International Hydrofoil Society Correspondence Archives...

Human Powered Hydrofoils

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(Last Update 11 Nov 02)

A 5-Man Team

[27 Apr 02] Here in San Diego, we have a 5 man team who have had some experience with a human powered hydrofoil like Brian Burgess proposed in the IHS newsletter, Spring 2002. We built a pedal powered craft. Instead of buoyant wings we used a submerged torpedo-shaped float that supported about 80% of total weight. It had elevons just aft of the center of gravity and a "Shutt Strut" on the bow. Two lightweight sausage outriggers rode the surface for stability until takeoff speed could be obtained. The idea was to take the static efficiency of a submerged body and combine it with dynamic efficiency of the hydrofoils so that someone other than an Olympic athlete could enjoy the hydrofoil experience. I was the chief test pilot and here is what we found: At rest the outriggers allowed the rider to sit quietly over the center of buoyancy pushing up from 18 inches below him. Of course as he accelerated the foils created lift. As soon as one of the outriggers lifted off the rider was in for a swim. We calculated that trouble would begin when the center of gravity was displaced about eight inches laterally from over the center of lift. The rolling and/or pitching vectors overpowered whatever correcting forces the foils could generate. The torpedo pops to the surface and the rider dismounts. We concluded that a smaller submerged buoyancy form may be helpful to low speed hydrofoil performance, but its buoyancy should be limited to say 25% of total weight. The hydrofoils must be large enough to assure pitch and roll authority over the destabilizing effects of the submerged buoyancy form. If the submerged buoyancy is too great the foils will be too small for control. -- Ray Vellinga (rvell@hotmail.com)

Human Power

[6 Feb 02] I have been editor of *Human Power* since 1984, but have recently handed over the editorship to Theodor Schmidt in Switzerland. Whether the handover is temporary or permanent depends on his experience. I must therefore do what I can to help him. He has a long history of experimental boats of innovative design, and I believe that he once belonged to the British association of hydrofoilers, the name of which I've forgotten. David Owers contributed an article for us on "Foiled Again!", and Steve Shutt and several others on their boats. I like to claim credit for the start of the human-powered-hydrofoil enthusiasm because I used to row (scull?) a shell of my own design and construction on the Charles River here in Cambridge MA early in the

morning in the 1970s. I became annoyed by the high-handed tactics of the Harvard Eight, which used to come around the river bends on the wrong side of the river with the coach in a motor boat yelling at me through a megaphone to get out of the way. So I added an entry to my thesis list at MIT: "Design and build a single-person human-powered boat that will be capable of overtaking the Harvard Eight on the Charles." A super student, Brad Brewster, took this on in 1978 and we tried hard together, but the New England winter made it difficult to succeed on the ice-covered river. I wrote our work up in *Technology Review* in October 1979, and this inspired several other projects. The principal one was organized by my friend Allan Abbott, whose *FLYING FISH* hydrofoil attracted wide publicity (including a cover article in *Scientific American*). When, much later, the *DAEDALUS* group returned to MIT from its triumphant journey of 119 km in a human-powered airplane from Crete to Santorini, some asked me what they should do next, and I suggested winning the DuPont prize for the fastest HP boat. The *DECAVITATOR* resulted from that effort, led by Mark Drela who also did much of the design and construction and powered the boat on the Charles. He won the prize at over 18 knots, much faster than the Harvard Eight could achieve. So you can see why I puff my chest out, even though I did almost zero. I thought that I would at least write a review of your AMV CD-ROM for *Human Power* and encourage enthusiasts to join your society. Whether or not I join I will decide later. I pedal a very slow boat with my wife and family nowadays at well below Harvard Eight speeds, and I keep well out of their way. -- Dave Wilson (dgwilson@mit.edu)

Response...

[6 Feb 02] This caught my eye, because David Gordon Wilson is a name that has been filed in my brain for many years. He was (probably still is) an eminent professor at MIT in the Mechanical Engineering Department. I recall seeing articles by him many years ago about human power for mobility, and I also recall seeing him on the first recumbent bike I had ever seen (which he had designed himself and would ride to MIT each day). Anyway, he's a star. -- Bill Hockberger (hockberg@erols.com)

Buoyant Foil Idea for HPV

[4 Feb 02] . I sit here on Cape Cod in the winter, relishing the Patriots going to the Super Bowl, and looking back on what a fun summer we had with this boat. I then realize it is time to say the thank-yous that are long overdue, and get into the next redesign of what is already a very successful boat. It weighs sixty pounds, as can be seen, is nothing more than an old wind surfer, a lawn chair, pedals, and a BIG prop. That is a three-blade 16" dia. with a 17 " pitch from an old Harken Waterbug. The drive gears are from a lawn spreader (aluminum 5 to 1 ratio). The prop shaft is from a string trimmer with a 45 degree geared bend at the bottom. It took us until August to make it reliable. This boat will do six mph all day long out in the open ocean. Two foot waves are fun, but three or more wash right over it. But what the hell, it's summer! We encountered some MAJOR drag here. At eight mph, there is a four inch wake behind it. We even tried to get it to fly, but could not overcome the drag of this hull at speed. No big deal. It is very seaworthy, and we learned a lot from it. The biggest problem we have with it is that we can't pedal as hard as we like without the gears skipping. The new design will be fully submerged airplane wing-shaped foils made from old body surfing boards. What I am figuring is this. Why not make my wings as buoyant as possible? Then, I won't need to waste weight building a floating hull. I will

use foam "noodles" as outriggers to make up for what the foils won't hold at rest. I can make a hollow tube frame out of aluminum, and a seat from nylon webbing. I've also got a line on some 1/4 inch thick thermoform sheets-you heat them with a heat gun (not a hairdryer) and shape them. The new drive unit will be a figure-eight chain drive with a seven to one ratio. I'll keep you posted better this time. -- Brian J. Burgess (treedude2@juno.com)

Trampofoil Substitute

[9 Nov 01] One year ago, I saw the Trampofoil's page. Do you have anything about this? -- Eduardo Arias García (eariasg@cranchile.com)

Response...

