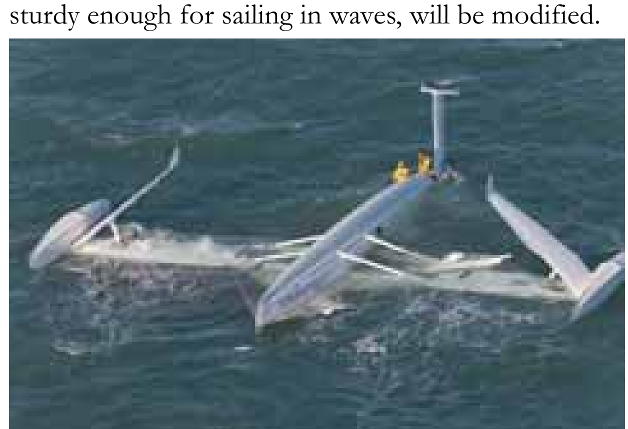


Photo: Gilles Martin-Raget

The Delta Sail Project - Fansail

I refer to Malcolm Henry's Delta Sail Project as featured in July 2008 Catalyst No 31. I also studied the same configuration using a Fansail in the late eighties. As some will remember the Fansail was a windsurfing sail flexibly attached to a board at the junction of the two masts. Being of symmetrical shape downwind turns could be performed without gybing. For boat applications, I mounted the boom of the Fansail (which held the two masts apart) flexibly onto the stubby mast which was rigidly mounted to the boat in the same manner as Henry's model. I also designed another version for windsurfing where the stubby mast was flexibly mounted to the board as per windsurfer universal joint fashion and the Fansail on the stubby mast as before. Whilst realising this has many degrees of freedom and would be difficult to sail it would have huge manoeuvring possibilities and could be of some fun. It could have restraining elements built in to limit the freedom and facilitate control. I took out patent applications for each but let them lapse.

I will say I still rather favour the concept. I have attached a photo of the model I made at the time.

Torix Bennett

Damned DDWFTTW!

I've just woken from a bad dream. Can the following scenario convince my fellow doubters? Or can they convince me that it is impossible?

1) Jack Goodman's machine is stationary pointing downwind.

2) The brake is taken off and the windage of the whole structure (chassis, pylon and stationary fan blades) starts it moving

3) The fan rotates gently to create a virtual circular spinnaker.

4) As the vehicle moves faster the fan generates a moving column of air so the virtual spinnaker is now moving towards the wind.

5) Assuming no losses (impossible but stick with me) when the machine is moving at true wind speed DDW the virtual spinnaker is moving at 1.6 x True Wind Speed (gear ratio of machine) giving a potential speed of 1.6 x V_T.

IF losses are no more than 27%, DDWFTTW has been achieved.

NOTES

a) I have deliberately used the word fan rather than propeller as the scenario needs the virtual spinnaker concept.

b) We accept that ice yachts and high speed boats tack down wind by accelerating the wind past the vessel

c) My armchair may have earned its keep!

Fred Ball

Sails

Something I've noticed about projects written up in Catalyst, is that often the rigs and sails used are whatever was to hand; begged, borrowed or otherwise acquired, and frequently not ideal to go with the "boat".

This is understandable - if your interest is in developing a novel hull, then designing (and paying for) the right rig to power it is going to be a long way down your list of priorities. However, at some point, depending on the project, it may become important to work up the rig.

This e-mail was prompted by the sight of Kim Fisher's Dart rig on the front of Catalyst 32 (October 2008). I used to race Darts and, although I experimented with trying to flatten the main by having no downhaul tension in VERY little wind, it didn't work. From the ripples and the way the dinghy in the background is sailing, there's enough breeze to set the sail properly. As this is obviously not a Dart, I would replace the downhaul with a much more powerful purchase so that it can be used to flatten the sail for stronger winds.

Another point about the Dart rig is that, although the jib is quite small, it adds a surprisingly large amount of power by improving the airflow across the back of the main.

Anyway, good luck to Kim. The Dart rig is maybe good for 20kn, but no way 50 or 60 (if L'Hydroptere ever holds it together)!

Chris Gould
Lochwinnoch

Vortex Eliminator End Plates

In 1979 or there about the AYRS newsletter had an article on 'Vortex Eliminators', which were wooden plates fitted horizontally to the aft end of a keel. This idea, I believe, was the forerunner to the USA America Cup winged keel.

In 1995 I purchased African Ocean, a Flica 37 cat and sailed it to Dubai, Oman, Africa, Med, UK and back to the Med, and Turkey, where we stayed for 11 years, chartering and as my home. She had the standard Bermudan sloop rig and shallow keels, about 75cms deep with 5cm x 10cm wooden protection strips on the bottom. Draught was 1 meter. My only regret was her light wind performance, especially windward; otherwise she was the perfect craft, full of simple, good ideas. (What other boat do you know has the 'wet' locker warmed by hot air from the fridge unit?) With 15 knots and more of wind she was in her element (17.5 knots whilst in the Red Sea) and I did not bother to reef unless there was 30 knts of wind. Thank you Richard Woods for undoubtedly the worlds best mid sized cat.

By 2001 I had lost the AYRS article but thought that I could remember enough to try these vortex eliminators for myself. I found an off-cut of 50 mm marine ply, enough to make 2 plates, each about 30cm by 60cm.After painting I screwed and glued them onto the aft end of the keels, so that they looked like two small wings. I had no idea as to the recommended size or the exact position but as the total cost was less the 50p (for the SS screws) I was not worried. These plates were still on her, undamaged even after a 45 Knt blow, when I sold African Ocean five years later.

What a difference they made to African Ocean's light wind performance! I can conservatively say she pointed 5 degrees higher and increased speed by almost one knot. A Prout 37 belonging to an oppo no longer out-sailed me, which she did before. Once the wind increased over 10 knots and the waves built up there was no noticeable difference.

I would not hesitate to put the same vortex eliminator plates on any boat – and if I had the original article concerning dimensions and position maybe they would be even better!

David Jackson AFM
Yachtmaster Instructor.
Turkey
africanoceansailing@yahoo.co/uk

Some remarks on the Catalyst.

I appreciate the Catalyst publications a lot. It amazed me to read about experiences with the Delta sail project in nr. 31. To inform you about the practical use of the original crabsail rig used on Polynesian canoes, I mention the site www.lapita-voyage.org which gives details of the two 11.50 m. long canoes used on a voyage of about 3800 nm. from the Philippines to the solitary islands Tikopia and Anuta far east of the southern tip of the Solomon islands. This boats designed by the Wharram office, are skippered by James Wharram and Hanneke Boon plus various crews on the canoe named Anuta and the German Klaus Hympendahl plus varying crewmembers on the canoe Tikopia.

Many pictures on the site and a fine map showing the progress of the voyage.

My compliments for the production of the magazine. This always is hard work. Personally I am stiil active developing details of the rating system for multihulls and discussing design details. This Texel rating system is not only used for racing but even more for informing owners about the performance they can expect of their vessels and how they can experiment, on paper (screen), with modified rigs etc. A virtual world too.

Please tell me if the AYRS now can receive Euros indeed. [We can - Hon. Sec] It is my task then to use the IBAN nr. and BIC code to instruct the paying on the same bank as I do now. It looks silly to put banknotes in an envelop and use snailpost.

Always make new mistakes. (Esther Dyson). My motto, which I need many times

Best wishes
Nico Boon

John Hogg Prize for 2008

On 10 January 2009, the Amateur Yacht Research Society announced the award of its John Hogg Prize for Innovative Yacht Research to Jack Goodman, of Florida, USA, for his "Flex-Foil Wind Generator", a stowable generator system that can be hoisted in the rigging of a sailing yacht. A description of the entry is published in this edition of Catalyst..

The announcement was made on the AYRS Stand at the London International Boat Show. Unfortunately Mr Goodman was unable to be present, so his prize of £1000 will be sent to him.

The runners-up are:

• Kim Fisher for his investigation of "Aquaplaning Wheeled Sailing Yachts"(published in Catalyst 32)

• Sven Yrvind for his small emergency sextant known as "Bris' Sextant" (published in Catalyst 32)

The other nominations (in order of surname) were:

- Richard Dryden -- Delta-shaped Sails(published in Catalyst 33)
- Malcolm Henry -- Improvements to a Delta (CrabClaw) Sail (published in Catalyst 31)
- Jon Montgomery -- Powersail - a design for a speed sailing boat (published in Catalyst 31)
- Sven Yrvind -- His Small Voyaging Boat (published in Catalyst 32)

The John Hogg prize was established by the Amateur Yacht Research Society in December 2000 to be awarded in memory of John Hogg, the distinguished yachting researcher, founder of Spinlock Ltd, who died on July 24th 2000. The prize, of a value of £1000, will be awarded for the most meritorious contribution to innovation in yacht science made by an amateur researcher. The prize was established by his family to celebrate John's life and work. The prize is open to anyone of any country, whether or not they are members of the Society.

Award of the Prize was adjudged by a Committee chaired by Michael Ellison, himself distinguished by his contributions to sailing hydrofoils and former Administrator and, more recently, Chairman of AYRS.

The next award will be made at the London Boat Show in January 2011. The closing date for entries will be 1 October 2010. Copies of the rules will be available from the AYRS Honorary Secretary, BCM AYRS, London WC1N 3XX, or email: office@ayrs.org.

Flex Foil Wind Generator

Jack Goodman

I was looking for an alternative source of electrical power to run the autopilot and running lights on our sailing catamaran. The boat has enough solar panels to run everything if there is at least a few hours of sun each day. On one passage we had rain and storms for five days and had to run the outboard motor to keep the battery topped up. A wind generator would have worked great for that trip. Most of the places we sail though have plenty of sunshine, and a wind generator would be unnecessary and in the way. Also, the wind generators on the market have some problems that I would like to avoid, such as:

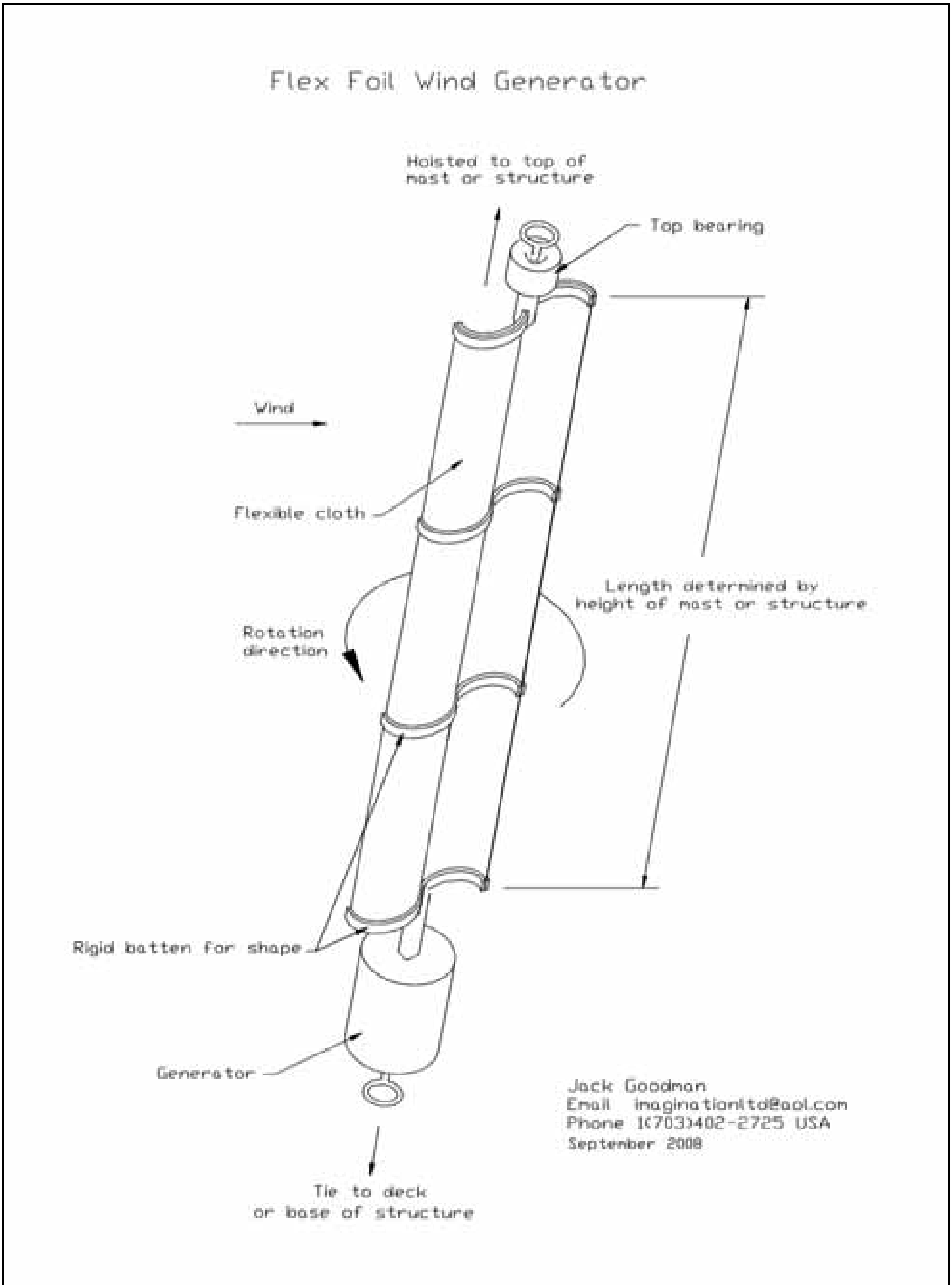
1. they are noisy and expensive.
2. they have to be permanently installed.
3. they have to be mounted high enough to keep them and the sailor from damaging each other.
4. when the wind picks up, most if not all of them have to have the blades tied to keep them from destroying themselves. The braking systems are notoriously unreliable and noisy.

