TU Clausthal

Project/Master's Thesis

Design, Simulation and Experimental Validation of a Squeeze Casting Die for a Porosity-Free Al-Sc-Er-Zr Alloy

1. Background/Current situation

Aluminum alloys containing scandium, erbium and zirconium can retain high strength at temperatures well above the ~220°C limit of conventional Al alloys, thanks to thermally stable nanoscale precipitates. However, producing high-performance cast components without porosity remains challenging. Squeeze casting can significantly reduce gas and shrinkage porosity by applying pressure during solidification, but it requires a specifically designed die for controlled filling, venting and solidification. For the Al-Sc-Er-Zn alloy system investigated in this project, no dedicated squeeze casting die currently exists at the institute. This project will focus on its design, simulation and experimental validation.

2. Goal/Objective

- Design a squeeze casting die (3D CAD) suitable for hand-operated, lab-scale direct squeeze casting of Al-Sc-Er-Zn alloy samples, with defined inlet, gas venting, and thickness-control features.
- Simulate mold filling, solidification and pressure application in MAGMASOFT to predict and minimize porosity and to verify achievement of the target final wall thickness.
- Use the simulation results to iterate and optimize the die design (gating, venting, pressure) prior to manufacturing.
- Characterize the cast samples metallographically (porosity content, microstructure) and compare experimental results with simulation predictions.
- Document the methodology, results and design recommendations.

3. Methodology

- Literature review on squeeze casting, Sc/Er/Zr-containing Al alloys, $L1_2$ precipitation, and porosity formation mechanisms.
- 3D CAD design of the die (cavity, punch, venting geometry, thickness shims) using standard CAD software such as Solidworks.
- Process simulation in MAGMASOFT (filling pattern, solidification, pressure transfer, porosity prediction) and design optimization based on simulation output.
- Coordination with the institute workshop for die manufacturing.
- Alloy fabrication and execution of squeeze casting trials, including melt preparation, pouring and pressure application.
- Metallographic sample preparation (sectioning, grinding, polishing, etching) and microstructural / porosity analysis by optical and, where relevant, scanning electron microscopy.
- Comparison of simulated vs. experimentally obtained porosity levels and dimensional accuracy; documentation of findings.

4. Key responsibilities

- Independently design the squeeze casting die as a 3D CAD model.
- Set up and run MAGMASOFT simulations and interpret the results to guide design decisions.
- Plan and safely carry out experimental casting trials in the foundry laboratory.
- Prepare and analyze metallographic samples and evaluate cast material quality.
- Maintain organized documentation of the design, simulation and experimental work.

5. Requirements

- Enrolled Master's student in Materials Science and Engineering, Metallurgy, Mechanical Engineering or a related field.
- Working knowledge of 3D CAD software (e.g. SolidWorks or similar).
- Interest in casting processes and materials science; prior exposure to MAGMASOFT (or casting process simulation in general) is an advantage but not required.
- Basic knowledge of, or willingness to learn, metallographic sample preparation and microscopy.
- Independent, structured and safety-conscious way of working in a laboratory / foundry environment.

6. Estimated Time Schedule

This project / Master's thesis is planned to run for six months, structured as follows:

Duration (weeks)	Milestone / Activity
2-3	Literature review; requirements definition; familiarization with squeeze casting principles and the Al-Sc-Er-Zn alloy system
3-4	3D CAD design of the squeeze casting die (cavity, punch, venting, thickness-control shims)
3-4	MAGMASOFT simulation: mold filling, solidification, pressure application, porosity and thickness prediction; design iteration
4-5	Die manufacturing coordination (workshop) and casting experiment
2-3	Metallographic sample preparation and characterization; correlation of simulation vs. experimental results
4-5	Data analysis, discussion, thesis writing, and submission

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