Case Study

Liquidmetal® Alloys in SCUBA Equipment

Industry
Sporting equipment

Challenge
Manufacture corrosion resistant, durable, light-weight SCUBA parts - creating a performance and economic advantage

SCUBA DIVING equipment endures considerably more stress and exposure to the earth's elements than most sporting equipment. One of the main components, a diver's lifeline, is the regulator system. The regulator provides breathable air to the diver from the tank, allowing for a comfortable and safe underwater experience. Stainless steel, brass, aluminum, and bronze have historically been the main metal materials used in regulator parts. These materials are used because of their durability, strength, corrosion resistance, low cost, and manufacturability. Stainless steel is the most common, especially for internal components. In search of better performance, SCUBA equipment manufacturers have introduced a new material – titanium.

Titanium regulators offer divers benefits like lower equipment weight, corrosion resistance, durability, and longer time between servicing. All of these attributes are critical in diving equipment due to the extreme demands for performance and consistency from users. While titanium has been advantageous in many ways, there are some drawbacks. It requires expensive and time-consuming machining to achieve final part geometry. Polishing is often necessary to achieve the common chrome surface finish found on titanium regulator parts. Titanium components can often limit or completely restrict cold water diving, often synonymous with deep or technical diving. Technical divers require their equipment to be highly reliable, accurate, and safe due to the extreme conditions they are diving in. Liquidmetal alloys offer similar, if not more, benefits compared to titanium while also overcoming titanium regulator complications.

Corrosion

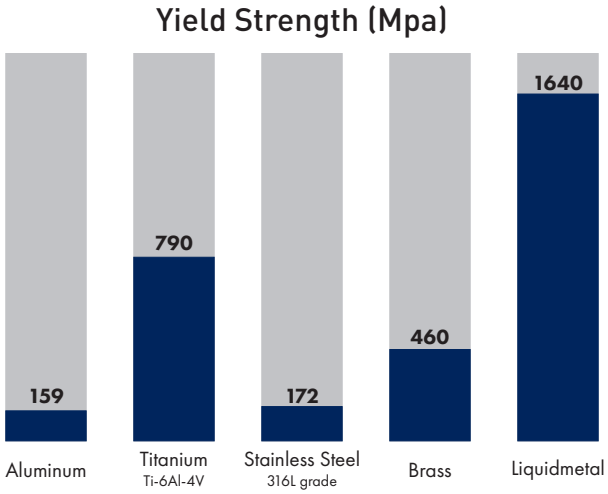
When discussing materials used in SCUBA equipment it is likely that the first topic to be discussed is corrosion. Exposure to harsh underwater, and often salt water, environments can break down metals and plastics very quickly. There is no single test for corrosion prevention,

but a common test that provides a good indication of corrosive properties is the ASTM B-117 salt-fog test. **Liquidmetal® alloys perform very well in the salt spray test**, showing insignificant signs of corrosion over 2000 hours. **The material proved to be well suited for marine environments** in this test. Titanium alloy Ti-6Al-4V has also been proven to perform well in ASTM B-117 in independent tests, showing little to no corrosion.

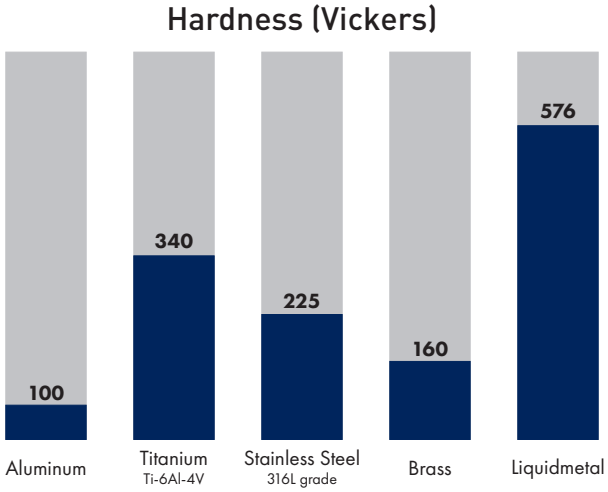
Other materials like brass and aluminum; depending on the grade, corrode quickly in the ASTM B-117 salt fog test. To combat this, a common solution to metals that corrode easily is coating or plating the material. While coating and plating options are abundant to manufacturers, the result is still the same: cost and time are added to the process. With Liquidmetal alloys you get the assurance that the equipment will not corrode in a marine environment, with **performance on par with the highest-grade coatings available - without spending a penny on post processing**.