Problems 3 and 4 are in conflict. When the wind is strong enough to require stopping the blades, the wind is howling, the boat is pitching around and the spinning blades look more like a blender. They are just daring you to climb up and try to stop them.

I have always liked vertical windmills because the generator is at ground level and there are no slip rings to deal with. Of course they have their problems also.

1. if the diameter is large enough to generate useable power they rotate too slowly, and need a gearbox to get the generator up to speed.
2. if you make them thin enough to get sufficient RPM, they are not rigid enough to support the length required to get enough area.
3. they are generally not very efficient for a given area.

My solution is a long, ‘S‘shaped, vertical foil made of cloth or similar flexible material about six inches wide. The ‘S’ shape is formed in the cloth by battens spaced every few feet and held in place by tension. The top end of the foil has a ball bearing swivel attached with an eye for hoisting. It is raised to the top of the mast by a spare halyard.


Flex Foil Wind Generator
Hoisted to top of
mast or structure
Top bearing
Wind
Flexible cloth
Length determined by
height of mast or structure
Rotation
direction
Rigid batten for shape
Generator
Jack Goodman
Email imaginationltd@aol.com
Phone 1(703)402-2725 USA
September 2008
Tie to deck
or base of structure

Flex Foil and generator in operating position.

The bottom end of the foil is secured to the shaft of a generator. The generator is simply tied to a cleat or toe rail of the boat with a short line, and held above the deck a foot or two. The flexible foil generators I have built are extremely quiet, are easily put to sleep by dropping the halyard, and can be stuffed in a sail bag when not needed. (See figure 1 and the photos)

I have built several prototypes, two of them forty feet long. I have experimented with split foils and foils of different sizes. The most successful cross sections have been pretty much a classical 'S' shape about five and a half inches across. A smaller cross section gives a higher RPM, but has less area exposed to the wind. I am currently getting about 800 RPM at the working load in 10 knots of wind. More work needs to be done to arrive at the ideal configuration. Anyone who has tried to collect data on sailboat performance using numbers alone knows the difficulty. Wind sheer, speed variability, temperature and humidity make accurate measurements almost impossible. I will need two equal length units working side by side at the same time. One as a reference and one with changes.

So far the best generators I have built make about half of the advertised power of commercial units of the same area. I expect to improve this to some extent, but they will never be as efficient as a propeller driven generator. That said, the power output per dollar can be fairly high, and area is limited only by hoist length.

A few of things that I would like to try with are;

1. tapering the foil, making it smaller at the bottom than the top, to accommodate the wind speed difference caused by shear.
2. different 'S' shapes to raise the working RPM.

3. designs that are more durable, less expensive and easier to build.
4. measuring the lift to drag ratio. It is, after all, a type of Flettner rotor that produces lift as well as mechanical energy. I have noticed that they sag to the side, not directly down wind.

Flex Foil and generator collapsed.

The foils do not have to be vertical, they may be horizontal if the wind direction is steady. Since the foil creates lift, they sag up instead of down.

I do not know the maximum length, but feel that is on the order of one hundred feet for a five or six inch diameter rotor. That comes to about fifty square feet of area, or about the same power output of a five and a half foot diameter windmill.

Since they behave much like a Flettner Rotor, I can envision a boat with an array of foils instead of sails. It would be propelled by the lift generated by the foils as well as by an under water propeller powered by the rotation of the foils. If hydraulics or a traditional gearbox were used, the rotors could have a much larger diameter and even be reefed.

Although Flex Foil powered generators are perfectly suited to sailing vessels, they can be used anywhere there is wind and suitable mounting structure is available. The turbines can be mounted in an array and geared together for use with a single generator.

Biography

Prior to retiring for health reasons, I was an engineering consultant in the Washington DC (USA) area. Over 30 years time, I worked in the medical, fiber optic, materials and liquid handling, military and solar energy fields.

Designing and assembling all sorts of instruments and widgets, has left me with a lot of interesting hardware as well as a small machine shop. When sailing doesn't get in the way, I like to experiment with the fun things I never had time for. Besides the Flex Foil wind turbine, I am currently making a surface foil assisted catamaran dinghy and experimenting with vortex generators on the mast, in front of the main sail.

Email imaginationltd@aol.com
Phone 1(703)402-2725 USA
September 2008

Delta-shaped sails

Richard Dryden

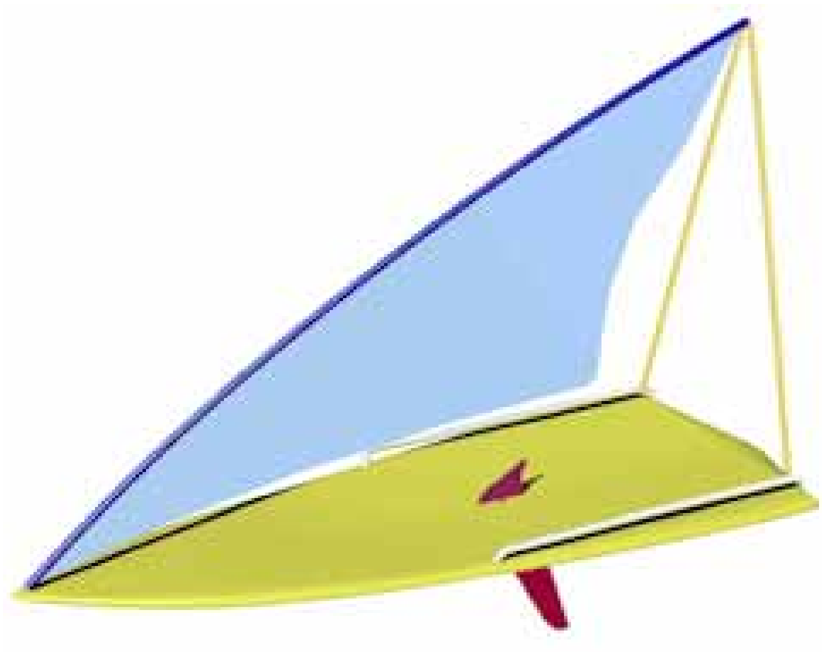


Figure 1*: Idea for Concept Boat competition entry*

Summary

In this discussion about delta-shaped and related sails, experiences with prototype sails are described first. The sails have a forgiving nature, providing significant lift as well as propulsion when sailing off the wind, and produce a relatively small heeling force. The results of a numerical simulation carried out by Adam Ryan are then summarised. In a discussion about the aerodynamics of sails (and wings) that have a conical or truncated conical form, it is hypothesised that vortex production from the tip of the sail is minimised by the curvature of the upper part of the sail to windward, by sweepback, and by washout. It appears that delta-shaped sails are particularly effective because of the way they manage airflow across them in three dimensions.

Definition

A delta-shaped sail has a highly-raked (ie: 40° or more from the vertical) leading edge supported either by a spar or a stay, a foot that is approximately parallel to the surface of the water, and a trailing edge that is approximately vertical.

There are several traditional sailing rigs that carry delta-shaped sails, for example the Lateen and Crab-Claw. A proportion of Jibs, Genoas, and Asymmetric Spinnakers could also be considered within the category of delta-shaped sails as broadly defined above. There are other rigs that carry sails conforming partially to the conical geometry of delta-shaped sails, for example Lug, Junk, Gaff, and Transition rigs – these will be referred to in this discussion as *truncated deltas*.

Introduction

The inspiration for this investigation of delta-shaped sails came from watching films of Australian 18-foot skiffs (*'Awesome Aussie Skiffs'* 1 and 2). These lightweight boats carry a crew of three who can trapeze out from the extensive wings on each side of the boat and carry a proportionately large sail area. In suitable conditions the Aussie skiffs are capable of planing on most points of sail. Sailing downwind, the crew hoists a large asymmetric spinnaker supported from a forestay and the craft follows a rapid zig-zag downwind course gybing from tack to tack. From viewing the films, it became clear that the spinnaker – in addition to generating considerable forward power - also generates lift, holding the bow of the craft up out of the water and reducing the risk of nose-diving into the back of a wave in front.

At the time, I was developing an entry for the Concept Boat 2005 competition. The brief was to design a craft that would encourage families out onto the water, and I was working with the idea of a lightweight craft that could be carried on top the car and that would be simple to sail. I decided that a simple sailboard-like craft would be best, with additional volume (and hence buoyancy) to support additional family members. After considering different sailing rigs, including standard sailboard rigs, I came up with the idea of a delta-shaped sail with a raked, curving spar supporting the leading edge of the sail and an A-frame from the back of the craft supporting the aft tip of the spar (Figure 1).

Test rig

To test the performance of this sail before continuing further with the design concept, I made a test rig for a Fireball dinghy. The spar carrying the sail was made from aluminium tubing bent into a curve and stiffened with spiral layers of carbon tape embedded in epoxy resin. The A-frame was made from aluminium tubing and supported from an aluminium cross-tube at the stern of the dinghy. The sail was cut from an existing Fireball sail and a mast sleeve added along the new leading edge. The curve of the leading edge of the sail exactly matched the curve of the spar so that when it was rigged in still air it hung flat below the spar without any built-in camber. Three horizontal battens were added. These were made from tapered carbon-fibre tubes (fishing rods) which narrowed towards the leading edge. The main sheet was attached to the clew of the sail and acted around a rope traveller tied to the ends of the cross-tube. This arrangement allowed trimming tension to be applied to the sail both downwards and backwards.

Onshore with the rig aligned appropriately towards the wind, it was clear that the unrestrained sail had a tendency to billow to the side and lift up (Figure 2). As it billowed, curvatures appeared both from front to back across the sail (horizontal camber) and from top to bottom (vertical camber). As a consequence of the curvature of the mast, the more the originally flat sail moved out to the side, the greater this 'ballooning' effect became. This can best be understood by thinking about the situation where the sail has lifted until it is flying almost horizontally alongside the spar. In this position, looked at from above, the spar appears straight and the curved leading edge of the sail has to conform with it. This results in slackening of the cloth between the mid region of the spar and the foot of the sail, encouraging cambers to form. This adaptive change in the sail from being relatively flat when sailing close-hauled to being more curved when sailing off the wind contributed to its effectiveness.

Figure 2: *Sail filling and lifting due to airflow across it*

Figure 3: *Sailing upwind*

On the water, the rig performed well (Figures 3 and 4). The spar and A-frame provided a stable, interference-free support for the sail. Compared with more conventional rigs, the low aspect-ratio sail with its correspondingly low centre of effort reduced the capsizing moment produced by gusts and stronger winds, giving the dinghy a more stable feel. In conditions ranging from Force 2 to Force 4 it was relatively easy to set a course and maintain it, and the sail seemed tolerant of sheeting angles. The dinghy could be sailed on all the usual points of sail, although it was noticeably slower on a dead run downwind, particularly in lighter winds. This was probably due to the reduced area presented to the wind by the fully-sheeted out sail. Under these conditions most of the wider aft parts of the sail were flying out almost horizontally to the side of the upper third of the spar, and the wind was being directed forward mainly onto the narrower, more vertical part of the sail near the bow.

To learn more about the airflow across and behind the sail, woollen tell-tales were attached in a grid-like pattern across both surfaces of the sail and streamers attached to the trailing edge at the top of the sail and at batten locations. It could be seen that on the windward side of the sail, the airflow in the vicinity of the surface was being deviated somewhat upwards as it passed from leading to trailing edges. The streamer at the top of the sail streamed smoothly behind with very little fluttering compared with the streamer at the foot of the sail.

Modifications to the rig concept

With the experience gained from the test rig, it was possible to return to the design of the rig for Concept Boat competition entry. To enhance the downwind capability in light airs, I decided to have a double-skinned sail that could be opened out like a spinnaker when required, doubling its area (Figure 5, a). On other points of sail, the two laminae of the sail would remain together (Figure 5, b).