[9 Nov 01] Trampofoil went out of business. For details, Click Here and look for the Trampofoil-related correspondence down near the bottom of the page. There is a similar product available from Engineering Café; see www.engcafe.co.za/. This website is provided for your information only. IHS does not recommend or endorse products and services. -- Barney C. Black (Please reply via the BBS)

Human Powered Boat Racing Results

[8 Oct 01] Ron Drynan has posted racing results and photos from the Buffalo HydroFest. For the racing results, Click Here, and for the photos, Click Here. Also, the Photo Gallery has been given an entirely new look, with thumbnail images for quick loading, and larger hi-res pictures available as desired. Visit http://www.HumanPoweredBoats.com/Photos.shtml to see the gallery, which is now separated into seven categories and includes over 280 pictures. -- Ron Drynan (info@humanpoweredboats.com)

Response...

[11 Sep 01] On a single webpage, Ron Drynan has gathered a collection of action photos that show the diversity of design in human powered hydrofoils. The craft pictured include *af CHAPMAN II* (Chalmers University of Technology), *AIR AMERICA* (Jim Gilmartin), *COGITO 00* (Team Cogito), *DECAVITATOR* (Massachusetts Institute of Technology), *FLYING FISH I*

and the very different *FLYING FISH II* (Allan Abbott, Alec Brooks), *HYDROPED* (Sid Shutt), *NEW FISICS* (Jake Free), *SCAFO* (Philipp Müller, Claus Abt), *SUPER PHOENIX* (Polcolosso Kinosaki), and *WET WING* (Jochen Ewert). Ron has also added a page to feature many of the "other" hydrofoil craft that he has come across, i.e. sailboats and solar powered craft. Note also that the Japanese Solar and Human Powered Boat Association has created a webpage at www.orange.ne.jp/~jsha/ with many interesting photos (not exclusively hydrofoils). -- Barney C. Black (Please reply via the BBS)

Propeller For Human Powered Hydrofoil...

[6 Sep 01] I'd like to know if it's possible to get a copy of Tom Schmidt's PropSim program to analyze props. Is it a program developed especially for hydro props? I'm interested in desiging a prop for a recreational hydrofoil that would travel at speed of 9-10 mph. And I'd like to know if you can send me information about what NACA profiles to use, how much "twist" it should have, etc. I have very little knowledge on propeller design, but from what I've seen on the *FLYING FISH* it uses a prop that has the following characteristics: it's 16" dia, the chord is 30-40mm at the hub, and the tips end in a point so it looks like a half ellipse. It also has thin section throughout the blade length (= low lift coefficient?) . I work as a CAD designer, and it would be easy for me to make a 3D computer model of a prop if I had all the information/specifications to design it. Then I could rapid-prototype a SLS (stereo-lithography) model of the prop in nylon, that would be used to sand-mold a magnesium prop that would be sanded and polished to an acceptable surface finish. Or I may make the prop out of carbon fiber. The key thing is the prop will be exactly the same as the computer model, thus reducing the chance of by-eye error. I don't have the skills to carve a prop by hand anyway. Voilà ! that's the story, hope to hear from you soon. -- Felix Audet (lorraine.amyot@sympatico.ca)

Response...

[11 Sep 01] I know Felix from the IHPVA boats mailing list, and met him at my Buffalo HydroFest last month. He's built a beautifully crafted two-seat pedal/prop catamaran (displacement only, no foils), but some scuzzball stole key parts of his drivetrain right off the campsite in Buffalo, so Felix and his brother weren't able to race that weekend. I let Felix run my LegShell through the Drag Races though, and he got some time in the other boats as well. I'm told he's just about ready for the first water test of his cat. I've also been e-mailing Theo Schmidt for a few years now, and he's been extremely helpful with event hosting suggestions (he's run some of the biggest in Europe), and in providing contacts for the WaterCycling video series. Theo's PropSim program has recently been put to the test by George Tatum of NCF (makers of the WaveBike). In all tests to date the actual results have been very close to those predicted by the program. It's fascinating stuff, and we just recently found out about Felix's CAD capabilities in his day job. I'm looking forward to seeing his results, and am especially hoping he follows through on the hydrofoil, because he's just the kind of builder who could pull off something variable enough to accommodate different riders in a recreational foil boat. -- Ron Drynan (info@humanpoweredboats.com)

Source of HPB Gearbox Advice...

[3 Sep 01] I have just finished building a prop-driven sail board that has entered a race and finished in first place. The pedal power was provided by my daughter. We plan to enter other Human Powered Boat (HPB) races in the future, since she running at 6 mph for a 100 meter distance. This is a displacement craft, but I hope to convert it to hydrofoils within the next few weeks. If you need any information on gearboxes, just ask. I have been designing all types of machinery on Auto-CAD for more years than I can count. -- George Ventz GEORGEVENTZ@msn.com

Human Powered Vehicle Videos...

