Effect of Solution Treatment on Microstructure and Mechanical Properties of Thick Plate 7150 Aluminium Alloy

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Introduction

Generally, the fracture resistance of Al-Zn-Mg-(Cu) alloys is very sensitive to the presence of coarse constituent (T-phase and S-phase) particles because these particles usually act as void/crack initiation sites and preferential crack propagation paths and thus greatly degrade the fracture resistance. Therefore, reducing the volume fraction of these remaining particles becomes essential for the improvement of fracture toughness of aged 7xxx alloys. On the other hand, the released solute atoms from the dissolved particles will lead to a higher density of strengthening precipitates in the matrix and then enhance the strength. In this work, the volume fraction of remaining constituent particles and the grain structure variation at different solution treatment temperature stages have been investigated to determine optimised solution treatment conditions. In addition, the microstructure, mechanical properties and corrosion behavior of the RRA treated samples were investigated.

Experimental procedures

The basic idea for obtaining an optimised solution treatment mainly includes: 1) determining the shortest solution treatment time corresponding to the lowest volume fraction of remaining constituents at 475℃ and defining the corresponding samples as 475℃-optimised samples, 2) carrying out solution treatment on these 475℃-optimised samples at 485℃ to determine the shortest solution time corresponding to the lowest volume fraction of remaining constituents and defining the corresponding samples as 485℃-optimised samples, and 3) in the same way determining the shortest solution time for 495℃- and 505℃-optimised samples. Subsequently, the 475℃-, 485℃- and 495℃-optimised samples were exposed to a retrogression and re-ageing treatment (RRA).

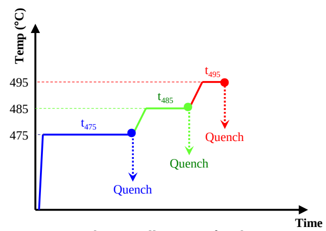

Fig. 1: Schematic illustration for obtaining the optimised solution treatment procedures.

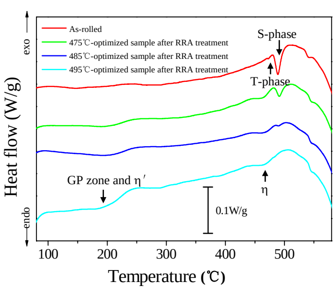

Fig. 2: DSC curves of the as-rolled and RRA-treated 475℃-, 485℃- and 495℃-optimised samples.

Results

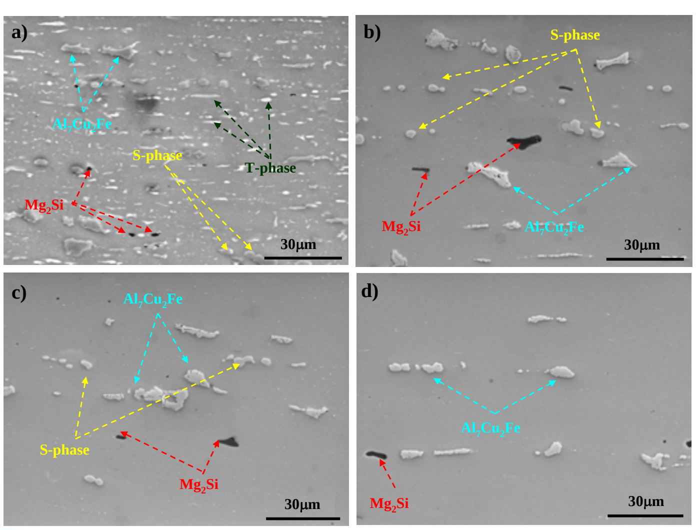

Fig. 3: The remaining phase particles in: a) as-rolled, b) 475℃-, c) 485℃- and d) 495℃-optimised solution treated samples. The phases labeled in the images are determined on the basis of EDS and DSC results.

