Research Programs

High Integrity Magnesium Automotive Castings (HI-MAC)

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Abstract

Vehicle weight reduction is a key enabler to meet future stringent CAFÉ requirements, and this can best be achieved by the use of more light weight materials such as magnesium. The purpose of this project is to develop (existing and new) metal casting process technologies and tools required to manufacture cost effective high integrity cast magnesium automotive chassis components and increase production of magnesium components requiring geometries and properties not possible with existing high pressure die casting (HPDC) process limitations. High Integrity castings are defined as sound castings with low porosity (meeting ASTM E-155 grade B or better), free of objectionable oxides and inclusions, with consistently high ductility and strength. This project will develop existing aluminum low pressure permanent mold and squeeze casting processes for the production of magnesium structural castings that will be used as suspension and chassis components. Processing costs as well as technical and manufacturing issues for each process will be developed and validated; limited parts will be produced, investigated for material properties, analyzed by NDE and tested both by static / vehicle methods.

Executive Summary

The use of magnesium automotive components in new vehicle applications can be utilized to reduce vehicle weight and improve performance. Magnesium sheet and wrought technologies hold potential for vehicle application, but application is long term. Perhaps the quickest near term path to increased magnesium content in automobiles is through increased use of metal castings.

Wider vehicle application of cast magnesium components offers a potential weight reduction of nearly 100 Kg per vehicle. The SCMD project has successfully demonstrated the re-design, conversion and production application of an aluminum cradle to magnesium, providing weight reduction of approximately 35%. Similar applications of magnesium castings for suspension and chassis components can be achieved. To produce affordable, high strength magnesium castings, it will be necessary to develop and optimize magnesium casting procedures (existing and/or new) and develop tools that support the casting process and reduce the cost of magnesium components.

The draft USAMP Mag 2020 document provides a vision that identifies the cost and quality of magnesium components, the need for engineering and manufacturing process development, and the lack of enabling infrastructure as key inhibitors to cast magnesium applications on vehicles. Specifically, the document vision identifies three key technology barriers that must be overcome to increase the application of magnesium cast components in vehicles by 2020.

- Lower manufacturing costs
- Improved casting quality requiring lower porosity and new casting methods
- Infrastructure development

Hi Integrity Cast Magnesium Components (HI-MAC) addresses the near and mid term metalcasting development needs identified in the Mag 2020 document drafts. Eliminating these technical barriers that currently inhibit magnesium casting production will move the automotive industry into a better position to realize emerging automotive magnesium component needs, build needed magnesium industry infrastructure and develop tools that will be needed to reduce the cost of magnesium components and enable sustainable production requirements. HI-MAC will address these three key issues:

- ***Development of Casting Tools:*** Develop technologies and tools that will be required for sustainable long-term procurement of cast magnesium automotive components (Tasks 3, 4, 5 and 6). These tasks will address the science and technological barriers that currently inhibit production and affect the affordability of cast magnesium components.
- ***Casting Process Development:*** Develop casting processes to facilitate production of cast magnesium automotive chassis components that cannot be manufactured using current process limits (Tasks 1, 2 and 7).
- ***Infrastructure Development:*** Development of casting processes and tools will include industry participation by automotive suppliers currently producing aluminum components (Tasks 1, 2, 7), the development of equipment uniquely suitable for the production of magnesium components (Task 2, 6) and development of a broader research and science base (Tasks 3, 4, 5, 8).

HI-MAC research will broaden the range for potential cast magnesium component applications by developing and optimizing manufacturing technologies that can produce a greater range of geometries and properties than are available today and encourage potential supplier base infrastructure through project partnerships. Additionally, HI-MAC will investigate and evaluate new and emerging technologies and develop tools that address critical technology barriers currently inhibiting magnesium application and component affordability. (Technical challenges are listed for each task and a detailed gap analysis is included in Appendix A). Casting process and tool development will be demonstrated by production of a magnesium control arm by low-pressure cast, squeeze cast and a new emerging casting process. Control arms will be delivered for static and/or vehicle testing.

Total project cost is estimated to be \$6.0M consisting of \$3.0M cash and \$3.0M in-kind. The estimated project time is 48 months.

Task 1: Squeeze casting process development Task 2: Low pressure casting process development Task 3: Thermal treatment of castings including research into stepped heat treatment and fluidized beds Task 4: Microstructure control during casting including grain refining and property improvement Task 5: Computer modeling and properties to enable prediction of casting quality and microstructure Task 6: Controlled Molten Metal Transfer and Filling Task 7: Emerging Casting Technologies Task 8: Technology Transfer

As one participant of the HI-MAC project, the WPI research team, along with the Technomics team is developing short cycle time, low cost heat treatment processes for magnesium components using the fluidized technology. Specifically, the following research is being conducted:

1. Evaluate Fluidized Bed Vs Conventional Furnace

One of the key problems to the feasibility of magnesium structural components is the prohibitively long heat treatment times required. Fluidized bed heat treating brings the advantages rapid heat rates in an order magnitude faster than conventional furnaces plus excellent temperature control (within +/- 3°F). Based on our previous experience, we will develop a fundamental knowledge base for heat-treating of magnesium alloys/components using fluidized bed technology. Specifically, we will conduct systematic experiments to establish optimal short cycle heat treating processes for commercial magnesium alloys. These experiments include:

- Study microstructure response of magnesium alloys under fast heating conditions using fluidized bed reactor.
- Characterization of mechanical properties of magnesium castings heated treated using fluidized bed reactor vs. conventional furnace.
- Establishment of optimal heat treatment schedules for magnesium alloys using fluidized bed technology.

This task will also include validation trials on automotive castings to confirm our findings. Finally, we will conduct a cost analysis comparison for fluidized bed and conventional technologies for heat treating high volume magnesium automotive parts.

2. Strengthening Kinetics Study

A fundamental understanding of the strengthening kinetics of magnesium alloys is critical for the development of short cycle heat treatment processes using fluidized bed technology. WPI/MPI will carry out the research work in order to establish the mechanisms for the strengthening kinetics of magnesium alloys. The research will focus on the characterization of the dissolution and precipitation process of the strengthening phases in magnesium alloys under different heat treating conditions. Advanced analysis methods such as Local Electrode Atom Probe (LEAP), TEM, and SEM will be employed in this study. In addition, extensive thermodynamic simulations will be carried out to fully understand the various phase transformations, and the precipitation process of strengthening phases in magnesium alloys under different heat treating conditions.

3 Step Heat Treatment to Enhance Material Performance

An investigation into step heat treating will be made jointly by Technomics and WPI/MPI. Our previous experience on Al alloys has shown that step aging results in a uniform distribution of precipitates, and enhanced aging kinetics. As a result, the mechanical performance of Al castings can be greatly improved. Recent studies on step solutionizing treatment of Al alloys indicate that step solutionizing treatment can enhance the mechanical properties of Al castings under T4 condition, particularly the yield strength of the component being considered. In this study, systematic step heat treating experiments will be performed with magnesium alloys to establish optimal step heat treating conditions. It is envisioned that the optimized step heat treating method can maximize the benefits of rapid heating with fluidized bed technology, and open up doors for a broad application of magnesium structural components for automotive applications.