[12 Jun 01] Well, I've finally finished the "WaterCycling 2000 - The State of the Art" video series! There are eight hours of fantastic footage on four tapes, with features on the great hydrofoil and expedition boats, racing coverage from 1986 through 2000 showing events from the North America, Europe, and Japan, and promo videos from 18 boat manufacturers. All told, there are over 200 different boats on these tapes. For a limited time, I'm offering the set for $25US to I/HPVA members, $30US for non-members, including shipping. After that, the Human Powered Vehicle Association (HPVA) will take over distribution, and the price will be somewhere in the $40-$50 range + shipping. All proceeds will be donated to the HPVA. Please visit www.HumanPoweredBoats.com/Forms/F_HH2000_VideoOrder.htm for a detailed segment listing and to order your copy. -- Ron Drynan (info@humanpoweredboats.com) website: www.HumanPoweredBoats.com

Propeller for Human Powered Hydrofoil...

[26 Mar 01] HELP! my brother (he's the engineer) and I (I design and build recumbent bikes) are building a hydrofoil. I've got a page full of data on the weight issues, drag, and foil design. I can't seem to find anything on propeller design, let alone where I could buy one. We are building one from an old wind surfer, and want to go around 15 knots. We are not out to challenge the world record, but we want it to go. We are both strong cyclists, and can exceed the normal human horsepower ratings for sustained output. (We both regularly ride 60 to 100 miles in a day, and can leg press 410 lbs 30 times.) Any way, we need an efficient, but fast prop. The weight of the boat with rider shouldn't exceed 225 pounds. We are thinking of sustained hp of 33 to .5. we know we can sustain a horsepower of.33 all day long. We have a gear box with a five to one ratio, so we are figuring prop speeds of 500 to 800 rpm. That is cruising at 500 to 550 rpm, at around 10 - 12 knots. and top speed runs at 700 to 800 rpm at who knows what speed. -- Bian Burgess, (treedude2@juno.com) and Mark Burgess (Wecamp@capeonramp.com) Cape Cod MA

Responses...

[26 Mar 01] For prop design info, see Martin Hepperle's site: http://beadec1.ea.bs.dlr.de/. *[This site has disappeared from the web. If anyone knows its new location, please notify the IHS webmaster!]* As for finding props, have you considered model aircraft propellers? They come in all sizes and pitches and you can probably find some made of carbon fiber as well. -- Tom Speer (tspeer@tspeer.com) website: http://www.tspeer.com fax: +1 206 878 5269

[26 Mar 01] Model airplane props are a possibility, but there is a potential problem. Most model airplane engines turn very high RPM and the propellers reflect this by having fairly small twist. The parameter of interest is called the advance ratio and is calculated as: vehicle speed / rotation rate (rad/sec) * blade diameter. This parameter determines the angle of attack seen by the propeller blade. Propeller designs are optimized for a specific advance ratio and efficiency can suffer quite a bit if operated at a different one. For some more info, see http://www.allstar.fiu.edu/aero/BA-Background.htm. That said, you might be able to use a large prop designed for a relatively low RPM 4 stroke engine or a geared electric RC engine. -- Marc Schafer (mschafer@alum.mit.edu)

[26 Mar 01] For a number of years I have been involved in a team participating in a solar and advanced technology boat race here in Canberra, Australia. Our team has been using a modified catamaran for this race. It is propelled by an 18 inch model aircraft propeller on a converted outboard leg which is driven by an electric motor. This year we will probably test a few different propeller options we have available with different pitch and diameter combinations. The reason why we are using model aircraft propellers for the boat is because the blades should be more efficient than the standard type of outboard propeller. We have so far not really attempted to analyze the propeller performance so I can't give you further advice just yet. I have however been searching for propeller analysis codes on line. I found one which appears to be fairly simple to use and should be ideal for obtaining the performance of aero type propellers. Input is diameter, number of blades, section type (a few choices), and the chord and pitch at various radial positions. See: http://beadec1.ea.bs.dlr.de/airfoils/propan.htm. *[This site has disappeared from the web. If anyone knows its new location, please notify the IHS webmaster!]* There is a company in Australia that produces carbon fibre model aircraft propellers of a large diameter which several of the entrants in our local boat race are using. The company is Bolly Products. You should be able to find out more details of their stock and prices at their web site: www.bolly.com.au. They do provide a mail out service. There would undoubtedly also be several suppliers of model aircraft propellers in your area. You may also want to try to track down and read the following article: Brooks, Alec N., Allan V. Abbott, and David Gordon Wilson, "Human-Powered Watercraft," Scientific American, December 1986. Features cover artwork showing the Flying Fish II human-powered hydrofoil. This issue includes an eight page article (pp 108-114) about this craft and a range of other human-powered vessels with illustrations and graphs. The cover of this magazine with Flying Fish II can be seen on the IHS "Popular Magazines" web page. Although details of the water propeller used for this human powered hydrofoil are not given, it is apparent from a sketch of the design that it is also a large diameter slender two blade design much like that of a large model aircraft propeller. -- Martin Grimm

[30 Mar 01] The suggestion of Jake Free's web-site was a good one, he's a carbon fiber artist who's been building HPB specific props and hydrofoil parts for many years. Geo Tatum of WaveBike has tried the Bolly prop with unsatisfactory results on his application, but notes that it may fare better at a higher rpm (he's geared 3.25:1). I've got some prop simulation data and a spreadsheet that's available for the asking, and Theo Schmidt of the IHPVA has produced a program called PropSim which I believe he'll send upon request - email: TSchmidt@MUS.ch. There are also some prop research pages linked from my site under the Research page, and I'd highly recommend posting your query on the IHPVA Boats mailing list - visit

http://www.IHPVA.org/ , click Mailing Lists to see the archives, and "More Info" to subscribe (it's free). -- Ron Drynan (info@humanpoweredboats.com) website: http://www.HumanPoweredBoats.com

8-Man Human Powered Hydrofoil...

