Comparing Cast and Wrought Aluminum Alloys

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Material Context

Aluminum is a very versatile material. It is corrosion-resistant, lightweight, strong, flexible, and durable. In addition, aluminum can be recycled without any reduction in its quality. Aluminum is most commonly used in transport applications and in construction, among many other areas of use. [2]

What are we looking at?

There are two main types of aluminum alloys. One is wrought and the other is castable. Wrought aluminum alloys are designed to be machined through removable manufacturing methods like milling, turning on a lathe, plasma cutting, etc. Castable alloys are designed to be melted and poured into a cast that has a shape in order to make the desired parts. Our goal with this project is to try casting both a wrought and castable alloy of aluminum and machine the casted part using a mill. We want to understand more about the casting and machining process, the internal structure of the alloys, and the environmental impacts of mining and creating these alloys.

Alloy Composition

The two alloys we looked at are 356 aluminum (our castable alloy) and 6061/6063 aluminum (our wrought alloy). We note 6061/6063 because we used a combination of the two, but their properties are so similar that the distinction is negligible for our purposes.

Primary Alloying Agents

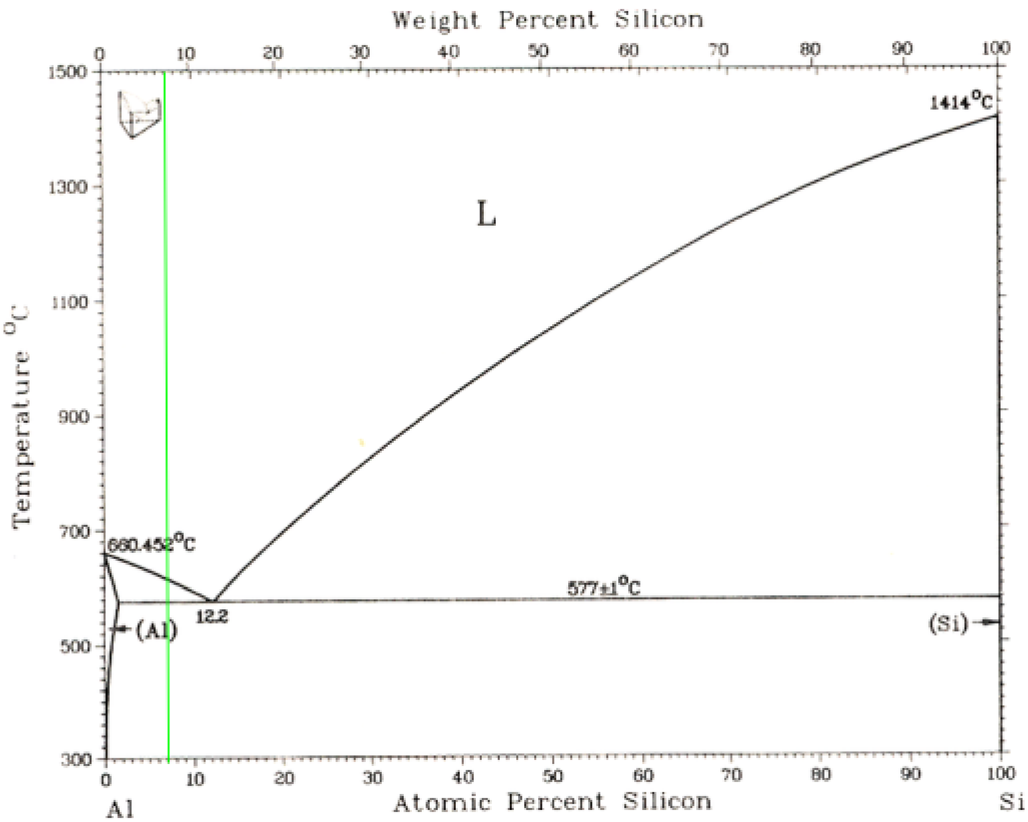
Silicon and Magnesium are the primary alloying agents in all 3 included alloys, so they are the elements listed in the below table. [2]

Alloy Designation	**356**	**6061**	**6063**
Weight % Silicon	7%	0.40% - 0.80%	0.20% - 0.60%
Weight % Magnesium	0.35%	0.80% - 1.20%	0.45% - 0.90%

