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Impact of homogenization on microchemistry and recrystallization of the Al–Fe–Mn alloy AA 8006

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ABSTRACT

The evolution of microstructure during homogenization and subsequent rolling and back-annealing is studied for the Al–Fe–Mn alloy AA 8006. Samples were produced with three different homogenization practices aimed at providing different states of microchemistry, i.e. solutes and second-phase particles. The microstructural changes during homogenization, cold rolling and back-annealing were tracked by a combined experimental and simulation-based approach so as to understand the underlying mechanisms that control the recrystallization behaviour of the alloy.

1. Introduction

Aluminium alloys of the AA 8xxx series containing iron and manganese near the ternary eutectic content are characterized by an interesting combination of strength and ductility at room temperature and retained strength at elevated temperatures. As an example, alloy AA 8006 with approximately 1.5% Fe and 0.5% Mn is a medium-strength aluminium alloy which finds wide application as Al foil, e.g. for containers, or for heat exchangers, air-conditioning, insulation, cable wrap and other technical applications (see, e.g., [1–4]). The interesting combination of properties is caused by the fine grain size which is stabilized by finely dispersed second-phase particles [5–7]. However, under inappropriate processing conditions, significant portions of the material are observed to consist of coarse grains highly elongated in the direction of rolling, mixed with small equiaxed grains. This partially recrystallized structure is considered to be inadequate due to its adverse effects on ductility and formability. Accordingly, recrystallization of the material at the end of the thermo-mechanical process chain is a crucial issue in attaining the fine grained microstructure required for the desired favourable material properties.

The aim of the present work is to understand the underlying mechanisms that control the microstructure of the alloy, by characterization of the evolution of species, volume and size of second-phase particles as well as their effect on static recrystallization. It has been demonstrated for several Al alloys that a suitable homogenization cycle may strongly improve the down-stream recrystallization behaviour [8–10]. Therefore, samples taken from an as-cast ingot were subjected to different homogenization treatments which were selected on the basis of producing different states of supersaturation/precipitation. Then the material was cold rolled and back-annealed in order to analyse the effect of supersaturation/precipitation on the resulting recrystallization behaviour. The evolution of phases was further simulated

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with a model designated *ClaNG* treating the evolution in microchemistry, i.e. variation in solute level and precipitation, during thermo-mechanical processing.

2. Experimental Procedures

2.1. Material and Mechanical Tests

Samples were taken from a direct-chill (DC) cast ingot of alloy AA 8006 which was produced on industrial scale in the casthouse at Hydro's rolling mill in Holmestrand, Norway. The composition of the alloy is given in Table 1. This material was subjected to three different homogenization treatments which were selected on the basis of producing different states of supersaturation/precipitation (see Fig. 1):

- One specimen was heated within 4.5 h to a temperature of 480 °C, held for 2 h and then water quenched. This treatment was aimed at mimicking the conventional preheating to hot rolling temperature without a specific homogenization step. This material – which will be referred to as material "LT" (low temperature) hereafter – is characterized by a fairly low supersaturation and a high density of second-phase particles.
- The second sample was heated within 10 h to 600 °C and then homogenized for 4 h at this temperature. This treatment, denoted "HT" (high temperature), led to a much higher supersaturation of Mn and a low density of second-phase particles.
- Finally, one specimen labelled "2S" was subjected to a two-stage homogenization treatment, which consisted of a homogenization at high temperature (3 h/600 °C), furnace cooling within 2 h to a sub-homogenization temperature of 500 °C, and holding for another 2 h at 500 °C, before the sample was finally water quenched. This two-stage homogenization cycle was aimed at reducing the supersaturation of Mn while maintaining a low density of second-phase particles in order to facilitate recrystallization.

Immediately after the various homogenization treatments the samples were water quenched so as to freeze the state of supersaturation/precipitation. Then, 20 mm thick slabs were prepared from the homogenized samples and rolled at ambient temperature down to a final thickness of 2 mm, corresponding to a thickness reduction of 90%. Finally, the cold rolled sheets were back-annealed at different temperatures ranging from 200 °C to 400 °C. For that purpose the samples were slowly heated within 5–8 h to the peak metal temperature MT, held for 2 h and finally cooled with −30 K/h down to room temperature.

Table 1 – Composition range of alloy AA 8006 and composition of the present material (all in wt.%; rest: Al).

Alloy		Si	Fe	Cu	Mn	Mg	Zn	Others
AA 8006	Min		1.2		0.30			Each 0.05
(Al Fe1.5 Mn)	Max	0.40	2.0	0.30	1.0	0.10	0.10	Total 0.15
Present material		0.12	1.47	0.06	0.50	0.04	0.01	

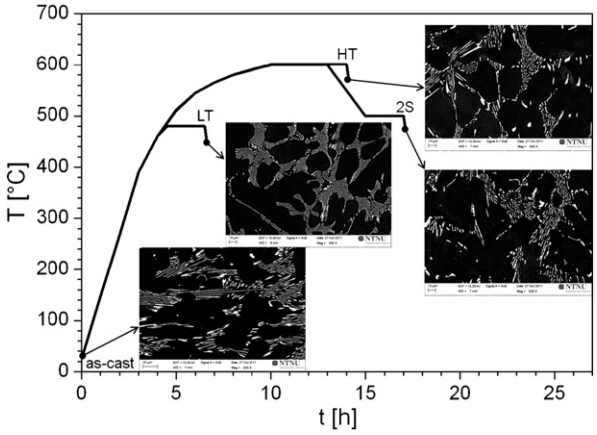

Fig. 1 – Temperature/time cycle of the various homogenization treatments as well as SEM-micrographs of the resulting microstructure (electropolished, BSE-image, 15 kV, magn. 500:1, see text for details).

Mechanical properties of the rolled and the back-annealed sheets were determined by conventional tensile tests. Standard size tensile specimens with 50 mm original gauge length and 20 mm width were machined parallel to the former rolling direction. For each material two to three parallel tests were performed. Furthermore, at all intermediate stages samples were taken for analysis of microstructure and microchemistry, i.e. the state of precipitation and solute level of the alloy elements. The various techniques will be addressed in the next subsections.

2.2. Analysis of Microstructure and Crystallographic Texture

For optical metallography samples were ground and polished according to standard metallographical techniques. The grain structure was revealed by anodical oxidation ("Barker etch") and subsequent investigation under polarized light in an optical microscope. Quantification of size and volume of large constituent phases was performed at polished samples. Additional etching for 1 min in dilute H_2SO_4/HF yields qualitative information on the density of dispersoid phases in the optical microscope. Furthermore, samples were electropolished and analysed in a FEG-SEM Zeiss Supra 55 VP equipped with a special AsB (angle-selective backscattered electron) detector so as to reveal size, shape and density of small, sub-micron sized dispersoids.

Macrotexture analysis of the sheets was performed by standard X-ray diffraction techniques [11]. From several pole figures the three-dimensional orientation distribution functions (ODFs) $f(g)$ were calculated by the series expansion method [12]. The ODFs were represented by plotting isointensity lines in three characteristic sections with $\varphi_2 = 45°$, 65° and 90° through the Euler orientation space.

2.3. Microchemistry Analysis

The composition of the second-phase particles was analysed by microprobe analysis using a JEOL Superprobe JXA 8200