[26 Feb 01] We are looking to build an 8 man human powered hydrofoil for a race in June. Our competitors in the race are 20 man catamaran / canoe crews. In fact the same boat has won the race for the last 4 years straight. We are looking at building our hulls from polystyrene / aluminum with a long crankshaft for the drive and running to a prop running a prop at 3,500 rpm with the crew pedaling at 60 rpm. We would like to contact other who have build such a boat or might have advice on what we should do, where we may get parts / assistance. We've drafted a spec for our crankshaft & built a demo. model. Each seating position is 24" wide. The shaft is made of 2" x 1" x 1/8" mild steel box iron. It's 16' long to seat 8 people. It seems a bit heavy. Are there any other suggestions? -- Healy Hynes (healy@hynes.ie)

Response...

[2 Mar 01] I worked on the MIT Decavitator project (http://lancet.mit.edu/decavitator/). Without drawings, I can't really say too much about your design, but I wonder if you considered using regular bicycle cranks and chains for the pedalers and then just having a drive shaft from the gearbox to the propeller? Some other students at MIT worked on a new version after I left. They used a .25" dia music wire for the propeller drive shaft, but it was only for a single person. -- Marc Schafer (mschafer@avidyne.com)

Human Powered Vehicle Website Features Hydrofoils...

[28 Jan 01]I enjoy perusing the IHS site, it's a great resource. Have you seen my human-powered hydrofoils photo gallery? The boats there represent some of the best in the world, and I'm sure you've heard of many of them over the years. I'm in the process of building a foil-assisted HPB (Human Powered Boat) to challenge the 24hr distance record in August, after which I hope to begin construction on a fully foilborne HPB for sprint racing. During that project, I'm sure I'll be enlisting the help of IHS members frequently! In other news, I'm very close to releasing a video series on HPBs, entitled "WaterCycling 2000 - The State of the Art". There are eight hours of edited footage on four volumes, with great sections on most of the famous hydrofoil HPBs. A detailed segments listing can be found at http://www.HumanPoweredBoats.com/Forms/F_HH2000_VideoOrder.htm, and all proceeds will be donated to the HPVA (Human-Powered Vehicle Association). I think some of your members might be interested in the tapes. -- Ron Drynan, VP/Water - HPVA; email: info@humanpoweredboats.com; website: http://www.IHPVA.org/hpva/

More on Foil Adjusters/Feeler Arms...

[19 Sep 00] Relative to the postings by Lochner, Grimm and Dixon, I am sorry that my files are so deeply burired in my attic or mini-warehouse that it would take a search team to find them. However, I will offer a few comments off the top on my head. While working as liaison between

Hook and the Navy we, at Miami Ship, used the Gibbs and Cox term "spatial anticipation" for distance between the Hook "Jockey", or surface feeler, and the forward foil center of lift. Because of the potential hazard of forward reaching anticipators we frequently discused designing aft facing feelers, which we facetiously called "regrettors" but never designed. After Marine Systems folded, John Gill joined Jim Wynne, and they did build a submerged foil boat with "regretters" which, to the best of my knowledge worked well. Unfortunately now both John and Jim are dead so I doubt at this time that I can dig up any data. Also, Gordon Baker made some experiments with "regretters;" perhaps you can get some data from Neil Lien. About 1956 Miami Ship built the *CIGAR* for which you have a story in your files by me and Bob Johnston. The Cigar had two incidence controlled submerged foils on two splayed struts forward and a single submerged foil aft attached to an extended shaft outboard engine. The craft was provided with a single surface feeler forward for altitude sensing and the pilot was provided with a joy-stick to modulate the feeler signal for elevation and to which he could provide differential incidence control of the forward foils for banking. Foot pedals were provided for steering. The Hook Jockeys did control altitude with pilot override but not pitch or roll; roll was done by the seat of your pants and pitch was a function of speed. I do not think the *ICARUS* Jockeys were too large or too widely spaced, but when scaled up to *HALOBATES* they were obviously too cumbersome. We knew this from the start but installed the feeler/incidence controlled system while developing an electronic autopilot with zero spatial anticipation and a coordinated turn and bank that worked very well on *HALOBATES &DUKW*. The system was later further developed by Marine Systems Corp. for *ENTERPRISE*. If you do use a mechanical control system with surface feelers, I highly recommend that you control flaps and not incidence of the foil. -- Jean E. Buhler, Naval Architect/Marine Consultant, 5169 S.W. 71 Place; Miami, FL 33155, phone: (305) 667-8385

Foil Adjusters For Human Powered Hydrofoil...

[7 Jul 00] I am a mechanical engineer and big hydrofoil enthusiast. My partner and I are currently building a prototype for a human powered hydrofoil for recreational purposes. I need some information on self-trimming foils. I have ridden a TRAMPOFOIL and do not want to use their canard configuration. I have seen photos of a hydrofoil trimaran that has some kind of rod dragging in the water which looks like it trims the angle of attack of the outrigger foils. -- Ben Lochner (benl@kingsley.co.za)

Responses...

