Research Programs

Aging Cycle Optimization for Aluminum Alloys

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Introduction

Aging of aluminum alloys is done to improve the alloy strength and other mechanical properties of interest. To optimize the properties, the aging schedule, i.e. aging time and temperature, is often chosen empirically. A more efficient way for optimizing the properties would be a model capable of predicting the microstructure and the properties as a function of aging schedule and the alloy compositions. A wide variety of mechanisms has been reported in the literature describing the interaction between precipitates and the motion of dislocation during aging. A micromechanical model for precipitation strengthening during aging of aluminum alloys can be developed based on the equations governing these mechanisms to predict the yield strength as a function of aging schedule. The model will incorporate the salient microstructural features, such as precipitate size, shape and distribution, to explain the strengthening during aging process.

Objectives

The Objectives of this project are:

- Develop a methodology and tool to optimize the aging cycling for Aluminum (cast and wrought) and other age hardenable alloys
    - Predict precipitate microstructure (including precipitate-free zones) and yield strength based on solutionizing and aging T (t) and as-quenched condition.
- Develop an optimization routine to help design the best aging schedule based on dimensional stability, yield strength requirements and heat treatment costs.

Methodology

The research methodology to be used for this project is summarized as follows:

- Evaluate and integrate existing models and methods
    - Shercliff and Ashby model
    - PrecipiCalc - Olsen
    - Pollock's yield strength
    - Quench Factor Analysis
- Use an simple readily available platform like Excel or MatLab
- Experimentally verify with selected experiments (lab and industry)
    - Jominy End Quench - quench rates and microstructure
    - Tensile samples - yield strength and microstructure

  - Dilatometer - dimensional stability
  - Selected parts

The project work is divided into the following tasks:

- Task 1 - Design of prediction and optimization tool
  - Determine the needs of the process engineers and applications engineers - via interviews and surveys
  - Identify the process parameters and user inputs
  - Identify the user required outputs
  - Literature survey
  - Evaluate capability of existing models
- Task 2 - Heat treatment experiments and microstructural characterization
  - Select alloys and heat treatment cycles for lab work
  - Experimentally generate data to calibrate and verify the sub-models for solutionizing, quenching, precipitation, yield strength and dimensional stability
  - DOE for solutionizing T(t), quenching and aging T(t)
  - Characterize microstructure in terms of precipitate structure (including precipitate free zones) via optical microscopy, SEM with EDS and TEM
  - Determine mechanical tensile properties and hardness
  - Determine dimensional stability during aging using a dilatometer
- Task 3 - Develop the modules and tool
  - Develop the modules based on results of Task 1 and data from task 2.
  - Apply the best physical principles to the models
  - Implement models in Excel or MatLab for easy availability and application
  - Develop optimization procedures
  - Integrate modules
  - Test tool results with laboratory experiments
- Task 4 - Tool validation and testing
  - Identify and alloy and an aging heat treatment to validate the tool
  - Industrially relevant part and alloy, heat treated in industrial equipment
  - Compare predictions with measured hardness, mechanical properties and microstructure
  - Compare the cost of heat treatment