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Catalyst

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Catalyst

Journal of the Amateur Yacht Research Society

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Robert Biegler

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Features

Front Cover: This picture was sent to the Editor by Michael Ellison, a Vice President of AYRS and also a member of the World Sailing Speed Records Council. WSSRC is considering recognising speed records for kite foiling, sail board foiling and wing foiling.

Innov-Sail – 29 to 31 May 2023 by John Perry

The author attended this three day conference which was advertised as an 'International Conference on High Performance Sailing Yachts and Wind Assisted Ships' and which this year was held at the Cite de Voile museum and conference centre in Lorient, Brittany. This is a conference mainly attended by professionals - i.e. yacht designers, staff from America's Cup teams, mainly French professional ocean racing teams together with university staff and students teaching or researching relevant subjects. I was one of just a handful present out of a hobby interest and that was not an issue with the organisers or with other attendees so I see no reason why other AYRS members should not attend such conferences. On my application form I gave AYRS as the organisation I was representing but I expect it would also be acceptable to state something like 'personal interest in sailing technology'.

Innov-Sail which takes place every three years in some place in Europe is one of a trio of international conferences covering sailing technology, the other two are the High Performance Yacht Design conference (HPYD) held in New Zealand and the Chesapeake Sailing Yacht Symposium (CSYS) held at Annapolis in the US. The three conferences rotate on a three year cycle and the program for 2024 to 2026 is:

- 2024 - HPYD No.8 – provisional dates 23 & 24 March – Aukland, New Zealand
- 2025 – CSYS No. 25 – Dates to be confirmed – Annapolis, US
- 2026 – Innov-Sail No. 7 – Dates to be confirmed – Stockholm, Sweden

So HPYD next year in New Zealand is going to be too far for most AYRS members to travel (although with at least one exception) but I understand that an on-line attendance will be made possible for this conference – not as good as attending in person (no banquet for one thing) but I will probably keep the dates free to watch the presentations on-line.

Plenty of opportunity for informal discussion at this conference

I would say that this was a friendly kind of conference – although most of the delegates were professionally involved in sailing it was clear that for many of them it was a hobby as well as a job – e.g. drawing super yachts during the week then sailing a dinghy with the family at weekends. So not difficult for an AYRS member to get chatting about sailing at this conference! The conference fee to attend Innov-Sail in 2023 was 250 euro. I think this is subsidised by various sponsors. A light breakfast and a three-course lunch was included on each of the three days and also a superb banquet on the second evening – the first course of the banquet was served at around 7:00pm and the final coffees and cakes appeared just before midnight. So you could say that the meals alone justified the conference fee. I have no idea whether the catering at the forthcoming HPYD or CSYS will be on a similar scale.

The opening keynote presentation was by representatives of Wisamo, the company which is developing clever inflated wing sails for commercial ships but the rest of the commercial sailing ship presentations were left for the third day. So the first two days were mainly about recreational sailing, with the emphasis for the first day on hydrofoils and for the second day on sail aerodynamics. The third day being about commercial shipping attracted a slightly different audience with a number of people from shipping companies attending that day only. There is now real interest in sails on commercial ships although it is not clear, to me at least, how much of this is motivated by the need for companies to be seen as progressive and 'green' as opposed to anticipation of real cost savings. Most of the projects in this field are about wind assisted ships rather than ships which are primarily wind powered but there are exceptions, one being the OceanBird proposal for a 220m length car carrying sailing ship https://www.theoceanbird.com/ another is the much smaller but ambitious Vela trimaran project https://vela-transport.com/. The cargo capacities for current wind assisted ship proposals are mostly quite small, perhaps a few hundred TEU (a measure of cargo capacity equal to one standard 20 foot container) and expected fuel savings are modest – typically 10%. One member of the audience did suggest that simply increasing ship size from a few hundred TEU up to the largest current container ships of around 10,000 TEU gives fuel savings per container mile of around 80% without any need for sails. Having said that, perhaps there will always be a need for smaller ships to serve smaller harbours and perhaps that is where sail assisted ships will first be seen.

Attempting to describe all the presentations here would be pointless since most of them are in the conference proceedings and available on-line but I will mention one not included in the official proceedings. This was a presentation by the team restoring the hydrofoil yacht 'Hydroptere' - https://lhydroptere.com/en/our-story/ . AYRS members will be aware that in 2009 Hydroptere achieved the outright world sailing speed record at 52.86 knots over 500m, the record previously having been held by windsurfers and then by kite surfers. Hydroptere held the record for a little over one year before it was regained by kite surfer Alexandere Caizergues, then other kite surfers held the record until Paul Larsen pushed it an amazing ten knots higher with Sailrocket. After its brief reign as world record holder, Hydroptere unsuccessfully attempted a Los Angeles to Honolulu record and was then abandoned in Honolulu and left to languish at anchor. Two enthusiasts, Chris Welsh and Gabriel Terrasse, were planning to bid for the wreck at an auction held by the harbour authority but met the night before the auction and decided to join forces to buy the boat rather than bid against each other. They managed to patch up the boat sufficiently to sail it to San Fransisco. Then, with help from the Airbus company, it was shipped to St Nazaire in France for a full restoration. The aim for the current phase of work is to restore the yacht as closely as possible to its exact state when it held the world record. Reference data will then be recorded under sail before starting the next phase during which the yacht will become a research vessel, basically a test bed for development of hydrofoils and sails. Certainly, an interesting project and one which would never be possible without a lot of enthusiasm, and some money. It was pointed out that Hydroptere is still the fastest ocean capable sailing boat in the world, at least in terms of peak speed potential.

Also included in the conference were visits to two companies located close by the Cite de Voile conference centre. Lorima is a yacht mast manufacturer and Avel Robotics makes carbon fibre hydrofoils. The author was at one time briefly involved with manufacture of carbon yacht masts using a filament winding machine and even at the time I knew that was the wrong way to do it since it is not possible to place truly longitudinal fibres, the best we could achieve was about 9 degrees off axis which is not really good enough. Lorima, and I think most other mast manufacturers, now make masts as two half sections in female moulds then glue the two halves together after completing all work needed inside the mast. During our visit to Lorima we saw the prepreg fibre being carefully placed into the moulds by hand following computer-generated layouts and also viewed the long autoclaves used to cure masts. There were a considerable number of mast sections in stock, some of them large enough that halyards could be threaded by crawling down insides. One mast in progress was actually large enough that you would not need to crawl, although you might need to stoop a bit – I understand that monstrous mast was destined for a commercial sailing ship project.

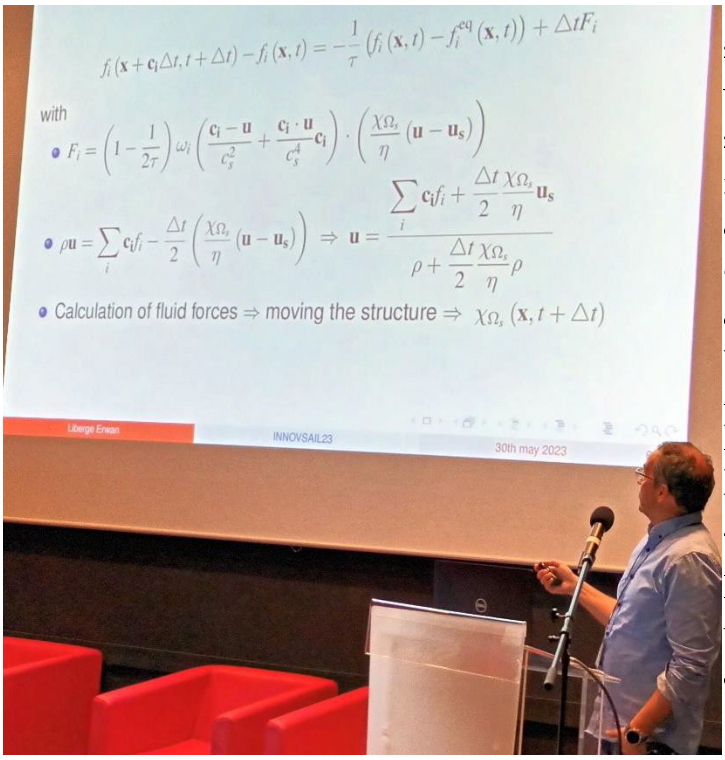
At Avel Robotics we watched a large robot placing carbon fibre tow to make hydrofoils for one of the fast-growing fleet of IMOCA60 ocean racing yachts, this is the main part of this companies business. These hydrofoils are curved like an elephant's tusk and different yacht designers prefer different curves so they rarely make two the same, at least not until one breaks which I hear does happen. I was surprised to see the way they are made – they are not made in a mould as one might expect. First, they make a few dozen curved strips which they referred to as battens. The battens vary in cross section dimensions and each batten tapers along its length. A large robot lays unidirectional prepreg tow onto release film placed on a flat platform to form each

curved batten. The battens are then cured in an autoclave before being glued together side by side to form the main structure of the curved foil with all the fibres aligned to resist bending. The varying cross section of the battens gives the taper of the foil towards the tip and also the hydrodynamic cross section. The glued assembly of battens is then overlaid with multi-axial carbon before final fairing and painting. A few of the foils have some lightweight core material but most of them are solid carbon composite throughout. The robot they were using was huge, like a double decker bus, if they ever run out of hydrofoils to make I would imagine the same robot could be used to make other composite parts.

Delegates on board the yacht 'Intrepid'

The conference delegates had the opportunity to actually go for a sail. I signed up for that and immediately after the final presentation of the day we trouped on board the 72-foot sloop 'Intrepid' which was conveniently parked on the pontoon right outside the conference centre. As we came aboard the three professional crew handed out auto-inflating life jackets but I don't think any of us had anticipated going to sea so we were all in smart casual dress, some with suits and even ties. Fortunately, the weather was perfect with warm sunshine and although it was blowing up to 20knots the big yacht surged along at ten knots+, upwind and downwind, with no spray coming even close to the cockpit. Its not like that on either our sailing dinghy or our trimaran! With four conference attendees working a 'coffee grinder' we raised the sails in the harbour entrance then tacked to windward westward off the beaches of Larmor-Plage then reached over to close by Ile de Groix before a run back into Lorient. This was by far the largest boat I have been on board while sailing. It was also an innovative design with a hydraulic lifting ballast keel and with a propeller and shaft that retracts fully into the hull while sailing.

So, was the Innov-Sail conference relevant to my own little experiments with hydrofoils? As I mentioned at an AYRS Zoom meeting, I have been experimenting with a hydrofoil running at an angle of dihedral (one tip deeper immersed than the other) while close to the water surface. This causes asymmetry in both the lift and drag forces and hence, for a tee foil configuration, there can be expected to be a torque about the strut that supports the lifting foil. From the conference I realised that I am not the only one looking into such effects which are clearly relevant to the tilted Tee foils on current America's Cup yachts and now some other racing yachts as well as the smaller Tee foils on wind and kite boards and many varieties of foiling sailing dinghy. I made a test rig which was displayed on the AYRS stand at the RYA show and I have also made a very preliminary investigation of the possibility of using OpenFoam CFD software to model a tee foil at a dihedral angle close to the surface but I find that OpenFoam has a pretty steep learning curve. I was pleased to hear at the conference that there is open source software called 'PUFFIN' that can be used to analyse hydrofoils, so I will be giving that a try and maybe reporting on it in due course.



1 A few of the presentations included substantial mathematics, some of the presentations included serious maths, but most could be followed without great maths knowledge.

The proceedings of this conference are all freely available on-line – the link, at least at the time of writing, is https://www.innovsail.com/ - there is a download button on that page for all the papers. Many of the papers are also due to be published in the Journal of Sailing Technology which is also available free of charge, the link ishttps://onepetro.org/JST.

Ps. - For the 2022 SailGP we invited AYRS members abord our trimaran to watch from at anchor. On the practice day before the first race day Josephine and I were sailing the trimaran at a sedate 12 knots just off Plymouth breakwater when we were passed at just a few metres distance by one of the SailGP boats sailing at perhaps 30 knots. This was quite scary, our anxiety heightened by the quite loud whistling sound generated by these hydrofoil sailing boats.

One thing I learnt from the Innov-Sail conference is that this is called tonal noise and although it is not fully understood it is due to unstable flow at the trailing edges of the hydrofoils which vibrates the foils at audible frequency. The sound is transmitted through the structure of the boat so it is potentially an annoyance for crew on a long passage. (The conference included a French Naval Academy presentation).

NWLG Windemere meeting - 6th June 2023

In attendance were Mark and Launa Hillman; John and Josephine Perry; Richard Fish; John Shuttleworth; Colin McCowen. We did a car share from Warrington to Mark's house. Richard offered to do the driving. His car was bigger and smoother than mine. Thanks very much Richard. I liked your calm style of driving. As you can imagine every topic under the sun was discussed, even a bit about boat designs.

On arrival we were treated to a wonderful lunch which Lorna had prepared. Then we walked down to the lake, Transported in an electrically powered dory, to a beautiful Windermere 17 Racing Yacht. Mark took Richard F, John S, and Colin Mc, For a fantastic sail up to the north end of the lake and then back down and round the islands at Bowness. There was a bit of shouting about keeping away from the red buoys which are supposed to mark the hidden rocks. They were all around us! We all had a turn at the tiller.

When the boat is heeled to 30 degrees it is quite difficult for four adults to find a sitting position and not slide down into the scuppers in the enclosed cockpit. The rules for these boats are that you are not allowed to climb out of the cockpit and sit on the gunwale. In the middle of the lake there were some really good breezes and the lead keeled boat possibly heeled over even more. Mark said to me “you can point her up higher if you like” I am still not sure if this was just some friendly advice or an urgent request?

I had to ask why there was a double main sheet? The answer was that by pulling on the two you could get the sail in quickly or by pulling on one you could get a bigger leverage force.

The afternoon’s meeting or jolly if you want to call it such was ended with tea and cakes and a light traffic journey home.

Richard Fish with small model of proposed wing sail.

I want to greatly thank all those who made this great and memorable day possible and for arranging such beautiful weather.

Colin McCowen

Balanced Foils Part 2,

Part 2 of a four part series Dr. Ian Ward Sydney, Australia

Design of balanced foils

During the development of balanced foils many unexpected issues arose due to the nature of pressure changes resulting from varying angle of attack and the foil shape itself. These issues are described below in detail, highlighting some of most the important features and experience of fully balanced foiling systems.

