INCREASED MELT EFFICIENCY IN ALUMINUM REUSE

Models can help streamline the use of secondary alloys in casting

A key sustainability benefit of aluminum is its ability to be melted and recast repeatedly, making it inherently recyclable. Recycling aluminum is an important way to avoid greenhouse gas emissions, since processing secondary aluminum takes only a fraction of the energy needed to make new metal from its ores.[1]

However, variations in chemistry affect just how energy-efficient the recycling process can be, and how much secondary aluminum can be used. The need for consistently strong, high-grade material in the aerospace and automotive industries contributes to a continuing demand for brand-new (primary) aluminum with very low levels of impurities.

The quality of the final product becomes harder to control when mixing in secondary aluminum, as well as the refractory materials (mostly oxides) used to protect melting equipment and the flux materials (fluorides and chlorides, etc.) added to improve molten aluminum quality. Currently, most of the process control and optimization in molten aluminum processing relies on trial-and-error recipes rather than theoretical precision, given a lack of analytical tools available to the industry. About 4 to 6% of the material becomes dross containing residual aluminum, which requires further processing to recover. This so-called melt loss represents another opportunity for increased efficiency.

A research team led by The Ohio State University has developed kinetic and thermodynamic computer models to increase the use of secondary aluminum and optimize melt processing and quality control. The models informed the development of a recycled aluminum alloy comparable in quality to those made from new aluminum.

PROJECT DESCRIPTION

This two-and-a-half-year project with industrial partners Alcoa and the North American Die Casting Association began in May 2019. First, the team performed thermodynamic and kinetic modeling of primary alloys, secondary alloys, refractory materials, and flux materials. The goal of this step was to characterize the accumulation of elements such as iron, magnesium, copper, and zinc, which happens during the continued usage and recycling of aluminum alloys. These impurities are difficult to remove during recycling, which restricts the range of used for recovered aluminum.

Modeling and experimental work helped define the ideal composition ranges for a secondary high-pressure die-casting alloy for structural applications. Second, the team conducted lab-scale testing to optimize melt treatment and evaluate refractory and flux materials. Finally, pilot-scale field testing validated alloy chemistry and control measures with improved refractory and flux materials.

PROJECT IMPACT

This project developed fundamental thermodynamic and kinetic models to increase the energy efficiency and casting quality of the aluminum melting process. New refractory and flux materials were discovered to improve the energy efficiency, and the team created a new recycled alloy with higher tolerance limits of impurities than primary die cast alloys to offer mechanical properties suitable for structural applications.

The die casting industry currently uses less than 10% of secondary alloys for structural die castings. The goal of this work is to at least double this figure to 20%, reducing the use of primary aluminum. Based on current industry rates, cutting melt loss in half will save about 85 million pounds of aluminum.

[1] Aluminum Extruders Council, Sustainability. https://aec.org/sustainability. Accessed November 13, 2023.

PROJECT NUMBER: 18-01-MM-08

NEXT STEPS

Based on this project, the team finds potential for further optimization that can increase the tolerance for impurities in secondary alloys. The models developed can be employed to adjust alloy chemistries that achieve a good balance between corrosion resistance and mechanical properties.

PUBLICATIONS

Luo, A.A.; Cinkilic, E.; Moodispaw, M.P. "Structural die cast alloys using recycled aluminum," US provisional patent application, 63/085,016, September 29, 2020.

Zhang, J.; Moodispaw, M.P.; Luo, A.A. *Increasing Melt Efficiency and Secondary Alloy Usage in Aluminum Die Casting: Final Report for REMADE Project: 18-01-MM-08*. November 2021. https://www.osti.gov/servlets/purl/1872208. Accessed November 10, 2023.

Cinkilic, E.; Moodispaw, M.; Zhang, J.; Miao, J.; Luo, A.A. "A New Recycled Al–Si–Mg Alloy for Sustainable Structural Die Casting Applications", Metallurgical and Materials Transactions A, 2022, 53A, 2861-2873, https://doi.org/10.1007/s11661-022-06711-4.

Luo, A.A.; Cinkilic, E.; Moodispaw, M.P.; Zhang, J.; Yan, X; Caron, F.; Brancaleon, P. "Increasing Melt Efficiency and Secondary Alloy Usage in Aluminum Die Casting," Transactions of North American Die Casting Association, 2021, Paper T21-063, presentation at 2021 Die Casting Congress & Exposition, October 4-6, 2021, Indianapolis, IN.

Cinkilic, E.; Moodispaw, M.P.; Luo, A.A.; Chu, Y.; Brancaleon, P. "Thermodynamic Modeling and Experimental Investigation of Refractory Materials Used in Aluminum Die Casting", Virtual Die Casting Congress & Tabletop, October 20-22, 2020.

Moodispaw, M.P.; Cinkilic, E.; Luo, A.A. "Thermodynamic Modeling of Solid Flux Interactions with Molten Aluminum," American Foundry Society Transactions, Paper 2021-034, presented at AFS Metalcasting Congress 2021, April 12-22, 2021.

Cinkilic, E.; Moodispaw, M.P.; Chu, Y.-L.; Yan, X.; Caron, F.; Luo, A.A. "Melt-Refractory Interactions during Aluminum Melt Processing," American Foundry Society Transactions, Paper 2021-041, presented at AFS Metalcasting Congress 2021, April 12-22, 2021.

PROJECT PARTNERS

The Ohio State University

Principal Investigator:
Alan A. Luo | luo.445@osu.edu
Jianyue Zhang, Michael Moodispaw, Emre Cinklic

Alcoa

Xianyan Yan, Francis Caron

NADCA
NORTH AMERICAN DIE CASTING ASSOCIATION

Paul Brancaleon

FOR MORE INFORMATION

EMAIL US AT CONTACT@REMADEINSTITUTE.ORG

OR VISIT US AT REMADEINSTITUTE.ORG

U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Acknowledgment: "This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Advanced Manufacturing Office Award Number DE-EE0007897."