Durability

Where Liquidmetal alloys may best separate themselves from the competition is in their strength, hardness, elasticity, and ultimately durability. In the following yield strength chart, Liquidmetal alloys have yield strength (1640 MPa) well above other materials, including ultra high strength, military grade titanium (758 MPa). This extraordinary strength allows Liquidmetal alloys to thrive in high stress environments.



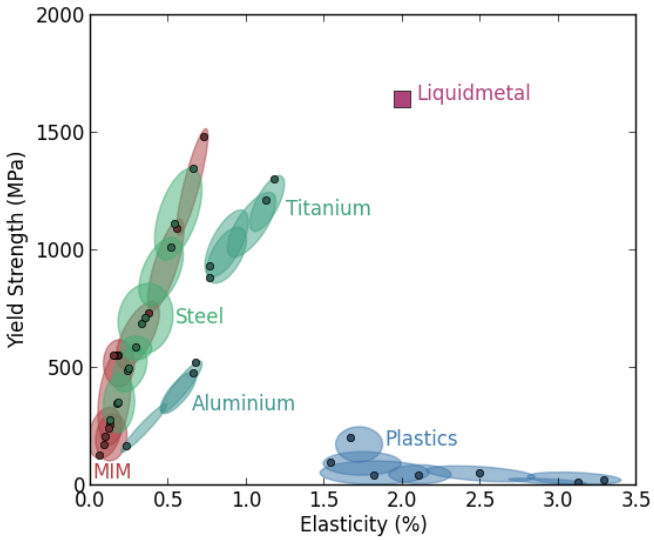
For functionality and aesthetic reasons, first and second stage regulator parts should be scratch and wear resistant. Below is a hardness comparison of Liquidmetal and other metals:



While this data does not mean Liquidmetal alloys are scratch proof, **they are certainly much more scratch resistant than comparable materials**.

Consistency and durability in the material through the life of the product will mean less maintenance and cleaning, and more visually appealing equipment.

Generally, high strength materials are very brittle and stiff. Liquidmetal® alloys are a unique combination of strength and elasticity unmatched by any other material.

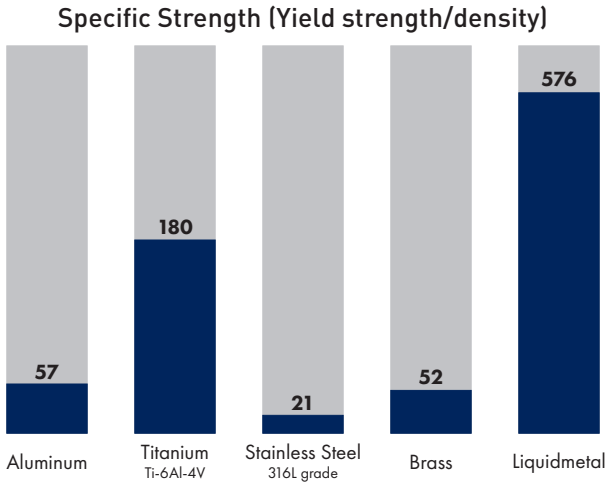


Liquidmetal LM001B can undergo 2.0% elastic strain before reaching its yield point. This is driven by the material's Elastic Modulus, which is 93 GPa, and its unique amorphous atomic structure. Because of this, Liquidmetal alloys have significant "give" without breaking, while also maintaining unmatched strength.

In terms of durability, it is very difficult to beat Liquidmetal alloys. The material characteristics shown above will give every diver the peace of mind when traveling, carrying equipment, or in the water that it will not scratch, dent, or break in contact with another object.