This double-layered approach opened a new possibility for reefing. The batten layout was changed – a lower batten was positioned along the foot of each sail lamina, and then an upper batten was positioned from the front lower tip of each lamina obliquely across the sail to the mid-point of the trailing edge. For reefing, the lower segment of each

Figure 4: *Sailing off the wind*

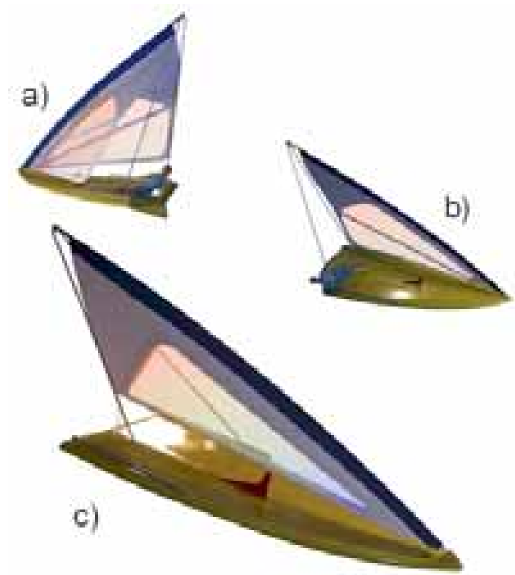


Figure 5: *Different rig configurations – a) sailing downwind with sail laminae separated, b) normal sailing with laminae together, c) sail reefed and A-frame feet moved forwards to lower spar and bring sail foot close to hull*

lamina could then be folded up in between the two laminae and fixed in position so that the upper batten becomes the new sail foot. The sheet for the sail would then be moved to eyelets adjacent to the ends of the upper battens. The sail, now halved in area, could be used either in its normal position to give greater headroom for those on board, or lowered for high-wind use by sliding the feet of the A-frame forwards along the side tubes until the new foot of the sail is close to the board (Figure 5, c).

The design, now called 'Flèche' because of its resemblance to an arrow, was submitted to the competition and later won the concept and design category.

Prototype Flèche

With the prize-money, a prototype Flèche was made (stages of construction are shown at www.transitionrig.com/fleche_prototype.htm). Initial test sailings indicated that a rigid traveller across the stern was needed for the main sheet, but in general the concept worked well (Figure 6). Sailing downwind with the two sail laminae separated proved to be easier to achieve than had been anticipated (Figure 7).

Numerical study of the Flèche rig

Adam Ryan, a student studying for a sports science degree at the University of Plymouth, modelled the properties of the Flèche rig using computational fluid dynamics (CFD). CFD is a method that employs the equations of fluid mechanics to describe a flow field on and around a surface. By numerically modelling the shape being studied and placing it within a defined fluid domain, the flow field characteristics can be calculated. To simplify the calculations, the leading edge spar, battens, changing sail shapes under load, and the

Figure 6: *Flèche going upwind with the sail laminae together*

Figure 7: Flèche going down wind with the sail laminae separated

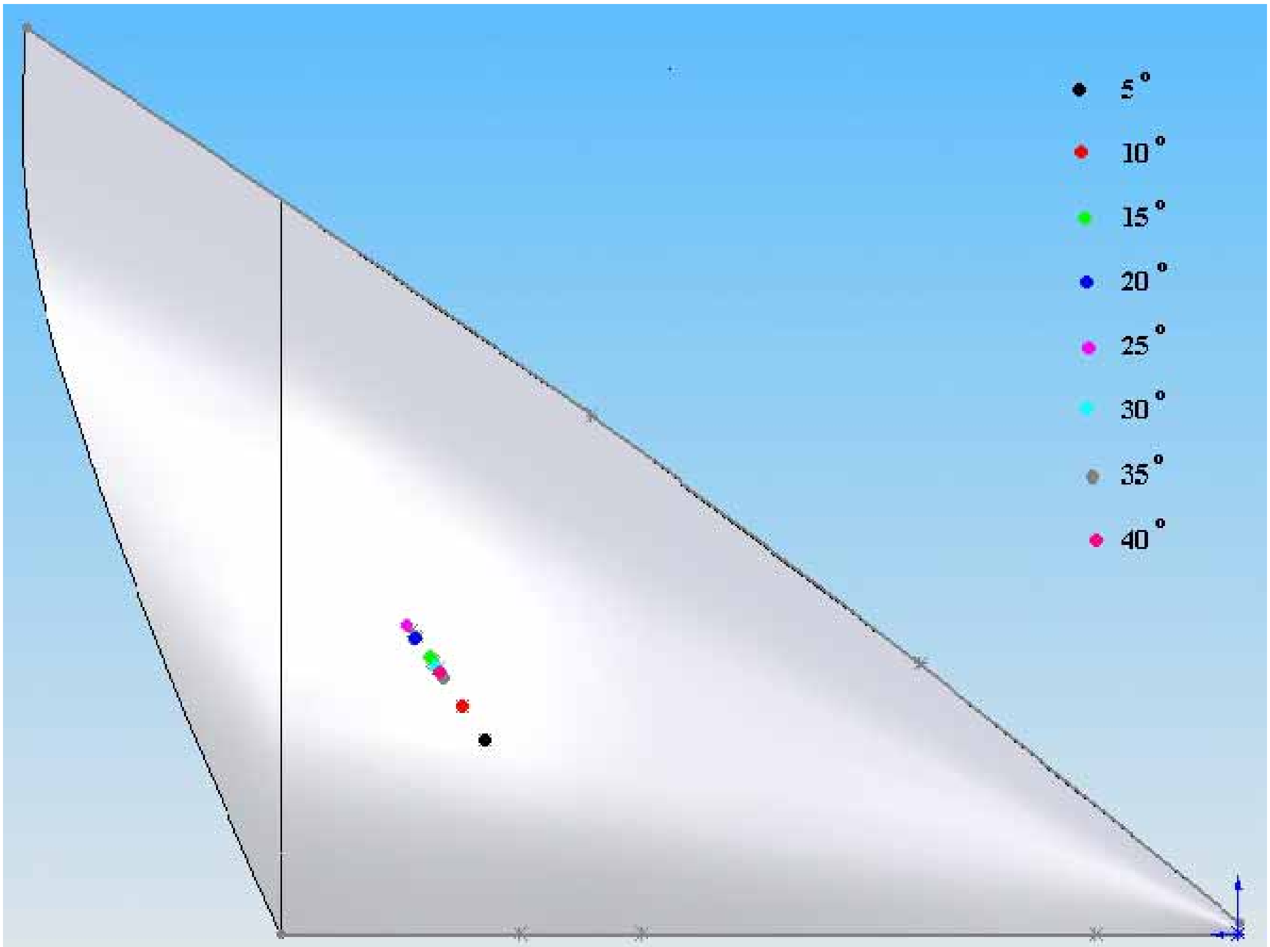


***Figure 8**: Movement of the centre of effort at different angles of incidence (from Ryan 2007)*

relationship of the sail with the hull were not modelled, so the results have to be interpreted with this in mind.

The simulated sail was studied at different angles of incidence to the airflow from 5º to 40º. The sail produced a maximum C_L (coefficient of lift) at around 30º, beyond which the sail stalled and the C_L rapidly dropped off whilst the C_D (coefficient of drag) increased. In terms of the greatest lift to drag ratio, the most efficient angle of operation was 15º. The centre of effort was at its lowest at 5° incidence and then steadily rose up and aft on the sail until 25° was reached(Figure 8). At higher angles of attack the centre of effort dropped back down again and forward. The largest heeling moment was produced at 30° incidence.

At smaller angles of incidence, the simulated Flèche sail produced more drag than Bermudan rigs, but performed more efficiently than them at higher angles of incidence. The low-aspect ratio (0.7) Flèche stalled at 31º compared with 14° and 25° for Bermudan rigs with aspect ratios of 6 and 1.5 respectively. However, compared with figures published for the Crab-Claw rig, the Flèche rig was relatively inefficient.

Computed streamlines illustrated the airflow around the sail (Figure 9). The streamlines showed good attachment up to an incidence of 30°, after which detachment began. Although the release of air at the top of the sail was clean, a large vortex was formed at the foot of the sail at higher angles of incidence as air spilled from the higher pressure windward side to the lower pressure leeward side. (Presumably this vortex would have been reduced if the hull had been included in the computational model.)

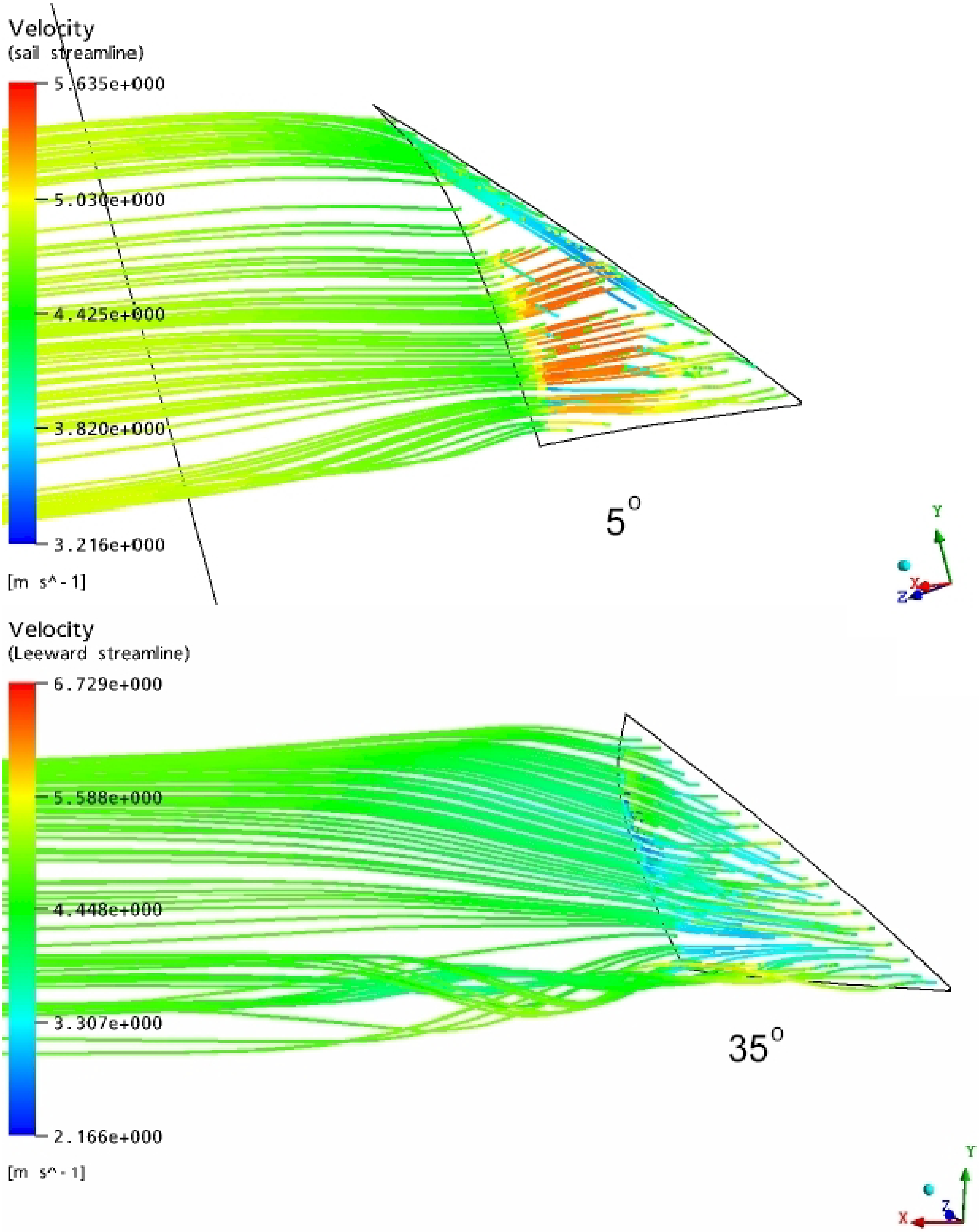


***Figure 9**: Streamlines with the sail set at 5° (above) and 35° (below) to the airflow (from Ryan, 2007)*

***Figure 10**: The form of an early hang glidering*

Key characteristics of delta-shaped sails

These studies involving full-sized prototypes and computational modelling have shown that delta-shaped sails have several characteristic properties:

- since they have a lower aspect ratio than most other sailing rigs, they have a correspondingly lower centre of effort which in turn results in a lower heeling moment for a given sail area (other conditions being equal)
- they can operate effectively at higher angles of incidence than other sails with a delayed stall, and this makes them tolerant in use
- other than when sailing close-hauled, the delta-shaped sails produce a significant amount of upwards-directed lift in addition to forward propulsion
- tip vortices are minimised, although a large vortex develops at the foot of the sail if it is not close enough to the hull or water to enjoy an endplate effect.

Aerodynamics of delta-shaped sails

It is interesting to consider the aerodynamics of delta-shaped sails and the related truncated-delta forms. I have come to the belief that the tolerant, efficient nature of these sails is due to the way that they guide the airflow across their surfaces and then release it cleanly from the trailing edge, particularly at the tip. These sail forms, and also certain wing forms found both in nature and in certain types of aircraft, have in common a conical geometry, and this results in several desirable properties. As a consequence of their overall 3-D form, conically-shaped sails seem able to manage the airflow smoothly across both windward and leeward surfaces. With their swept, slightly washed-out tips, and with the upper parts of the sail curving to windward, they appear to have an ability to suppress drag-inducing tip vortices.

It is helpful to consider the geometry of early hang gliders. The concept for these fabric wings was first patented in 1951 by Frances Rogallo (Messenger and Pearson, 1978). Each wing consisted of a conical billow of cloth supported by the sweptback leading edge and the midline fuselage tube (Figure 10). The longitudinal axis of each billow halves the angle between the leading edge and midline, converging on each side towards the nose of the glider. Different parts of the wing have different angles of incidence in relation to the approaching airflow, the regions close to the midline having a more positive angle of incidence, and the regions towards the wing tip having reduced angles of incidence. (This is sometimes referred to as 'washout'. It is comparable to 'twist' in the upper parts of a sail.)