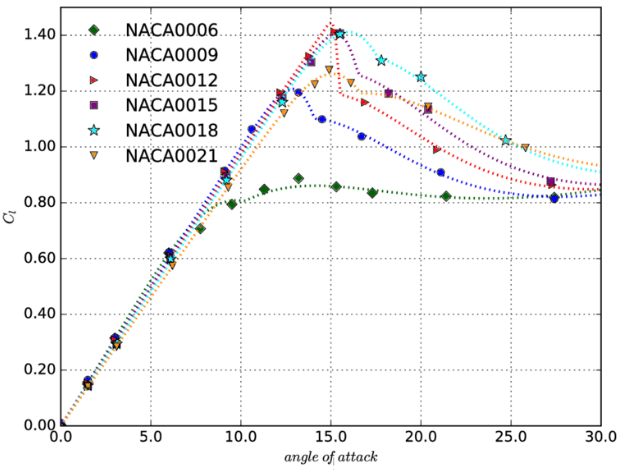
Angle of attack provides lift

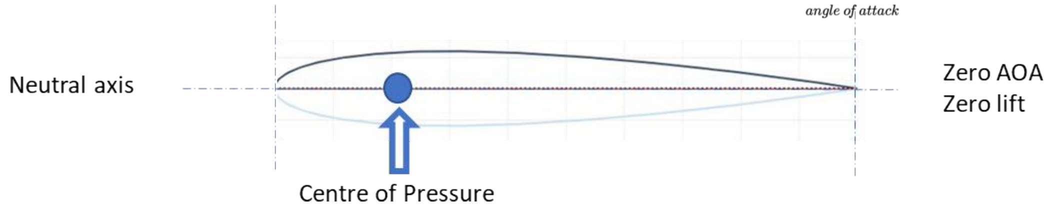
Lift from any foil, even a flat plate, is generated by its effective angle of attack to the water flow. All foils including flapped foils have an angle of incidence at which they produce no lift. Any change to this angle will produce lift in proportion to the angle of incidence, until it stalls.

Defining angle of attack

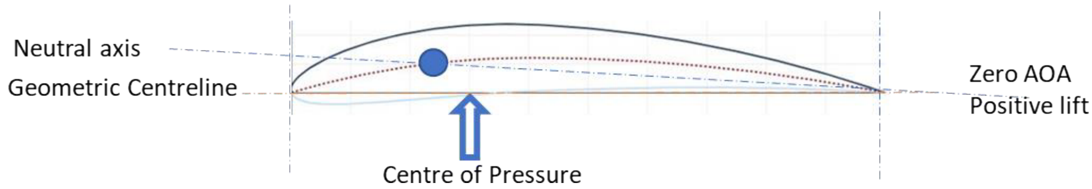
The "natural" properties of any hydrofoil are its neutral axis and its centre of pressure. All foils have an angle of incidence at which they produce no lift which can be defined as the 'neutral axis' or 'zero lift line'.

For symmetrical foils, the neutral axis coincides with the 'geometric centreline' or 'chord line' of the foil and it produces no lift at zero angle of attack. Lift is only generated by altering the angle of attack.

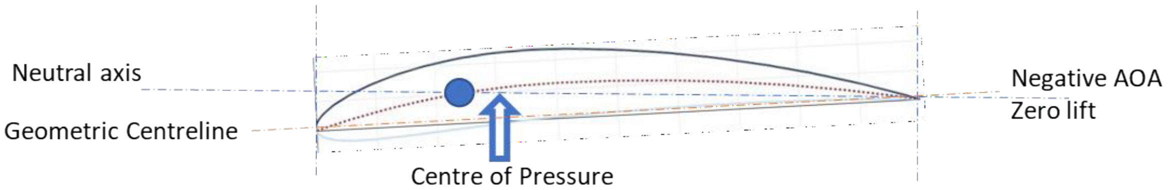




Asymmetric, cambered foils however, have a neutral axis which is offset from the geometric centreline due to their asymmetric shape, this is effectively an 'inbuilt' angle of incidence. They also have a centre of pressure which moves fore and aft significantly with changes in angle of attack.

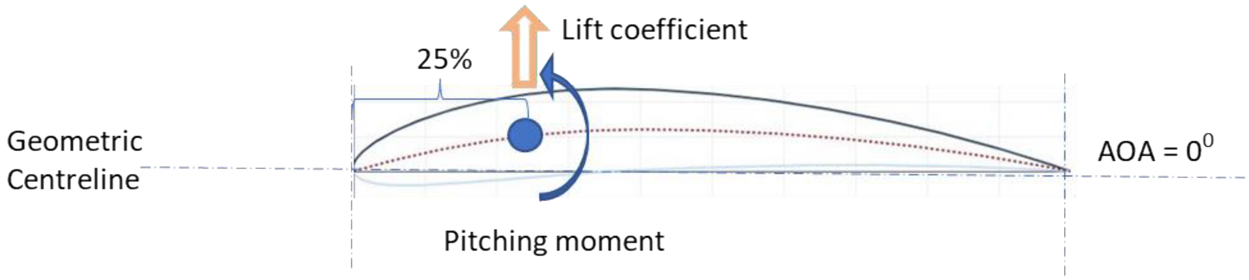


As a result, they may produce zero lift at “negative” angles of attack when compared with the geometric centreline.



By convention, the geometric centreline of a foil is defined between perpendicular tangents to the extremities of the section. This is not the actual centreline of neutral or zero lift, unless it is a symmetrical foil, it just a convenient way to geometrically define a centreline of the foil and the chord.

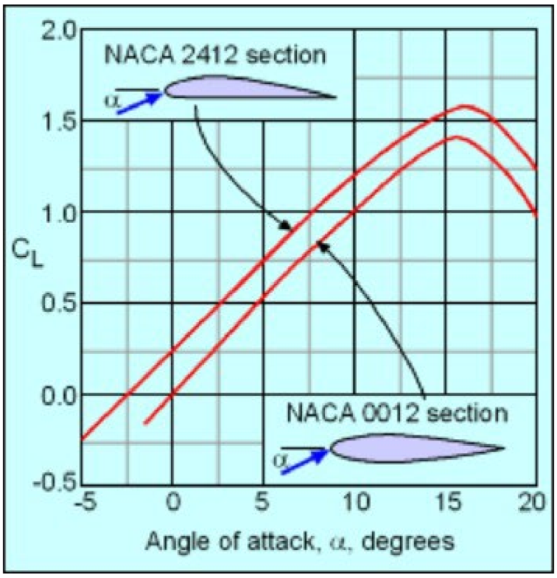
This geometric centreline defines the referenced “Angle of Attack”. For the sake of convenience, the geometrical centre is defined at 25% chord from the front. This is done to make it easy to describe and compare the performance of foils of various shapes, without needing to specify the centre of pressure for each individual foil shape, identify its actual neutral centreline and determine its movement with each change in angle of attack.



The variation in position of the centre of pressure is then defined as producing a ‘theoretical’ pitching moment about the artificially defined geometric centre, which is at the same location for all foils and it is the geometric centreline which defines the angle of attack.

In this analysis, a symmetrical foil produces zero lift at zero angle of attack, however asymmetric foils with camber have an offset neutral centreline, so they ‘produce lift even at zero angle of attack’ based on their geometric centreline, which is not the same as their neutral or effective centreline.

Misconceptions



This convention provides a very useful standard method of defining and comparing foils, but it unfortunately creates the 'notion' or even an 'illusion' that asymmetric foils are somehow able to magically develop positive lift at zero angle of attack, which symmetrical foils are not. This in turn 'conjures' a mistaken belief that this lift is perhaps not associated downwash or increase in drag, implying that you get something for nothing, when in fact, this is just a function of how the shape and centreline are defined by convention.

This is the same situation for flapped foils, which effectively increase lift through a change in camber of the foil, rather than changes in angle of attack of the fixed section. It is therefore often construed that flapped foils are somehow 'far more efficient' than articulated non-flapped foils, despite the fact that they are used highly successfully on helicopters, propellers, boat rudders, and GP50 catamarans etc.

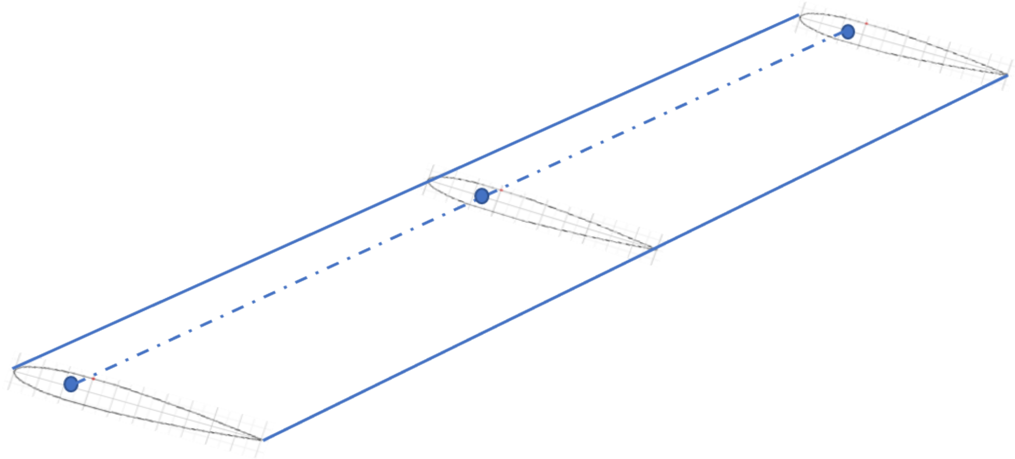
A good practical comparison of performance is the Skeeta with its balanced foil and the Waszp with a flapped fixed foil. Both boats have very similar size, weight, sail area and foil size. They take off at the same windspeed and sail at similar speeds upwind, while the Skeeta is a little faster downwind. The balanced foils of the Skeeta however, are much more practical to rig, launch and operate.

Such misconceptions about differences in the efficiency of various foil types are rife throughout the common understanding of how foils work, which has had an unfortunate influence on the acceptance of various foil designs and configurations.

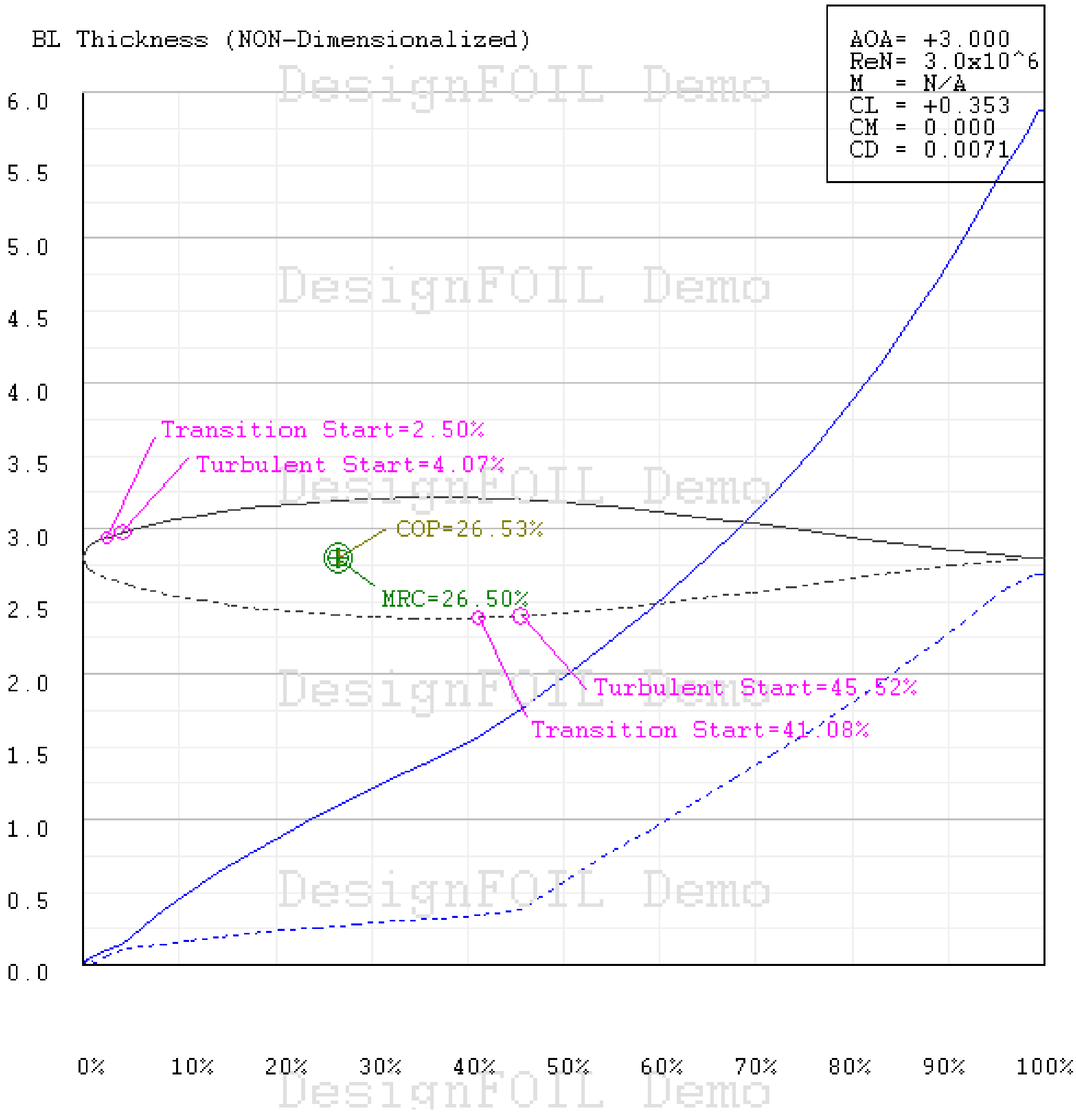
I have experienced several 'experts' including designers of foiling systems who have claimed that both centreline foiling systems and balanced foils without flaps 'cannot work' or are 'highly inefficient' and yet practical experience has proven otherwise. These foils are not only efficient, but also highly practical as described above.

Simple symmetrical balanced foils

The simplest balanced foil is symmetrical in profile, straight horizontally and rectangular in planform with its axle on the centreline, close to the centre of pressure.



Symmetrical foil

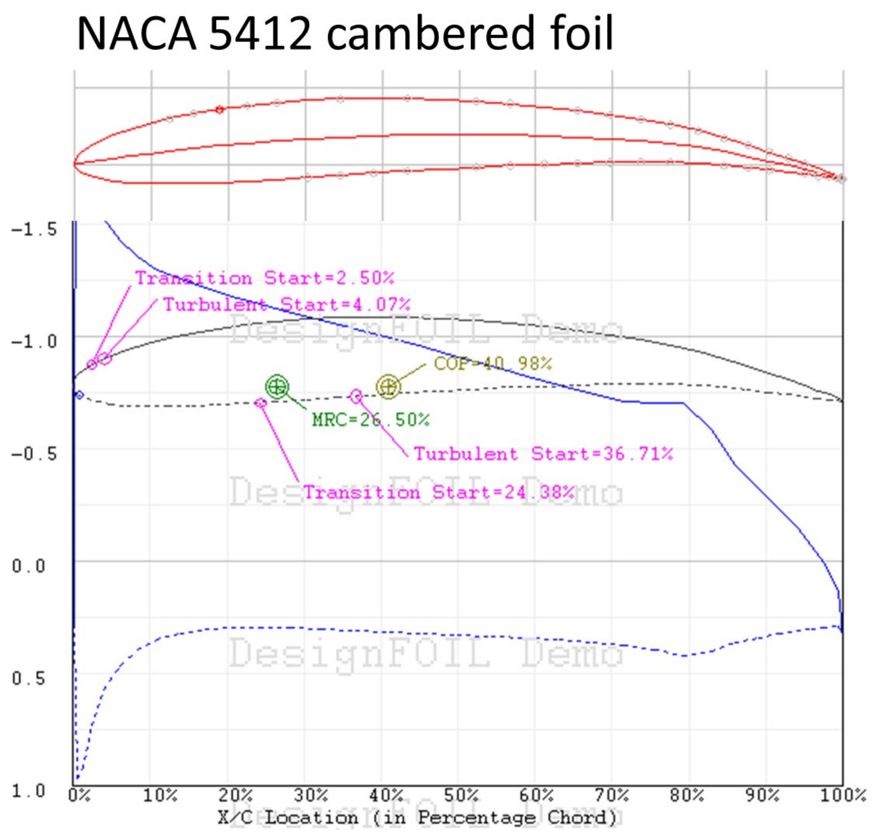


The above graph shows a pressure distribution analysis and the centre of pressure for this section which is located on the centreline and moves very little with changes in angle of attack. The axle pivot can be located at or near this point with little change in forces acting with changes in the angle of attack.