[11 Jul 00] Self trimming is most easily achieved by using a canard (single small foil forward, main lift aft with dual foils)all surface piercing, configuration. A better design, though, is a single V in the rear with a fully submerged section between the V sections. _/ -- Nat Kobitz (KobitzN@ctc.com)

[11 Jul 00] In response to your message, I think the hydrofoil trimaran you are referring to may be the 'Rave' which is a relatively small recreational sailing boat (www.ravepage.com). If you are able to get hold of the Nov / Dec 1999 issue of Multihulls magazine, it features an article on a race meeting of a number of these sailing hydrofoils. There are also a number of posted messages or items on the 'Rave' in the IHS website as far as I recall. The rod dragging though the

water either side of the boat does indeed serve as the means of adjustment for the angle of the foils (or perhaps it has flaps) mounted on the outriggers of the 'Rave'. I say this as the linkages at the top of the rod are quite clearly shown on one photo in the issue of Multihull I mentioned. In that design, it seems that as the rod becomes submerged it is pulled back by the drag of the water and this in turn increases the foil angle and hence lift on the foil such that the craft rises again. The more common alternative is to have a surface sensor or feeler arm which projects forward of the foil unit and has a relatively small planing surface mounted on its tip. The planing surface then skims above the water surface such that when it encounters a wave, or the craft settles, the feeler arm is pushed upwards and the foil or flap angle is again increased proportionally via a pushrod which hoes down the inside of the foil support strut. The solar boat of Marquette University is an example of a design that uses this approach. I recall they have a web site about their design but I don't have the details. There are also a number of human powered hydrofoils which operate on the same principle such as the Flying Fish and Decavitator, for which I think there are some web sites as well. I don't think it is an easy task to determine the size of the surface sensor arm, the planing surface, the linkage arrangements or the pivot point of the foil unit such that a stabilization system that works well is obtained. I certainly don't have any experience in doing this so perhaps others could help. The book by Christopher Hook and A.C. Kermode 'Hydrofoils Without Formulae Series' published by Pitman Paperbacks in 1967, gives a good description of the use of mechanical surface sensor systems for foil control. This book is likely to be on your local library bookshelf if any hydrofoil book is. Christopher Hook was one of the early (if not the first) developers of fully submerged hydrofoil designs. In the late 40's, electronic autopilot systems for controlling the attitude of hydrofoils were not really available so Mr. Hook developed his designs using mechanical sensors. The use of a mechanical surface sensors on each of the two bow foils helps to control heave (height above water), pitch and roll. It is usually not necessary to have a surface sensor for the rear foil(s) as they tend to be controlled by the change in attitude of the boat as a whole. The angle of incidence of the rear foil(s) then just need to be adjusted once on shore so that they are carrying the desired percentage of the craft weight when sailing in calm water. -- Martin Grimm (seaflite@alphalink.com.au)

[22 Jul 00] Fully submerged foil hydrofoils are unstable, so some type of angle control is needed. For height control, the front foil has to have angle control, so it is much easier if the front foil is small. (I think that rear foil angle control is possible, but the control algorithms would be very complicated. It's like reversing a trailer) When *DECAVITATOR* was made, there was a lot of trouble with V-foils with ventilation. On the other hand, I saw on "Tomorrow's World" on the BBC, about 10 years ago, a human powered hydrofoil with a V-foil at the front. I think that it was a canard configuration. As with a fully submerged foil, making the front foil small reduces magnitudes of the problems of the ride height control. Anyhow, for a foil angle control, the immersion depth must be measured and from that the foil angle must be set. The simplest method is a surface skate, like on the TRAMPOFOIL, but it doesn't have to be in front of the foil, and it can be arranged to alter the angle of a foil that is separately pivoted. If you look at the drawings of *TALARIA III*, you can see one such arrangement. If you want to have automatic roll control, it can be done by having two separate ride height control systems either side of the center of the boat. However they have to have enough roll authority, so they have to be large and widely spaced if the center of gravity is high. Trimarans are quite low and have a broad beam so they are easier to give roll control like this, although the sail force has to be considered. Two early hydrofoils, *ICARUS* and *HALOBATES*, had very large surface skates to give roll authority

because the craft were high and not very wide. (There are photos and info elsewhere on the IHS site about all the hydrofoil craft I have mentioned above). -- Malin Dixon (gallery@foils.org)

[22 Jul 00] You would do well to visit Jake Free's web site and note the already made self trimming foils which he has for sale in his product section. Go a bit down the page to: INTERNAL PUSH/PULL/FLAP ATTITUDE CONTROL STRUT. all carbon fiber (above, and right) has hinge and flap foil, internal push/pull rod to control attitude. -- Warren Lemoi (savitar@earthlink.net)

[22 Jul 00] What you describe may have been a "drag link", which was a concept first explored about 1960 to self position trailing edge flaps on fully submerged foils to control height or submergence. It was basically an attempt at a mechanical autopilot. The drag link was a vertical vane or rod pivoting at the top, where it was connected to the trailing edge of the foil strut. As the foil and strut lowered into the water the drag link would pick up drag, pivot and through mechanical linkage within the strut transmit the turning moment to the foil flap, thereby increasing lift. As the lift increased the foil (and strut) would lift, reducing drag on the drag link. The drag link would return to its neutral position (sometimes augmented by a return spring), and through the linkage return the foil flap to neutral. That was the theory. In practice it was a mechanical nightmare. It had no way to anticipate height needs, which later electronic autopilots solved with forward/downward looking (radar) height sensors. Even with dampers the drag link concept tended to oscillate. -- Charlie Pieroth (SoundTM@ix.netcom.com)

Follow Up...

[8 Sep 00] I have had a great response on my question, and and thanks everyone for their contributions. Warren Lemoi's answer was the closest to what I have been looking for. I have decided to go with a mechanical mechanism working on the same principle but using a control cable and spring mechanism instead of a push pull rod. This mechanism can then be controlled from my steering mechanism. -- Ben Lochuer" (benl@kingsley.co.za)

Determining Foil Size and Profile For Human Powered Hydrofoil...

