SUMMARY OF THE DISSERTATION THESIS

Title: Roll Bonding and Age Hardening of a High-Strength Aluminium-Magnesium-Silicon Alloy for Battery Cooling Plates

Submitted by M.Sc. Lei Li

With the increasing penetration of electric vehicles, advanced thermal management systems of batteries require high-strength cooling plates. Roll bonding of Aluminium-Magnesium-Silicon (6xxx) series alloys offers a promising solution for such applications. The successful manufacturing of these roll-bonded plates strongly depends on a comprehensive understanding of the thermal-mechanical history throughout the entire process chain, consisting of roll bonding, solution annealing, quenching, inflation and ageing. This dissertation systematically investigates the coupled roles of material processing, microstructural evolution, heat treatment, and mechanical properties to establish the fundamental processing windows required for industrial production.

First, the precipitation and dissolution behaviours of aluminium alloy EN AW-6014 sheets throughout heating and subsequent cooling prior to roll bonding were established. The results demonstrate that heating peak temperatures before rolling play a decisive role, governing both dissolution during heating and precipitation during subsequent cooling. Crucially, cooling between the furnace exit and the roll gap promotes the formation of coarse precipitates. Second, following the rolling step, a sufficiently high solution heat treatment temperature of 560 °C is found to be suitable for the effective dissolution of β-Mg_2Si particles to achieve a complete solid solution state.

The third and fourth part of this work evaluates the influence of natural ageing (NA) over a wide time range on gas forming behaviour during inflation and subsequent artificial ageing (AA) responses. Natural ageing up to 7 days increases strength and the necessary inflation pressure but exhibits only a minor effect on final channel geometry and thickness distribution. For extended NA of 4 weeks, however, the drastically increased flow stress triggers premature interfacial bond failure before significant deformation can occur. Furthermore, while NA impairs the response to AA at lower temperatures, this negative effect is fully eliminated at an elevated AA temperature of 200 °C for 30 minutes, where accelerated precipitation kinetics yield high hardness levels regardless of the prior NA duration.

The final part explores an integrated process chain – utilizing a high-temperature roll bonding process with immediate water quenching – as a potential route to eliminate the post-bonding solution heat treatment step. While solutionization can be successfully achieved during pre-heating, rapid thermal dissipation during rolling restricts interfacial bonding and recrystallization. This leaves a fibrous, non-recrystallised microstructure with limited ductility and insufficient interfacial bonding strength, rendering the integrated process unsuitable for downstream channel inflation. Measures to improve this integrated process have been suggested.

Collectively, this study clarifies how coupled thermal, mechanical, and microstructural evolutions

govern bonding quality, strength development, and formability in roll-bonded aluminium alloy 6014 sheets. By developing the processing parameters established in this work, a final yield strength of approximately 240 MPa is achieved – representing a three-fold increase over conventional non-age-hardening aluminium alloys (5005 + 5754 combination) – while maintaining comparable channel geometries required for next-generation battery cooling systems.