Phase Diagrams & Microstructures

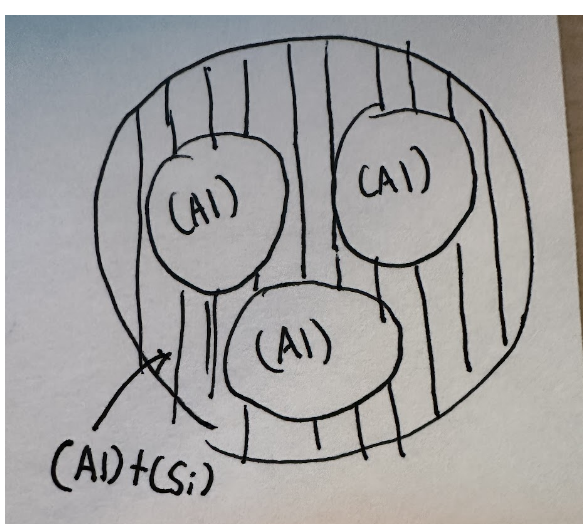
To understand more of the differences between the two alloys we looked at the phase diagrams for the main alloying elements in each alloy. The green line represents the weight percentage of the given alloy.

Aluminum 356

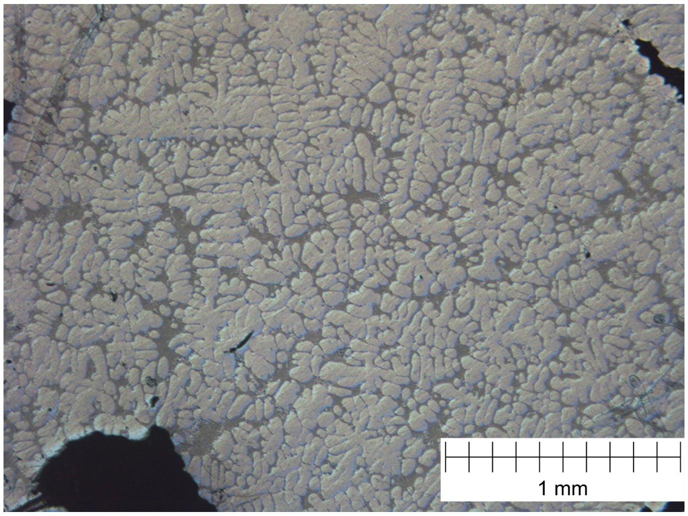


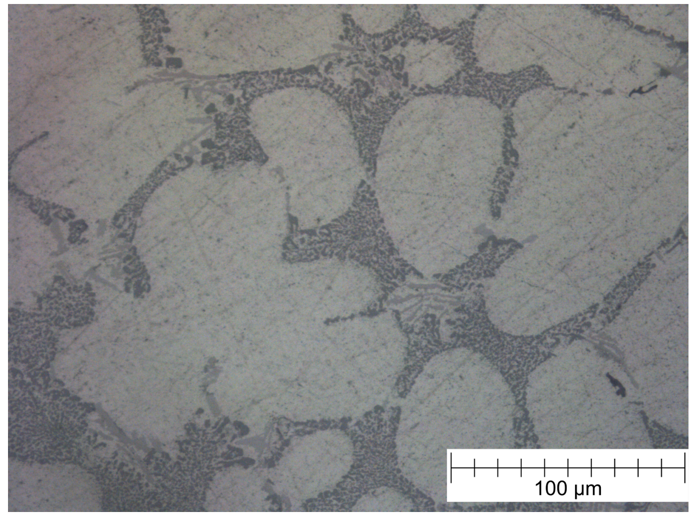
[5]

Based on this, we'd expect there to be (Al) surrounded by (Al)+(Si) as shown in the image below.