[11 Jun 00] I am not an engineer although I do have a technical background. I am familiar with aircraft operations as I am a general aviation pilot. My design goals are a craft which weighs approximately 200 lbs with occupant and a design speed of around 10-15 mph. Here are three specific questions:

1. I found, in one of the responses on the FAQ's, a formula to ballpark foil sizing. The formula read as follows: $L = 0.5 \times CL \times RHO \times A \times V^2$ where, L = Lift (total craft weight supported by the foils in Newtons); CL = Coefficient of Lift (between 0.25 and 0.4) ; RHO = Water Density; A = Total vertically projected area of submerged foils; and V = Speed in meters per second. Questions: a) What is the Coefficient of Lift figure, and why was 0.25 and 0.4 given? Are these desired figures, or do all foils range between these figures? b) I don't understand what the 'Total vertically projected area of submerged foils' (A) is... should this be total horizontally projected area? Am I missing the point here? c) My assumption is that I would simply solve for 'A' to obtain the desired foil area?

2. I believe I understand that surface piercing foils are self-stabilizing and do not require control surfaces. It seems most of the surface piercing foils I've seen are either 'V' shaped, or more half-circular shaped, if that makes sense. Any benefits over one or the other? Are there other types?
3. Would one of the NACA Symmetrical foils be a good choice for the parameters I listed above?

Any help would be greatly appreciated. -- Wade Bissell (wbissell@uswest.net)

Responses...

[11 Jun 00] Here are some thoughts in response to your inquiry:

- How about buying a *Flying Fish* for about $7000? You can get to the company that sells them at: http://members.aol.com/jfreeent/hf.htm.
- The Coefficient of lift is almost defined by the equation that your read in the FAQs. A clearer way of writing the equation is L = CL x A x P, where P is the dynamic pressure. The dynamic pressure is the pressure increase that a gauge with its opening pointing straight forward would measure. The dynamic pressure is given by P = 0.5 x RHO x V x V, which gives the same value for the lift. Another way of looking at the dynamic pressure is the water pressure needed in a hose to give a jet at that speed.
- The coefficient of lift is used because it has no dimensions, so you don't need to define units for it to be meaningful. The coefficient of lift will depend on the wingform, the angle of attack and the aspect ratio. There are one or two other things but they won't make much difference. Before you run in fear, let me try to explain the terms:
    - The wingform is the shape exposed if you were to cut off the foils with a vertical cut parallel to the forward-backward direction. The more curved the wingform, the bigger the coefficient of lift. The more like an airplane wing, the larger the coefficient of lift that can be produced without a lot of drag or stalling.
    - The angle of attack is the angle between the longest front-back line through the foil and the horizontal. The bigger the angle of attack, the bigger the coefficient of lift.
    - The aspect ratio is the ratio of the wingspan to the length of the longest front-back line through the foil. The aspect ratio doesn't have much direct effect on the coefficient of lift, but the larger the aspect ratio, the larger the coefficient of lift can get and the less the drag that is caused by that lift. Large aspect ratio foils (say more than 8 or so), with a sophisticated shape and a big angle of attack can get coefficients of lift above 1.0, but they are difficult to make. If you can keep the coefficient of lift below 0.5 then almost any flat shape will work (that's why paper airplanes work) On the other hand, 200 lbs including occupant doesn't leave a lot weight left for an engine, so you may need to put more effort into wing design to get the drag low enough for you to pedal it. A low coefficient of lift means a

larger wing or a higher speed, both of which mean more drag. The wings on human-powered hydrofoils are usually almost the same shape in all respects as a glider wing.

- By vertically projected area, what is meant is the area of the shadow if the sun is vertically overhead, and the foils are in the normal flying attitude.
- As to your assumption "that I would simply solve for 'A' to obtain the desired foil area," yes, it's as easy as that.
- Have a look at www.onspec.co.uk/trampo and Bob Hogden's TRAMPOFOIL page. Unfortunately Trampofoils aren't made any more.

-- Malin Dixon (gallery@foils.org)

[11 Jun 00] I am pleased to see that your questions concerning the equation for hydrofoil lift have already been answered by Malin Dixon, but I thought it may be helpful if I elaborate further. When I prepared the response for Jim Wolbert (which you saw in the FAQs), I did skip over a bit of the background to try to keep it brief. The range of coefficients of lift I had suggested were obtained by "reverse engineering" the details of a number of existing hydrofoil designs where the submerged foil area, displacement (i.e. the weight of the craft) and speed were all known. These craft ranged in size from small human powered hydrofoils such as the *Flying Fish* and *Decavitator* through to large passenger-carrying surface-piercing hydrofoils of Supramar and Rodriquez design. Despite that range in vessel size and speed, the coefficient of lift for the foils remained in the band from 0.25 to 0.4 which is why I proposed that range. Staying between those limits can be considered to be good design practice.

On the matter of projected foil areas we are both thinking alike but are simply using the opposite terminology! When you refer to "total horizontally projected area" you refer to the area projected onto a horizontal surface. When I referred to "vertically projected area" I meant vertically projected onto a horizontal surface. The reason I used the term "total vertically projected area of submerged foils" rather than simply "total foil area" was because I had surface-piercing V-foils in mind as well as the horizontal foils more common on fully submerged hydrofoil designs. For V-foils, it can effectively be considered that only the area of the foil as seen from directly above (Malin has nicely described this in terms of the shadow that is cast) is making a useful contribution to supporting the weight of the craft.

