

Research Programs

Clean Metal Castings

Partners:

The Cast Metal Coalition (CMC)
The American Foundrymen Society (AFS)

Research Team:

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The goals of the program are to secure for the U.S. metal casting industry a preeminent position in the global market through technological competence and innovation, and through monitoring of international standards via benchmarking. The research focused on developing a technology for clean metal processing capable of consistently providing a metal cleanliness level fit for a given application.

Specifically, the deliverables of the program were to:

- *Quantitatively assess the level of melt cleanliness prior to casting.*
- *Mitigate melt contamination by hydrogen and inclusions via novel gas covers and fluxes.*
- *Develop enhanced technologies for separating second phase inclusions from aluminum melts based on a thorough understanding of the fundamental mechanisms of high-temperature- phase separation.*
- *Assess the feasibility and the potential of using electromagnetic forces to separate second-phase inclusions from molten aluminum.*
- *Correlate the required casting performances with a minimum acceptable level of melt cleanliness.*

The program of research involved the following tasks:

- **Development of melt cleanliness assessment technology.**
- **Development of melt contamination avoidance technology.**
- **Development of high temperature phase separation technology.**
- **Establishment of a correlation between the level of melt cleanliness, processing effects, and the resultant as-cast mechanical properties.**

Details of current projects addressing these tasks are given below:

Development to Melt Cleanliness Assessment Technology

Two distinct projects are pursued in this task. One is to optimize the reduced pressure test, which is widely used in industry, and a second project is devoted to develop a novel sensor to detect inclusions in molten aluminum.

Optimization and Standardization of the Reduced Pressure Test

The objective of this project is to develop a standardization method for the Reduce Pressure Test (RPT) through the optimization of sample evaluation methods and sampling variables for repeatability, reproducing and accuracy.

The repeatability, reproducibility, and accuracy of the various RPT sample evaluation methods are optimized through gauge repeatability and reproducibility studies and linear regression analysis of Taguchi matrices where the matrix data are the results of signal-to-noise calculations and linear regression analysis. The knowledge gained through this comprehensive study has been compiled into an optimized test method that is the AFS's recommended practice for performing the Reduced Pressure Test.

Development of a New Melt Cleanliness Assessment Device

A perennial problem facing the aluminum casting industry has been the inability of the manufacturer to detect inclusions and monitor the level of cleanliness prior to pouring the casting. Though there are several sensors available, none of them are effective nor economically justifiable.

The WPI team has developed a novel sensor where Lorentz forces are applied to molten aluminum in a proprietary manner, forcing the inclusions present in the melt to separate out and to agglomerate. Subsequently, optical and other ancillary devices are utilized to detect the presence of inclusions. An alliance has been established with Heraeus Electro-Nite to commercialize such a device.

Development of Melt Contamination Avoidance Technology

The objective of this project was to study and understand the aluminum melt contamination process and particularly to develop and prescribe methods to reduce both melt oxidation and hydrogen pickup. In order to achieve these goals, the following strategy was followed:

- Characterize the physical properties and effectiveness of various fluxes using thermal analysis flux, x-ray diffraction and microscopy.
- Determine the effect of flux composition on the interfacial tension between aluminum alloy melts and fluxes.
- Develop and optimize the composition of environmentally friendly fluxes.
- Conduct laboratory trials with the optimized fluxes and evaluate their effectiveness.

Development of High Temperature Phase Separation Technology

The objective of this project was to expand existing knowledge about phase separation technology used in clean metal processing of aluminum alloys. Specifically, the research focused on sedimentation, flotation and electromagnetic separation. To design and implement efficient melt treatment process, it is important to develop a clear understanding of the physics of the basic mechanisms involved in phase separation. The goal was to develop comprehensive, reliable models of the processes. These models were used in the design of a reactor, rotor/spinning nozzle for melt treatment, in the optimization of the operating parameters, and in the investigation at the effectiveness and the ideal method of deploying electromagnetic separation in aluminum melt treatment.

Establishment of a Correlation Between the Level of Melt Cleanliness, Processing Effects, and the Resultant as Cast Mechanical Properties

A variety of melt refining techniques has been proposed for the casting of aluminum alloys over the years. These include several methods of degassing and filtration of the melt before it is cast. However, the casting processes inherently introduce some gas and other particles that render the metal unclean. In such an eventuality, it is possible that the cast parts will not reflect the amelioration in properties rendered to them by the melt refining treatments. Such treatments are extremely cost-exhaustive and hence become a liability if they are rendered null and void by the casting process itself.

In view of the above, our primary goal was to develop a technology base for clean metal processing that is capable of consistently providing a metal cleanliness level fit for a given application. In this context, performance and mechanical properties of the resultant casting are also influenced by the processing methodologies used in addition to the level of melt cleanliness. Hence, this task aims at providing a benchmarking reference base that correlates cleanliness levels <-> processing conditions <-> mechanical properties for a given alloy and a specific application.