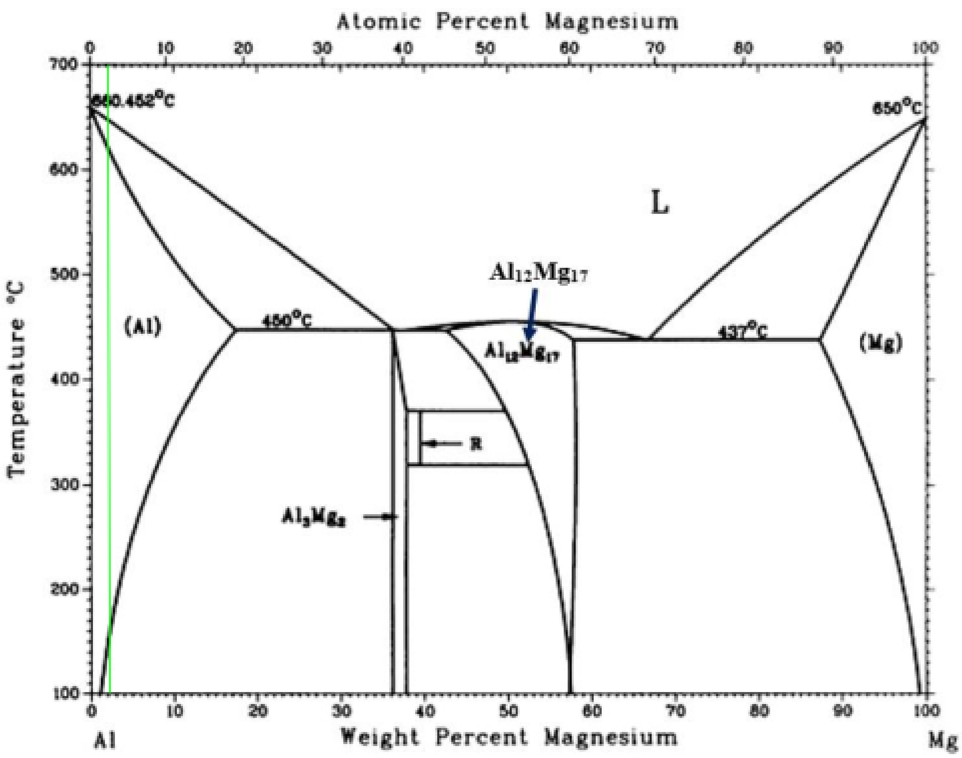


The aluminum dendrites are surrounded by Si/Mg and intermetallic phases. In addition, in the more zoomed-out images, volume defects (shrinkage pores) are apparent in the 356 samples. Although we did not do mechanical testing ourselves, pores generally make the material weaker and more prone to failure. [3][4]



