ORNL Manufacturing Demonstration Facility
Technical Collaboration **Final Report**

Demonstration of the Impact of Thermomagnetic Processing on the Solution Heat Treatment and Aging Kinetics in a Cast Aluminum Alloy[1]

Eck Industries, Inc.

Project ID: MDF-UP-2012-011
Start Date: 11/15/2012
Completion Date: 10/31/2013
Company Size: Small business, <250 employees

Summary

ORNL worked with Eck Industries, Inc. to compare the heat treatment response of cast aluminum alloy A206 when processed in a magnetic field with that of a conventional heat treatment. Alloys treated using magnetic field processing demonstrated reduction in heat treatment times from fourteen hours to four hours with mechanical properties equal to, or better than the conventionally processed alloys. These results show that magnetic field processing can reduce the time, cost and energy intensity of heat treatments in aluminum casting.

Background

Work in ferrous materials has demonstrated the modification of kinetics, phase equilibria and solubility limits using magnetic field processing. These processing modifications can result in modified microstructures that may retain alloying elements in solution, negating the need for a solution heat treatment, or may increase maximum solid solubility limits, which may improve the strength of the alloy. For example, the microstructure of cast A206 aluminum alloy shows significant amounts of copper in the eutectic phase (see Figure 1). Long (8-12 hour), high temperature (985°F) solution treatment is required to dissolve the copper, which is then captured in a supersaturated solid solution during quench, followed by a 4 hour aging or precipitation treatment at 200°C designed to form a finely dispersed precipitate at the grain boundaries. Even longer heat treat times are required to meet mechanical property requirements in heavy sections. This new process can potentially reduce an energy intensive solution heat treat, and could more effectively dissolve the copper resulting in improved mechanical properties.

[1] Research sponsored by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Advanced Manufacturing Office, under contract DE-AC05-00OR22725 with UT-Battelle, LLC.

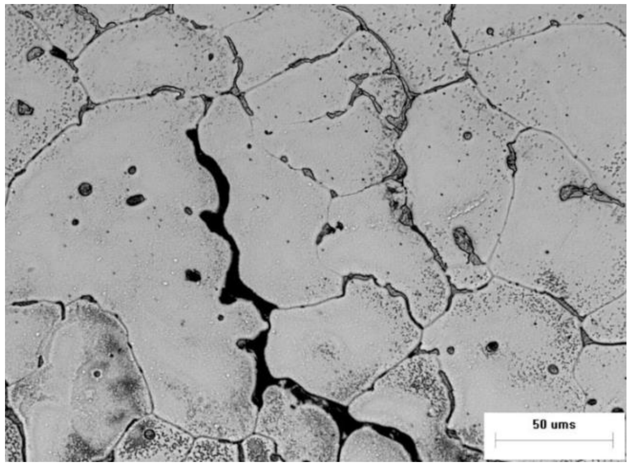

Figure 1. As Cast Aluminum Alloy A206 showing Cu at Grain Boundaries.

Technical Results

Aluminum alloy A206 samples of standard chemistry were cast at Eck Industries and supplied to ORNL in both the “as cast” and T4 (solution treated only) conditions. Samples were processed at ORNL during solution and/or aging conditions.

The “as-cast” samples were given a solution treatment at either 510°C or 530°C for two hours. Aging times for solution treated samples in the T4 condition were varied from 30 minutes, one hour and two hours to determine the impact of reduced treatment times resulting from the new process.

Processed samples were then tested at Eck Industries for tensile strength, yield strength and % elongation (Table 1). The data indicate that mechanical property goals can be achieved with reduced processing times under magnetic fields.

- For samples supplied in the “as cast” condition, full solution occurred in two hours under the new process, or less than 20% of the standard 10 hour cycle time.
- For samples supplied in the solution treated only (T4) condition and precipitation treated, aging occurred between 30 minutes and one hour under the new process, or in less than 25% of the standard 4-hour aging cycle time.

Table 1. Treatment Times and Conditions with Mechanical Properties

Standards	Solution Time	Solution Field	Aging Time	Aging Field	Tensile (Ksi)	Yield (Ksi)	% Elongation	
T4 Standard	600	NF	N/A	N/A	50,000	30,000	10.0%	
As Cast 1	120		N/A	N/A	55,900	47,800	3.5%	
Test Bars As Supplied By Eck								
T7 Standard	600	NF	840	NF	50,000	40,000	3.0%	
As Cast 2	120		120		58,200	51,100	3.0%	
As Cast 3	120		120		62,800	50,000	5.5%	
T4-1	240	NF	30		62,800	42,000	10.9%	
T4-2	600	NF	240	NF	57,800	52,300	2.5%	
T4-3	600	NF	60		58,900	48,900	4.0%	
T4-4	600	NF	240		52,600	37,300	6.0%	

NF=No Field, WQ=Water Quench

The mechanical property data suggests that aging times can likely be further reduced since the yield strength of samples processed by the new method was much higher and the elongation lower than conventionally processed T4 samples. The potential for further reduction in the aging time is supported by resistivity data collected from initial experimental runs that were used to guide estimates of the rates of precipitation hardening. The resistivity technique documents the microstructural evolution of the alloy during treatment. In this case, the precipitation of the hardening phase will increase the voltage of the sample and therefore the resistance, since precipitate interfaces impair current conduction. Subsequent coarsening of the precipitates reduces the voltage/resistance of the material.

