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Center for Advanced Non-Ferrous Structural Alloys
An Industry/University Cooperative Research Center

Solution Heat Treatment and Precipitation in Al-Si-Cu and Al-Si-Cu-Mg Die Castings

Fall 2019 Semi-Annual Meeting
Colorado School of Mines, Golden, CO
October 9 - 11, 2019

Students: Spencer Randell & Dawson Tong (Mines)

Faculty: Steve Midson (Mines)

Industrial Mentors: Paul Brancaleon (NADCA)

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COLORADO SCHOOL OF MINES

IOWA STATE UNIVERSITY

Solution Heat Treatment and Precipitation in Al-Si-Cu-Mg Die Castings

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- Students: Spencer Randell & Dawson Tong (Mines)
- Advisor: Steve Midson (Mines)

Project Duration
Undergraduate: May 2019 to December 2019

- Problem: Historically die castings have not been heat treated, but recent technology developed in Australia allows conventional die castings to be heat treated with minimal blistering. However, A380 (Al-Si-Cu) die casting alloys are not exhibiting the expected strength increase during heat treatment.
- Objective: Perform a review of the published technical literature for Al-Si-Cu(-X) type alloys to determine if reasons for low strengthening during heat treatment for Al-Si-Cu foundry alloys is understood.
- Benefit: Understanding of the heat treatment of aluminum die castings will help to optimize mechanical properties, allowing them to better compete with alternate fabrication technologies.

Recent Progress

- Performed a review of the literature of precipitation in Al-Cu, Al-Si-Cu and Al-Si-Cu-Mg casting alloys
- Performing additional heat treatment trials

Metrics		
Description	**% Complete**	**Status**
1. Review the published technical literature of as-cast and heat treated properties for Al-Cu, Al-Si-Cu and Al-Si-Cu-Mg casting alloys	100%	●
2. Perform additional experimental work to optimize heat treatment for conventional die castings	5%	●
3. Utilize high resolution x-ray diffraction to characterize precipitates	0%	●

Technical Problem and Industrial Relevance

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- Traditionally die castings have only been used in as-cast condition
  - New technologies allow die castings to be T6 heat treated
  - SHT + quench + age without blistering
- Heat treating die castings provides significant improvement in mechanical properties
  - Die castings can better compete against other foundry processes
- Precipitation of the main alloy classes not well understood
  - Al-Si-Cu and Al-Si-Cu-Mg

Previous Research: Impact of Aging Treatment on Hardness in T6 Temper

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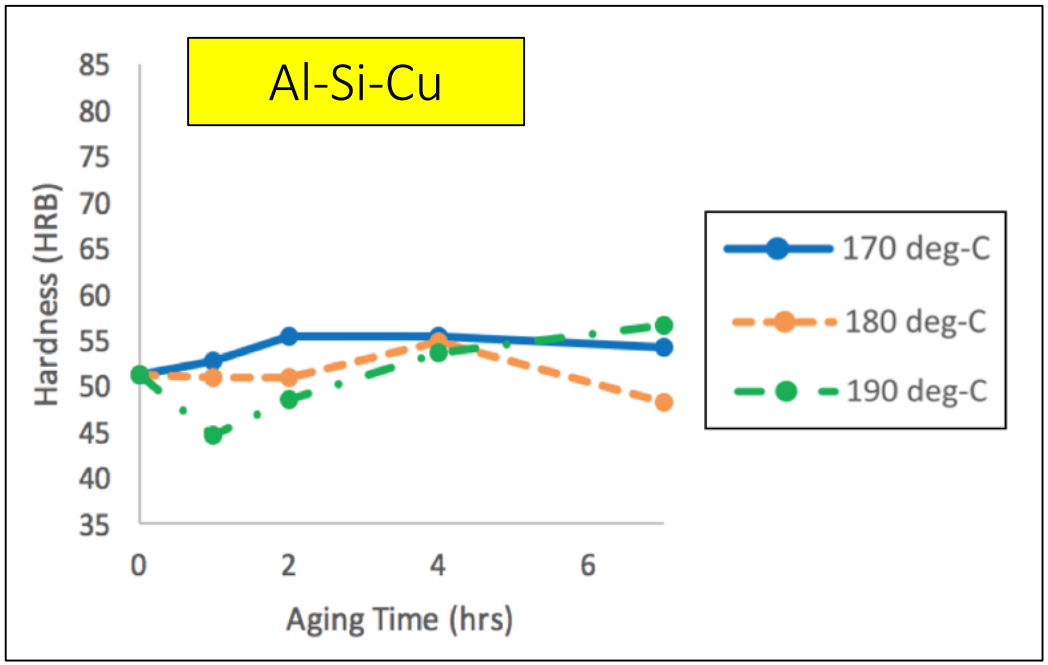