A major benefit of symmetrical foils is that pushrod loads remain consistent despite large changes in their angle of attack. System loads can therefore be kept very small. Also, the foil can be disengaged, and it will feather in the flow with low resistance for displacement sailing.

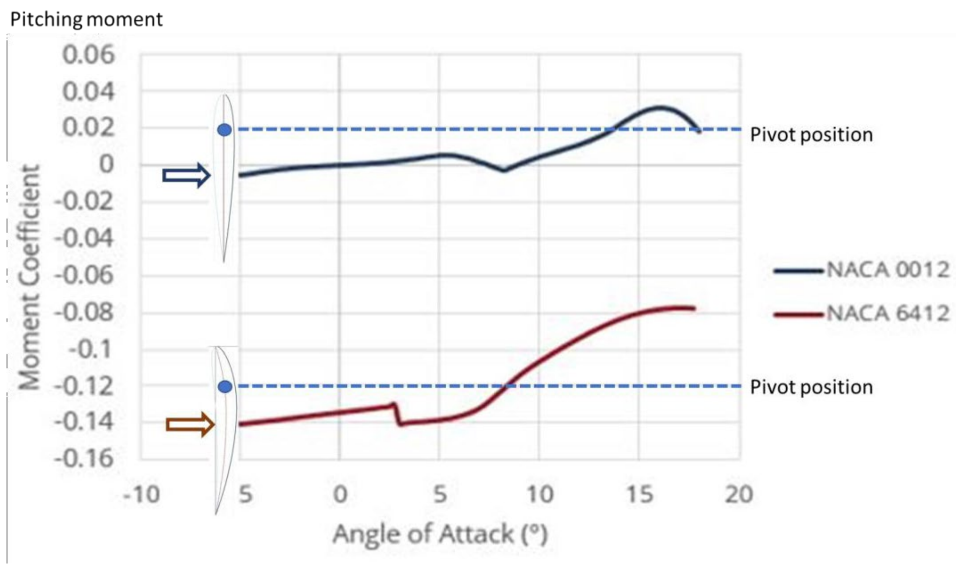
Cambered foils

Cambered foils offer several key advantages over symmetrical foils. They typically have less drag at moderate angles of attack to produce the same lift. They also have a higher stall angle, enabling smaller foils at lift-off and hence reduced drag overall.



Movement of centre of pressure

For cambered foils, the centre of pressure can be well aft and moves significantly fore and aft with changes in the angle of attack. In this example below the centre of pressure has moved to 3 times further than for a symmetrical foil.



The pitching moment changes as centre of pressure moves forward when angle of attack increases. This makes design of the location of axle pivot much more complex than for a symmetrical foil.

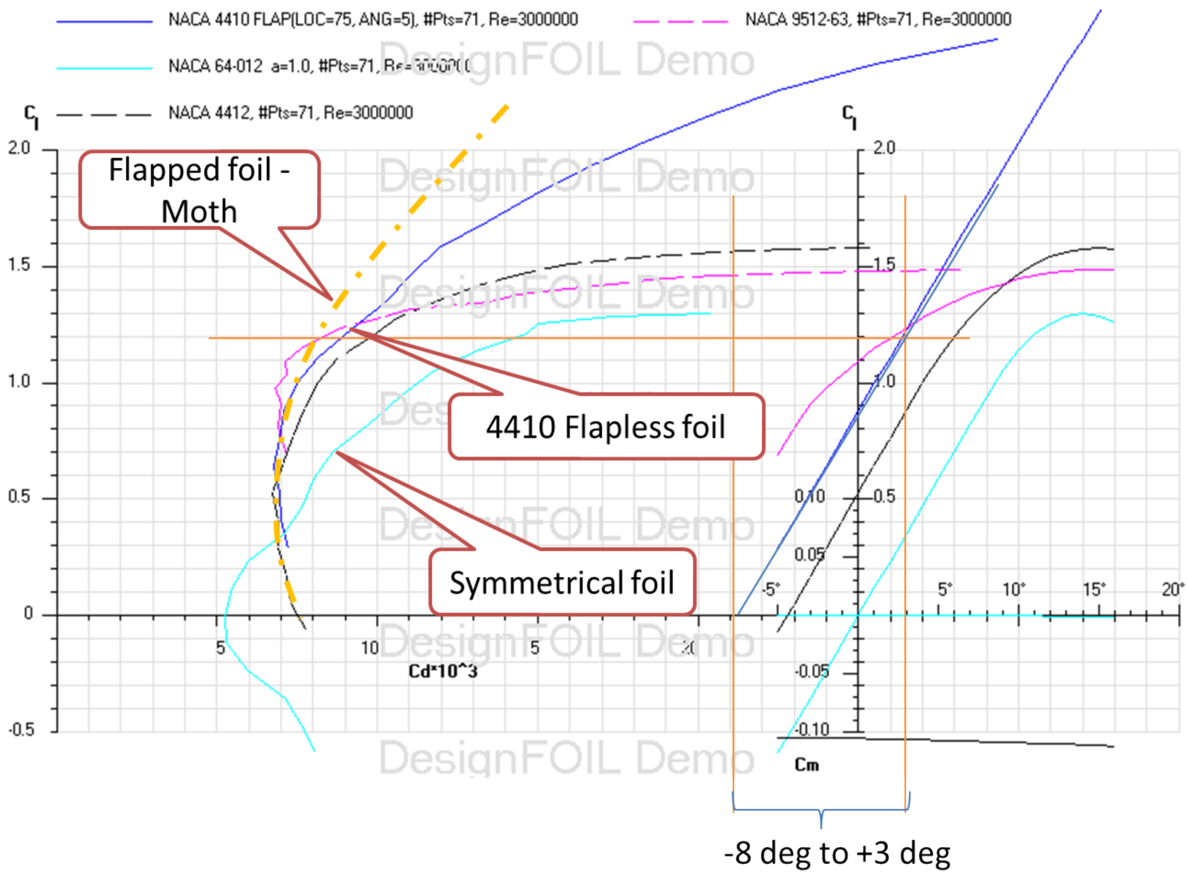
Foil shape

While a balanced foil system works perfectly well with a symmetrical foil, cambered foils allow a significantly higher angle of attack before stalling, which enables more lift at take-off and with less drag. The asymmetric shape of a cambered foil influences the performance of the foil in both positive and negative ways.

While there is less drag at take-off and upwind with a cambered foil, there may be slightly increased drag at higher speeds and at low angles of attack. In order to properly describe the behaviour of balanced foils, both cases for symmetrical and asymmetrical foils shapes will be considered separately.

Flapped foils have the advantage of relatively low drag at high speeds and the possibility to produce high lift coefficients for take-off, with relatively low drag and high stall angles. The comparison below shows the differences. During normal running of the foils at moderate speeds such as upwind sailing from 12-18kts, there is little difference in performance with a cambered foil, provided the flap is aligned with the foil. If the flap is not aligned, drag increases significantly.

Comparing foils



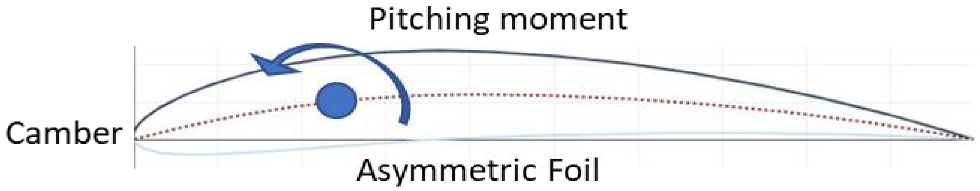
The ideal foil shape may in fact be a combination of both flapped and fully articulated foils, where entire foil pivots, but it also has a flap to provide even more lift at take-off, enabling even smaller foils. To date I am not aware of anyone trialling this.

Asymmetric foils suck

When a freely articulated asymmetric lifting foil was first trialled, it was found that an unexpected behaviour occurred. With foil inserted from below in the centre case, but retracted for launching, the boat was caught by a gust from behind when sailing off the beach. The boat sped off downwind, then promptly sucked the foil straight out of the bottom of the boat! It did not just fall out, it was sucked down hard.

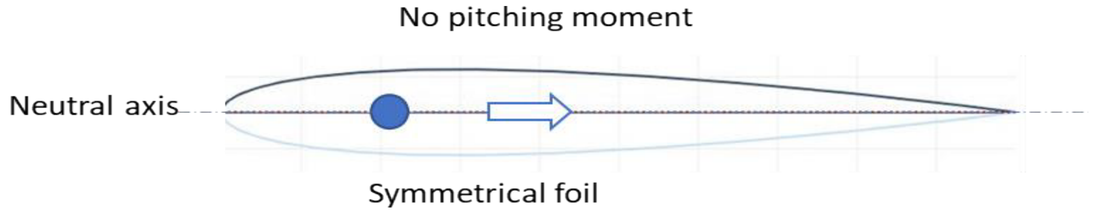
Then, when sailing in displacement mode with the foil pinned in position, but with wand/pushrod disengaged, the boat was sucked down by foil, pushing it into water, making it quite slow and even causing it to nose dive when driven hard.

As soon as a small positive load was applied to the pushrod, the boat lifted and sailed normally. Subsequent investigation revealed that an asymmetrical shape of the foil has a pitching moment, which makes it pivot downwards, providing negative lift or 'suck'.



Pitching moment causes the asymmetrical foil to rotate down and suck

In systems designed to disengage, for low drag displacement sailing, it was decided to use a symmetrical lifting foil, which solved this issue. In another case, the vertical foil was set up to be inserted from above and the adjustable wand height used to control the asymmetric foil.

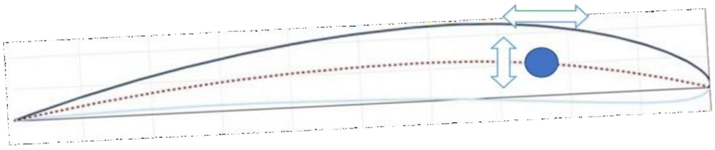


Symmetrical foil has no pitching moment, so it does not rotate and suck.

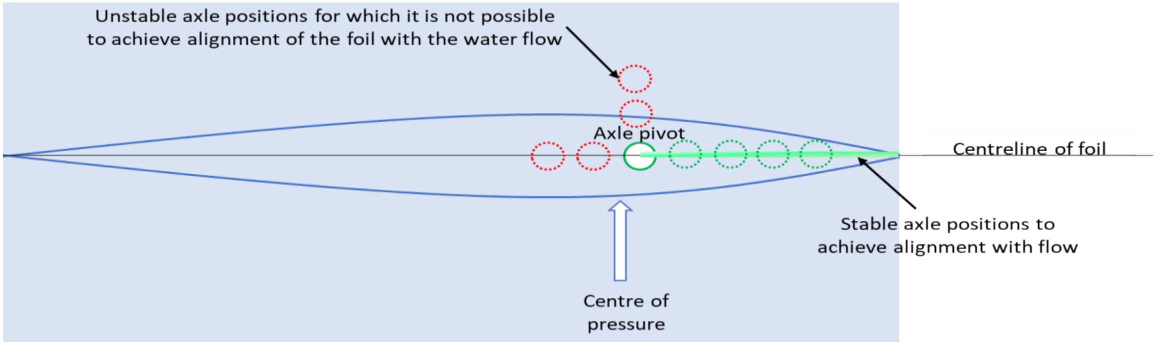
Clearly it has been important to modify the design to overcome the shortcomings of a foil that sucks. On the other hand, a sucking foil may be highly beneficial in a twin foil system to provide righting moment from the windward foil if required.

Pivot location

The foil shape dictates the position of the centre of pressure. Both vertical and fore & aft positions of the pivot are critical to the balance of the foil. Planform & sweep affect the fore & aft position and balance, as do dihedral/anhedral and horizontal curvature of the foil.

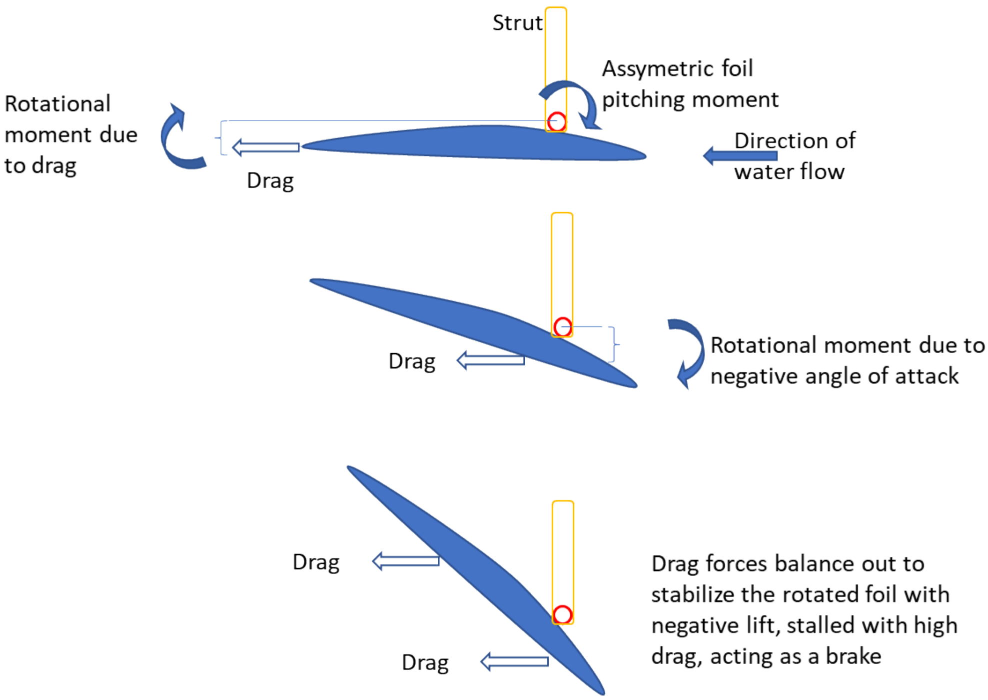


For a symmetrical foil, there is a range of axle positions for which the foil will trail neutrally with the flow, if left to its own devices. If the axle is located behind the centre of pressure or above or below the centreline the foil will become unstable and immediately pivot to a stalled position and lock itself there.



