Effect of working temperature on the evolution of morphologies in cast Al-20 wt% Si alloy, processed through SIMA process.

UG PROJECT Report

BACHELOR OF TECHNOLOGY

in

METALLURGICAL ENGINEERING

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INDEX

LITERATURE SURVEY

1)Effect of Strain Induced Melt Activation Process on the

Microstructure and Mechanical Properties of Al-5Ti-1B Treated Al-7Si Alloy

Author: Chandan Choudhary, H. N. Bar, A. K. Pramanick, K. L. Sahoo & Durbadal Mandal

- Formation of Ti-based intermetallic compounds $TiAl_3$ and $Ti_7Al_5Si_{14}$ below 900°C, potentially influencing the microstructure.
- Solidification starts below 626°C, suggesting a critical temperature range for the microstructural evolution and mechanical properties in the alloy.

1. **Composition of the Alloy:**
   - Aluminum (Al)
   - Silicon (Si)
   - Titanium (Ti)
   - Boron (B)
2. **Temperature:**
   - Solidification starting temperature below 626°C.
   - Formation of intermetallic compounds below 900°C.
3. **Addition of Silicon (Si):**
   - Si content varying from 3 to 7%.
4. **Presence of Intermetallic Compounds:**
   - $TiAl_3$
   - $Ti_7Al_5Si_{14}$
   - $Ti(AlSi)_3$
   - $Ti(Al_{1-x}Si_x)_3$
5. **Solidification Process:**
   - Peritectic reaction ($L + TiAl_3 = \alpha$ solid solution) involving the Al melt and intermetallic compounds.

2)Effect of strain-induced melt activation processand thixoforming on microstructure and mechanical properties of 319 aluminum alloy

Author: Z. Delbari Ragheb, S.G. Shabestari, Y. Najafi

Microstructural Optimization through Strain-Induced Melt Activation (SIMA):

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  - Optimal conditions identified: semi-solid temperature of 560°C, 60% solid fraction, 30% pre-deformation, and 30 min isothermal holding time (G.S.30.30.560).
  - Achieved a spherical structure in grain-refined and modified 319 aluminum alloy.
  - Improved characteristics observed in the G.S.30.30.560 specimen, including highest average shape factor of α-Al (0.88) and lowest average size of α-Al phase (56 μm).
  - Pre-deformation impact: With increasing pre-deformation, average shape factor increased from 0.67 to 0.88, then decreased to 0.65, and average grain size decreased from 65.5 to 56 μm, then increased to 76 μm.

Enhancement of Mechanical Properties through Thixoforming:

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  - Thixoforming process resulted in a significant increase in hardness from 78.1 ± 1.91 HB to 115.6 ± 1.73 HB (48% increase).
  - Mechanical properties improvement demonstrated in tensile tests:
    - Ultimate tensile strength increased by 30% (from 208.92 MPa to 296.78 MPa).
    - Yield strength increased by 69% (from 125.18 MPa to 211 MPa).
    - Elongation increased by 180.5% (from 5.49% to 15.29%).
    - Toughness increased by 289% (from 770.5 × 106 J/m3 to 2997.03 × 106 J/m3).

3)The Effect of Modified Strain-Induced Melt Activation (Modified SIMA) Process on Al-Si Alloy

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  - **Date**: Published on January 28, 2020
  - Author: Chandan Choudhary, K. L. Sahoo & D. Mandal
  - **Abstract**: Investigated the development of hypo-eutectic aluminum-silicon (Al-Si) alloy through the modified SIMA process. The microstructural features of modified SIMA-processed Al-7Si alloy included fine, globular α-Al grains and uniformly distributed fragmented eutectic silicon3.

4)Phase Evolution and Mechanical Behavior of the Semi-Solid SIMA Processed 7075 Aluminum Alloy

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  - **Authors**: Behzad Binesh and Mehrdad Aghaie-Khafri
  - **Abstract**: Investigated the microstructural and mechanical behaviors of semi-solid 7075 aluminum alloy during the SIMA process. The study involved applying uniaxial compression strain at ambient temperature and subsequent semi-solid treatment at 600–620 °C for 5–35 minutes. The results highlighted the importance of microstructure in thixoforming processes1.

5)Effect of thixoforming and precipitation hardening on microstructure and Mechanical properties of Al-10.5Si–3Cu-0.2Mg alloy produced by strain induced melt activation process

S.G. Shabestari, M. Abdi, S. NaghdaliThixoforming after the SIMA process significantly enhances the alloy's mechanical properties, increasing ultimate tensile strength by 29%, yield strength by 37%, and elongation by 6% compared to the as-cast condition.