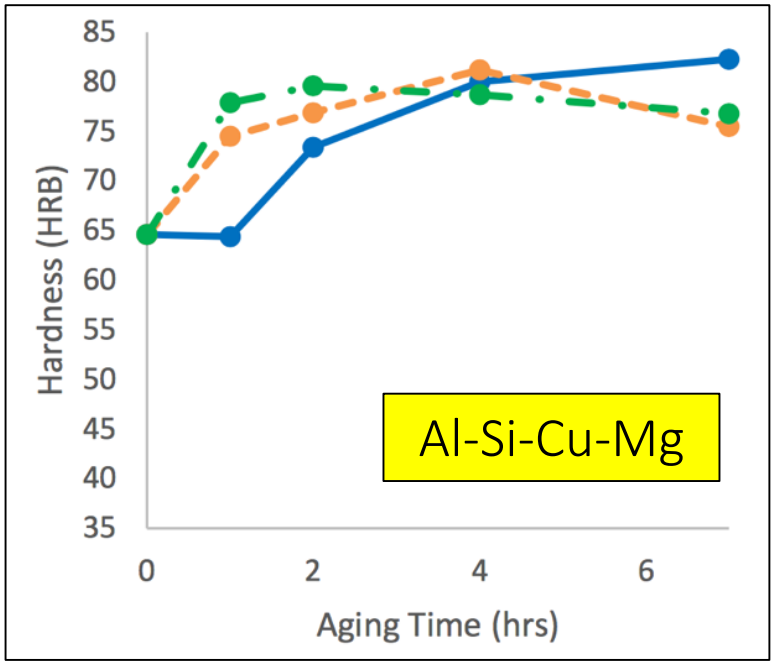

- No age hardening
  - Max hardness of 56 HRB

- Significant age hardening
  - Max hardness of 83 HRB

- Addition of 0.3% Mg significantly increases age hardening response

Source: Midson et al. 2015 NADCA Congress

Approach

- Research performed in two steps
- <u>Step 1:</u> Summer student (Spencer Randell)
  - Preliminary evaluation of the published literature
    - Has this phenomena been explained?
  - Characterize precipitation in these alloy types
    - θ-phase (Al_2Cu), Mg_2Si, Q-phase ($Al_5Cu_2Mg_8Si_6$), others

ASM Handbook Data

- Data from the ASM Handbook
  - Al-Si-Cu
  - Al-Si-Cu-Mg

Alloy	Chemistry			T6 heat treated properties		
	Si	Cu	Mg	0.2% YS (ksi)	UTS (ksi)	Elong. (%)
319	6.0	3.5	<0.1	27	40	3
354	9.0	1.8	0.5	41	55	6

- Alloy 354 (0.5% Mg) has better properties than alloy 319 (<0.1% Mg)

Mechanical Properties of Permanent Mold Castings

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Alloy	Condition	0.2% YS (ksi)	UTS (ksi)	Elongation (%)
Al-Si-Mg	As-Cast	15	31	18
Al-Si-Cu		18	44	17
Al-Si-Cu-Mg		29	55	11
Al-Si-Mg	Peak Aged (T6 Heat Treated)	35	44	11
Al-Si-Cu		29	54	11
Al-Si-Cu-Mg		54	70	3

- Data from Sjölander & Seifeddine
  - Measured on tensile samples machined from 4 mm diameter permanent mold castings

Source: Sjölander & Seifeddine, 2011

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- Al-Si-Mg alloys
  - Moderate strength after age hardening
  - Good elongation

Source: Sjölander & Seifeddine, 2011

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- Al-Si-Cu alloys
  - Low strength after age hardening
  - Good elongation

Source: Sjölander & Seifeddine, 2011

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- Al-Si-Cu-Mg alloys
  - Moderate strength after solution heat treatment
  - Excellent strength after aging, poor elongation

Source: Sjölander & Seifeddine, 2011

Future Work

- Step 2: Undergrad student (Dawson Tong)
  - Continue to perform heat treating trials with Al-Si-Cu alloys
    - Can significant precipitation hardening be produced in magnesium-free ternary Al-Si-Cu alloys?
  - Utilize high resolution x-ray diffraction to characterize precipitates in Al-Si-Cu and Al-Si-Cu-Mg alloys
    - θ-Al_2Cu versus Q-$Al_5Cu_2Mg_8Si_6$

Questions?

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