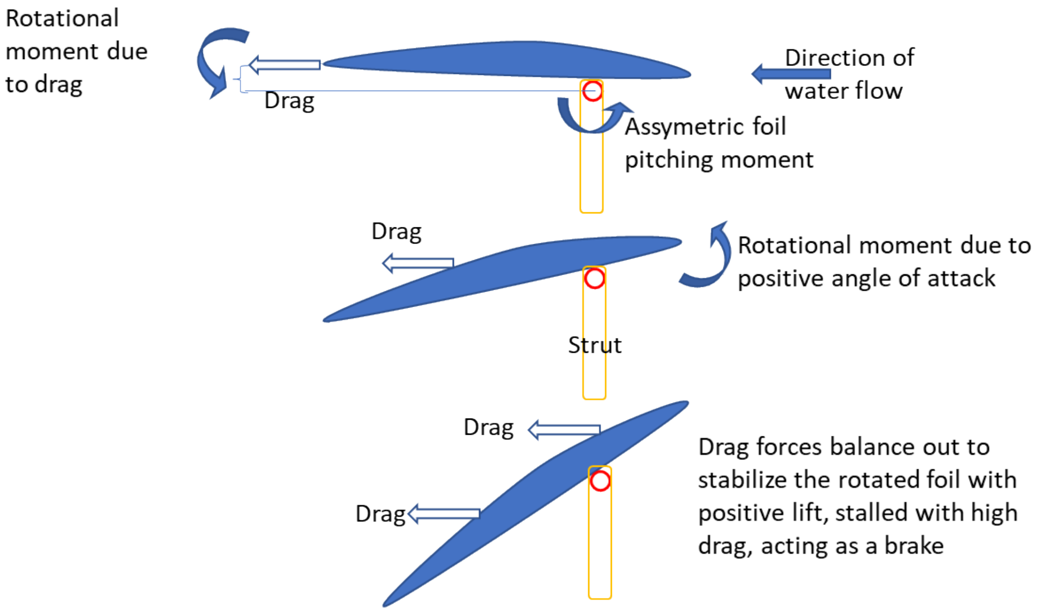
Vertical position

When the biasing force (tension or compression) is removed, the foil is left free to rotate with the flow of the water. If the foil pivot is above the centreline of the foil as shown below, this results in pitching of the foil downwards due to the misalignment of the foil drag and pivot.



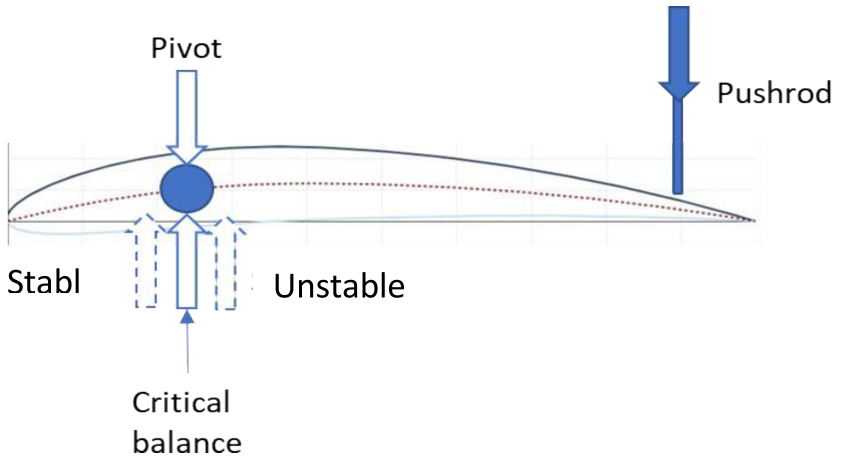
This means this foil system is unstable and will produce negative lift if left to freely rotate.

On the other hand, if the pivot is located below the centreline of the foil, it will pivot upwards and stall.



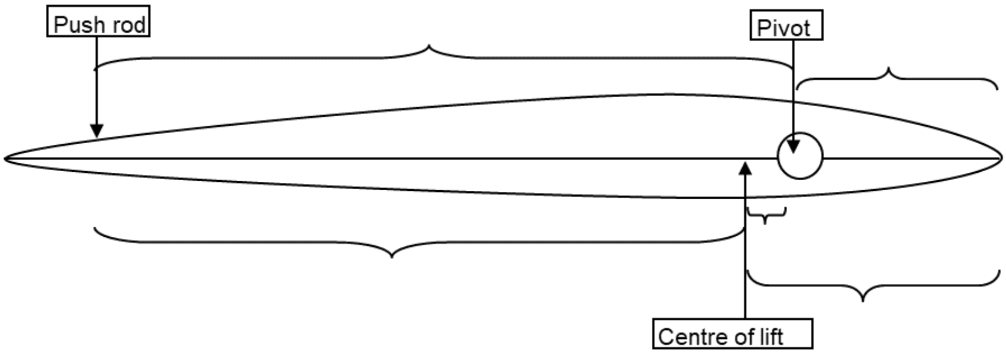
Fore & aft position

With the pivot aligned along the centreline of the foil, the fore and aft position of the pivot becomes very important. As the foil design approaches "critical balance" the centre of pressure moves closer to the load pivot.



Pushrod loads

To determine the position of the axle, it is important to understand the loading being applied to the pushrod. If the foil is designed to lift say 200Kg, then if the pivot is located very close to the centre of pressure, it is possible to have very small loads of just a few grams on the pushrod to control the foil. As the pushrod is in turn



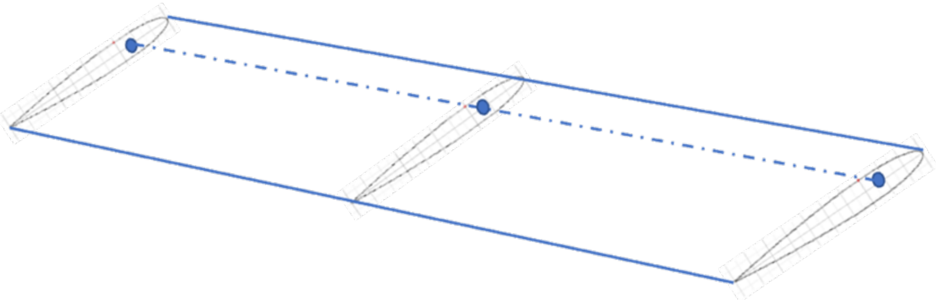
controlled by a wand, it is useful to have a backload on the system of say 1-2Kg in order to maintain compression in the connections and to push the wand against the water surface. This load can therefore be determined by the offset of the axle pivot. A calculator has been developed for this purpose. If the load exceeds 3-4 Kg, there is a back pressure on the entire wand control system, which pushes the wand paddle into the water. Excess back pressure through the pushrod and wand can significantly reduce the angle of attack and even prevent the boat flying altogether.

Chord mm	**100**		Pushrod m	**60**	
CL %	**42.0%**				
CL mm	32.0				
Load Kg	**200**				
Pitching	**0**			incl pitch	Pushrod
Pivot mm	%	Lever	Kg	Kg	Kg
0	0%	32.0	200.0	200.0	106.67
5	5%	27.0	168.8	168.8	82.84
10	10%	22.0	137.5	137.5	60.50
15	15%	17.0	106.3	106.3	40.14
20	20%	12.0	75.0	75.0	22.50
25	25%	7.0	43.8	43.8	8.75
26	26%	6.0	37.5	37.5	6.62
27	27%	5.0	31.3	31.3	4.73
28	**28%**	**4.0**	**25.0**	**25.0**	**3.13**
29	29%	3.0	18.8	18.8	1.81
30	30%	2.0	12.5	12.5	0.83
31	31%	1.0	6.3	6.3	0.22
32	32%	-	0.0	0.0	-
33	33%	- 1.0	-6.3	-6.3	0.23
34	34%	- 2.0	-12.5	-12.5	0.96
35	35%	- 3.0	-18.8	-18.8	2.25
36	36%	- 4.0	-25.0	-25.0	4.17
37	37%	- 5.0	-31.3	-31.3	6.79
38	38%	- 6.0	-37.5	-37.5	10.23

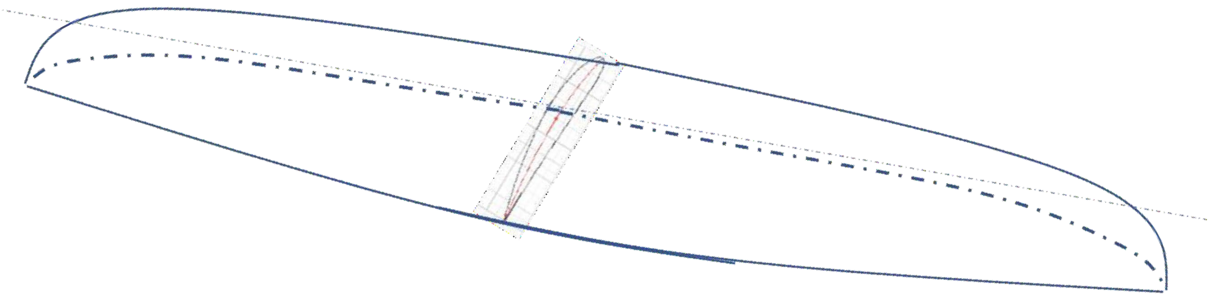
This analysis shows the influence of pivot position on pushrod loads for a symmetrical foil

Effect of foil plan shape

In plan view, a simple straight, square foil is fully balanced and works rather well.

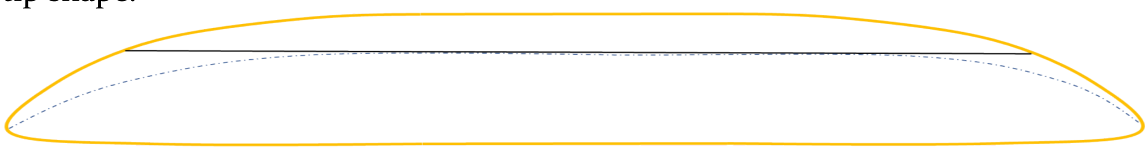


To improve efficiency of this basic foil, it is common practice to increase its aspect ratio, taper and shape of the wing tips. Unfortunately, this can have a rather negative influence on the performance of the system, as the shape in plan view greatly affects the balance of the foil. The further that the centreline of the shaped foil deviates from the pivot axis, the more load is applied to the pushrod, mechanisms and wand. In fact, it was found that this can prevent the boat from taking off altogether.



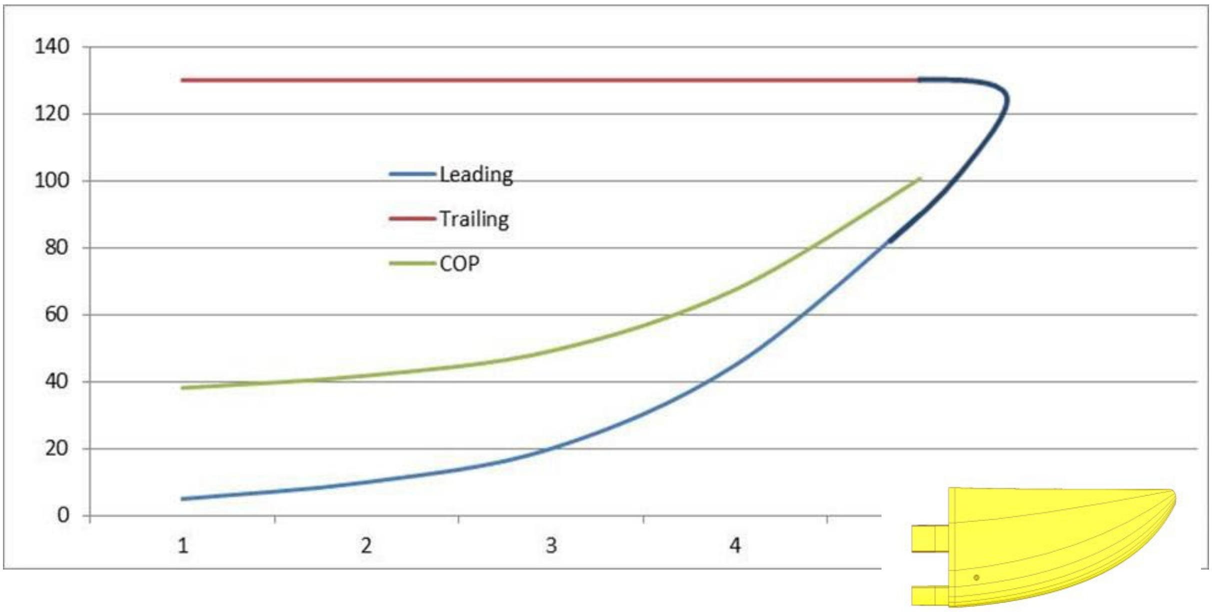
A series of trials was conducted with different wing tip shapes, which began to define the characteristics of balanced and unbalanced foils. These results are presented below.

Initially, it was found that a Shark Fin shaped wing tip with a swept back tip profile prevented the system from taking off and flying controllably. It was discovered that this was due to there being far too much loading on the pushrod due to the aft swept tip shape.



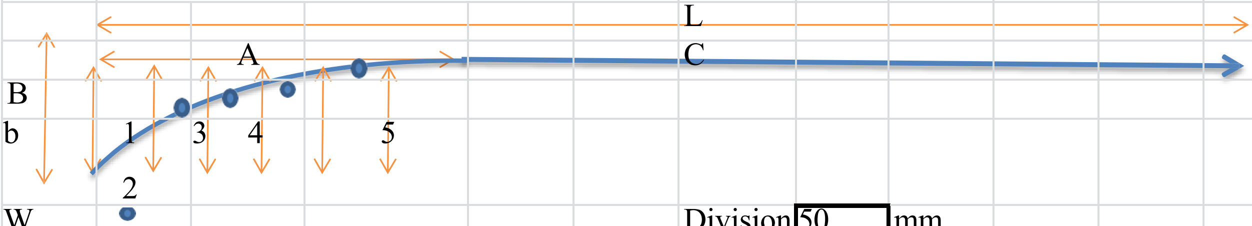
Analysis highlighted that the alignment of centre of pressure of the foil, was well aft of the pivot line of the axle, which increases the effective load on the pushrod

It was decided to remove these loads by developing a neutral foil shape, with a slight negative pitching moment. Testing this foil was first important indication of powerful effects of imbalance. Trials were at first highly frustrating, as its performance was highly



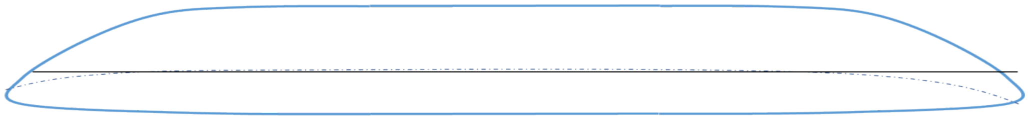
inconsistent. On some runs, it would take off and fly, on others, it would drag, stagger and stall during take-off. On yet others, it would suck the boat deep into the water with no sign of any positive lift at all. To analyse the effect of wing shape on centre of pressure, a simple calculator was constructed in a spreadsheet which determines offset in centre of pressure at sections throughout the width of the foil.