- The combination of thixoforming and precipitation hardening effectively reduces or eliminates harmful intermetallic phases while enhancing mechanical properties by uniformly redistributing small precipitates throughout the microstructure of the alloy.

1. Temperature: Specifically, the appropriate temperature for semi-solid treatment, which was determined to be 569°C.
2. Holding Time: Different holding times (15, 20, and 25 minutes) at 569°C in the semi-solid state were examined for achieving optimum uniformity of α(Al) globules.
3. Pre-deformation: Various levels of pre-deformation (10%, 15%, and 20%) were applied to the alloy during the SIMA process to investigate its effect on the size and morphology of α(Al) globules.
4. Thixoforming: The thixoforming process was utilized after the SIMA process to observe its impact on the mechanical properties of the alloy.
5. Precipitation Hardening: The alloy underwent precipitation hardening after thixoforming to assess its influence on the microstructure and mechanical properties.

OBJECTIVE

Effect of working temperature on the evolution of morphologies in cast Al-20 wt% Si alloy, processed through SIMA process.

This presentation includes the work which we have done till now. Till now we have observed and evaluated the properties physical and chemical before performing the SIMA process and this presentation includes results and observations about the same. Later, we are going to perform the SIMA process on the same alloy and are going to compare the properties of both types of material's morphologies.

ACKNOWLEDGEMENT

We would like to express our sincere gratitude to all those who have contributed to the completion of this research project. Firstly, I would like to thank my supervisor, Prof. J.K. Singh for his guidance, and support throughout the entire research process. Their insights and expertise have been invaluable in shaping this project.

Furthermore, I am grateful to Mr. Ishwari (Research Scholar) for his assistance in data collection and analysis, as well as their helpful feedback and suggestions.

Thank you all for your contributions to this project.

THEORY:

Al-Si hypereutectoid alloy:

Al-Si hypereutectic alloys are a type of cast aluminum alloy containing a silicon (Si) content exceeding the eutectic point (typically around 12-13 wt% Si). It contains of primary Si and a matrix which is a eutectic mixture of Aluminum and Silicon.

Strain Induced Melt Activation (SIMA) process:

SIMA utilizes a combination of plastic deformation (strain) and controlled remelting to achieve a finer and more equiaxed morphology for the secondary phases.

The alloy is first cast, then deformed at high temperatures to refine its grain structure and store strain energy. In some cases, additional cold working further intensifies this stored energy. Finally, the deformed material is heated to a specific temperature range where some melting occurs. This molten region, guided by the stored energy, fragments the coarse secondary phases and encourages them to adopt a more spherical shape. This refined and spheroidized microstructure translates to improved mechanical properties. The finer and rounder secondary phases become less effective at concentrating stress, leading to enhanced strength, ductility, and toughness for the entire material.

Researchers are focusing on establishing a clearer understanding of how the specific microstructural features obtained through SIMA (e.g., size, shape, distribution of secondary phases) translate to the final mechanical properties of the material. This knowledge can be used to design SIMA processing routes for achieving targeted property profiles.

MATERIALS REQUIRED:

Silicon rich Aluminum bar, Aluminum scrap, furnace, Hacksaw, Wire-cutting machine, Light-Microscope, Density measurer, Vicker's hardness Machine.

PROCEDURE:

First, we have Silicon rich Aluminum bar, then we added Aluminum scrap in it in order to lower the Silicon concentration to 20%. This we did by performing casting in furnace for 1 hour at 800 degrees Celsius. Then we cooled the melt using permanent mold casting. During casting we used hexachloroethane in 10 grams of quantity which acts as a degasifier.

After cooling the dimension of our Al-Si bar obtained were 21.5 cm x 2.7 cm x 6 cm.

We then cut the sample using hacksaw for small pieces and wire cutter for large pieces in order to perform different operations like microstructure observation, density measurement, chemical analysis and hardness measurement.

RESULTS AND DISCUSSIONS:

- **Chemical Analysis**

S.No.	Element	Composition (wt%)
1	Aluminium	79.7
2	Silicon	19.6
3	Iron	0.334
4	Copper	0.0775
5	Manganese	0.0578
6	Tin	0.119
7	Chromium	0.0180
8	Calcium	0.0046
9	Strontium	0.0398

- **Optical Analysis**

We after cutting the Aluminum Silicon alloy bar into small pieces prepared small pieces for optical analysis too. Then we performed grinding, paper polishing and cloth polishing simultaneously.