This simple geometry provides stability around all three major axes (pitch, yaw, and roll). Thus, if the wing is perturbed in flight, it will automatically dampen the perturbation and return to stable flight. (Stability is enhanced by placing the pilot below the wing and thus lowering the overall centre of gravity to give added pendulum stability. The more recent hang gliders have reduced sweepback and double-skinned wings that have a thicker aerofoil section to improve performance.)

It is immediately apparent that there is a kinship between the arrangement of early designs for a hang glider wing and the delta-shaped sails being discussed here. Although the wing most usually operates in a more horizontal position, and the sail more vertically so that the aerodynamic vectors are

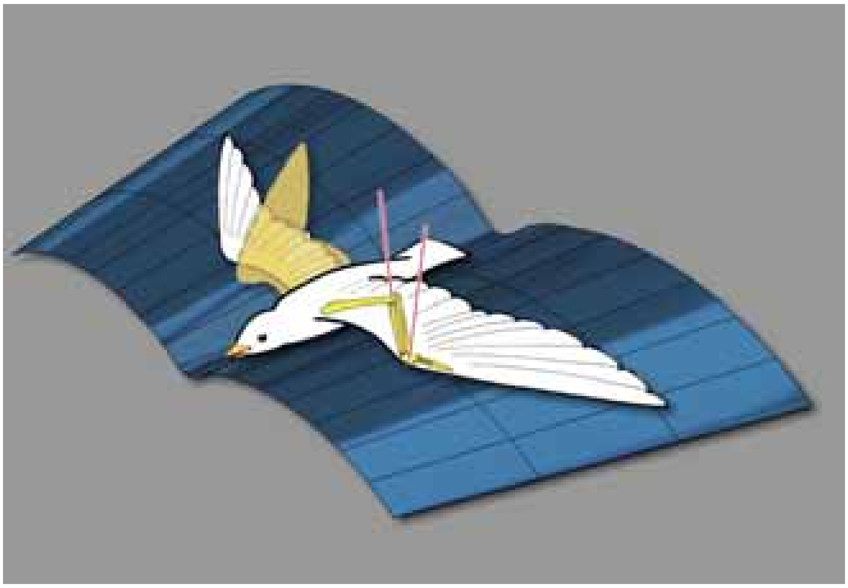


Figure 11: *The variable conical geometry of a bird's wing – the axes (pink) of the joints at the elbows and wrist are principally normal to the imaginary conical surface shown in blue. As the wing flexes and extends, this conical form is maintained*

arranged differently, nonetheless it is probable that patterns of airflow across their surfaces are comparable. Furthermore, the inherent stability of this conical form may also contribute to the good-natured feel of delta-shaped sails, a point that was touched upon in the discussion of Lewis (2003).

The wings of birds that are efficient gliders generally have washout (increasingly negative angle of incidence) towards the tip, and the tip is commonly directed downwards (anhedral) and backwards (sweep). This was first noted by the pioneer of flight Otto Lilienthal (1889). During development of the Transition Rig (Dryden, 2004), my studies of bird wings (for example: those of the gull) indicated that their wings also conformed to a conical geometry Figure 11). Thus they can be considered as truncated deltas, conforming to part of a conical surface. I found that in general the axes of the wing joints were set normal to such a surface (plus or minus a limited range of movement for control during flight), allowing the conical form to be maintained as the wing flexed, extended, and folded (Figure 11).

To generalise, it appears that there is something beneficial about arranging the tip of a foil – either sail or wing – with a curve towards the high pressure side (i.e.: windward side of sail, or underside of wing in normal flight), swept backwards, and with a reduced angle of incidence (wings - Figure 12, sails – Figure 13). Presumably this configuration limits the spillage of air around the tip of the foil and thereby minimises vortex production and drag. It is my impression that delta and truncated delta rigs benefit from this arrangement. This is a working hypothesis that it would be interesting to test.

There has been a continuing discussion about the Crab-Claw rig. In most respects, the Crab-Claw conforms to the definition given above for delta-shaped sails, the main difference being that the longitunal axis of the rig can be

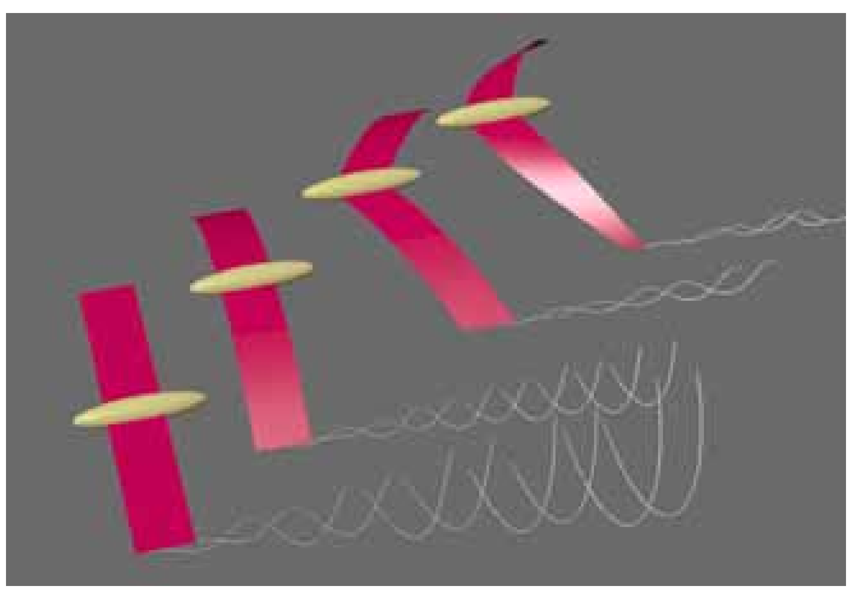


Figure 12: Hypothesis: *tip-vortices produced by different wing configurations – straight wings produce large vortices (left); anhedral wings produce smaller vortices (second left); sweptback anhedral wings produce smaller vortices still; sweptback anhedral wings with washout produce minimal tip-vortices (right)*

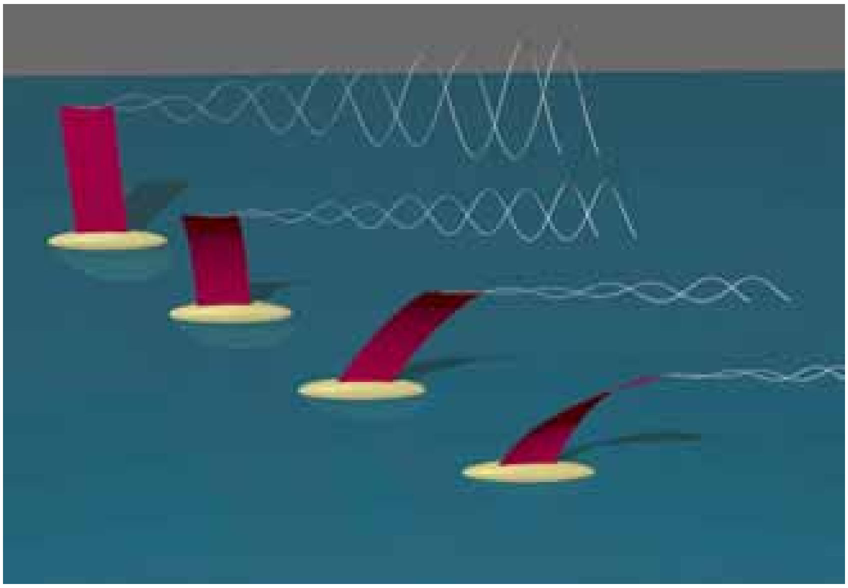


***Figure 13**:* Hypothesis: *tip-vortices produced by different sailing rig configurations – a vertical wing sail (back left) produces a large vortex; a vertical wingsail that curves to windward produces a smaller vortex (second from left); a wingsail that both curves to windward and is also sweptback has a reduced tip-vortex (third from left); a wingsail that is curved to windward, is sweptback, and twists so that the tip is at a reduced angle of incidence in relation to the apparent wind has the smallest tip-vortex, and hence, drag (right)*

On the basis of my experience with delta-shaped sails and the foregoing discussion, I would add that the Crab-Claw rig probably generates minimal tip vortices both at the top of the sail and the clew, and that this contributes to the rig's efficiency. The numerical simulation of the Flèche rig by Ryan (2007) did indeed show vortex generation along the foot of the sail that became more marked with increasing angles of incidence, and this may lend support to the view of Marchaj (1996) with regard to leading edge vortices, but the simulation showed that vortex production resulted in a rapid increase in drag as the sail approached the stall, so it seems unlikely that this mechanism accounts for the overall efficiency of the Crab-Claw rig.

tilted to different angles in the vertical plane according to the course being sailed. This means that the foot of the sail is not always parallel with the surface of the sea. Marchaj (1996) presented evidence from wind tunnel tests of models that the Crab-Claw was much more efficient than more commonly used rigs such as the Bermudan, particularly at high angles of incidence. He suggested that this was due to the formation of leading edge vortices on the leeward side of the sail which increased the lift being generated, rather like the wing of Concorde when flying at slow speed and a high angle of incidence. More recently, Slotboom (2005a, 2005b) has questioned this analysis and proposes that the efficiency of the Crab-Claw is due to optimal camber and angle of incidence of the sail in its different positions.

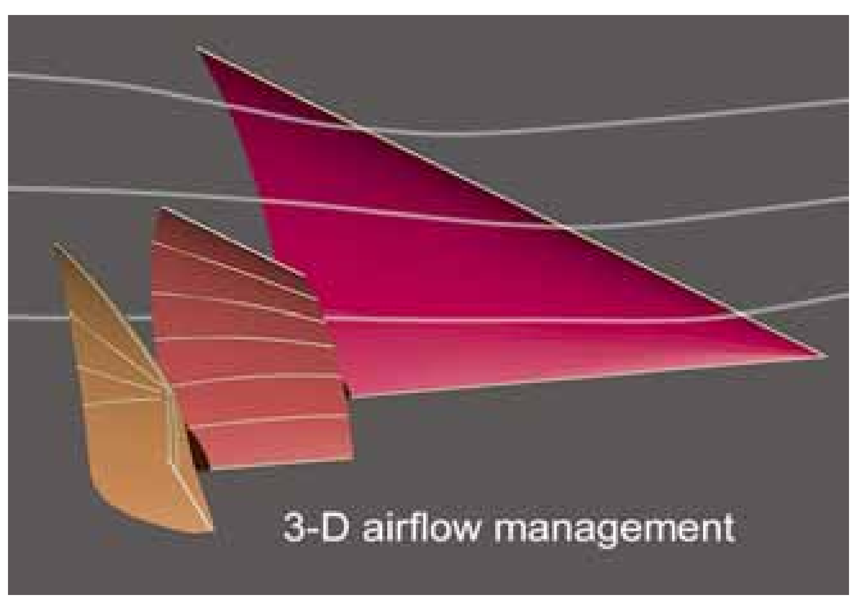


***Figure 14**: A delta-shaped sail (back right) and two truncated deltas – the Transition Rig (front left) and Junk Rig (mid position. The airflow across the delta-shaped sail is suggested by streamlines*

Conclusion

It has been recognised for a long time that delta-shaped and truncated delta sails possess many admirable properties. For example they are efficient, forgiving, have a low centre of effort and thus are less likely to produce capsize, produce lift as well as propulsion, and can be supported by masts and spars that are not unduly stressed due to the low aspect ratio. Prototypes and simulations of the Flèche rig have given a little more insight into the aerodynamics of delta-shaped sails, and have drawn attention to the way that tip vortices may be minimised by this configuration. These sails have an effective way of managing airflow across them in 3-dimensions (Figure 14), and are worthy of further investigation.

Practical applications

It is hoped that these observations will encourage others to experiment further with delta and truncated-delta sails so that we can understand them better and improve their performance. Given their positive attributes in terms of aerodynamics and handling, they might have applications for example in speed-sailing, open ocean sailing, and recreational sailing.

Hopes for the future

The CFD simulations by Adam Ryan (2007) showed a large vortex forming at the foot of the Flèche sail as air spilled under the sail from the high-pressure windward side to the leeward side. This effect became particularly marked at high angles of incidence. The vortex increases the drag of the sail and reduces its efficiency. To simplify the calculations, the interaction of the sail with the hull and water surface was not included. If the gap between sail and hull can be minimised or - ideally - closed, then vortex formation could be inhibited or prevented. (This is sometimes known as the 'end-plate' effect. In the 1980s windsurfers began to take advantage of the improvement in performance that can be gained by 'closing the gap'. They achieved this by altering the cut of the lower part of the sail and by adjusting the rake of the rig in use in order to close the gap.) The Flèche sail has been shaped with the aim of keeping this gap as narrow as possible, but in practice the size of the gap changes as the sail is trimmed according to the course being sailed.

There are several ways in which the gap might be effectively closed when using a Flèche-type rig out on the water. One way would be to trim the sail to the course required, and then slide the feet of the A-frame forwards to lower the spar supporting the sail until the foot of the sail is as close to the hull as possible. The A-frame can then be locked in this position until the next change of direction. Another way would be to close the gap with cloth extending from the foot of the sail to an attachment along the midline of the hull. There would need to be some way of adjusting the amount of cloth made available to accommodate changes in sail trim, so perhaps a spring-loaded conical roller could be arranged along the midline to take up any slack in the gap-closing cloth.

