Investigation of Aluminum Alloy 3104 for Manufacturing Sand Cast Aluminum Plaques

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EPICS team MSE Bronze received 3104 aluminum, a wrought aluminum, to cast plaques for the local community; however, its suitability for casting was unknown. 3104 and A356 aluminum samples were fabricated through sand-casting to be tested and analyzed to better understand the potential of using a wrought aluminum compared to cast aluminum to produce quality plaques that are cost- and time- efficient.

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Project Background

- EPICS MSE Bronze team received scrap aluminum alloy 3104 to sand-cast commemorative aluminum plaques for the local community.
- 3104 aluminum is a wrought alloy and not traditionally used for sand-casting.
- 300-series aluminum is typically used to sand-cast due to its primary alloying elements increasing their castability.

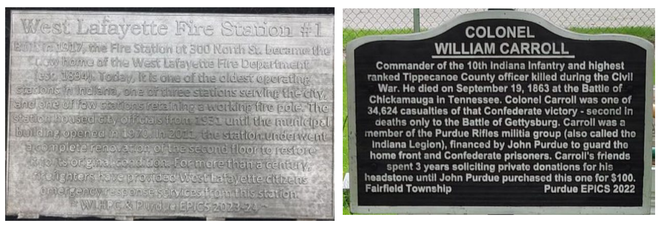

Figure 1. Examples of previously cast 3104 aluminum plaques.

- Previous EPICS senior design team worked to create a repeatable method of manufacturing sand-cast 3104 aluminum plaques, consisting of gate system design and heat testing.
- This project furthers previous work by investigating the use of wrought 3104 aluminum versus cast alloy A356 aluminum to gain insight of the properties and behavior of 3104 aluminum in sand-cast plaques.

Preparations & Methods

Hardness Testing
Previously cast plaques were cut into 3-inch squares to measure hardness at various points of the plaque. Testing was done on the Rockwell C scale at 5 different spots per sample for a sample size of 50 for each metal.

Scanning Electron Microscopy (SEM) and Electron Dispersive Spectroscopy (EDX)
Samples from previously cast plaques were polished and etched to reveal the microstructure under Phenom SEM. EDS was used to confirm that the scrap 3104 aluminum alloy was 3104 aluminum alloy.

Surface Analysis
The surface of as-cast dog bone samples were analyzed for roughness and surface uniformity using optical microscopy.

Time-Cost Analysis
The plaques were assessed by number of days needed to cast one good+ plaque at one plaque cast per day and the cost to fill one mold, approximately 10 lbs. Data was collected from current and previously sand-cast plaques using a standardized gating system developed by the previous senior design team, and the lowest score indicated the best material.
+ Quality level determined by EPICS MSE Bronze quality guidelines.

Hardness Tests

Table 1. Rockwell hardness C values for sand-cast A356 and 3104 aluminum plaques.

HRC	A356	3104
Mean	36.2	28.3
Standard Deviation	4.4	5.3

- Hardness testing revealed that A356 aluminum plaques have higher hardness values alongside a lower standard deviation compared to plaques cast with 3104 aluminum.
- Testing demonstrated minimal overlap of hardness values, indicating distinct differences in hardness characteristics among the materials tested. This may imply that 3104 aluminum is less durable and less resistant to wear or vandalism[1].

SEM/EDX

3104

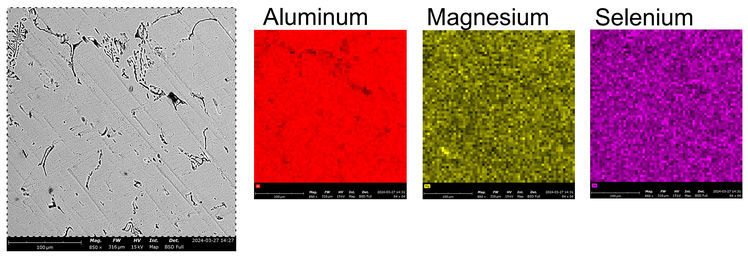

Figure 2. SEM EDX of sand-cast 3104 aluminum.

Table 2. EDX composition of sand-cast 3104 aluminum.

3104	Atomic Conc., %	Weight Conc., %
Aluminum	97.53	96.72
Magnesium	1.93	1.73
Selenium	0.54	1.55

- 3104 aluminum is indeed 3104 aluminum[2].
- The small, uniform precipitates indicate an increase in the strength and a reduction in ductility.
- Magnesium may indicate increased corrosion resistance but lower strength.
- The inclusion of selenium may be machine error or included by the manufacturer during manufacturing process.