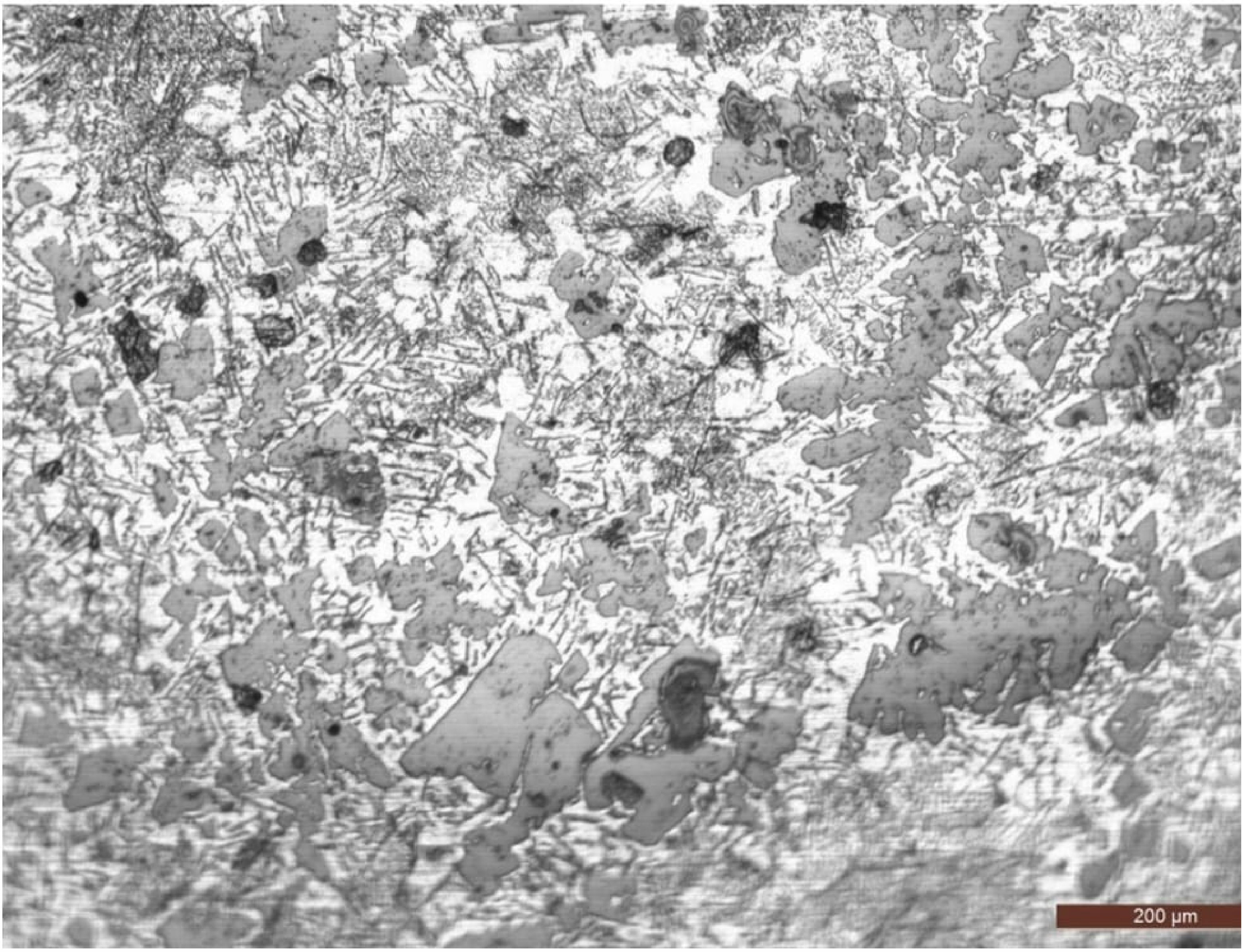

Fig- Al-20 wt% Si alloy. Here black phase is primary Silicon and white and dark is Al-Si matrix.

- **Density Analysis**

In order to get density, the principle which we used was Archimedes principle.

S.No.	Density (g/cc)
1	2.62
2	2.653
3	2.64
Average	2.639

- **Hardness Analysis**

In order to measure the hardness of the sample we used the Viker's Hardness Machine. Prior to this we polished the sample so that we can observe the indentation properly. Then we performed the harness test with 1kgf load.

S.No.	Hardness (Hv)
1	63.9
2	57.6
3	54.4
Average	58.63

CONCLUSION:

Density: 2.639 g/cc

Hardness: 58.63 Hv

By the analysis of the cast sample, we can see a non-uniform distribution and irregular morphology of primary Silicon.

These findings indicate that there is a scope in the microstructure of our sample in order to improve its properties.

SOURCE:

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  3. https://www.sciencedirect.com/science/article/pii/S092583882301455X