Rather than aiming to close the gap, it may be possible to reduce vortex formation by adopting the strategy of the Crab-Claw rig, using the vortex-inhibiting qualities of a concave leech and a sweptback tip at the bottom of the sail as well as at the top.

If the John Hogg Memorial Prize is awarded to this project, it will be used to carefully investigate each of these strategies and also to test the hypothesis introduced above that there is minimisation of tip vortices by these sails.

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30th October 2008
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A Captive Kite-Sail Design

J G Morley

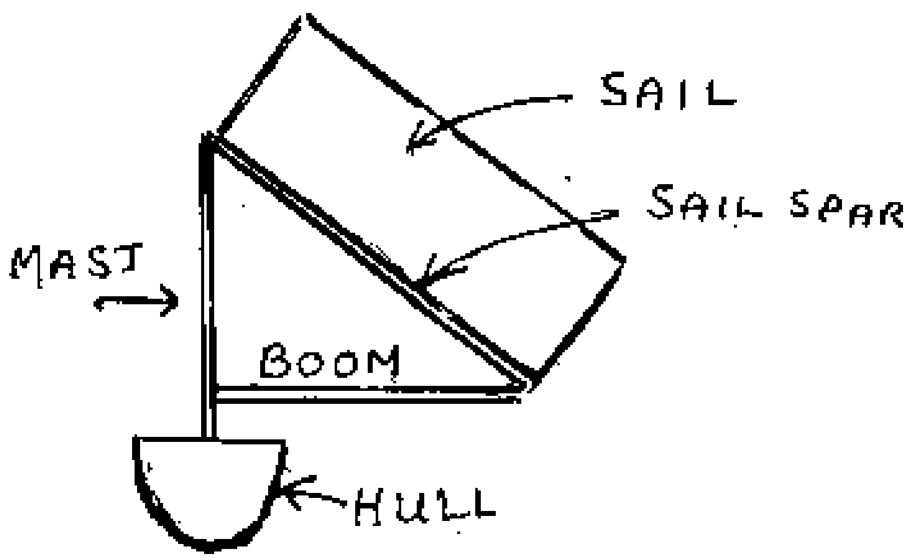


Fig 1

TECHNICAL OBJECTIVES

The overturning effect of a conventional rig is avoided by the use of an offset angled sail. This allows the overturning effect to be always balanced by an offset lifting effect. This arrangement allows the use of a much larger sail than would otherwise be possible. The lift generated by the sail also reduces the displacement of the boat thus reducing the hull drag and enhancing boat speed. The design differs from all previous designs in that, under appropriate conditions, a very high fraction of the weight of the boat is supported by the lifting effect of the sail so that the boat becomes almost airborne. Under these conditions very high boat speeds are possible. These depend primarily on the boat weight, the sail area, the true wind speed and boat speed. When met the boat will continue to accelerate until restrained by increasing keel and rudder drag or until the sail power is reduced. The reason for this is as follows. As the boat speed increases so does the speed of the apparent wind. The increase in apparent wind speed causes an increase in the lifting power of the sail thus further reducing hull drag. If this decrease more than compensates for the increase in hull drag, due to the increased boat speed, the boat will continue to accelerate. This phenomenon has indeed been observed with an experimental rig ref. (1). However fundamental problems were encountered with the use of a manual control system due to "inconvenient gusts of wind from the wrong angle" The same problem has been encountered very recently by the "Vestas Sailrocket", ref (2). Here the lifting effect became large enough to lift the boat completely from the water.

In order to avoid these difficulties a sail arrangement has been designed which gives automatic control of both apparent wind direction and apparent wind speed. This is achieved with the use of standard sail boat construction technology. The arrangement is structurally simple and enables the boat to operate with the sail in the offset angled arrangement, as described above, or upright in the form of a conventional rig. Because the sail adjusts automatically to changes in the direction of the apparent wind, it is possible to change course rapidly without the need to trim the sail. It is necessary to tack, as with a conventional rig, and the procedure is somewhat different in detail. In order to prevent the possibility of the boat being lifted from the water when the wind strength is sufficiently high, automatic means can be provided by which the sail is made to spill wind before this can occur.

Sail Design (Basic considerations)

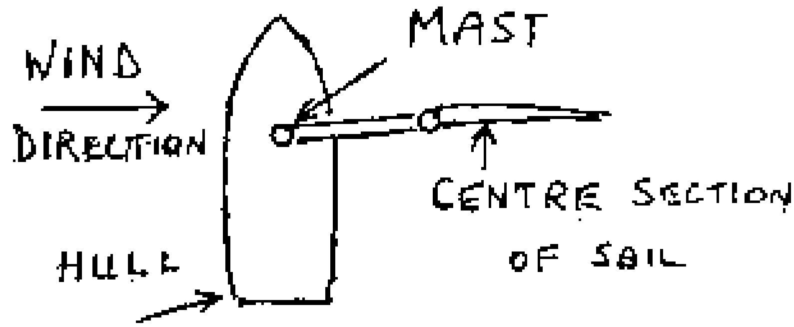


Fig 2a

The process by which the sail adjusts its alignment due to changes in the direction of the apparent wind is described here. The arrangement consists of a vertical mast, a horizontal boom and a sail spar supported from the top of the mast and the tip of the boom .(Fig. 1). The sail spar carries a rectangular sail, which is supported at an angle of about 45 degrees to the vertical. The sail assembly can rotate freely in azimuth about the mast and the sail can be rotated about the sail spar to various set positions. We consider the centre section of the sail to be representative of the whole and this is shown in plan view in Fig. 2. If the sail is aligned with the axis of the horizontal boom, the assembly acts as a simple wind vane aligning itself to the direction of the wind. (Fig 2a) If we now rotate the sail about the sail spar to some arbitrary setting, (Fig. 2b) a horizontal side force (defined here as horizontal lift) will be generated as well as a horizontal drag force. The lift force and the drag force are generated over the whole area of the sail but can be replaced by single forces acting at the centre of effort of the sail. For the rectangular sail illustrated this will be at a point midway along the length of the sail and about one third of the width of the sail measured from the leading edge. The lift force will tend to rotate the assembly in one direction about the mast and the drag force will tend to rotate the assemble in the other direction. The side force is produced because the sail now shows an angle of incidence to the oncoming wind. However as the sail assembly rotates about the mast under the influence of this force the angle of incidence made by the sail to the wind diminishes. The sail assembly will therefore be rotated to some position at which the system is in balance. If the sail is rotated further about the sail spar, the horizontal boom will take up a new equilibrium position at which the sail possesses a larger angle of incidence to the oncoming wind so that the side force is increased. This is illustrated in plan view in Fig.3.. The ability of the side force and the drag force to rotate the assembly is governed by the magnitude of the particular force multiplied by the minimum distance between the line of action of that force and the axis about which rotation is occurring. (Technically termed the couple). This is illustrated in Fig.3. Therefore as the sail is rotated further about the sail spar, thus increasing its angle of incidence at equilibrium and hence the magnitude of the sideways force, the effectiveness of that force in rotating the whole sail assembly about the mast is diminished because the distance between its line of action and the mast is diminished.

We now have to consider the effect of the aerodynamic characteristics of the sail on the stability of the system. Both lift and drag forces change as the angle of incidence of the sail is changed. These forces are usually characterised by CL and CD as coefficients of lift and drag. The lift force acts in a direction perpendicular to that of the wind and the drag force acts in the same direction as the wind. Typical values are shown in Fig.4a. The lift force is initially zero when the sail is edge on to the wind although a significant drag force is developed. The lift force increases very rapidly as the angle of incidence is increased and the drag

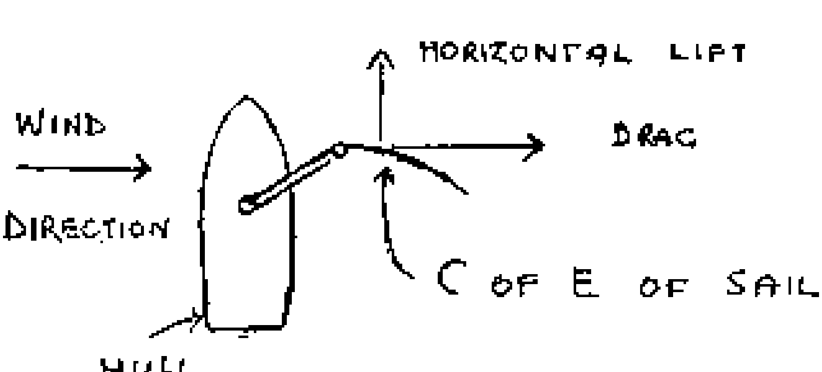


Fig 2b

force also increases but at a much slower rate. It follows that the ratio of the lift force to drag force will have a maximum value at some particular angle of incidence. (Fig. 4b). The magnitude of the lift force developed for this condition will generally be appreciably less than the lift force developed at a larger angle of incidence. As previously pointed out, if the angle of rotation of the sail about the sail spar remains fixed, the angle of incidence made by the sail to a fixed wind direction will change as the sail assembly rotates about the mast. As a consequence the sail assembly will rotate to a position at which the angle of incidence of the sail produces the appropriate lift and drag forces to maintain the sail assembly in equilibrium. The same effect is produced by a change in the direction of the wind. If this changes the sail assembly will rotate until the forces causing rotation of the sail assembly about the mast are again in balance. If the wind changes direction so that the angle of incidence of the sail is diminished the sideways lift force is reduced. The drag forces are still present and they cause the sail assembly to rotate so as to increase the angle of incidence of the sail. If the change in wind direction increases the angle of incidence of the sail the sail assembly will rotate about the mast until the angle is incidence is reduced so that the system is again in balance.

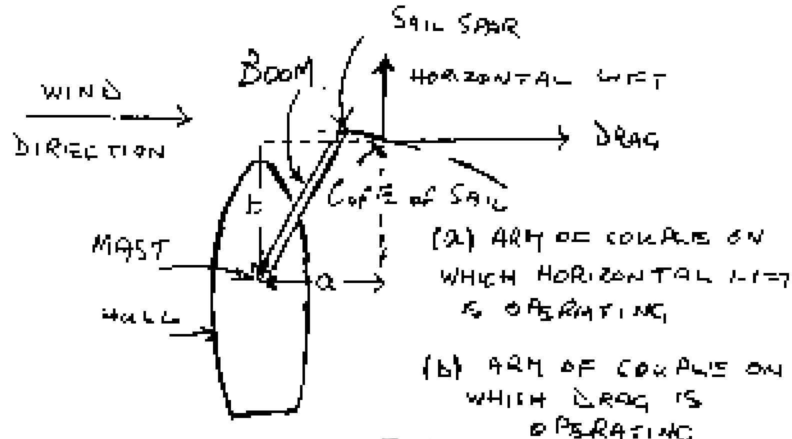


Fig 3

The sail will be operating most efficiently when the boat is going into wind if its lift to drag ratio has a maximum value. The rotation of the sail about the sail spar can be adjusted until this condition is achieved. It follows that, when the sail is set so as to generate the maximum lift to drag ratio, the sail assembly at equilibrium will have rotated by its maximum amount about the mast from the initial wind vane condition.

