Precipitation kinetics during non-isothermal treatments of AA6xxx alloys

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Introduction

AA6xxx alloys are widely used in wrought form thanks to their good response to bake hardening. Indeed, their strength can be improved by appropriate heat treatments. Nevertheless, the thermal history of these alloys can be very complex. During the production process, the temperature of the alloy varies considerably. In most cases, the heat treatments are non isothermal and thus motivate this study.

Objective

The precipitation of an AA6xxx alloy is investigated during non-isothermal treatments, namely continuous cooling and heating. The objective is to determine some critical cooling and heating rates to avoid the precipitation and to understand the different factors influencing this latter. The study is based on the evolution of the electrical conductivity and tensile test measurements as a function of the cooling/heating rates and natural aging (NA). And finally, the quench factor analysis (QFA) model is modified to take into account the effect of the NA and consider multiple quench precipitates with different solvus temperatures. This modified model is used to determine the evolution of the conductivity and yield stress as a function of different cooling rates and NA time.

Experimental methods

Continuous cooling

Samples are solution heat treated (SHT) and quenched. Samples are SHT for 60s above 540°C. The quench is conducted using different cooling rates (0.0022-1900°C/s). The conductivity measurements are made 10 min to 3 months after cooling. And tensile tests are done one week after the quench. The cooled samples are machined to a NA of one week after the cooling and T62 corresponds to a AA (205°C; 30min) done one week after the quench.

Continuous heating

Tensile samples are machined from T4 6xxx material. They are heated at different temperatures between 250°C and 550°C according to different heating rates (0.04-110°C/s). The tensile tests and the conductivity are performed one week after heating.

Quench factor analysis

QFA model¹ is modified to take into account the effect of the NA and consider multiple quench precipitates with different solvus temperatures.

Take home message

- This work has determined a critical cooling rate of 6°C/s to keep the strength of this alloy.
- This work has determined a critical heating rate of 12°C/s to avoid precipitation.
- Position of the β” and MgSi during heating have been determined.
- Conductivity and Rp0.2 can be calculated with QFA model according to the cooling rate especially for cooling rate higher than 6°C/s and relevant results are obtained for simulation of the NA.

Reference