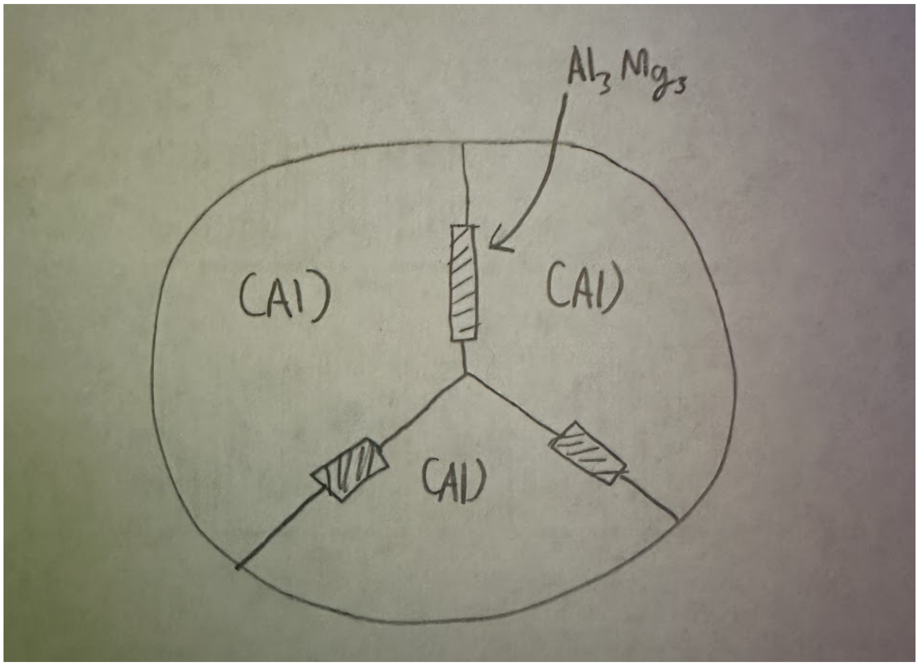


Aluminum 6061

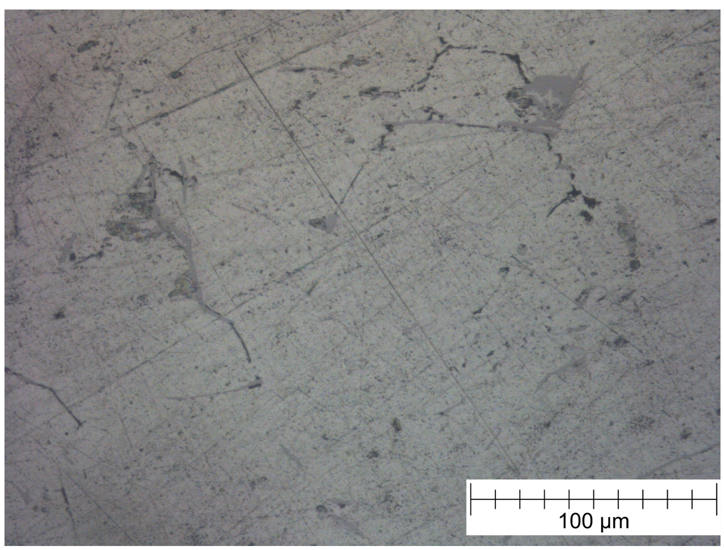


[7]

Based on this phase diagram when everything is cooled, we expect there to be mainly (Al) with small Al3Mg2 precipitates between the (Al) crystals as shown in the photo:



In the wrought alloy, the aluminum phase takes up the vast majority of the volume, as is expected given the much smaller quantity of other elements in this alloy. Although some imperfections are apparent, the wrought alloy does not contain shrinkage pores as the cast alloy does.



How do we acquire these materials?

Aluminum is generally found in an ore called bauxite which through the Bayer process is refined into alumina. From there the alumina is smelted into aluminum, usually using the Hall-Heroult process. The Bayer process has many steps. After the first few, red mud is created and released, before the process is later finished and alumina is created. The Hall-Heroult process is slightly simpler as it just requires smelting the alumina, though it does release some greenhouse gasses in the process. [1]

Mining Impacts

Guinea is one of the biggest mining locations for bauxite. Looking into the effects of mining on the local communities, we found that not only are there environmental problems, such as the creation of red mud and the destruction of farmland, but there are also social impacts within these communities.

The mining companies in Guinea end up destroying farmland without compensating the people who live there to make up for the loss of food in addition to their farming jobs. Although the companies are somewhat following Guinea's laws, the laws require that land be registered under the owner's name. Due to other government issues, this in most cases doesn't happen, which means the government doesn't have to require the companies to compensate the people who own these lands as they don't technically own them. This also means that companies don't need consent from the farmers or people that live there. If it's not owned by the people, because the land isn't registered, then it is owned by the government and given away without consulting that community.

Some companies do provide some compensation, but it isn't enough for the farmers to find new land or some other replacement for the food source they lost. Sometimes with the land taken from them, the farmers need to find completely new jobs to support themselves and their families. Most farmers in Guinea find this hard as they haven't been trained for other jobs.

Even if companies don't take all of the lands for mining, the remaining fields are covered in the dust produced by the mining that gets everywhere from the fields to the insides of homes and into meals. This means that mining contaminates the ground as well as the air in villages surrounding the mines. Many locals believe the dust has triggered respiratory illnesses among the communities.

In addition, mining affects the water sources in these areas. The water is in some cases polluted by red mud as it drains down from the mines. The red mud is waste produced when turning bauxite into alumina and makes the water toxic. [8] Red mud contains portions of water-soluble aluminum and chromium. While these portions are small, they are toxic. [6] At one point, a community in the Boké region had to rely on La Société Minière de Boké, a mining company in Guinea, to supply them with water. Sometimes the water was dirty, so the community members held onto their small supply of clean water until the next clean delivery.

The water sources near the mines are stressed further as more and more people come to work for the mining companies. With more people and worse water quality, leading to less water, there was a much higher need for access to water. In some of these communities, women walk long distances or wait for long periods of time just to obtain water for themselves and their families.

Even with constant meetings between community leaders and members of the mining companies, there have still been little to no changes. [8] To improve the lives of these people, the companies as well as the Guinean government need to take more responsibility. Their government should enforce more regulations to protect its people, but they aren't the only ones at fault. While Guinea has one of the world's largest exporters of bauxite and alumina, it isn't the only location where communities are being used only for their natural resources. The companies need to understand and acknowledge the hurt and damage they cause, so they can start working on solutions to improve the lives of the communities they invade.