We now have to consider the influence of the angled sail on the behaviour of the system. Fig.5 illustrates the situation where the sail is set so as to generate maximum lift to drag values. This is shown in plan view (Fig 5a) and in elevation (Fig 5b) looking downwind. The angle made by the sail assembly to the wind is governed by the lift to drag ratio of the sail. However it is only the horizontal component of the lift generated by the sail which influences the rotation of the sail assembly about the mast. The sail is now set at an angle of approximately 45 degrees to the vertical when seen

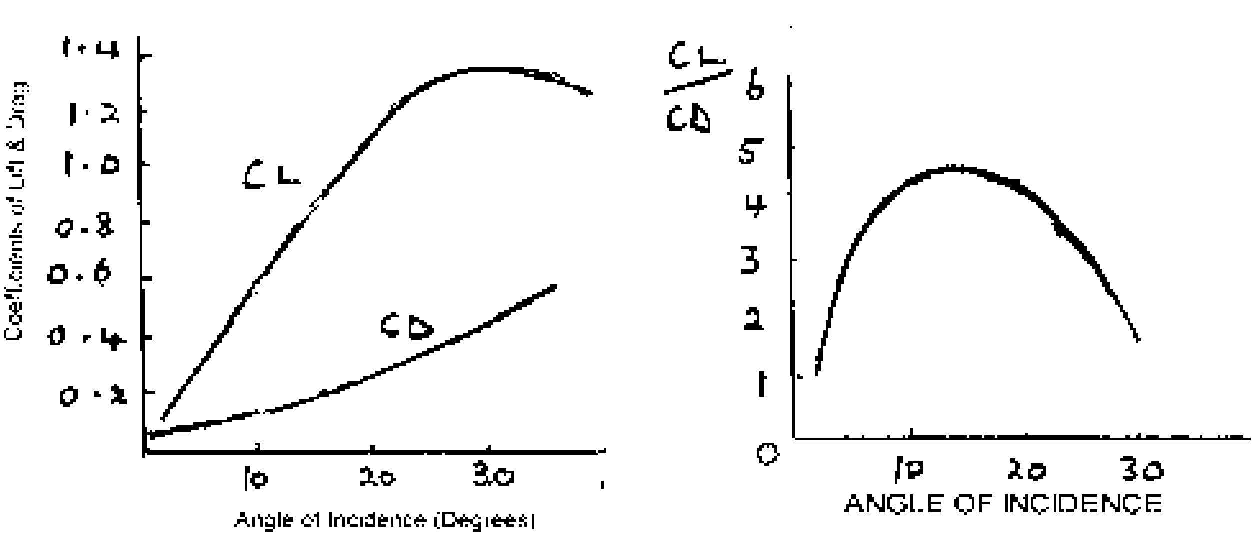


Fig 4 a & b

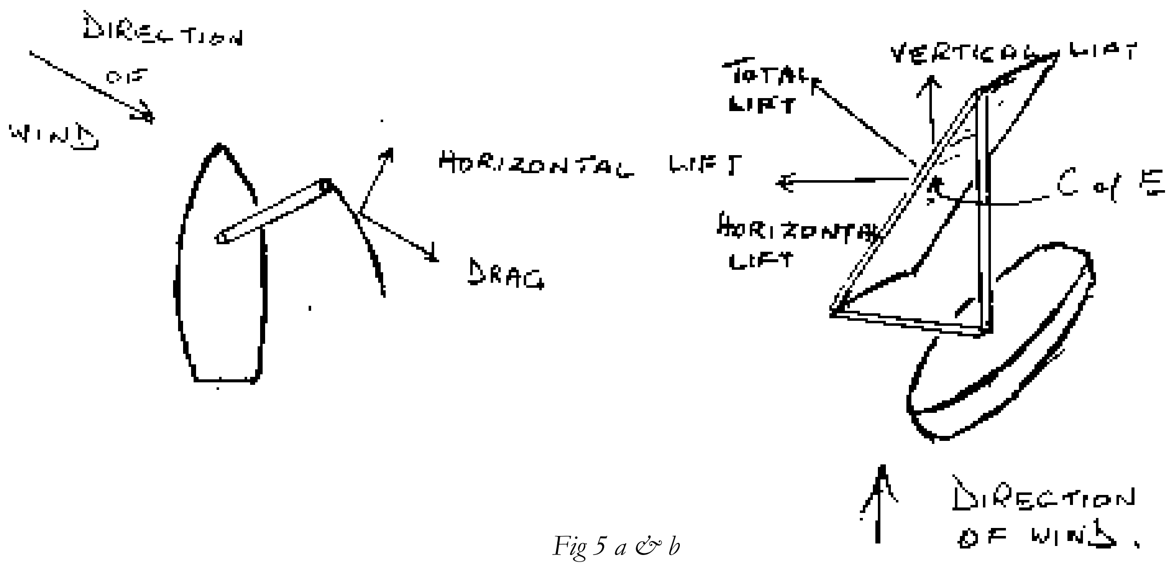


Fig 5 a & b

down wind. The total lift force generated by the sail can therefore be considered to consist of a vertical force and a horizontal force each having a value of about 70 percent of the total lift force. The effective horizontal lift to drag ratio of the sail is therefore reduced by this factor. In order to eliminate the heeling effect it is necessary for the sail to be set at an angle of approximately 45 degrees to the vertical when viewed downwind. If the sail is carried downwind of the sail spar, as illustrated, this can be achieved without the necessity for an excessive length of sail boom. If the sail is carried forward of the sail spar a much longer boom is required in order to ensure that the sail is set at 45 degrees to the vertical under operating conditions.

Tacking is achieved by rotating the sail about the sail spar to the weathercock position, with the boat then heading into wind, and then continuing the rotation of the sail about the sail spar until the sail assembly has been caused to rotate about the mast to a position on the other side of the boat when it is again set at an angle of 45 degrees to the vertical. During this procedure the sail is no longer aligned at 45 degrees to the vertical so a heeling effect will be generated. This effect has been calculated, using an iterative mathematical technique, and is found to be minimal. The reason for this is as follows. As the sail is rotated about the sail spar, so that its angle of incidence at equilibrium falls, the horizontal lift generated by the sail falls rapidly. However its ability to hold the sail into wind falls much more slowly because the arm of the couple, on which it is operating, is increasing rapidly as the sail assembly is rotated about the mast.. (See Fig.2c). It follows that the sail maintains a large angle to the vertical as the forces developed by it are falling. Eventually, as the sail becomes more nearly vertical, the drag forces developed by the wind becomes predominant and these, of course, do not influence the heeling effect.

The above remarks apply to automatic stabilisation during changes in the direction of the apparent wind. We also have to consider the stabilisation mechanisms necessary to deal with fluctuations in the velocity of the apparent wind. This is best achieved by arranging for the sail to spill wind when the vertical lifting force approaches the weight of the boat and crew. It is, of course, possible to achieve this manually by hauling in or paying out a main sheet as is done to prevent capsizing with a conventional rig. However, because of the runaway situation which will be encountered, once the boat reaches a critical speed, automatic control of the lifting effect may be thought to be desirable.. This can be done quite straightforwardly and a possible arrangement is described in the next section which outlines the construction of a possible demonstration boat.

Outline of a Possible Practical Design

The sail is expected to be developing forces comparable to the total weight of the boat and crew but the control loads which have to be applied to rotate the sail about the sail spar can be reduced to small values by the use of twin main sheets. The arrangement is illustrated in Fig.6. A main sheet is attached to each side of the sail. When the sail is

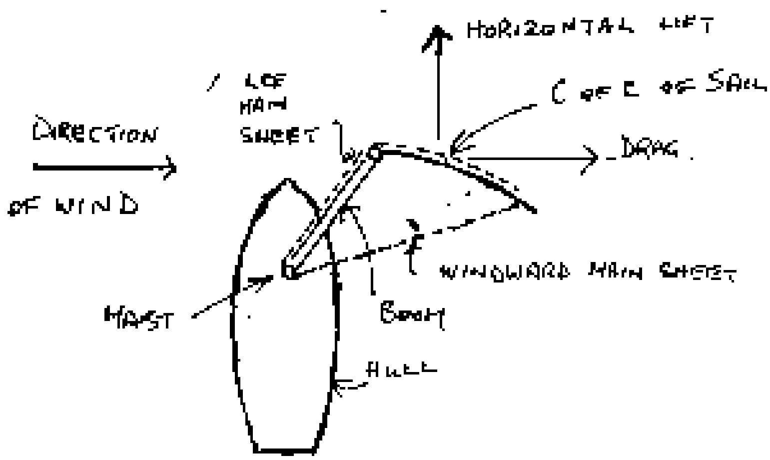


Fig 6

rotated about the sail spar the lee main sheet passes by the lee of to sail so that the load it applies to the sail is effectively at the sail spar. The centre of effort of the sail lies between the effective attachment points of the main sheets Thus the load required to rotate the sail about the centre of effort of the sail is the difference between the loads applied to the main sheets. This can be quite small. The bulk of the aerodynamic load generated by the sail is supported by the sum of the loads carried by the twin main sheets which are loaded in tension. This reduces the aerodynamic loads on the mast and spars. The arrangement can function in the manner described provided that the lower end of the sail spar is free to move with the upper end of the sail spar pin jointed to the top of the mast. In this way the aerodynamic load carried by the sail is supported by the main sheets. It is convenient for the twin main sheets to pass round a pulley at the foot of the mast with subsidiary lines, attached to the main sheets, used to rotate the sail. By arranging for the centre of effort of the sail to be nearer the attachment point of the windward main sheet than the attachment point of the lee main sheet (effectively the sail spar) the sail will spill wind if the windward main sheet is released. It is possible that effective control of "lift off' can be achieved manually by releasing the windward main sheet since this will cause the sail to rotate about the sail spar thus reducing its angle of incidence. However automatic means of spilling wind can be provided and these are described later in this document.

It is convenient to have the system capable of being configured as a conventional rig in congested waters and in very light winds. A possible means of achieving this is illustrated in Fig 7. The boom is attached to the mast by a sliding joint and carries another sliding joint at its outer end. This sliding joint is pin jointed at the lower end of the sail spar. Thus, by raising and lowering the sliding joint on the mast, the sail spar can be moved from a vertical position to an angle of about 45 degrees to the vertical. The double

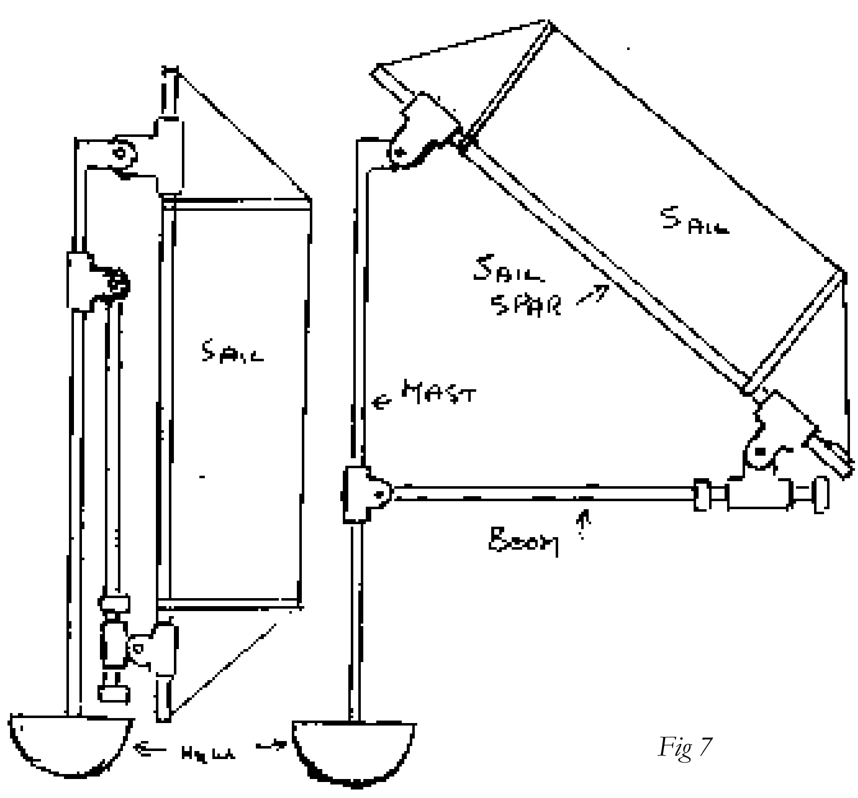


Fig 7

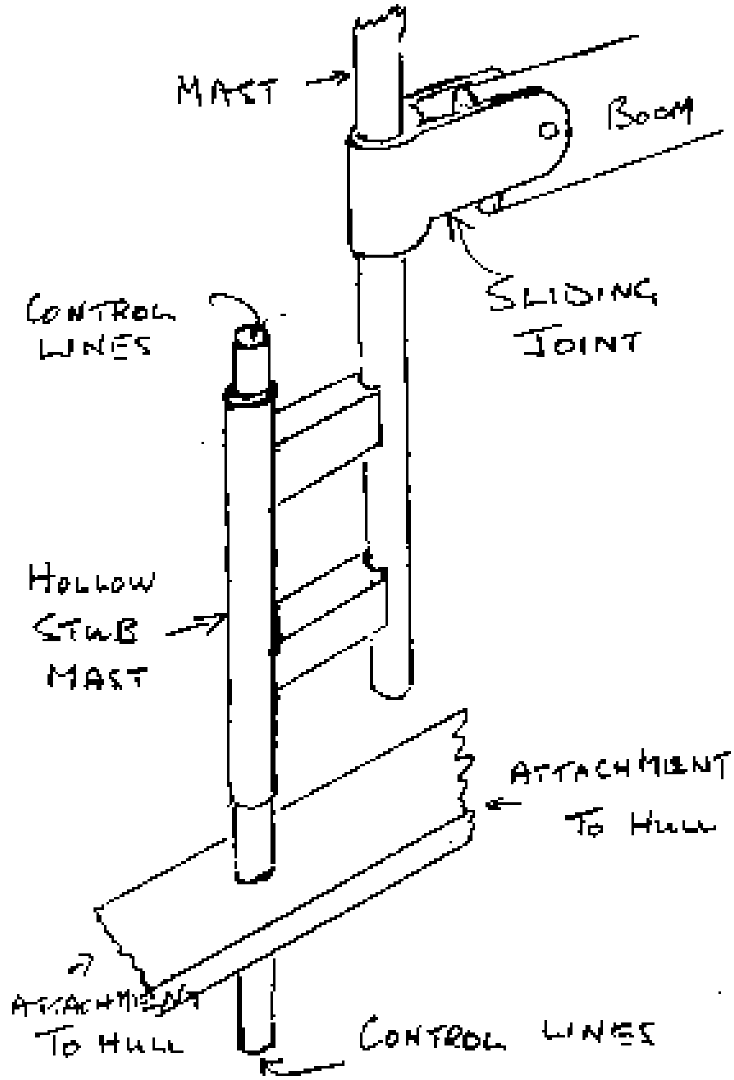


Fig 8

requirement that the sail spar should be able to be moved by operating the sliding joint on the mast and at the same time be free to move outwards when the aerodynamic load is carried by the main sheets, can be achieved by arranging for the boom to carry two stops thus allowing free movement of the lower end of the sail spar within pre set limits

We now have to consider the tacking procedure. The first step is for the sail to spill wind and be set in the weathercock position. This can be done by using the twin main sheets. If the wind strength is insufficient to hold up the sail in this condition the geometry can be reconfigured with the sail spar positioned in a more nearly vertical position, If the sliding joint which attaches the boom to the mast is raised, the sail spar becomes more nearly vertical and the twin main sheets become slack. The sail is thus free to weathercock about the sail spar as the sail spar itself becomes more nearly vertical. As this occurs the whole sail assembly will weather cock about the mast. At the same time the boat is being turned head to wind. The sail is now set on the opposite tack by hauling in the appropriate main sheet and at the same time lowering the sliding joint attaching the boom to the mast. The sail is thus raised and the load generated by the sail is again carried by the twin main sheets. The boat is now set on its new course.