To explain this reasoning a little, I will use an example with which you are familiar, an aircraft. The lift generated on a wing acts at right angles to its surface and as such, if the wing is horizontal, the lift acts in the vertical direction opposing the weight of the plane. When the aircraft is in a banking turn, only part of the lift on the wing acts in the vertical direction and the rest acts sidewards into the turn. In the extreme case of the aircraft in a 90 degree bank, none of the lift on the wing acts vertically to oppose the weight. So, for that third case, even though the actual wing area has not changed, the amount of wing area as seen from directly above has reduced to zero just as the component of lift in the vertical direction has done. The two foil sections on a surface piercing V foil are essentially acting like two banking wings stuck together so that the component of the lift force on one half of the V-foil is "wasted" in pushing against the equal but opposite component of lift produced on the other side of the foil. However, the dihedral angle of a V-foil (the angle of the foil sections to the horizontal when viewed from in front) is

not that large on typical surface piercing hydrofoils, normally between 15 to 35 degrees. As a result, a reasonably high proportion of the total lift that is generated still acts in the useful vertical direction to support the weight of the craft. I have simply found it more expedient to calculate the lift on the basis of the foil area as seen from above as that avoids having to separately account for the component of lift on the various foil elements which acts in the vertical direction.

Another, and perhaps better way of calculating the vertical component of the lift generated by an inclined hydrofoil is to calculate the lift perpendicular to the foil surface (LT) first and then obtain the vertical component of that lift (the part that supports the craft weight which I will define this time with the symbol LV), by using trigonometry:

LT = 0.5 x CL x RHO x AT x V^2 is the total lift generated perpendicular to the foil surface, where AT is the area of the foil perpendicular to its surface.

Then, the component of lift in the vertical direction is given by: LV = LT x Cos(THETA), where THETA is the dihedral angle defined previously. Combining the two equations gives: LV = 0.5 x CL x RHO x AT x Cos(THETA) x V^2, but now it can be seen that part of the previous equation actually represents the submerged area of the foil when viewed from above (previously referred to simply as A): A = AT x Cos(THETA).

So we have now come full circle back to the form of the equation as I had originally presented it for the vertical component of lift in terms of the foil area as seen from above: LV = 0.5 x CL x RHO x A x V^2 . (in my previous reply to Jim I had simply referred to LV as L).

Now, re-expressing the equation in terms of foil area gives: A = LV / (0.5 x CL x RHO x V^2) and applying this equation to your case with the following particulars...

- LV = m x g = 90.7 kg x 9.81 m/s^2 = 890 N (200 lbs)
- CL = 0.25 to 0.4
- RHO = about 1000 kg/m^3 in fresh water, 1025 kg/m^3 in salt water
- V = 4.5 to 6.7 m/s (10 to 15 mph)

...leads to a foil area viewed from above (A) from 0.099 to 0.352 m^2 in fresh water or 0.097 to 0.343 m^2 in salt water depending on the speed and CL values which are used. As you can see, there is not much difference in the required foil area whether you are in salt or fresh water. The speed of the craft and the lift coefficient of the hydrofoils has a far greater impact.

For a nice high aspect ratio fully submerged foil with an efficient foil profile (or wingform), you should be able to get away with a combined area of foils on the low side of the range above. On the other hand, if you have a stumpy foil with a "rough" profile, then a higher area will be necessary. In the latter case, the resistance will also be greater. Even if a *Flying Fish* off the shelf is not what you are after, it would be worth your while looking at the foil arrangements on that type of craft or the similar human powered *Decavitator* for some good tips on the optimum foil design for a human powered hydrofoil -- Martin Grimm (seaflite@alphalink.com.au)

Trampofoil Goes Under...

[21 Mar 00] I am hoping that you may be able to give me a little insight on the Trampofoil as the home page has disappeared and pictures on the internet are of poor quality or focused on the wrong areas. I am an Engineering science student doing my fifth year at Auckland University in New Zealand. Part of our studies involves a final year project, and I have selected one on building a water craft similar in principle to the Trampofoil. Part of this project will primarily involve modelling this craft and how it works. Ultimately we will build a full size craft and test the design, and other students in the years to come will want to improve on this project. For me this projects goes for the whole of 2000. More to the point, I am very interested in how the Trampofoil.-- John Ballinger (sponno@yahoo.com)

Response...

[9 Nov 01] There is a similar product available from Engineering Café; see www.engcafe.co.za/. This website is provided for your information only. IHS does not recommend or endorse products and services. -- Barney C. Black (Please reply via the BBS)

[21 Mar 00] Sadly the Trampofoil company in Sweden has failed. Only about 100 units were sold. They were too expensive and not well enough advertised. I take it that you have seen the photographs at www.onspec.co.uk/trampo. Like all hydrofoils, the Trampofoil has a wing that supports the weight by hydrodynamic lift. The rear wing is 2.9m in span and has a chord of 0.1m and is under the step, taking just about all the weight. 6 knots will give enough lift. The front wing is about 0.4m by 0.05m. Ride height control is by a skate that controls the angle of the front wing. The rudder also joins the skate to the front wing and supports the front wing. The skate, rudder and front wing form one rigid assembly, which is rotated to steer the craft and tilts freely, controlled by the skate. The angle of the rear wing adjusts itself because the front is held at the correct height by the skate, and as the rear becomes deeper, the angle of attack become larger. The Trampofoil is unstable in roll, and the rider has to shift his weight to the side to keep it upright. However it takes several seconds to roll over so this is easy. Propulsion comes from the rider jumping. The body that joins the step to the front wing is flexible, so that as the rider pushes down, the rear wing points down (negative angle of attack), so the lift force is slightly forwards. As the rider pulls his feet up, the angle of attack is positive, so the wing rides up and the lift force is backwards, but it is smaller because there is less weight on the wing at that time. This is how a bird flies. Like the Trampofoil, the big muscles move the wings up and down relative to the center of gravity. Like the Trampofoil, the angle of attack is negative on the downstroke. The birds alter the angle of attack actively, but it is passive on the Trampofoil. However some control can be achieved by jumping on the front or back of the step. The Trampofoil cannot be started from in the water. It is easiest to start from a jetty where a single push can get the rider and Trampofoil to the minimum flying speed. Also, before the start, the rider can hold the Trampofoil and himself, in the same attitude and height as during flying. So the rider just needs to add speed. Beach starting is possible, but much more difficult. The rider stands in water about 10cm deep, holds the Trampofoil wings just under the surface. Then he pushes the Trampofoil forwards. On its own, it flies at about 1 knot, so it's flying immediately. The steering is not held at this point, but the exact direction of launch isn't important. The rider holds either side of the step and accelerates until the water is about 40cm deep. He then jumps

