**EXCEL BLADE DESIGN**

We're going to 3D-print 3 prop-hub sets for fore blades, and I'd like 3 prop-hub sets for aft blades. Then we will test them, in a pool, the water tunnel, and/or the Parkinson (green) wind tunnel. The data will heavily influence our final design for the fore and aft propellers.

You'll need to start with an excel sheet, like the one I posted at the beginning of November, with the green "Try 2" tab. Just copy-paste that sheet, and make a few changes. Do so before proceeding.

* Start with pitch --> 0.4-0.6 (we want as high as we can get away with)
* Then pitch-over-diameter ratio --> 0.8-1.1 (0.5 would be tugboat, 1.5 would be speedboat)
* Make sure your stationing matches your diameter
* Start your stationing at 0.03m or 3cm, as the hub will take up 3 cm in radius

v\_stream is the speed of the intake water, to the propeller disk. We assume 1m/s for the sub fore blades, and 0.5m/s for the aft blades. v\_stream is always less than v\_submarine, due to boundary layer effects. v\_str for the half-size test blades is a tricky proposition: if we go in a pool, we’ll call it 0.5m/s. If we go in the water tunnel, 2m/s. Only the smallest of the 3 proposed blades in the table below can fit in the water tunnel, so only that set can have a v\_str set to 2m/s.

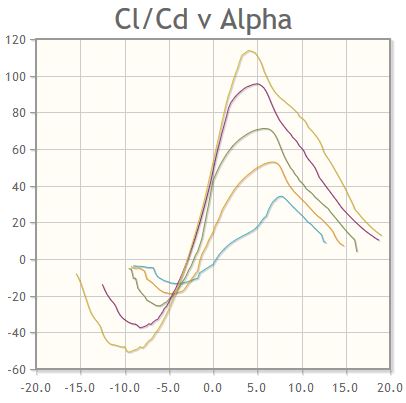
Rotational speed is generally 3Hz underwater, but we think 4 is a safe target, with our upcoming rotary drive. We even hope for 6Hz, but there's no way to be sure. The wacky thing is that since we’ll be testing half-size propellers, we should do higher rotational speeds – pick 8, 10, or 12Hz ***for your half-size propellers***.

The way the spreadsheet works, left to right, is by making a triangle from v\_str (intake direction), v\_tan (direction tangential to rotation), with the hypotenuse along the underside of the airfoil. This gives a local Reynolds number, along the underside of the airfoil. Using the pitch equation:

I got a total angle, and compared it with the angle prescribed by the velocity triangle, i.e., beta. Beta will always be lower than the total pitch angle. Subtract beta from the total angle, and compare with stall angle: a negative value means stall is not exceeded, a positive value means stall is exceeded (the cells will turn pink). We mentioned not to exceed stall angle, which we learn from the Airfoiltools website graphs. Now you need to know about the lift-to-drag ratio vs angle of attack graphs. In these graphs, you'll see peaks in the ratio. This is the angle you generally want to use. While lift itself is not maximized, drag is fairly low, which means the propeller can spin more.

Here's the graph for the NACA 2411 airfoil. We would be operating at the Reynolds numbers in

swamp orange and swamp green. So the ideal angle of attack is about 6°.



**MAKE HUBS**

When you 3D-print your propellers, you will be printing complete hub-plus-3-blades assemblies (also 5 blades, for the aft set). Therefore:

1. CAD the blade first
2. CAD a hub
3. Print the hub, to check on Nov. 18 if my bearings will fit
4. Mate 3 blades into your hub assembly, save as an STL file on a flash drive, and then you’re ready to 3D-print

However, your hub must be able to fit a bearing, so we can spin the prop. I recommend your hub have the following dimensions:

* Diameter: 6cm
* Length/thickness: 4-5cm, or more, to make your blades flush at the shank
* Fillet the edges, if feasible

And the hole in the hub for the bearing:

* Diameter: 2.25cm
* Depth: probably 1-1.5cm. The bearing is about 8mm thick.

The simplest design is to have a blind hole in your hub, and press-fit the bearing in. Some glue may be necessary, but preferably not. If you have a more clever design, go to it, but make sure it works….

The bearing inner diameter is 10mm, so we’ll use 3/8” aluminum rod (with tape) to spin the props.

**MAKE PROPS**

Ideally, every one of you will design two iterations of one type of blade: one for fore set, one for aft set.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Propeller #** | **Full Span (length), cm** | **Chord (width), cm** | **Thickness range (cm)** | **NACA Airfoil** | **Skew** | **Designer** |
| 1 | 20 | 6 | 0.3-1.2 | ? | 0-10° | Kevin, Paul |
| 2 | 24 | 8 | 0.3-1.2 | 2411 | 0-10° | Isaac |
| 3 | 28 | 8 | 0.3-1.2 | 2411 | 20-30° | Devin, Stephen |

Keep in mind that I’ve given the full span and chord above. We will be 3D-printing **half-size models**, in order to test. So the lengths above will be 10, 12, and 14cm, and the chords similarly will be halved. Recall from above that your proposed rotational speed will be 8, 10, or 12 Hz, as well.

For the aft set, make the following changes:

* Blade length 85% of the fore blade length
* v\_str 50% of v\_str for fore blades

*Some CAD advice:*

1. Get the .dat file from airfoil tools page of an airfoil (to right), to get x-y ordinates for your airfoil
2. Put into Excel, to separate and manipulate numbers. Add a z column, with 0’s
3. Plug those numbers into a .txt file
4. In SolidWorks, right at the start of a new part, go to Features🡪 Curve 🡪 Curve through xyz points. Import your .txt file, et voilà
5. You now have an airfoil. Click on the curve, and “Convert Entities”
6. Click on the plane, and go to Reference Geometry🡪Plane. Click the plane of the sketch, and in the number box, click 5-20 planes (depends on your stationing, and patience).

At this point, opinions differ. You can extrude the airfoil, and convert entities, to get sketches on each plane. But you must enlarge and shrink them. Alternatively, you can make scale coordinates for each plane (tedious, but reliable). Then make points at the front and back of ***each*** sketch, and run splines through them as guide curves. Then loft.

Then comes the issue of rotation. Finding the centroid of a sketch is easy, via Evalute🡪Mass Properties. You can put a dot at that point, having designated it with construction lines. However, you need ***an axis*** to rotate. I’m going to talk to Connor in Fins about this, to get you a solution. Experiment.

In any case, if you have an airfoil, and airfoil sketches of different sizes and rotations on various planes, and you can draw splined guide curves connecting their dots you can loft yourself a pretty sweet propeller.

Good luck, and ask questions!