Wing Tip Centre of Pressure Calculator

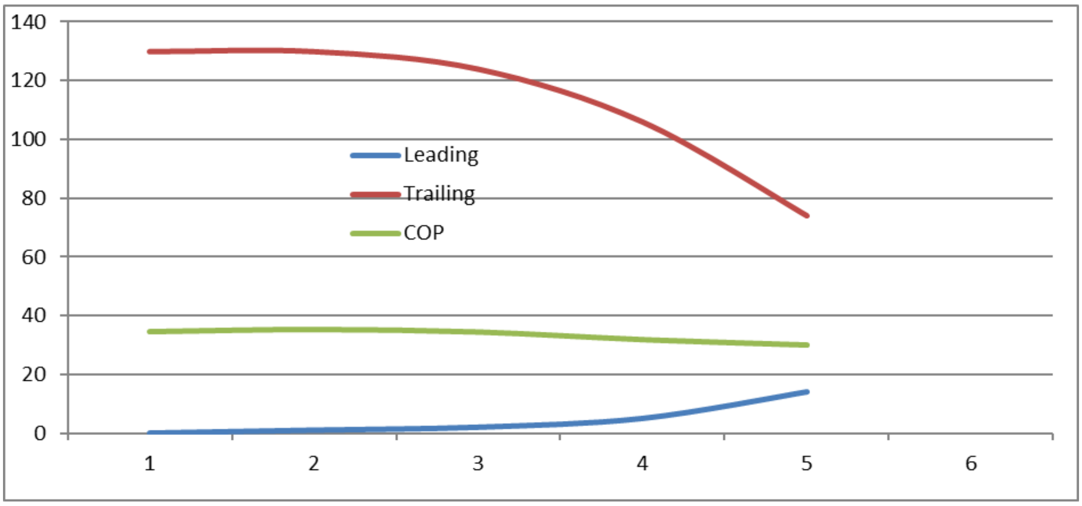


						Division	50	mm			
	Overall			5	4	3	2	1			
COP	27%		COP	27%	27%	27%	27%	27%			
A	250		A	50.00	50.00	50.00	50.00	50.00			
B	130		B	130.00	130.00	130.00	130.00	130.00			
W	130		b	128.00	120.00	107.00	80.00	45.00			
C	900		Area	64.00	60.00	53.50	40.00	22.50			
F	160	Kg	COP mm	35.92	41.80	51.36	71.20	96.93			
L=C+2A	1400		Lever	1.47	7.35	16.91	36.75	62.48	Half total	Total	
Area	1820		Force	5.63	5.27	4.70	3.52	1.98	21.10	42.20	Kg
Load/area	0.087912		Moment	8.27	38.77	79.51	129.23	123.58	379.36	758.71	Kgcm
Pushrod dist	117		Pushrod force						4.60	9.19	Kg
Pushrod Lever	82.55	mm									

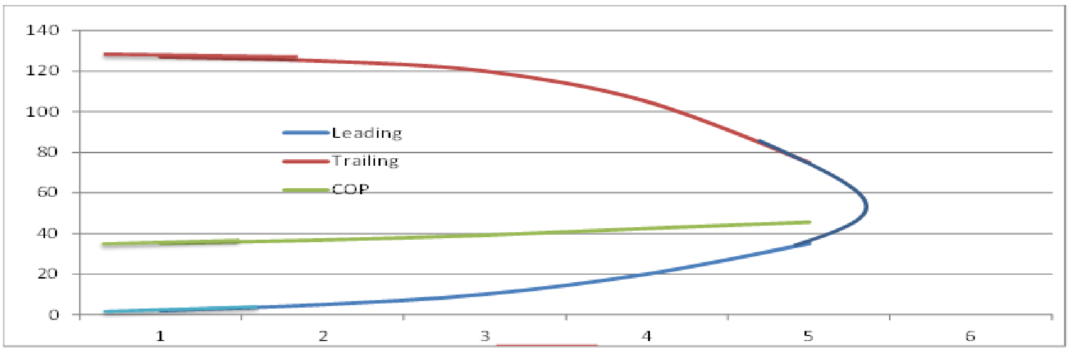
Analysis of the modified foil tips using this calculator showed that it was unstable due to the centre of lift of the foil being slightly forward of the axis pivot line of the foil. It could decide seemingly at whim to flip down and suck with no chance to lift off, alternatively it may lift positively and stall, or perhaps sometimes lift and run as intended.



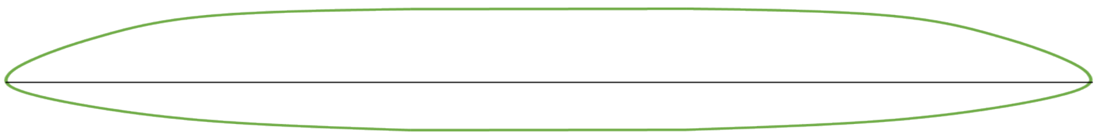
Wing tip with negative pitching moment



In the end it was decided that a 'Spitfire' wing tip shape maintained balance in the foil with the centre of pressure just aft of the pivot axis across the entire width of the foil, while enabling a tapered high aspect shape for improved efficiency.



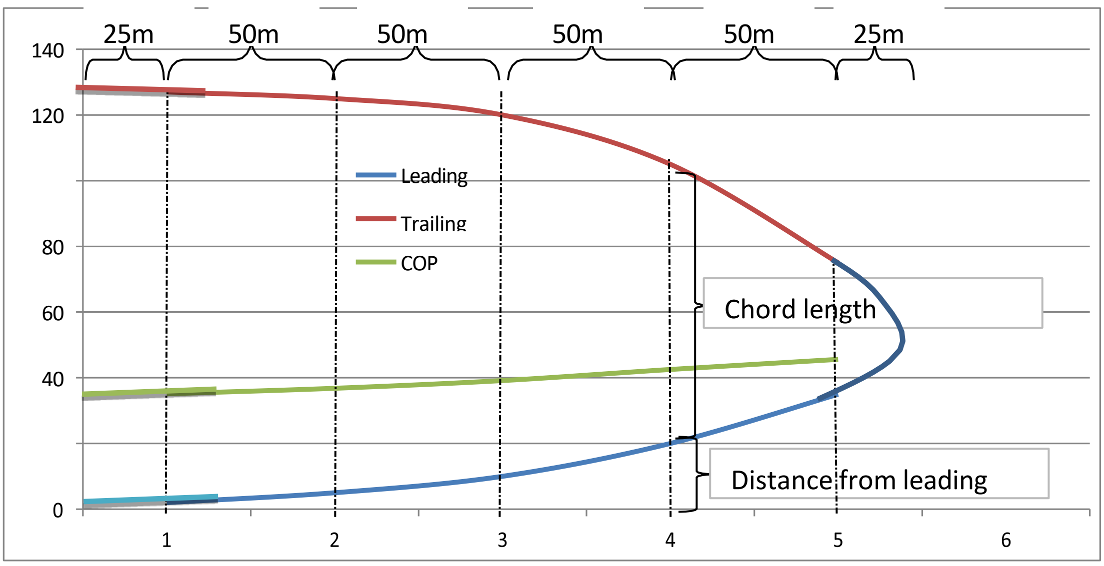
Proposed Spitfire wing tip with small positive pitching moment



Below is a table of the wing tip design planform shapes with their calculated pitching moment expressed as the pressure exerted on the pushrod. The original square tip worked fine but could do with a little more load on the wand. The Sharkfin shaped tip placed 8.4Kg on the pushrod, which is excessive. While the unbalanced tip became unstable with -.46Kg on the tip, allowing it to pitch up. In the end, the Spirtfire tip shape was designed to give 2.0Kg load on the pushrod.

Square Tip	5	10				Pushrod Load
Leading Chord	125	120				1.34Kg
Shark fin Tip	5	10	20	45	90	8.4Kg
Leading Chord	125	120	110	85	40	
Spitfire Tip	2	5	10	20		2.01Kg
Leading Chord	125	120	110	85		
Unbalanced Tip	0	1	2			-0.46Kg
Leading Chord	130	129	122			

Below is a sketch of how the planform is developed from the figures given in the table



Other wingtip plan shapes

Spitfire wingtip shapes are not the only way to produce a balanced foil. Trials with many other shapes in both moulded carbon fibre and extruded aluminium with injection moulded tips have been produced and all work well, provided they are properly balanced around the pivot axis.

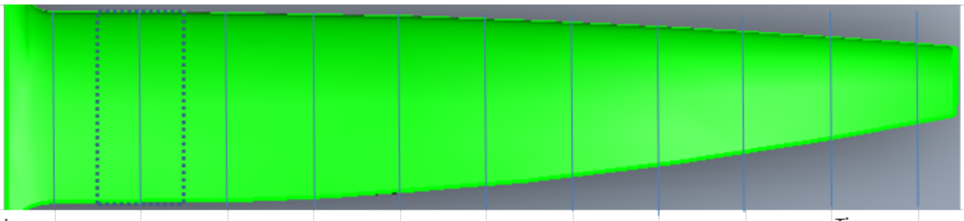
Balanced wing tip shapes

Horizontal anhedral, dihedral & curvature

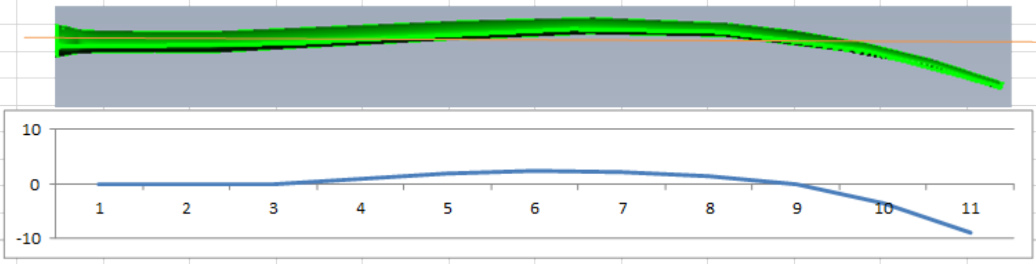
Another aspect of improving foil efficiency is to modify foil shape in the vertical plane to reduce tip flow vortex drag and provide anhedral or dihedral stability.

Initially, a test foil was constructed with anhedral wing tips as illustrated below. While appearing to have good lift at take-off, the boat tended to sail closer to water surface as it went faster. It was discovered that this was due to significantly increased pushrod load as boat speed increased. This was in turn found to be due to drag force of the tips acting below the pivot axis, which increases as boat goes faster.

In a similar manner to the balancing of forces in plan view, a simple calculator was created to analyse the forces acting above and below the pivot axis. It was found that the loads above and below the pivot axis could be offset to produce a balanced foil with low pushrod loads at all speeds.

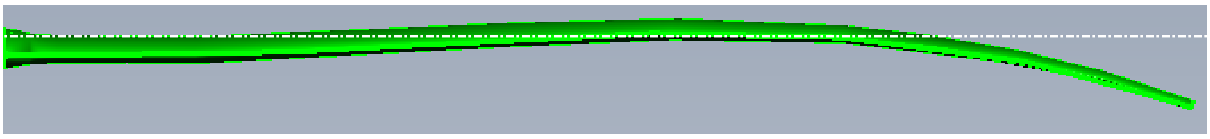


		Centre									Tip		
	Gap	0	1	2	3	4	5	6	7	8	9	10	
	35	35	35	35	35	35	35	35	35	35	35	35	
Height	mm	0	0	0	1	2	2.5	2.1	1.5	0	-3.5	-9	
Chord	mm	100	100	100	95	90	85	80	75	70	65	60	
Area		3500	3500	3500	3325	3150	2975	2800	2625	2450	2275	2100	
Moment		0	0	0	3325	6300	7437.5	5880	3937.5	0	-7962.5	-18900	**17.5** Result



Analysis of the drag forces above and below the pivot axis

Based on this analysis tool, it was possible to design a 'gull wing' foil, with some sections above the pivot axis, balanced by others acting below the axis. Net result being a balanced foil, which still met design requirements for an anhedral foil tip.



Balanced 'Gull Wing' foil with foil drag balanced above and below the pivot axis

Unstable characteristics 'Trip-Stall' phenomenon

To design a balanced foil with an 'asymmetric' shape is particularly challenging. This is because the centre of pressure moves fore and aft as angle of attack changes.

As explained above, it is important to maintain low pushrod loads, especially at high speeds and low angles of attack. Despite having a foil with balanced plan shape profile and a balanced horizontal profile, this is not sufficient to ensure stability.

This is because it is important that centre of pressure at high angles of attack, especially during take-off, does not make the foil unstable, otherwise it may trip or lock up, causing an immediate breach or stall.

