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Microstructure Analyses of Aluminium Alloy 2195 Flat-rolled Products

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BACKGROUND

The weldable, ultra-high strength aluminium alloy 2195 (Al-4.0Cu-1.0Li-0.4Mg-0.4Ag-0.1Zr) is regarded as competitive structural material for cryogenic fuel tank of launch vehicle. Although microstructures and strengthening mechanism of this alloy have been widely studied, most of these studies have been done on the laboratory-made alloy in aged conditions that are significantly different from the alloy from commercial productions. This poster is to report the results of microstructure analyses on alloy 2195 flat-rolled products fabricated by CHALCO.

EXPERIMENTAL

The flat-rolled products of alloy 2195 undergo many procedures such as homogenization annealing, hot rolling, intermediate annealing, cold rolling, solution treatment, pre-stretching and ageing. Microstructures of three typical product states, i.e. hot-rolled plates, cold-rolled and T851 aged sheets, were examined by optical microscopy, scanning electron microscopy and transmission electron microscopy.

RESULTS AND DISCUSSION

Hot-rolled microstructures

The microstructure of the hot-rolled plate contains a uniform fibrous structure under the optical microscope, Fig.1(a). TEM images show fine substructure and polygonization character for such hot-rolled structures, Figs.1(b) and (c), suggesting that a dynamic recovery occurred during the hot rolling.

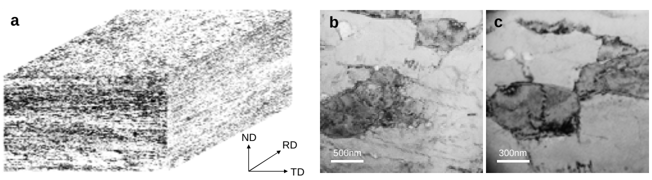

Fig.1 Optical micrograph (a) and TEM images (b, c) showing microstructures of a hot-rolled plate.

Cold-rolled microstructures

The cold-rolled sheet contains a "pan-caked" grain structure under the optical microscopy, Fig.2(a). TEM images show fine elongated subgrains and a high density of dislocation cells within the subgrains , Figs.2(b) and (c).

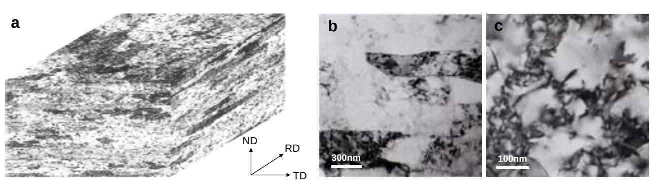

Fig.2 Optical micrograph (a) and TEM images (b, c) showing microstructures of a cold-rolled sheet.

Strengthening precipitates in the aged product

TEM observations show the microstructure of 2195-T851 aged product contains predominantly a dense and uniform distribution of $\{111\}_\alpha$ T_1 (Al_2CuLi) plates, Fig.3(a), together with a small fraction of $\{001\}_\alpha$ θ' (Al_2Cu) plates, Fig.3(b). Table 1 gives the typical mechanical properties for 2195-T851 sheet strengthened by these precipitates.

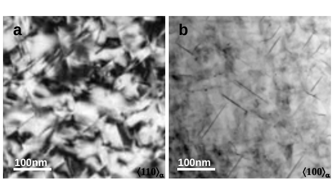

Fig.3 TEM micrographs showing T_1 and θ' phases

Table 1 Mechanical properties of 2195-T851 Sheet of 5mm

Tensile direction	Mechanical properties		
	UTS (MPa)	YS (MPa)	EL (%)
L	577	544	9.4
LT	567	541	10.2
45°	533	491	12.5

Undissolved particles inside products

SEM analyses reveal that there exists a large amount of undissolved intermetallic particles in all three product states, i.e. the hot-rolled, cold-rolled and aged, as shown in Fig.4. The cold-rolled sample, Fig.4(b), has a finer and more uniform distribution of these particles than the hot-rolled one, Fig.4(a). This is possibly due to the larger total deformation amount for the cold-rolled product. It is apparent that the aged product has fewer particles, Fig.4(c), than those as-rolled products, suggesting that the solution treatment prior to aging results in a partial dissolution of the particles.

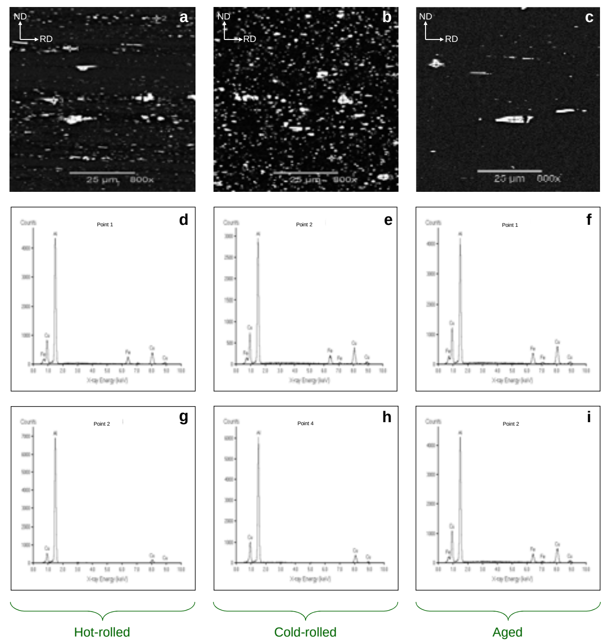

Fig.4 SEM back-scattering images and EDX spectra recorded from undissolved intermetallic particles existing in hot-rolled (a, d, g), cold-rolled (b, e, h) and aged (c, f, i) products.

EDXS analyses show that there are two types of intermetallic particles in both hot and cold rolled products. It is identified that larger-sized and irregular-shaped particles are the Al_7Cu_2Fe phase, Fig.4(d,e), and smaller-sized and round-shaped particles are a Cu-containing phase, Fig.4(g,h). In contrast, only Al_7Cu_2Fe phase remains in the aged product, Fig.4(f,i), suggesting that the Cu-containing phase is fully dissolved into the α matrix during the solution treatment.

The existence of the Al_7Cu_2Fe phase in all product states suggests that most of the intermediate heat treatment procedures during production, including homogenization, intermediate annealing and solution treatment, have little effect on this detrimental phase. It is well known that the formation of Al_7Cu_2Fe phase will consume some Cu atoms in the α matrix and decrease the volume fraction of Cu-containing, strengthening precipitate phases. Therefore, more attention must be paid to impurity control during the commercial production of aluminium-lithium alloys.

CONCLUSIONS

- The hot-rolled plate has a uniform fibrous structure and a very fine, polygonized substructure.
- The cold-rolled sheet has a "pan-caked" grain structure and elongated subgrains with high density dislocation cells.
- The microstructure of the 2195-T851 aged product contains predominantly a dense and uniform distribution of T_1 (Al_2CuLi) plates, together with a small fraction of θ' (Al_2Cu) plates.
- There are large amount of coarse, irregular-shaped Al_7Cu_2Fe particles existing in all product states, most of the intermediate heat treatments have little change to this detrimental phase.

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