There are two possible positions for the helmsman. He could be carried on a seat at the foot of the mast on the opposite side to the sail assembly. This has the advantage that the weight of the helmsman can be used to balance the gravitational weight of the sail. The hull(s) can then be little more than semi submerged floats. Alternatively he can be positioned in the hull in the conventional way. In either event it is necessary to consider means by which control lines can be passed from the helmsman's position either to the tiller or to the sail. Fig. 8 illustrates one means by which this can be done. Here the sail assembly is attached to a short hollow stub mast that provides the vertical bearing around which the sail assembly is free to rotate. The hollow stub mast provides a passage through which the control lines to the tiller or the control lines to the sail can be passed. This feature also provides a means by which automatic control of "lift off' can be achieved. This is shown schematically in Fig.9. The separate control lines attached to the main sheets, as shown in Fig 9, are used to trim the sail by rotating it about the sail spar. (see Fig 6). The vertical bearing about the stub mast is free to move axially as well as being free to rotate in azimuth. The vertical movement is restricted by a helical spring in compression. As the vertical lift generated by the sail increases, the spring becomes more compressed and this movement can be used to slacken of the main

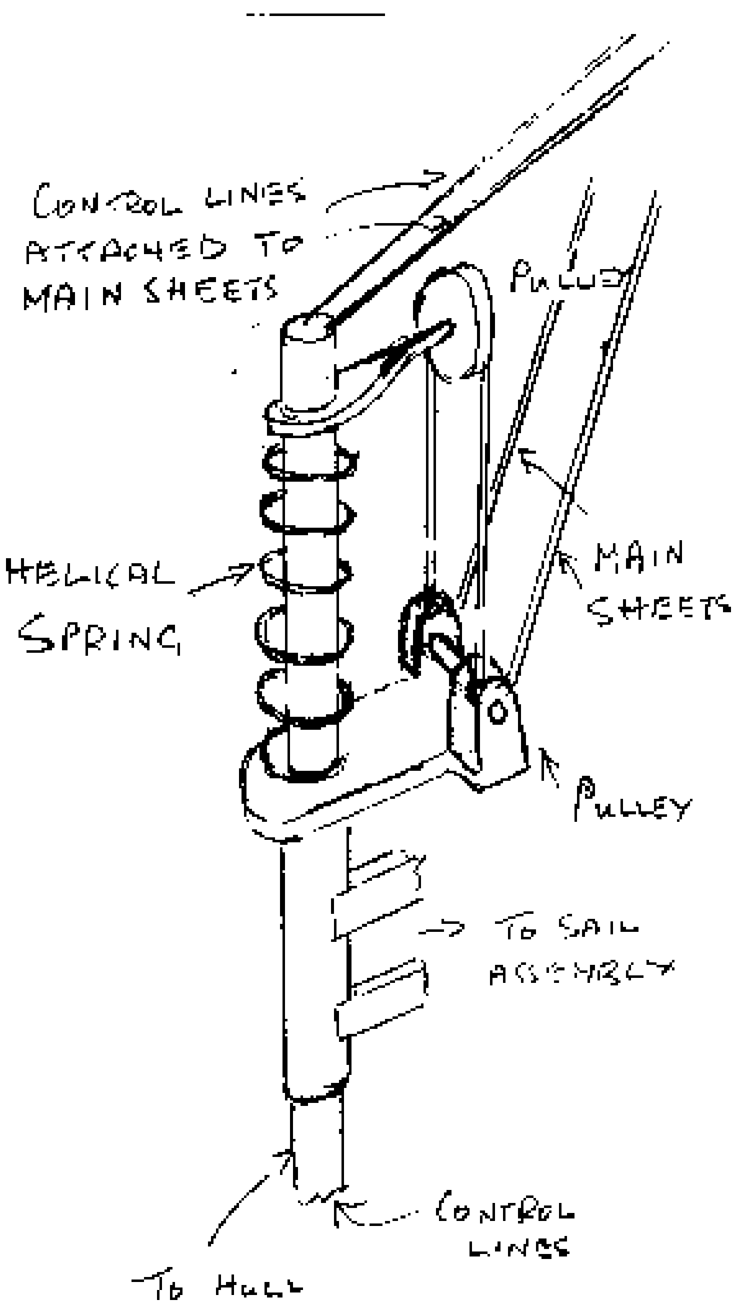


Fig 9

sheets. In this arrangement the main sheets pass through pulleys attached to the sail assembly and the top of the stub mast. Thus, as the spring becomes compressed the main sheets become more extended. As the main sheets are extended the sail spar moves outwards and upwards until it is restrained by the outer stop on the boom. Further extension of the main sheets then allows the sail to weathercock about the sail spar thus spilling wind. The spring characteristics and the geometry of the system is chosen so that the vertical lift generated by the sail can not exceed an acceptable level.

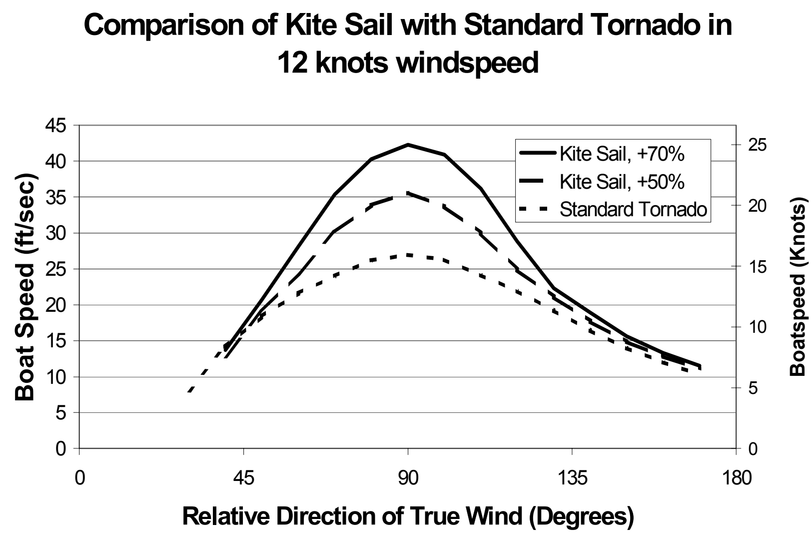
Predicted Performance and Design Requirements

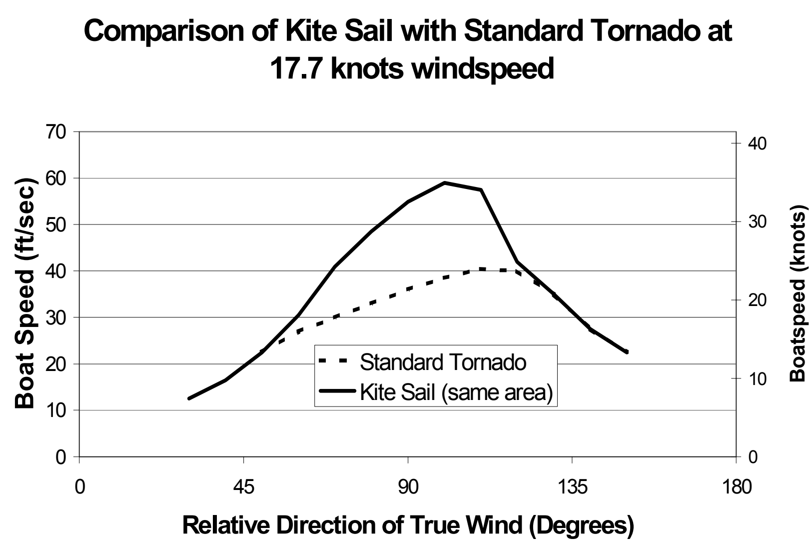
A theoretical analysis has been made of the physical factors governing the speed of a sailing boat. These take into account the hull shape displacement and length and the sail area and its aerodynamic characteristics. The computed hull drag takes into account the boat speed since this determines whether the hull is behaving as a displacement hull or a skimming hull or in an intermediate condition. The skimming hull resistance, of course, differs from that of a displacement hull. The drift is computed and the effect of keel size is also taken into account. True wind speed and direction are also taken into account. The validity of the analysis has been checked by comparing its predictions with published performance data for the “Tornado” catamaran.

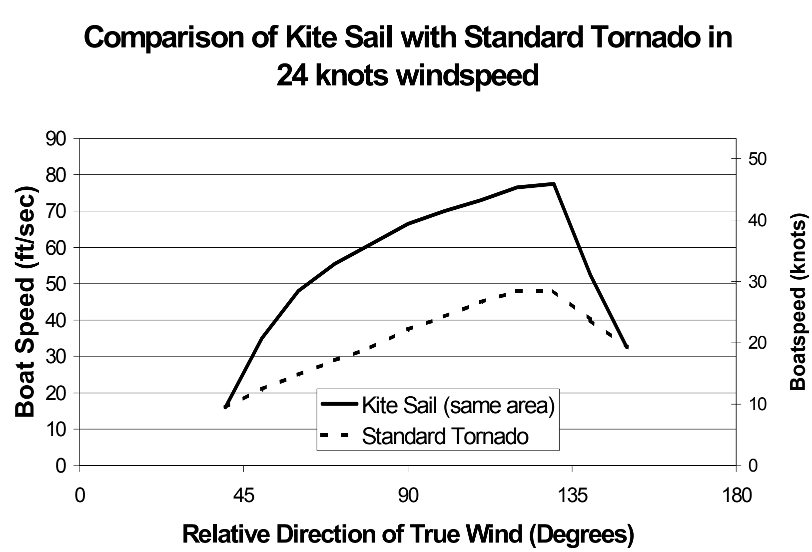
Data used in the computation has been obtained from relevant published sources and performance figures very close to those observed are predicted. Only simple geometric modifications are needed to deal with the kite sail configuration so the programme would be expected to be equally applicable to this design. Predicted performance data is shown in Fig 10 which refers to a “Tornado” catamaran. This graph predicts the behaviour of a standard “Tornado” catamaran compared with the same boat fitted with a kite sail of various sizes for a range of true wind directions. A true wind speed of 20.4 ft/sec was used in the calculations since a maximum boat speed of 28.2 ft/sec had been observed for these conditions. This is very near the predicted maximum boat speed of 26.95 ft/sec. (lower curve, Fig 10). The theoretical analysis also predicts that, for these conditions, the “Tornado” would be on the point of capsizing which is what would be expected for a high speed run. Because capsizing cannot occur with the kite sail system a larger sail area can be utilised. The two other curves show the predicted performance figures for the same boat and wind conditions but with a larger sail area and in the kite configuration. The upper curve relates to a sail area increase of 70% and the middle curve to a sail area increase of 50%). Very substantial increases in boat speed over a wide range in true wind directions are predicted.

The analysis predicts that, for very light winds, there is no advantage in using the kite sail configuration if the sail area remains the same. The reason for this is as follows. For the same sail area, the angled sail produces only about 70 percent of the forward thrust of a vertical sail. Therefore, unless the reduced hull drag caused by the corresponding lifting effect more than compensates for this reduction, there is no advantage in using the kite sail configuration. The circumstances under which it becomes advantageous to use the kite sail configuration depends on several factors. These are - the true wind speed, the ratio of sail area to hull weight and the sail and hull characteristics. However as discussed above, since overturning is no longer an issue, a much larger sail area can be contemplated than would otherwise be possible. This could make it practicable to use the kite sail configuration in light winds.

The kite sail configuration enables much higher wind speeds to be accommodated than would be possible with a conventional rig. Predicted performance figures for a kite sail rigged "Tornado" at much higher true wind speeds are shown in Figs 11 and 12 For these computations the kite sail area has not been changed from that of the standard "Tornado". Comparison is made with a conventional "Tornado" where the angle of incidence of the sail has been







Figs 10,11, 12 (top to bottom)

reduced sufficiently to prevent overturning. Because of the much enhanced boat speeds expected with the kite sail configuration at higher true wind speeds, the keel drag becomes the speed controlling factor under these conditions When this occurs in the computations for a wind speed of 30 ft/sec (Fig 11) the keel area is reduced from the standard 5 sqft to 2 sqft. When the wind speed is 40 ft/sec (Fig 12) the keel area at high boat speeds is reduced to 1 sqft. The conventional larger keel area is of course required to prevent excessive drift on courses where the boat speed is much reduced. The computations also show that it is necessary to reduce the angle of incidence of the sail in the kite configuration at the high boat speeds. Otherwise the lifting effect of the sail would exceed the weight of the boat. This is predicted to occur even though in Figs 11 and 12 the sail area is taken as the same as the standard "Tornado"

A further factor has to be taken into account in the design of a kite sail system. High boat speeds are only achievable once a threshold speed has been reached. This depends on the ratio of sail area to boat weight and on the true wind speed. At this critical condition, as the boat speed increases, the reduction in hull drag due to the enhanced lift more than compensates for the increase in hull drag due to the enhanced boat speed. The higher the ratio of sail area to boat weight the lower the true wind speed at which this will occur. This can be calculated for any particular set of circumstances. It is also desirable to minimise hull drag in order to make it easier to reach the critical boat speed.