Casting Process

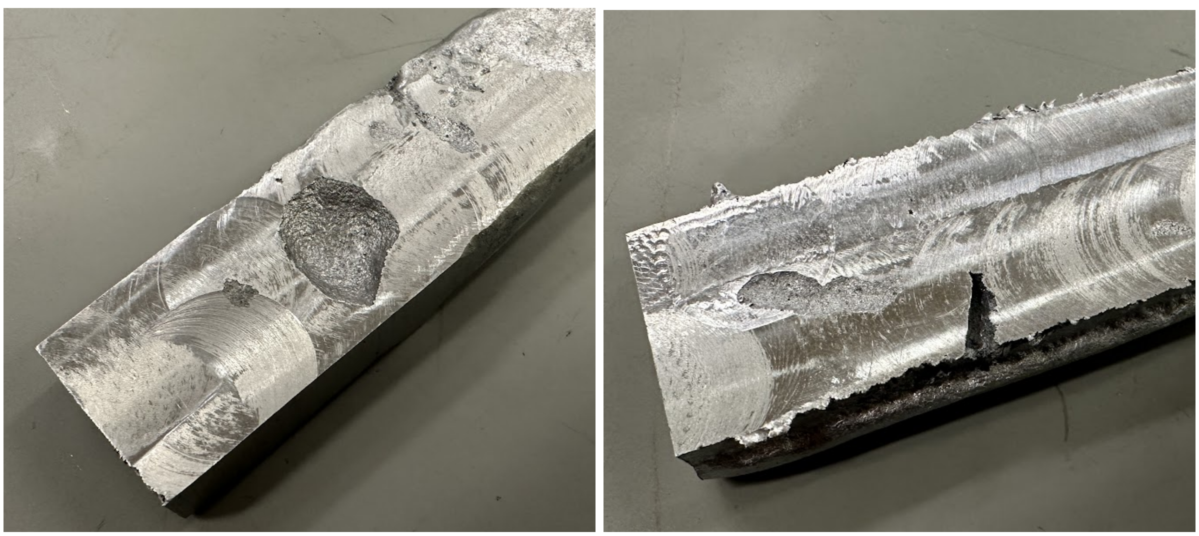
We decided to use the process of sand-casting to cast our parts, which became more tedious and time-sensitive than we originally anticipated. Our first attempt required us to sift some hard sand into a very fine softer sand. Once we sifted the sand, we had to make it harder again with water, but instead of the rock-sold version we started with, the sand for our molds had to be malleable so we could press the molds into it. After placing our molds, we made our first attempt at casting with the wrought alloy… it didn't go so well and instead of two rectangles we ended up with a singular rectangle with a bunch of air pockets on the bottom. The goal was to cast two machinable pieces so that we could see how 6000-series aluminum machines compared to 356 aluminum. Since there were so many air pockets on our first try, we decided to try again. However, we waited a few days between casting and had to resift the now-too-hard sand. With the sand sifted and wet, we were ready to place our molds. This time we placed multiple so that we didn't have to remake them if we needed to cast them again. This time we made both pieces (6061/6063 and 356). The pieces were vaguely rectangle-shaped with some blobs attached at the end, but we decided to cut off the blobs and machine the rectangular parts.


Casting Results
356 on left, 6000-series on right

Machining Observations

After both pieces of aluminum were cast into a rectangular shape, we tried 2 different machining operations on them. We performed a profile milling job on one of the sides, and an end milling job on the top and noted what happened during the machining process.

One of the things we found is clamping cast aluminum is very difficult because the metal spills out of the mold and the mold is not very precise. This caused two problems. One is that the pieces of aluminum would move around as we tried to machine them. This caused there to be circular marks created on the machined part when doing an end mill operation. The profile milling seemed to be okay and when looking at it by eye seemed to have a smooth surface finish. The other issue with the uneven clamping surface for these metals is it led to them becoming very hot. Even with cutting oil, the parts were significantly hotter to touch than other pieces of aluminum that have been machined in a similar way. The cutting oil was smoking as well.



The circular artifacts from the end mill process are visible on both the 356 (left) and 6061 (right)

We could also see many of the imperfections in casting the material with the size of the chips created through the machining process. They were very uneven which is not ideal for when machining. This could have also been due to human error with too little or too much material being taken off at any time due to uneven feed rates.

When comparing the machinability of the two alloys, there were no apparent differences between them.

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