A356

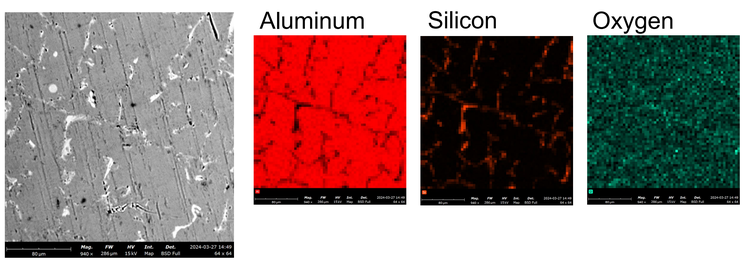

Figure 3. SEM EDX of sand-cast A356 aluminum.

Table 3. EDX composition of sand-cast A356 aluminum.

A356	Atomic Conc., %	Weight Conc., %
Aluminum	82.27	84.61
Silicon	9.94	10.64
Oxygen	7.79	4.75

- A356 aluminum exhibits large, clearly defined silicon precipitates. This may indicate higher strength and better fluidity during casting but poorer results from finishing techniques such as anodizing.
- The presence of oxygen indicates a susceptibility to oxidation that 3104 aluminum does not appear to have, a characteristic that could complicate finishing techniques such as anodizing.

Surface Analysis

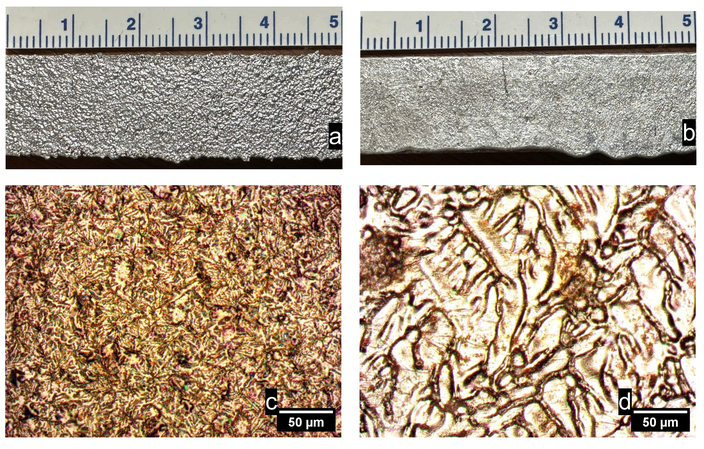

Figure 4. Visual imaging of A356 (a) and 3104 (b) aluminum dog bone samples and optical imaging of A356 (c) and 3104 (d) aluminum dogbone samples.

- A356 has a considerably coarser and less smooth surface finish than 3104 aluminum.
- 3104 may be better suited for finishings like power coatings due to its smoother surface

Time-Cost Analysis

While it was clear that 3104 aluminum could be used to cast plaques, the time and cost required to cast each alloy was unknown.

Table 4. Matrix comparing number of days needed to achieve a good+ cast, cost, and the weighted score.

	Weight	A356	3104
Number of Days	0.7	2	1
Cost, per 10 lb*	0.3	$75.00[3],**	$0
Score		24	0.7

*Cost does not include shipping costs
**Aluminum prices vary by vendor and by year

- Casting times are similar for 3104 and A356 aluminums, but plaques cast with A356 aluminum require twice as much time.
- A356 aluminum is more expensive than 3104 aluminum.
- Assuming 3104 aluminum will continue to be available as cheap scrap metal, 3104 aluminum is the more cost- and time- effective material.

Conclusions

For a cost- and time- effective and quality plaque, 3104 aluminum is acceptable for use.

A356 aluminum has greater hardness values due to its alloying elements. However, the time needed to cast a good+ 3104 aluminum plaque is half that of A356 aluminum. Furthermore, 3104 aluminum has a finer surface, reducing the need for grinding after casting. It also may improve its performance with powder coating, producing a higher quality plaque.

Recommendations

For a more robust understanding of how sand-cast 3104 aluminum acts, it is recommended that future teams investigate:

1. Response of powder coated 3104 aluminum plaques to environmental factors,
2. Effects of finishing steps such as powder coating and anodizing on surface hardness and cracking,
3. Impact tests of cast 3104 aluminum compared to A356 aluminum
4. Dendritic growth in 3104 aluminum, and
5. Mechanical effect of alloying 3104 aluminum with silicon during casting.

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References

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