The design assessments proposed here are based on computations relating to the "Tornado" catamaran. For this boat the sail area to boat weight ratio is about one square foot of sail area to three pounds of boat weight (including crew). The analysis indicates that, for operation in lighter winds, it would be beneficial to have a higher sail area to boat weight ratio for a kite sail system so a possible target would be one square foot of sail area to two pounds of boat weight. The use of a rectangular sail, as proposed above, lends itself to this requirement since a rectangular sail has twice the area of a triangular sail of the same overall dimensions.

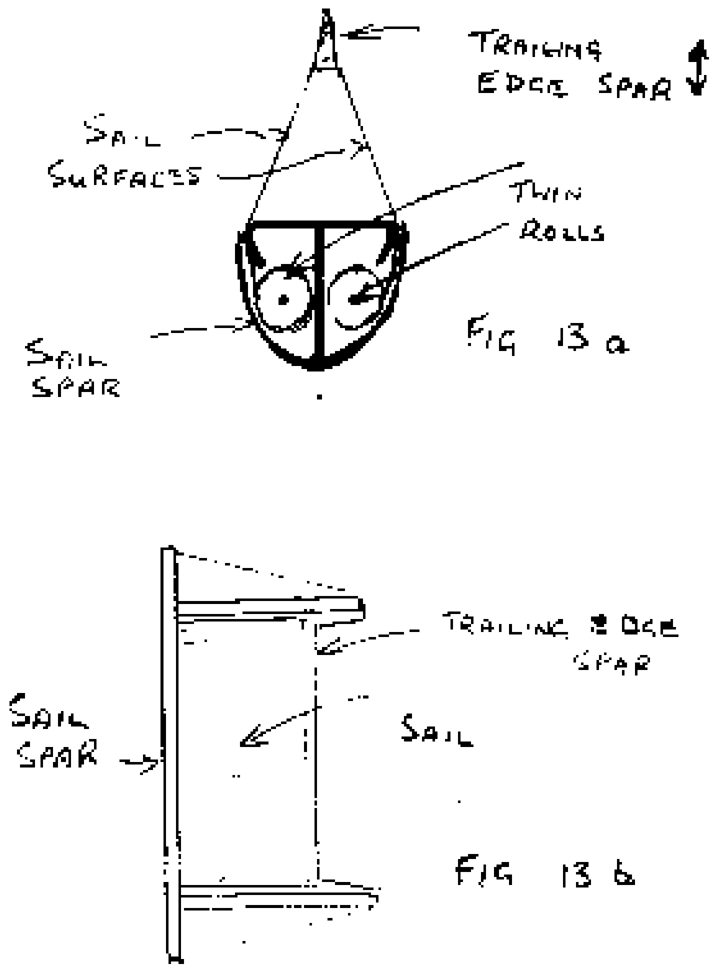


Fig 13

Longer Term Considerations

On a longer term basis it seems worthwhile giving attention to the size of the underwater appendages. As indicated above, at the very high boat speeds envisaged, only very small keel and rudder sizes are required. For the keel areas used in the "Tornado" computations the angle of incidence of the keel required to produce the necessary lateral force was only about one percent The hydrodynamic resistance of the keel would be very much reduced if a smaller keel was fitted operating at an angle of incidence of about five degrees. This might require the keel to be capable of rotation about a vertical axis depending on which tack the boat was operating. Also we have to consider the very wide range in boat speeds which would be encountered. At low boat speeds a large keel area would be required so this might require the keel to be in the form of a dagger board which could project under water by varying amounts depending on the boat speed.

The very wide range of boat speeds envisaged, with corresponding large variations in the apparent wind velocity, make it necessary to consider the feasibility of varying the size of the sail. For a small one man boat this might be done by having several sizes of sail available to fit a standard hull. An alternative arrangement is illustrated in Fig 13. Here the sail spar forms the nose cone of a symmetrical aerofoil. It carries internally two rolled sail textile surfaces which are attached to a rear trailing edge spar. The trailing edge spar can be moved outwards and inwards to vary the area of the sail. The geometrical arrangement ensures that the sail profile retains a reasonable approximation to an aerofoil section regardless of the actual sail area. This is necessary in order to preserve a high lift to drag ratio for the sail which will in any event exceed that obtained with a single surface sail. This arrangement allows the sail to be reefed as is illustrated in Fig. 13a. Fig. 13b illustrates the means used to control the area of the sail. It should be noted that, since the mast and boom (when upright) are always aligned in the same way to the apparent wind, they to can have a streamlined section ensuring minimum drag at all times.

The maximum boat speeds envisaged are much greater than those encountered with existing sailing boats. We therefore have to consider the influence of sea conditions on the boat performance. The situation differs from conventional circumstances in that the boat, at high speed, will be almost completely airborne. The nearest analogy that can be envisaged is that of a float plane nearing take off conditions. It therefore seems reasonable to expect a kite sail boat to be capable of operating in sea conditions acceptable for float plane operations.

J.G.M.

References

[1] In "Aero-Hydrodynamics of Sailing" by C.A. Marchaj 2nd Edition 1993 Page 550, Published by Adlard Coles Nautical. A and C Black (Publishers) Ltd 35 Bedford Row London WC 1 R 4JH

[2] "Vestas Sailrocket" CATALYST Number 32 October 2008

Chairman’s Notes

Fred Ball

The wet summer of 2008 seemed to pass very quickly with little accomplished. I seem to have spent most of my time hacking back excessive vegetation from the ponies’ fields: they don’t like long grass and if you just leave it dies and weeds take over!

I have however been sailing with my sons in their boats including a most enjoyable Thursday / Friday trip with Tim in his Freedom 22 to Newtown Creek, nice refreshing swim Friday morning and back home to a wet and soggy weekend.

Other things of note included a a drive to Suffolk to see the International Human Power Vehicle Association Championships (where I saw a human powered hovercraft and appreciated AYRS hospitality from Kim Fisher on my way home; refreshments and a view of his wheeled boat) a Model Engineering Exhibition at Ascot (one of the exhibits was a Stirling Cycle engine powered Thames skiff and I’d forgotten my camera!) the Southhampton Boat Show (leaving with a lasting impression of flying bridges stacked high in the sky) and Weymouth Speedweek where I won a prize for third fastest boat; I must have picked my moment well as there were at least three other boats which had they sailed the course on my best day should have beaten me easily!

I also managed several trips to Calshot with Slade to help him with his floating generator experiments including making a smaller model to try and demonstrate the capsizability of multihulls with heavy generators at the top of a mast (pylon) very difficult so far without manually heeling the creation.January is the time for me to wish you a happy New Year and good enjoyable sailing (boat building, theorising etc.)

The New Year always begins with the London Boat Show where it is a pleasure to meet many of you. This year I had the additional pleasure of announcing the John Hogg competition results where although Jack Goodman the winner was unable to attend I was able to present Kim Fisher with his ‘runners up’ prize.

As a sail or oar boating person I was surprised to find that the LBS exhibits that most impressed me were an open launch “Electra” (just over 7 metres loa. 750kg weight including batteries and Lynch type electric motor, speeds up to 15knots, if cruising at 5-6 knots, 8 hours running time) and a very neat and flexible hybrid power unit by Yanmar and a development company on the Isle of Wight (options included battery only drive, diesel only drive or drive while maintaining the batteries}

At the AYRS meeting at Thorpe we had a very entertaining talk by Andrew Hall, a member of the Stirling Engine Society (www.stirlingengines.org), about Stirling engine powered boats (historic and recent) and the opportunity for members to advise on the design of a suitable design of boat to maximise the performance of what is an efficient but low power device.

Other speakers reported on their projects and Roger Callum gave me a copy of an article from the Aeronautical Journal of January 1982 entitled “Hydrodynamics and aerodynamics; cross fertilisation in research and design”, well worth reading so I hope to get a few copies so that they can be lent to interested people.

So that’s January gone! It will soon be December!!

Fred Ball

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**

March 2009

7th **AYRS Southwest UK Area Meeting**
2pm 7 Cross Park Road, Wembury, PL9 0E near Plymouth. A short coastal walk (not more than three miles, less if the weather is bad) setting off at 14:30hrs; back by 16:00ish, so if you don't want to come on the walk join us then. After tea we will show slides and talk about boats. Details from John Perry, 01752 863730 j_perry@btinternet.com (note the underscore in that email address).

20th – 21st **19th Chesapeake Sailing Yacht Symposium (CSYS)**
St. John's College in Annapolis, Maryland. The CSYS is dedicated to advancing the study of both the art and science of sailing yacht design technology. Held every two years, topics include sail aerodynamics, hydrodynamics, hydrofoils, performance prediction, structures and other issues. To view a complete list of papers and to register visit: www.csysonline.com

April 2009

26th **Beaulieu Boat Jumble**
The National Motor Museum, BEAULIEU, Hampshire, UK. AYRS will be there!

May 2009

2nd – 4th ***Broad Horizons* – AYRS Sailing Meeting**
Barton Turf Adventure Centre, Norfolk UK, NR12 8AZ. Contact AYRS Secretary AYRS Secretary, BCM AYRS, London WC1N 3XX, UK; email: office@ayrs.org. Note: All boats limited to 1.2 metre max draft!

3rd **Windsurfing 4 Cancer Research - Sunrise to Sunset**
Get sponsored and go windsurfing for the day to raise money for cancer research. (You don't have to sail all day!) Main event at Hayling Island UK, but you can sail anywhere. See http://www.sunrisesunset.ws for sponsorship forms and further information. Organised by Nick Povey of the Speedweek team.

11th – 15th **AYRS Portland Sailing Meeting**
Castle Cove Sailing Club, Old Castle Road, Weymouth, DT4 8WJ. This is the warm up for Weymouth Speed Week and we will be doing towing trials on the model of Icarus 3 and more testing on the new timing systems. The format is we use the club Monday to Friday during the day and they tend to invite us to use the club in the evening if members don't need it. Tea and coffee with biscuits is on tap all week and we ask for a donation of £30 each for the CCSC. Contact: Robert Downhill, email: icaruswsr@tiscali.co.uk.

23rd-26th **UK Home Boat Builders Rally – Norfolk Broads**
Barton Turf Adventure Centre, Norfolk, UK. For details see http://ukhbbr.wordpress.com/future-events/barton-turf-rally-may-2009/

June 2009

5th – 7th **Beale Park Boat Show**
Beale Park, Pangbourne near Reading, UK. Open-air boat show with a number of boats available to try on the water. AYRS will be there again, selling publications. Contact: Fred Ball, tel: +44 1344 843690; email frederick.ball@tesco.net

October 2009

10th – 16th **Weymouth Speedweek**
Portland Sailing Academy, Portland Harbour, Dorset UK. See www.speedsailing.com.

14th **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

How to supply information for publication in Catalyst:

The Best way to send us information:- an electronic (ascii) text tile (*.txt created in Notepad, or Word, with no formatting at all, we format in Catalyst styles). Images (logically named please!) picture files (*.jpg, gif, or *.tif). If you are sending line drawings, then please send them in the format in which they were created, or if scanned as *.tif (NEVER as .jpg because the format blurs all the lines).

Film photos should be scanned at a resolution of at least 300 ppi at the final size and assume most pictures in Catalyst are 150 by 100mm (6 by 4 inches). (Scan slides at 1200dpi.) A digital photograph should be the file that was created by the camera. A file from a mobile phone camera may be useful. Leave them in colour, and save them as example *clear_and_complete_title.jpg* with just a bit of compression. If you are sending a CD, then you can be more generous with the file sizes (less compression), than if emailing, and you can then use *.tif LZW-compressed or uncompressed format.

For complex mathematical expressions send us hardcopy or scan of text with any mathematical characters handwritten (we can typeset them), but add copious notes in a different colour to make sure that we understand. We can also process MS Equation and its derivatives. Include notes or instructions (or anything else you want us to note) in the text file, preferably in angle brackets such as <new heading>, or <greek rho>, or <refers to *image_of_jib_set_badly.jpg*>.

Otherwise: — If you write in longhand, and sketch (in black ink) or include photographic prints, and trust to snail mail (a copy, never the original) then all should be dealt with in due course (if we can read your handwriting - Seriously, clear black typescript, double spaced, is MUCH better!). If you have trouble understanding anything in this section, email to ask.

As examples, the polar diagram p16 of *Catalyst 28* was re-created from a second generation photocopy, photos of shunting in the Champion article in *Catalyst 27* (pp 19-21) were screen grabs from a video supplied on DVD. The rest of the images in that article were scanned from photographs, and the text was OCRed (Optical Character Recognition software) or keyboarded.

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