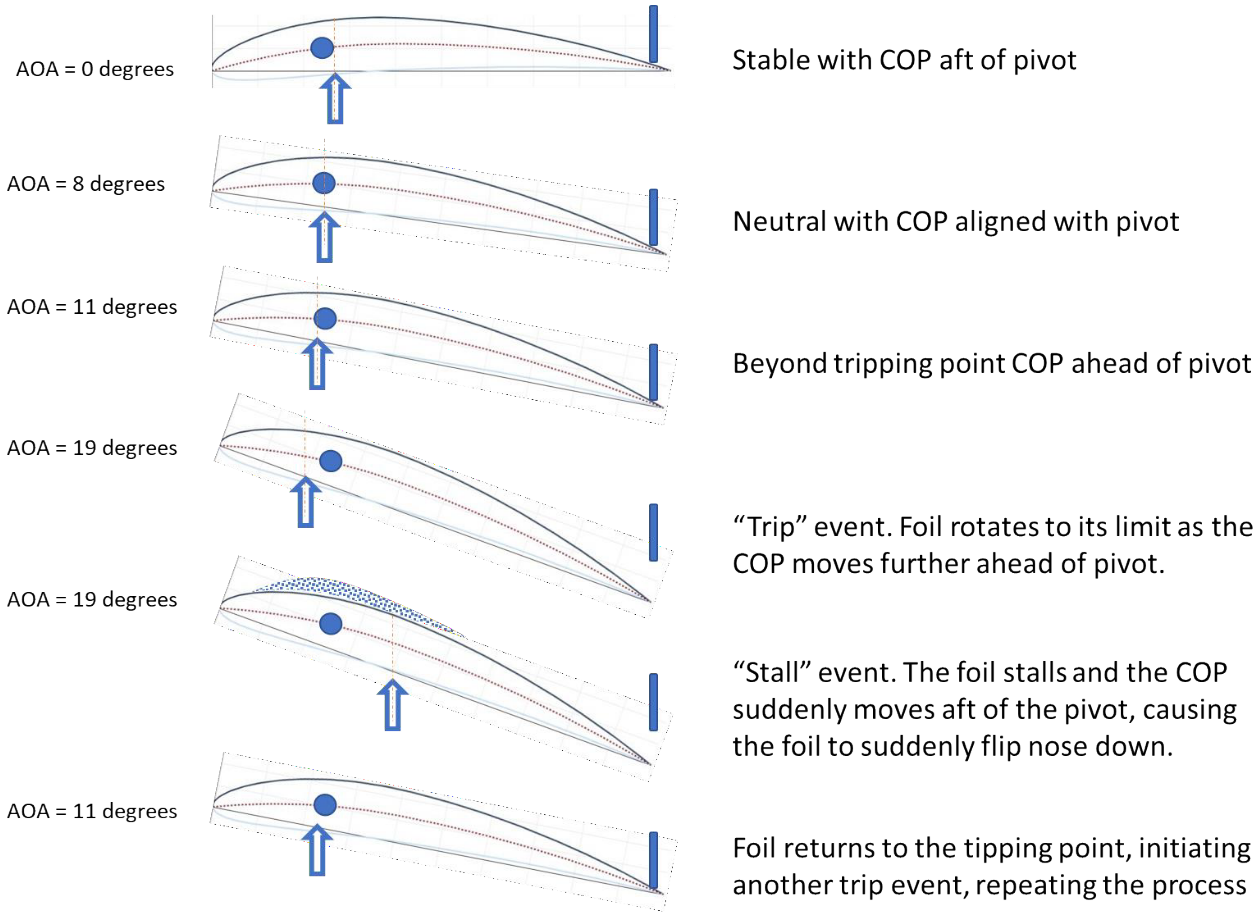
During initial trials of some asymmetric foils, it was found that a rather unexpected behaviour occurs if the system is not properly balanced. Most unnerving being a regular, repeated clunking sound as the whole boat jars during take-off. In some cases, the boat takes off and thereafter flies normally, but in others, the foil stalls and the boat will not take off at all. The characteristics seemed inconsistent and depended on how far forward you sit and how hard you drive the boat during take-off.

Investigation revealed an interesting sequence of events described and illustrated below.

'Trip-Stall' events

Stage 1) Initially at low angles of incidence, the foil is stable and operates with low drag as expected.

Stage 2) As the boat accelerates and starts to lift, the angle of incidence increases due to the wand and pushrod. As the angle increases the centre of pressure 'COP' moves forward.



Stage 3) As the boat lifts from the water and begins to rotate, the angle of attack increases further, to the point where the centre of pressure moves ahead of the axle pivot.

Stage 4) At this point, the foil undergoes a "Trip" event, where it rotates upwards freely, unrestrained, and well beyond the angle of attack which causes stall of the foil.

Stage 5) The foil then 'Stalls'. As the foil stalls, it immediately loses lift and the boat fails to take off, but at the same time, the centre of pressure of the stalled foil now suddenly moves well aft, tipping the foil downwards once again.

Stage 6) The foil now returns to a stable condition and the angle of attack is restricted once again by the pushrod, flow is restored and the boat begins to lift again.

This process is then repeated on a regular basis at intervals of around two seconds as the centre of pressure moves fore and aft in rapid succession. The foil rotates from one extreme to another, impacting alternately between the vertical foil and pushrod. This makes a regular loud clunk, clunk, clunking sound, jarring the entire boat as it hits each stop. This is termed a 'Trip/Stall' event.

To address this issue, there are several possible actions. Firstly, a limiter can be installed, which restricts the maximum angle of attack, so that the foil does not rotate far enough to stall. The result being that the boat can lift and fly, without changes to the foil shape or pivot.

Also, as described in the previous sections, there are several other ways to address the issue of foil imbalance such as foil shape, camber, pivot axis, dihedra/anhedral, wing tip shape etc, all of which can be altered to produce the desired characteristics. This trip-stall behaviour was not found to occur at all with symmetrical foils, as the centre of pressure remains relatively stable as the angle of attack changes.

Another simple method to prevent the issue was to add a small recurve flap at the tail of the foil on the centreline, which moved the centre of pressure far enough aft to prevent the 'Trip' event initiating. This does however increase the pushrod loading.

Simple calculators, akin to those used to determine pushrod loads have now been developed which make it possible to design foils with respect to changes in the centre of pressure with angle of attack, dihedral/anhedral and curvature, wing tip shape etc.

Once each of these potential sources of imbalance are fully understood, it is possible to design a fully balanced foil with good all-round performance. Ideally the foil should meet all requirements of high lift and low drag during all phases of take-off and high speed sailing, with appropriate wand feedback to control the boat ride height.

Skeeta using fully articulated balanced foils

This article on Balanced foils is Part 2 of a four part series Dr. Ian Ward Sydney, Australia

Artificial Intelligence, (AI) by Richard Fish

AI, is everywhere, unseen, it is changing our world. This article is my understanding of how on a small scale it can be employed to improve sail efficiency.

This may seem like on odd article for a Catalyst article, but it has relevance to my current project. With the assistance of a Howard fund grant, I am building a 6m LOA Proa with inflatable spars. The object being to dynamically study the flow field around the sail and to use the data generated to control sail shape and attitude.

The bare bone of AI is that we can allow a computer algorithm to learn to see the linkage between measured electronic outputs from sensors positioned around a sail and in turn create an output that will control a response in sail attitude and shape.

Machine and deep learning

Machine learning and its big brother, Deep learning, are training protocols that create routines to enable microprocessors to effect proportionate control responses from complex and often noisy, data streams.

Machine and Deep learning are used to create “artificial intelligence”. They are employed by Google, Microsoft, and every business on the web to understand their customers to provide better, focused services and products. (Will this personal data capture evolve to be the next version of slavery that inspires global riots in the decades ahead?) It enables fly by wire systems in aircraft and controls points systems across the railway network, it makes our home heating and our cars more efficient. They measure our response to advertising and can influence how we vote in elections. They are capable of recognising the face of one person in a crowd of one hundred thousand.

If you wish to automate a complex process it is difficult to write a computer programme to provide automatic responses that are efficient and accurate when there is a huge amount of diverse sensor data, the significance and validity of which varies with seemingly low predictability. The tools that are available to control the process may themselves have adverse effects on the outcome. (Playing the main sheet in response to a gust will reduce weather helm and heeling moment which will affect leeway and drag, the timing and degree of the helmsman’s action to increase speed through the water is an art! Which of these outcomes will be most significant?)

To understand a process, you must be able to assess it, you need to know where information comes from and, to be able to control the process, you must understand how numerous complex inputs affect the outputs. The data that you receive from your senses and physical inputs that you are able to affect may not provide the control responses in a manner that is either proportionate or logical.

In essence these learning protocols take a quantity of data and the outcomes that you are looking for and look for patterns in the data that coincide with the desired output. A classic illustration would be to sort ten thousand pictures of cats and dogs into two sets of pictures, one containing just cats and one just dogs.

Interesting, isn’t it, that you don’t think how you might describe differences, they all have four legs, hair of similar colours, eyes, ears, and tails – you just know that cats are cats. For the computer to be able to recognise the differences, it has to be trained by telling it which of the pictures (input data) contain cats and which dogs (desired outcome). After say 500 or so pictures, the computer may be getting an idea of what you are looking for, so the next step is to feed it another couple of hundred to check that it has got the idea. If it has, then let it loose on the rest! If it doesn’t separate them reliably, then you train it some more.

It is often straightforward to gather huge quantities of data from around the action you want to enable. The data that is most significant is that which has the greatest effect on the outcome, to quote popular TV comedy sketch "Today I have mainly been eating beans."

But how do the machines do it? -Average and gradient – just like plotting a course, where am I most likely to be now? And in which direction am I going to go to the next waypoint?
If you have one input and one output, you can draw a graph, at time x, y happened. Pop the dots on the graph then draw a straight line through the dots that best represents your interpretation (best guess) of what is happening. Y = mx + c where m is the rate of change and c a bias. By knowing this relationship between x and y you can make an estimate of y from a value of x that you haven't measured. For example: If you take a random value of x on the line you have just drawn, this new point is now an estimate of y at a that value of x, (called y hat).

Generally, unless you are very lucky, the data points collected are scattered about the line (best guess), it is an average of where you might expect the points to land. This process is called linear regression.
Of course, you have a lot of data that doesn't exactly fit, so it may be easier to classify the data by how well it fits. This is called Logistic regression where the points land above and below the line and are assumed to be distributed about the line in a binomial distribution, (other distributions are available) the classic bell-shaped curve. This allows the point to be given a value between 0 and 1, depending on its position within the distribution. 0 and 1 being the extremes and the centre of the bell being 0.5.
This "weighting" assigns a value to the point according to its probability of recurrence (and therefore its significance in whether dogs' eyes can be blue for example).
Of course, there are other ways to sort and classify data. If the data is homogeneous i.e. it is only dogs and cats and doesn't contain random guinea pigs, rabbits and ostriches, then you may be able to sort it with a decision tree. This a version of twenty questions. This system doesn't need maths and has no noise, (dealing only with nice clean data (no mice or chinchillas))
However it is also a system that doesn't self-learn easily (not parametric) or have the ability to predict, other than in the end to say you have 6572 cats and 3428 dogs if the next picture is from the same data set there is a 66% likelihood that it will be a cat.

Decision trees are initially a relatively simple way of dealing with controlled closed data sets. They can be expanded by creating new questions from exceptions that don't fit the existing structure. (Decision trees will grow to create a "random forest".) The dangers are that because the answers can only be yes or no, they may also create anomalies based on the order in which questions are asked. Also, as the data isn't weighted, it is possible to create redundant pathways which may separate significant data from the final outcome.

The big news here, and what we are working up to, are **Neural Networks** on which Machine and Deep learning are based. These were initially thought of as a way of replicating how the brains structures work to recognise patterns.
This is done by clustering (lumping together similar features) and classifying (labelling) what we see, hear, smell, touch, and taste. We register both similarities and differences. As we encounter new experiences (data input) we train our minds to notice these similarities and differences – that looks like a cat with long brown fur - "cat" is the cluster which is extended to include a "long brown fur" - classification. (Labelled output). This is essentially how networks are trained. A feature is given a label and the classes are expanded to include all the subsets that include the relevant features.

It is possible even for simple systems to self-learn unsupported, that is without a teacher attaching labels. However, the outcomes will be based on the most obvious differences – you may end up with a pile of black dogs and cats and a pile of brown dogs and cats.

Like a decision tree, a neural network comprises layers of decision making "nodes" each of which looks to answer a question. However, rather than just being yes or no, the answers are weighted by their significance, (logistic regression) and rather than just having the two lines out (yes or no). The output of the node then passes to all the nodes in the next layer where again the next nodes can make a judgement on its own question based on the value assigned to the information it receives.

Because each node guesses its output based on probability, the final outcome will also be a guess. Gut instinct if you like! The accuracy of the guess is constantly improved by training, effectively feeding back the discrepancy in the value assigned to the data in each individual node improves the validity and accuracy of the guess.

Picture goes in - 50% likely to be a cat - guess a cat.
Truth - 50% likely to be a dog - error 50% of time, in this picture, where the decision was wrong, the nose was a bit longer.
Modify decision, cats with longer noses are more likely to be dogs.

Only this is happening at a pixel level, thousands of pictures, billions of pixels. A bit like doing a sudoku or crossword, 0 and 1, a's and b's, recognising pattern in structure.
Loss is the process of assigning validity to each bit of data. There are many different formulas for loss functions (mean absolute error, mean squared error, …). They are different ways of representing distribution spread about the mean line.

There are two main types of loss; Regression and Classification. Where Regression deals with the validity of data (for example, this data is less relevant because it close to border). And Classification label (for example, this data is relevant because ref refers to the shade of brown).

Exactly how long does a nose need to be, to be a dog's nose. In each sample there will be examples of cat noses that are longer than a dog's i.e. lion v pug. The significance of the length of the lion's nose is reduced by the significance of other features, for example hair colour or eye shape. Additional classes can alter the significance of all other classes if they themselves are deemed significant. Each layer of neural network is focused on a feature, in this example comparing the rate of change of shading between adjacent pixels, looking for a specific pattern. The more layers of nodes an algorithm has, the more features it will be able to recognise and the "Deeper" the ability of the network to unravel data.
Machine learning is a shallow version of deep learning, it is suitable when sensor data has fewer dimensions and when it is more closely related to desired outcomes. It therefore will require fewer layers of nodes to sort the data.

Interestingly like the arguments over nature and nurture in forming personality, it can often be seen that a weak algorithm trained on lots of data is more successful than a strong algorithm trained on a low volume of data.
The algorithm is not just the number and arrangement of question asked of data but also ways in which answers are averaged, and their validity weighted and distance and direction to the next significant point assessed.

It is quite possible to over train models or to include features that are not part of your intended subset. For example, if most photos of cats are taken indoors your algorithm may be including aspects of bookcases as a feature of "cats" or that most dogs have green background (pictures having been taken on the lawn)! Or possibly that more cat pictures are taken face on and dogs are taken in profile. Which may create in the algorithm Features decisions that may occur in the training set that don't occur in real world data.

The nodes themselves each modify the description of the data they receive and then decide its relevance and what it should do with it. Should it ignore it, average it, add it, multiply it, subtract it, or any other function that will enhance its significance? It must then decide whether what it has created is of a level large enough to be passed on to the next layer. i.e. a significant probability that the feature is there. The values of these features "add up" until the last layer where the output node must finally decide if the feature label exists and gives a binary output "0" or "1" - yes or no. These regression models have been with us since the dawn of computing as they are valuable to code breakers. Their abilities grow exponentially in line with the power and size of the systems, and they are the corner stone of artificial intelligence that has the ability to remove a huge proportion of jobs that employ the vast majority of people the world over. I know it is just change and that it happens all the time. But it is not going away. Wealth is a one trick pony that has a vested interest in controlling and subjugating lesser threats. It is an arms race that we are told is in our best interests. The "wealth" of our society was initially built on the enslavement of people, and we have, like locusts, grown fat on the enslavement of hydrocarbon, is the next injustice the enslavement of our personal data? Feeding the greed of our own desire. I can resist anything but temptation!
The deeper the network is, the better able is it to spot clusters without the supervision of a person labelling the data, particularly if it has a huge data set to sort. Most of the data we float off into the cloud is unsorted unlabelled data and there is a lot of it. So, cloud data is continuously mined by deep learning algorithms looking for clusters and creating linkages. These "unseen" clusters usually reveal opportunities to develop profitable business models.
There are of course two sides to data revelations; the usual things we all do without thinking about it and unusual things a small number do to take advantage of the unwary. Banks and governments can use same techniques to spot fraud and dishonest behaviour.