onto the Trampofoil, jumping off the bottom with one foot and landing with the other knee on the step. He then climbs up and starts jumping. If that doesn't sound too difficult, on a steeply sloping beach, there is one step from standing to jump and the whole lot takes about 2 seconds. There is no way of slowing down quickly. The rider just stops jumping and coasts. It's possible to dry land if the jetty is undercut so that the end of the wing can fit under. It's also possible to stop at the corner of a jetty, but timing the stop is difficult. Emergency stopping is by jumping off the back and catching the step to stop the Trampofoil as water drag on the rider stops him. I've been pulled by a boat while on a Trampofoil, and the tension in the rope was about 50N (just my guess from feeling the tension) at about 10 knots. Please tell me if there is any more information that you want. Jake Free sells other human powered hydrofoils. They cost about US$5,000. They all have floats so that they can water start and they are propeller driven. There is a link to his website from the IHS photo gallery. -- Malin Dixon (gallery@foils.org)

Build Your Own Hydrofoil Bike...

[4 Apr 99] I recall seeing on television 5-6 years ago a film bit on a kid who simply attached a small foil/ski to a 10-speed bike frame, and powered it with a propeller attached to the pedal/chain assembly. He began in the water chest-high at a standstill, and the bike frame ultimately lifted out of the water under his own steam. It seemed pretty simple in principle, and he outran a 5-man crew with it. Any info? I would love to build one.-- Tom Kane (tkane@vicon.net)

Response...

[10 Apr 99] Tom, I have not heard of this particular means of making a hydrofoil, but it sounds too easy to be true, especially the part about starting from a standstill in chest high water. You can buy a hydrofoil "bicycle" called the Trampofoil, and this is a professionally designed and manufactured item that you can use without being an Olympic athlete. For making your own, there is some info on the web about the *DECAVITATOR*, which was put together by a team of MIT students. There is also a Human Powered Vehicle Association, which may have heard of the TV show you mentioned. Popular Science and other magazines have run articles about how to build your own hydrofoil in the past... all motor powered that I know of. I suggest you explore the IHS Links Page and the page on Popular Magazine articles http://www.foils.org/popmags.htm. If you do find out info about this TV show, let me know the details so I can post them on the website. Thanks. -- Barney C. Black (Please reply via the BBS)

A Personal Trampofoil Page...

[1 Jan 99] We have a web page about our new Trampofoil. Feel free to add it to your links page. *[Done. Good photos of this interesting water vehicle. - Ed.]* The effort required is about like running. I'm 44 years old and not at all athletic. My best distance so far is about 200 yards. It seems to be getting easier the more I do it, as I develop the proper cadence and technique. I don't think I'll ever be doing long distances on it. The experience is like a cross between a pogo stick and a hang glider. You have the sensation of "flying" a wing. If it gets too slow it stalls. You have to keep the turns coordinated by matching the bank to the yaw rate like an airplane. The steering bar controls the yaw axis and you shift your weight left and right to roll. The roll axis is

well damped by the 9-1/2 ft wing span. Pitch is taken care of automatically by the bow foil and surface sensor. It is an elegant design, the designer has reduced the hydrofoil to its basic elements. He's taken away everything not required for flight. The quality of the extrusions and construction are very good. -- Bob Hodgen (RobertHodgen@compuserve.com)

Jake Free's Human Powered Hydrofoils For Sale...

[9 Dec 98] One of, if not the busiest commercial human powered hydrofoil website is at: http://members.aol.com/jfreeent/hf.htm. Here there is lots of information on how to build your own boats, a source for hydrofoil parts, lots and lots of scientific data, a history of human powered hydrofoils, and lots of links. Included is an image (© Jake Free) of the world's first hand /foot ("Orbital") powered hydrofoil If you would be interested in some fresh-out-of-the-file-images of our hydrofoil prototypes, let me know. -- Jake Free [JFreeEnt@aol.com]

[24 Aug 97] Can anybody tell me, if it is possible to build a one-man hydrofoil, which is powered by muscle (pedal) and, if yes, where to get plans? -- Ingo Fengels (fengels@datacomm.ch).

[2 Feb 98] I am interested in finding any technical details as to how the Trampofoil works (www.trampofoil.se). Could somebody tell me how it produces its forward motion, lift and stability? Mark Welte (mwelte@ocean.com.au)

Response...

[2 Sep 97, updated 22 Nov 00] The TRAMPOFOIL® Human Powered Hydrofoil website at www.trampofoil.se has closed down and the product is not longer produced. There is a website devoted to it that you can visit: Click Here. -- Barney C. Black (Please reply via the BBS)

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