Weight

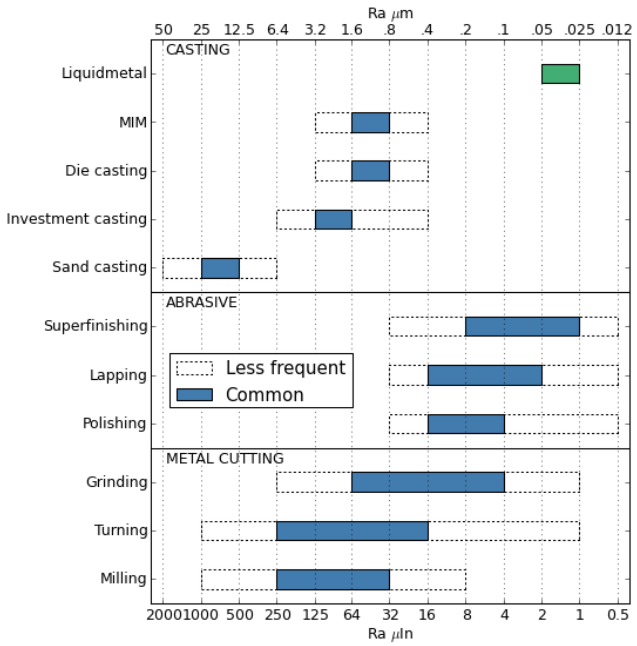
One of the characteristics that makes titanium so appealing to SCUBA equipment manufacturers is its light weight. Titanium has an extraordinary strength to weight ratio at 180, as seen in the chart below, but no material compares to Liquidmetal alloys.



Titanium (4.4 g/cm3) and aluminum (2.8 g/cm3) have lower density than Liquidmetal alloys (6.04 g/cm3), but none of the crystalline materials compare to the strength to weight combination. This allows less material to be used in a high-pressure application, and achieve the same strength with less weight. Lightweight equipment is valuable to almost every diver, and **Liquidmetal alloys could be the next step to tipping the scales for lighter equipment**.

Surface Finish

Functionality is the main priority for any SCUBA regulator part, but maintaining aesthetics is critical as well. First and second stage regulator parts that are visible come with many different surface finishes. These parts are often machined steel or titanium, resulting in a polished finish. Machining is very expensive and time consuming for complex parts like the DIN/Yoke converter and regulator. The molding process produces incredible surface finish right out of the mold.



An as-molded Liquidmetal part typically has a surface roughness of less than 0.05 µm (2 µin). This is a significant benefit compared with other processes that require additional processing to meet a surface spec of this quality. Die cast alloys and metal injection molding (MIM) components typically have surface roughness values that range from 0.8 – 1.6 µm (32 – 64 µin). Liquidmetal's atomic structure allows incredibly precise replication of tool surfaces, allowing very fine details, textures or highly polished surfaces to be imparted in a single step during high rate production.

Liquidmetal Molding Process

Right now, most metal SCUBA regulator parts currently on the market are machined. Unlike machining, where designers must consider the cost and time to remove material to achieve a final geometry, the Liquidmetal process allows designers the freedom to design products for efficient assembly and functional requirements. This eliminates material scrap and the sensitivity to incremental costs associated with discrete machining steps required to produce final part geometry.

In short, **the Liquidmetal molding process allows for the molding of complex SCUBA equipment parts, with almost no post processing necessary**. Because the molding process is similar to plastic injection molding, many of the same design rules are employed. Here are a few basic guidelines to follow for identifying and designing candidate Liquidmetal parts:

- Part weight up to 80 grams
- Maximum dimension of 100mm
- Outer draft angles of 0.5° to 3°
- Inner draft angles of 1° to 5°
- Wall thickness 0.6mm to 4.0mm
- Dimensional tolerance of ±.025mm for critical dimensions

Conclusion

Whether recreational or professional, all divers demand the highest level of performance out of their SCUBA equipment. The Liquidmetal® process is designed around consistency, precision, and simplicity, making it a perfect candidate for regulator parts. Liquidmetal alloys perform among the best, if not the best, in corrosion, strength, weight, elasticity, hardness, and durability tests- all critical to the success of SCUBA equipment. **The molding process allows the material to mimic the mold exactly, resulting in remarkable surface finish and one-step production**. The DIN/Yoke converter, bio filter, or various second stage parts have highly complex geometries, making them great candidates for Liquidmetal alloys. These parts that previously required many hours of machining, and the costs that come with that, can now be molded in one step. Not only will these parts benefit from unique high performance characteristics of the material, but also the molding and manufacturing process that comes with it.

Stainless steel, aluminum, brass and other traditional metals have historically dominated the market. Titanium has improved the technology in many ways, but has several limitations. Liquidmetal alloys overcome those limitations and more, making it, quite possibly, the next revolutionary metal on the SCUBA market.

Talk to the experts.

Wondering how Liquidmetal alloys might work for your application? We invite you to speak with Liquidmetal Technologies scientists and engineers, who are available to discuss this innovative, industry-changing process. We are challenging everything you know about metal parts processing. Why not challenge us?