Most data streams arrive in time order, and the time it takes can be highly significant or largely irrelevant. Sorting photos is not a time dependent operation. We shop at the supermarket once a week, we book to see the dentist every six months. Rolls Royce use streamed data to predict maintenance schedules on jet engines rather than stipulating rigid hours of running maintenance, (this is because planes running short haul routes in the tropics will have different wear characteristics to planes running New York to Tokyo over the North Pole).
Big data also helps the NHS predict interventions for heart disease, diabetes & etc. There has also been debate as to how life assurance companies use data to price premiums.
In other words, models become accurate enough to cast forward in time to predict probable outcomes.

Tensors

Each element of data received by algorithm is immutable, it is fact, it is not in itself changed. It is the interpretation of the data stream that gives each element relevance and validity. It is the relevance and validity attached to the data that allow interpretation. The information attached each bit of data is called a tensor.

Tensors are sophisticated vectors. A vector has quantity and direction, such as a boat's speed and bearing, when you can add them together with vectors for tide and leeway to give a resultant, you are forecasting your future position based on known information. This all works in two dimensions, north/south and east/west. In an aeroplane it would be three dimensions, up/down. To simplify the visualisation, we think of them like a graph, Cartesian coordinates x, y, z. All planes at right angles to one another, we establish this system so that the coordinates are independent of one another, if you move along x, it does not affect y or z.

Tensors are used to describe a quantity of information moving through a neural network. The weight or value of the information that is received is a numeric representation of an occurrence in the real world and it is unlikely to be linear, (signal strength varies as the cube root with distance from the source, can an artist's impression of a shadow be seen logically??) Also, the directions of the components that we can measure, and need to modify, are not at necessarily independent (and therefore not at right angles to one another). They may be represented by more than three components.

To describe a tensor, we refer to its shape. The data a tensor holds can have many dimensions.

A number by itself is just seen as representing a quantity and is termed a scalar, in effect, a tensor of zero dimension (it doesn't project in any direction).A vector is a one-dimension Tensor, for example, a simple one line array [4,2,6] of shape (3) because the array contains 3 elements in 1 line. In a Cartesian system (x,y,z) this would represent a position, for example. It assumes a known and stable origin and a scale of measurement that remains consistent

A matrix is an example of a 2 dimensional tensor [(4,7,2)

(5,3,8)

(1,7,4)]

is a (3,3) shape – 3 vectors of 3 numbers.

Tensors larger than two dimensions are simply referred as tensors. Shape (2,3,4) would look like

{[(2,5,3,9) [(9,0,4,6)
(5,8,4,7) (2,5,8,4)
(0,4,6,2)], (1,2,5,3)]} 2
arrays of 3 vectors containing 4 numbers.

These additional values attached to the information may represent changes in origin position, value of the measurement unit or colour, hue and saturation or the market value of tomatoes, country of origin, ground water availability, demand, and time of year. Etc.

So, we have a stream of information, the weight of which is represented by a number that may not be linear, acting in a direction that the coordinates representing it, are not independent. Flowing through a network of millions of interconnected decision nodes where the last layer can modify the probability established in the first layer or any layer in between, repeatedly until the discrepancy between the real world and the predicted outcome tend to Zero.

Didn't Zaphod Beeblebrox have a spaceship that worked like that?

This is not something that is going to be done on a pc! This stuff runs on huge, very expensive computers using sophisticated secret algorithms.

Well yes and no!

If you are sorting video files or looking for fake news or looking for the 1 person in 10 million who would like a holiday on the moon in ten years time and are willing to pay for it now. (Hm' that infinite probability drive might be a go'er, now where do I get the cash)

There are a number of these devices, deep learning centres, not spaceships shaped like a running shoe, out there, some are free to use and some you pay for your time on.

IBM have one called Watson
Microsoft one called Azure
Google one called Tensorflow

Amazon in their webservices area one called Sagemaker
and many more.

When companies offer these expensive services for free, you must wonder what they get out of it, could it be that they watch you and your data developing something from which they would like to profit? - always read the small print.
Of course, there are many small problems with only a few inputs and outputs that don't really require huge data crunchers to solve. For example, how many people would quite like an interactive version of one of those funny little graphs that tell you how fast your boat actually is on all points of sailing? And for which many boats already have copious streams of NMEA data readily available: Wind speed and direction from a mast head wind indicator, true course and speed from a GPS, speed through the water, angle of heel, theoretical tide data etc. All this can be poured into a spread sheet and averaged and connections made at leisure. As the performance picture emerges, the skipper can begin to contemplate the wrinkles it shows up. How much speed do you lose when reefing or, by hanging on, is the extra force lost in excessive angle of heel and weather helm?
Gather data, average it, look for the changes that influence improvements. Record the changes, compare results. Etc. it's not special. We do it all the time. In this scenario we can use the accurate sensing and number crunching to inform and train us, the operator.

Getting systems to work.
The actual process requires identifying exactly what you want to do, collecting a body of data from your sensors, and a body of data that represents the "Truth". And then using it to train your chosen model on a cloud service. Then testing it before converting it to run on your own hardware and checking its validity.
Timing and noise data steams
Sensors output data in their own fashion. Some output an analogue signal, usually a small voltage that is proportional in size to the action that it is measuring. (This will probably be a tiny signal that will require amplification before it is transmitted.) Digital signals are a stream of on states and off states that sometimes switch when a threshold is achieved or possibly in proportion to the rate of change of the action. NMEA signals are quite sophisticated streams of characters bunched up with labels attached. Some signal streams you can dip into and catch a lump of relevant data. Others must be watched as the next bit of signal is a rate of change from the last and unless you know what the last one was you don't know where you are. Some sensors only issue a signal sporadically.
Noise is interference with the signal at source, within the transmission line or within the processor. Analogue signals are generally more prone to source and transmission noise than digital. Though - think AM versus DAB radio, AM hiss, crackle and drifting, Digital DAB all or nothing.
So, there will be a variety of different signals, some hidden in a bunch of other stuff that you don't want. All of them talking, if not a different language, certainly a different dialect, some of them shouting at the same time. Some just nodding in your direction occasionally. They need to be filtered, averaged, and presented to the number cruncher in its own time in a manner that it understands and that represents the action you are trying to measure. The number crunching microprocessor will then turn them into a tensor.

Setting a goal
The goal informs; what sensors you require (both for the inputs you either will or won't be able to control and the outputs you are observing), what actuators you require (to control the inputs), what control mechanisms and wiring you will need. The sensors will need to be matched to the scale of the action observed and the ability of the system to recognise the responses so

Amplifiers and signal conditioning elements will also need to be specified.

Signal conditioning

A data set for training should be: - recorded from the same sensors, in the same positions and at the same times as you will eventually use the model. It works best if the data is of a similar size, and micro controllers like it to be presented as a number between 0 and 1, as it will be processed as a float. So, average it and subtract the average or divide it into its largest value. If there is an area in the response curve that is particularly significant, the number may be squared etc. to enhance the response.

Select a suitable architecture for your model to train.

The architecture and the data are co-dependent, that is, the type of data, the number and type of sensors and the type of output dictate how much memory and processing power and speed are required

Train the model.

The model starts out with all its parameters within the functions as random settings. Each time it is fed with a new sample from the data set the weights and biases within each function are modified by a process known as regression to improve the accuracy of the final prediction. Each time the training data runs through the network is known as an epoch. When the improvement in the prediction is so small that the error is acceptable the model is said to have converged. The errors are measured in two ways, loss and accuracy. Loss is the estimation of how close the model is to producing the right answer every time and accuracy is the percentage of the time that the model gets it right. Loss tends to 0, accuracy tends to 1.

If the model fails to converge the two most likely reasons are either the model can't get its head around the problem – it doesn't have enough nodes and layers to be able to create enough features (called under-fit) or it has too much power, in which case, it will know the training data too well and be inaccurate on real world data (over-fit). Or, of course, there really is no correlation between the inputs and resultants.

Testing and validating.

The data set is usually split to be used 2/3 for training, 1/6 testing 1/6 validation. Each should be representative of the real-world data set.

Training progress is measured by including random elements from the validity data set in the run of training data to calculate the accuracy of the model. The final step is to run the test data to confirm that the model is working.

The next steps in the project.

The next steps will be the practical stuff, choosing hardware, building it into the boat. Then data collection and processing. Selecting a suitable algorithm, running it. Then converting the model to run in the real world.

Howard Fund revisited

The Winners and the Losers

Mike Howard

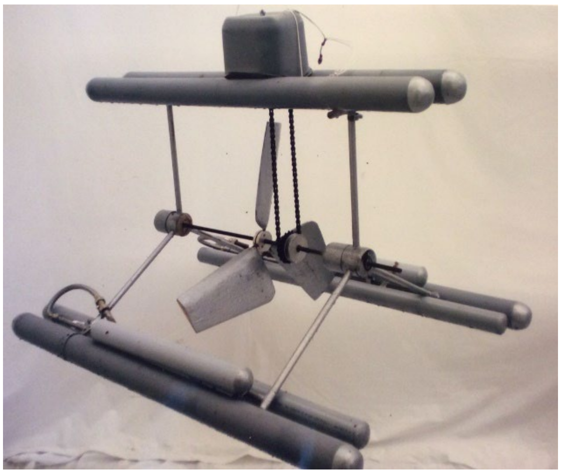
*A restricted fund, aptly named The Howard Fund, was first established in 2006. By 2009 the full sum of £42,000 had been received by AYRS from the Executors of AYRS member, the late Mr Donald Howard (no relation). Mr Howard's brief to the AYRS Committee was '**to use the money to provide grants to members for further development of their practical ideas**'. Over the years the AYRS Committee have added certain 'rules' to help them make a rational decision when vetting member's applications for funding. In the April 2022 edition of CATALYST I outlined the origins of the Howard Fund and detailed the Rules governing Applications.*

I have always been an enthusiastic supporter of this Fund. Not only have I witnessed first hand the benefit it can bring to a project, I am also a great believer that often projects are put on the 'back burner' due to lack of funding. Even the most committed and wealthy of AYRS members may not want to utilise their own savings to prove their own hypothesis. Sometimes, a gentle financial push from the right direction can see a project not only started but brought to a successful conclusion. In the following article I have endeavoured to bring to light the dozen or so 'Winners and Losers' in a bid to encourage other members to have a go!

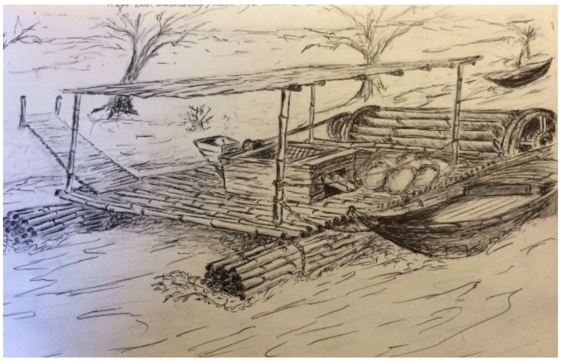
WINNERS

C S Watson (2009/2010)

Chris Watson's first foray into developing one of his own ideas began in 2008. His objective was to develop a simple submerged turbine which would be tethered to the seabed and which would generate electricity utilising the ebb and flow off the tide or river currents. His application to the Howard Fund appeared in the July 2009 issue of Catalyst magazine. In this article he outlined the work he had accomplished so far. AYRS granted him £1000 and with this sum Chris not only developed a 'Tethered Turbine' but went on to develop a 'Floating Waterwheel'.



After a visit to the river Ganges in India, Chris was encouraged to build his equipment from low cost and recyclable materials so that these devices could be built and operated in impoverished areas of the World. One of his 'Floating Waterwheels' eventually powered a sugar cane crushing plant. He also touted his ideas around Government funded establishment, The Carbon Trust and a commercial company, Marine Current Turbines. Whilst his ideas were met with some enthusiasm, reservations were expressed regarding the tethering of his device to the seabed.



Chris told me, "I felt really guilty about committing 'household funds' to what may have turned out to be a complete failure. The AYRS Grant 'kickstarted' the practical development of these two projects and numerous other ideas which have kept me occupied for over fifteen years." Amongst Chris's other triumphs was the YELLOW ALERT which was a simple craft which could be deployed by Beach Lifeguards. The second improved model was jointly developed with Kim Fisher, himself a retired Product Development Engineer. The RNLI gladly accepted four of Chris's previously developed craft for use during training sessions. Currently Chris and Kim are developing a forward facing rowing device aptly named 'ROTAROWER. The prototype of which Kim showed off at a recent AYRS ZOOM Meeting.

Over the years there has been a number of articles in Catalyst putting forward ideas for generating electrical power from river or tidal currents. We are now well entrenched in an age where sustainable energy has become a necessity. Let us hope that more AYRS Members might utilise the Howard Fund to develop their concepts in this expanding arena. *References: Catalyst 54.*

Mike Howard (2010/2011)

Morley Tethered Kite Sail Project

In 2010 Mike Howard was successfully awarded a grant of £3000 for the above project, which was the inspiration of another AYRS member, the late John Geoffrey Morley. John was in his late 80's and was unable to undertake any of the practical work which was why Mike had applied for the grant. Effectively, Mike undertook the practical work under John's supervision.

John Morley was a retired Scientist and University Lecturer with outstanding theoretical and industrial experience in aerodynamics and advanced composite materials. John had no sailing experience. Mike Howard was a qualified Naval Architect, and a retired Senior Design Engineer and Project Manager and had countless years of experience in the development of prototype equipment. He had started sailing at the age of eleven.

The project was conducted over a period of three years *(yes! Three years!)* commencing with a land based prototype being designed by Mike and manufactured with the assistance of several members of the North West Local Group. John and Mike tested this prototype on an open beach at Ainsdale which overlooks Liverpool Bay.

The full size prototype was entirely designed, manufactured, commissioned and tested by Mike with technical guidance provided by the inventor, John Morley. Like most inventors, John was constantly seeking improvements and the prototype went through several major design changes before a finished prototype eventually reached the water in 2013. Frustrated by the constant changes, Mike sought an interim solution.

After the encouraging results obtained from the land based Static Demonstrator, the rig from the latter was mounted on an INTEX two man inflatable dinghy. A lateen rig is available for this dinghy and several YouTube videos shows it can be sailed quite successfully.

Trials took place on a local marine lake (Crosby Watersports Centre) in 2013. They proved to be inconclusive. In spite of many different combinations of mast to leeboard positions being tried, the trials failed to indicate that this hull could be driven by a Morley Tethered Kite Sail. This was put down mainly to an inadequate sail area. However the trials did highlight balance issues between the apparent Centre of Effort of the Morley Tethered Kite Sail and the Centre of Lateral Resistance of the hull and its appendages.

The full scale prototype was mounted on an ENTERPRISE class sailing dinghy. This class of dinghy was chosen by Mike as he had previously owned and sailed two of them. Sailing trials were conducted on the same marine lake in the Summer of 2014. Minor gear failures and high winds frustrated the early trials. However once afloat the dinghy became unmanageable with the sail tending to set further and further aft, until the dinghy was running before the wind. After three sessions the trials were abandoned.

