# Choosing Materials for Use in the Ocean

bluetrailengineering.com/post/choosing-materials-for-use-in-the-ocean

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If you're building a car, an airplane, a VEX robot, or anything else that stays on the land or in the air, there are thousands and thousands of materials from which to choose. But if you need to operate in the ocean, you've got to be much more selective. The main issue is corrosion: the ocean is like a giant vat of acid just waiting to corrode away anything that falls into it.

This Tech Tip is only meant to be an introduction to the subject, but hopefully it will get you started on the right path to avoiding or minimizing corrosion. So let's go through the basics of corrosion as it applies to various materials:

**Metals**

For corrosion resistance, any metal component exposed to seawater should be either brass, bronze, 316 stainless (also known as A4 stainless), titanium, or perhaps aluminum. Nickel alloys also do well, and there may be other less-common metals that will work well too (such as gold, but I'm guessing your budget won't permit its use). Avoid non-stainless steel like the plague. Also be careful with 304 (a.k.a. 18-8 or A2) stainless steel or basically any type of stainless other than 316. 304 stainless is much more prone to corrosion than 316 stainless, and is generally not recommended for use in seawater. Bare 6061 aluminum (the most common alloy) is okay, but anodization will make it better. There are other less-common but more corrosion-resistant "marine" aluminum alloys. In any case, aluminum has the potential to be very problematic if it's in contact with another metal (see Galvanic Corrosion below).

Titanium is the metal of choice for use in the ocean, as it is for all intents and purposes corrosion-free. It is expensive, but usually worth it for critical applications. Blue Trail Engineering uses titanium where appropriate on many of its products, such as on the output shafts of our servos.

If you research corrosion further, keep in mind that it's fruitless to ask, "Will this metal corrode in seawater?" The answer to that is "Yes." The real question is whether it will corrode *enough* to affect your particular project. In other words, it's almost always the RATE of corrosion that matters. Given enough time, almost any metal will dissolve away in seawater, but often that's on the order of decades, and you may only need it to last a few weeks or months.

6061 aluminum bracket, 316 stainless nut, brass bulkhead connector, PVC pipe, and polyurethane cable after 155 days in the ocean.
Along the same lines, as you think about corrosion of metals in your application, make sure that you decide first whether you care about cosmetic corrosion (the metal simply becoming tarnished or rusty-looking) or only about actual structural loss (a metal corroding away enough to affect its strength). For instance, brass will readily tarnish in seawater, but will keep its structural strength for a relatively long period of time.

The picture to the right is a great illustration of these principles. It shows the front end of SeaCharger's thruster pod after 155 days in the ocean. The large aluminum piece is technically corroding a bit (notice the white spots), but not enough to matter. There is some corrosion on the 316 stainless nut, but again, not enough to matter in this application (by the way, this seems to be "crevice corrosion," another topic to research if you're interested). And if you look closely, you can see tarnishing of the brass bulkhead connector (just to the left of the bright white piece), which is also just a cosmetic issue. However, if these components needed to last for 10 years in the ocean, then we might want to change to titanium or plastics.

This handbook from the Woods Hole Oceanographic Institution has a lot of useful info about corrosion of metals in seawater.

**Plastics**

Delrin (a brand name of acetal or POM) is a great material for use in the ocean. ABS is also fine, and it has the advantage of being bondable with epoxies and urethanes, whereas Delrin is too slippery to be bonded. Nylon will swell and get soft when exposed to water, but it could still be appropriate for certain applications. I've found that PVC pipe works fine in the ocean (see the above picture). Urethanes/Polyurethanes often work well in seawater, but it would be wise to consult the manufacturer of the particular material to be sure.

3D-printed parts could work but make sure you test them to make sure they don't soften in water and that they are strong enough for the application. If you're trying to make a waterproof enclosure with a 3D-printed part made on your own 3D printer, good luck. It will probably leak water through the walls, and the surface finish probably won't be good enough for O-rings to seal against it. However, this does not necessarily apply to professionally 3D-printed parts, such as SLA parts. They can be smooth enough and non-porous enough. Just make sure you check their UV resistance and water resistance.

**Composites**

Fiberglass composites and carbon fiber composites are fine in seawater. I use West Systems epoxy for my composite work, but there are many epoxies that will do just fine. Note that carbon fiber is a conductor and is extremely noble (see the Galvanic Corrosion section), so never let it come in contact with a metal or the metal may crumble to pieces.

**Galvanic Corrosion**

Just Google this and you'll find a plethora of information, or look at this writeup from the Stainless Steel Information Center. Basically, any time you have two metals in contact with each other in the presence of seawater, one of those metals will corrode. But the rate of corrosion is highly variable, so it may not be an issue. You want any metals that are in contact with each other to be close together on the galvanic series. Be aware that carbon fiber, although not a metal, is conductive and is extremely "noble," so it will corrode other metals that come in contact with it.

If you want to join two components together and they are made of different metals (or carbon fiber) that are far apart on the galvanic series, you need to put a piece of plastic or something in between them so that they don't make electrical contact. For instance, let's say you want to join a carbon fiber plate to an aluminum plate, using a stainless steel screw. Without any insulation between the materials, the aluminum would corrode very rapidly. The stainless steel screw would start to corrode too. But if you just use a plastic sleeve around the screw and plastic washers between the carbon fiber and aluminum, you shouldn't have a problem (this technique was used to separate the aluminum piece from the stainless screw and nut in the picture above). Just make sure that the sleeve and washers have a bit of thickness to them, since you can get galvanic corrosion if the materials are almost touching even if they aren't actually touching. And use a multimeter to make sure that there is no unseen electrical path between the two materials.

Sometimes when you're making a carbon fiber component, you can put a layer of fiberglass in the "layup" to act as an insulator. For instance, the rudder on SeaCharger was made of carbon fiber and pivoted around a 316 stainless rod that was bonded into the rudder. I put a layer of fiberglass cloth in the layup where the rod was bonded in to make sure that the 316 stainless and the carbon fiber did not make electrical contact.

Alternatively, if you have different metals in contact with each other, you can protect them from corrosion with a “sacrificial anode.” A sacrificial anode is just a chunk of metal from the least noble end of the galvanic series, typically zinc. If you screw it to your assembly, it will be the first thing to corrode, but will keep the other materials from corroding. But after a while the sacrificial anode will corrode away completely, at which point its protection will be gone.