This effect is demonstrated in Figure 2 which shows one of the test sets for the 200°C aging condition. Of interest is the dramatic difference in resistivity (as reflected by the recorded voltage from V=IR relationship where R is resistance, V is voltage, and I is current) response between field and no-field conditions that suggest the magnetic field causes the precipitation reaction to occur in an accelerated fashion even upon heat-up to the aging temperature. This observation supports the high strength achieved in very short aging times reported in Table 1 for magnetically processed samples. Similar differences in response were observed for the resistivity tests conducted for the solution heat treatment step.

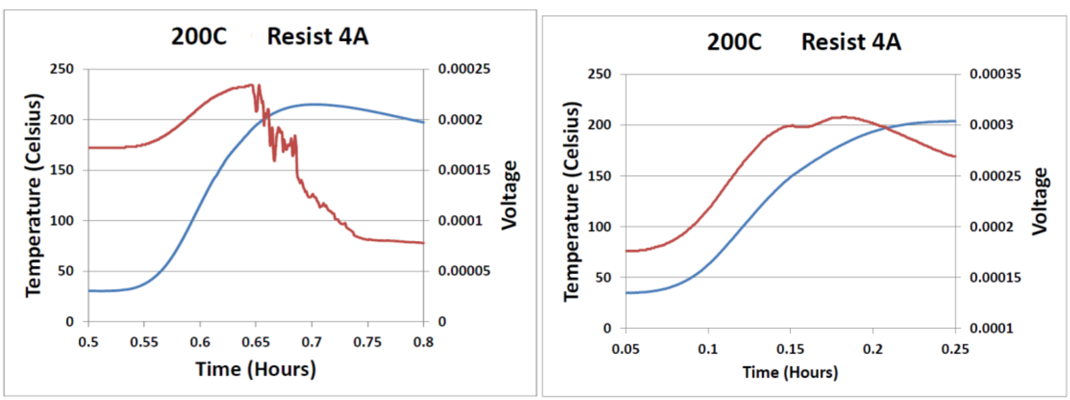

Figure 2 The new process (right) 200°C aging heat treatment resistivity measurements (red lines) when compared to the old process (left) case suggest that a significant amount of precipitate formation and therefore strength increase occurs rapidly in this heat up step (blue lines) as the voltage remains above the initial value for this condition which supports the high strength values achieved in significantly shorter aging times.

Impacts

The reduction of the solution heat treat and aging cycles of cast aluminum using the new method of processing automotive parts will have significant beneficial energy, emission, and economic impacts by reducing the time and temperatures needed for these treatments. Reduction of cost of these components will help make lighter weight aluminum part more competitive with standard steel components and enable lighter weight vehicles. Processing aluminum castings with this new method will create significant savings in the manufacturing of light weight auto parts and will contribute to transportation fuel savings by enabling lighter weight vehicles.

Conclusions

The project metric of reducing the overall cycle time was met through reductions of treatment times to 20-25% of standard. These results warrant further development of this technique to enable industrial adoption. A full understanding of solution and precipitation kinetics requires additional study. It is unknown if this technique can result in higher mechanical properties as well as even shorter heat treat times. Some results suggest that lower temperatures as well as shorter times can be used to heat treat this alloy.

About the Company

Eck Industries, Inc. is a privately-owned fourth generation family business with over 64 years of experience in the aluminum foundry industry. Eck delivers aluminum castings to customers in the military, hybrid vehicles, commercial trucking, aerospace, medical, industrial and energy markets.

Eck was incorporated as Eck Foundries, Inc. in May 1948. The business was built on orders from Harley-Davidson, Wisconsin Motors, West Bend Outboard and Johnson Motors. From 1948 to 2010 Eck grew from operating in a 7,200 square foot garage with 8 employees and 5 customers to a plant with 210,000 square feet, over 250 employees and 110 customers.

Eck Industries Inc. was awarded the Casting of the Year by the American Foundry Society for a challenging hybrid driveline housing that was successfully converted from a fabrication in 2011, and was recognized in 2012 by Modern Casting magazine as the Metalcaster of the Year for innovations in alloys, processes and application development.

Points of Contact

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