Sadly, John Morley was unable to witness the trials of both the INTEX dinghy or the ENTERPRISE Full Size Demonstrator due to his failing health and immobility. This eventually led to a great deal of misunderstanding and a breakdown in the professional relationship between Mike and John.

Mike spent a great deal of time trying to analyse what had transpired during the trials which he had conducted. While onboard it was very difficult to understand what was happening while engaged in trying to keep control of the course. He came to the conclusion that a variable twin daggerboard system was required to balance the swinging of the rig in varying wind speeds. He suggested a twin daggerboard proa might be a solution. Mike did conclude that the rig was too 'fiddly and time consuming to rig and was not, in his opinion, 'commercially viable.'

Understandably, a major disagreement ensued between John Morley and Mike Howard. The former has spent twenty years developing static models powered by desk fans and he was not going to concede defeat quite so easily. He accused Mike of not understanding how to set the rig.

John went on to build a land yacht version of his rig which Mike helped to design and manufacture. John also commissioned a radio controlled model but without Mike's assistance.

Sadly, John Morley died in January 2016 before either of his new ventures could be tested. A total of £5,700 was expended on the development and trials of the Morley Tethered Kite Sail project. This figure does not include the two latter projects which John undertook as his own expense.

The Final Report on the Morley Tethered Kite Sail appeared in the January 2016 edition of Catalyst, together with an article by John Morley, refuting the results. After his death the rig was broken up and disposed of. This idea did not perform as predicted. Maybe further development utilising a twin daggerboard hull might have proven a practical solution. At least it was given a go!
References: Catalyst Nos.. 14, 33, 38, 39, 43 & 50.

John Thurston (2012/2013)

John Thurston presented the AYRS Committee with a pencil sketch showing a bicycle based human powered boat propulsion system. The Committee must have been impressed; John had been an architect in his working life, after all. Sadly

John was in the early stages of dementia and as the illness took hold he found it impossible to complete his project. There is no record of a final report and no information was ever published in Catalyst about John Thurston's project.

Charlie Coish (2012/2013)

Charlie Coish is the brother in law of AYRS Member Bob Downhill. Bob has a long association with Weymouth Speed Week and has served on the AYRS Committee. Charlie was also a regular at Weymouth. Bob's involvement with the second incarnation of the ICARUS foiling catamaran spurred him to come up with a novel design for a foiling sail craft. His concept comprised a roughly circular disc shaped hull supported on foils on which was mounted two ex aeroplane wings set vertically in a biplane configuration.

To test out his idea Bob built a hull eight foot (2.4 metres) square and a couple of inches (50 mm) deep. This was christened by competitors at Speed Week 'The Garage Door! A set of surface piercing hydrofoils, fabricated in steel by Charlie Coish, were bolted to each corner of the hull. This craft was intended to be towed but the power boats available at Speed Week failed to tow it fast enough for it to become foil borne.

Charlie subsequently appeared at another Speed Week with a second generation craft This was expertly fabricated in aluminium alloy, with a sailboard hull attached to its upper surface. It was intended to be rigged with Windsurfer sails. This version never performed at Weymouth Speed Week.

At yet another Speed Week Event Charlie appeared with a third version. This comprised a lightweight space frame and hulls constructed from aluminium tube and sheet materials. It was modular for transportation, but even so, it was still quite heavy when assembled. On its first towing trial the rudder shaft bent. Although no written records (apart from this article) exist it seems that the Howard Fund Grant was well spent even though the final results were disappointing.

Martin Walford (2013/2014)

Frankton Folding Dinghy

This is a story which appears in both the Winners and Losers category!

Martin Walford had been a member of the Royal Cruising Club for many years and had cruised extensively in a number of different sailing yachts. This story begins in 2012 when Martin approached Mike Howard to help him with the design of the 'ideal yacht's tender'. Martin and Mike met up and between them drew up a list of important parameters. From this list Mike prepared a number of conceptual designs utilising 3D solid modelling software. By a process of elimination and development a final outline design for a folding dinghy was agreed several months after they had first met.

A full set of 3D images, parts and assemblies, together with 2D CAD drawings were produced by Mike using AutoCad Inventor solid modelling software and from this data costs were obtained for a prototype build in plywood. Later in 2013 a submission was made to AYRS for a Howard Fund grant which was rejected on the grounds of impracticability. The story continues in the 'LOSERS' section of this article.

Subsequently, Martin was awarded an ex officio grant of £500.00 in 2014 after he displayed and demonstrated the finished prototype at the Beale Park Boat and Leisure Show in June 2014.

Alex Quertamont (2017/2018)

Roto-Duplex Rig

This has been a long term project for Alex who commenced building an 18 foot (5.5 metres) plywood cruising yacht in 2015. He modified the design along the way to take his version of the Roto-Duplex Rig. This concept was first developed in the 1960's but Alex has used modern materials and his own design expertise to construct a lightweight and efficient version.

His efforts have been adequately described in articles appearing in the pages of Catalyst. He was awarded a grant of £459.00 in 2018, An article of the sea trials appeared in an edition of this magazine.

References: Catalyst Nos. 53 & 59.

Richard Walker (2018)

AYRS MicroTransat Challenge 2018

The MicroTransat Challenge was conceived in 2008 as a competition to see who could sail a tiny, unmanned sailing craft autonomously across the Atlantic Ocean. There have been numerous attempts over the ensuing years by individuals, college and university teams, but no one has yet succeeded. (*SB Met managed an unmanned Atlantic crossing but it was not conducted autonomously).*

In 2017 Richard Walker published an open letter in the AYRS Discussion Forum asking if his idea of mounting a challenge was mad! It was Mike Howard who responded and over the next few months a team of six AYRS 'experts' was formed. They included two Naval Architects, one a Boat Builder, one a Design Engineer and Project Manager; a Mathematician, an IT Consultant, a second year University student studying Marine Engineering and an experienced yachtsman with extensive offshore cruising knowledge.

It was to be a costly project with the rugged 2.4 metre long craft capable of surviving an Atlantic storm and the requirement to launch about one hundred nautical miles off the Spanish coast. Assuming the sailing craft arrived at its pre-programmed destination, then the costs of shipping it back to the UK from the Caribbean also had to be allowed for.

After a comprehensive study of the previous challengers and the boats and equipment they had utilised on their challenges, (*there was a lot of information freely available on the Internet)*, a detailed specification and cost estimate was drawn up. An application to the Howard Fund was submitted in November 2017.

A working relationship had already been established with both University Technical College, Warrington (*assistance with prototype*

Main hull (above) and floats (below)

engineering) and Glyndwr University, Wrexham *(development of shock resistant mounts and guidance software)*. The two research projects had been submitted in detail to the Senior Engineering Tutor for selection by the 2017 student intake.

Several meetings had taken place between the key members of the MTC project team and members of staff of the National Oceanographic Centre in Liverpool, who are part of the Natural Environmental Research Council (NERC), and who operate an unmanned self propelled autonomous research craft. A lot of useful, practical knowledge was gained in the waterproofing of marine low voltage electrical connections and validation of the course the project team was embarking upon. They also promised to gift the project with some watertight electrical glands which were surplus to requirements. An offer of funding by the AYRS Committee was made in early February 2018. The conditions relating to the release of funds required the project to be almost self funding up until the latter stages of the programme. Lobbying of the AYRS Committee by several individuals in the project team, requesting them to reconsider their decision, sadly fell on deaf ears. As a result, in April 2018, Richard Walker turned down the offer and the project was abandoned after almost thirteen months of continuous development. *References: Catalyst No. 54.*

Mark Hillmann (2017/2018)

Self Righting Proa Mark Hillman is an experienced yachtsman with offshore and trans-Atlantic crossings under his belt. Like many AYRS members before him he is captivated by the potential of offshore cruising multihulls. In his case, it is the proa which he chose to develop. His aim with this project is to design a foolproof system to ensure his proa is self righting in the event of total inversion.

He applied for a Howard Fund grant in 2017 The AYRS Committee, unhappy about the potential risk to life if Mark were to build a full size prototype, approved a grant for a scale model with a separate sum for the development of a reefable soft shell wingsail.

Mark has built a third scale model of his proa (three metres long) on which he has conducted some initial trials. The Covid-19 pandemic put a premature end to his work afloat as water sports were banned on Lake Windermere during the Covid-19 Lockdowns. An interim report appears in this issue of Catalyst.

References:

Catalyst Nos. 51 & 64.

Charles Magnan (2020/2021)

Amphibious Trimaran for the Disabled This too is a story which appears in both sections of this article. Charles' first article on the development of a multihull suitable for sailors with limited abilities appeared in the January 2004 Catalyst magazine. His 'FREE SPIRIT' design captured the essentials for a craft which could be launched, sailed and recovered by a single handed sailor. Charles Magnan's project was described in the pages of Catalyst 58 – April 2021. Again this has been an ongoing project for Charles.

In the April 2021 issue of Catalyst Charles introduced the readers to his latest incarnation, CHALLENGER 2. This design has evolved after conversations between Charles and sailors currently sailing the fifteen foot long Challenger trimaran used by Sailability. Sailing was recently dropped from the Paralympics as it was deemed an elitist sport, not accessible to many disabled sailors and at least partly due to the lack of specialised launching facilities. CHALLENGER 2 incorporates many of the desirable features that disabled sailors want from a two man race capable trimaran. The craft is designed to fit into a standard ISO freight container so that it can be easily shipped to overseas venues. It also incorporates many of Charles' systems for launching/recovery and mobility once in the water. Charles has since gained a grant from the Lottery Fund for the development of the sail system. *References: Catalyst No. 58.*

PENDING

Richard Fish (2022/2023)

Research in the distribution of wind pressure over the surface of a sail Richard submitted his preliminary ideas to the AYRS Committee in December 2022. His aim is to build a six metre long proa to be used as a stable platform on which he can mount several different sail configurations. He has already partially developed a means of data logging the air pressure generated by the wind and its distribution across the surface of a sail. His application for a Howard Fund grant was agreed in principle by the AYRS Committee in January 2023, with the actual award subject to Richard submitting his detailed costs and the amount of grant he is seeking.

LOSERS

Charles Magnan (2008)

Amphibious Trimaran for the Less Able (withdrawn) This was an earlier version of Charles Magnan's FREE SPIRIT amphibious catamaran for the disabled sailor. A fully detailed article on his design appeared in the October 2009 issue of Catalyst magazine. Charles decided to withdraw his application. *References: Catalyst Nos. 15 & 36*

Hungarian Group (2010)

Hydrofoil Flying Boat

Here is another mystery. Whatever this project was to achieve is certainly unknown. It would be interesting to know simply to see if it has now reached a stage where it might be reconsidered.

Martin Walford (2012)

Frankton Folding Dinghy

As you will have read in the preceding section Martin Walford was not deterred by the refusal of AYRS to approve a Howard Fund grant. He decided to go ahead and build the folding dinghy anyway, financing it with a small inheritance he had received. However, around about the same time, the Royal Cruising Club and the Yachting Monthly jointly sponsored a Dinghy Design Competition. Martin, as a member of the Royal Cruising Club, decided to enter the competition. The design of the folding dinghy was modified to comply with the specification required by the rules of the competition. In hindsight this proved to render the finished dinghy too bulky and too heavy for its original purpose. Once the design was suitably modified a presentation document was produced and Martin submitted his entry. Martin did not win the competition. The judges determined that Martin's folding dinghy '*was well engineered*'.

A kit of nested parts, was ordered from Swallow Boats in Cardigan, South Wales, which were routered from seven standard sheets of marine plywood. Standard and bespoke metal parts were ordered from local engineering suppliers and manufacturers and marine parts bought from local yacht chandlers. A twenty foot (6.1 metres) long shipping container located on a small industrial park was hired as a 'building shed'. The dinghy was assembled during March and April 2014. It was then transported in a small van to Martin's London home, where it was finished and painted.

In June 2014 Martin exhibited the Frankton Folding Dinghy at the Beale Park Boat and Leisure Show. His stand, by sheer coincidence, was sited next to the AYRS stand! The boat was demonstrated on shore, afloat under oars and sail and attracted a fair amount of attention. As a result of Martin's resilience in carrying out this risky project, the AYRS Committee awarded him an ex officio grant.

Martin did not win the RCC/Yachting Monthly Dinghy Design Competition. The winner was an untried, poorly illustrated concept, but who am I to disagree with three eminent Yachtsmen! He

did receive the praises of the judging panel who noted '*a well engineered design*'.

Why did Martin choose the name 'Frankton' for his folding dinghy? Well 'Blondie' Hasler of 'Cockleshell Heroes' fame is Martin's hero. Operation Frankton was the code name for the daring World War Two raid on the German occupied port of Bordeaux which was carried out between 7th and 12th December 1942.

Richard Dryden (2012)

Transition Rig Richard Dryden's Transition Rig was an attempt to develop a folding mast and sail which could be stowed horizontally. Its application at full size was aimed at retrofitting commercial cargo ships with auxiliary wind power. The articulating mast with its fully battened sail mimicked the action of a bird's wing. Richard fitted three small sails to a Mirror sailing dinghy and successfully demonstrated that they worked efficiently in close proximity to one another. His proposal was to attract a grant of £3000 out of a total budget of £7000 to develop a prototype sail. Other parties have since developed telescopic wingsails which fold down into an open topped ISO freight container. Did AYRS miss an opportunity here? *References: Catalyst Nos. 33 & 37.*

In conclusion, applications for the Howard Fund have been few and far between over the span of the last fourteen years. Some might see this as an indication that AYRS Members are quite happy to spend their own money on developing their own pet projects in relative secrecy. This is certainly true in certain instances which have come to light. Personally, I feel that the AYRS Committee have been rather harsh in the way they have dealt with applications in the past. Does it really matter whether a project has been started or not? Does it matter if the Applicant has spent any of his own money already? 'Kickstarting' a project is a phenomenon which is embraced in the Twenty First Century. AYRS should embrace it too. If AYRS is to continue to have a useful role in the modern world we need to exploit innovation. There are still lots of marginal areas within the marine sector, which are ignored by the big players, where AYRS could score a hit. It is just a question of seeking out those minor areas where innovation could have an impact. What really matters is that AYRS does not dwell on its past glories but 'puts itself out there' and continues to promote innovation in a practical way. Without this essential ingredient AYRS is failing to engage in the very essence of its foundation. The AYRS Committee's original concept for the Howard Fund was to offer annual grants worth £5000 over an 8 Year period. In reality, the uptake has fallen far short of this target. Mr Howard's desire to offer grants to would-be inventors, experimenters, developers has fallen far short of the mark. His legacy remains unfulfilled. Finally, I would like to offer my apologies if I have missed anybody out of my lists. Information with regards to Howard Fund applications has not in the past always appeared in the Catalyst magazine. Our archives have been rationalised over the years and now hold little of merit. Perhaps, someone out there can enlighten me.

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

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