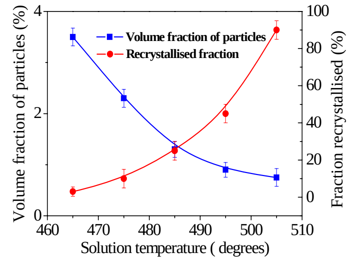

Fig. 4: Volume fraction of remaining particles and recrystallised fraction for solution treated samples

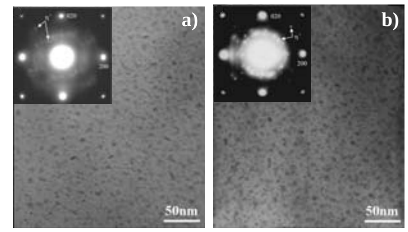

Fig. 6: Bright field images observed along <001> direction of RRA-treated: a) 475℃- and b) 495℃-optimised samples. The corresponding SAD patterns are inserted in images a) and b), respectively.

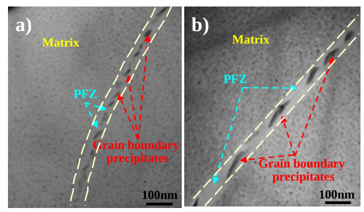

Fig. 5: TEM bright field images of grain boundary precipitates and precipitate free zone (PFZ) in RRA-treated: a) 475℃- and b) 495℃-optimised samples.

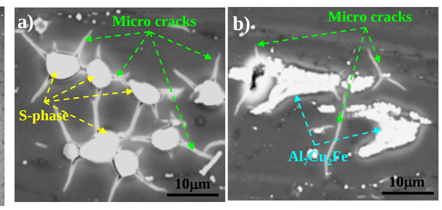

Fig. 7: SEM observation of the 475℃-optimised sample surface after 48hrs immersion in 3.5% NaCl solution: a) near S-phase and b) near Al_7Cu_2Fe particles.

Table 1: Chemical compositions of grain boundary precipitates, matrix and PFZ in RRA-treated 475 ℃- and 495 ℃-optimised samples determined by using JEOL 2011 TEM Nano-EDS with a probe size of 10nm.

Conditions	Detect areas	Al (at%)	Zn (at%)	Mg (at%)	Cu (at%)
495℃-optimised sample after RRA treatment	Grain boundary precipitate	56.6±9.4	19.2±4.1	16.1±2.2	**8.1±1.4**
	Matrix	87.6±4.2	6.6±2.1	4.2±1.4	1.5±0.7
	PFZ	95.2±5.1	2.1±0.8	1.9±0.5	0.8±0.2
475℃-optimised sample after RRA treatment	Grain boundary precipitate	60.8±8.7	19.9±5.1	15.1±2.5	**4.2±1.0**
	Matrix	87.5±5.6	6.2±2.1	4.9±1.5	1.4±0.5
	PFZ	95.6±4.3	1.9±0.7	1.8±0.5	0.8±0.3

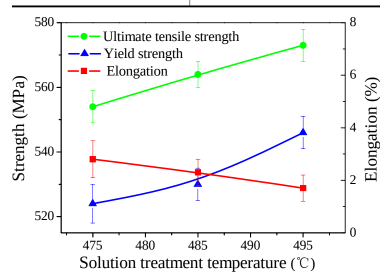

Fig. 8: Tensile properties of RRA-treated 475℃-, 485℃- and 495℃-optimised samples.

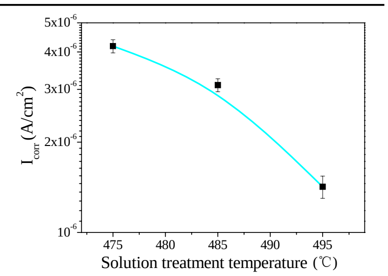

Fig. 9: Corrosion behaviour of RRA-treated 475℃-, 485℃- and 495℃-optimised samples.

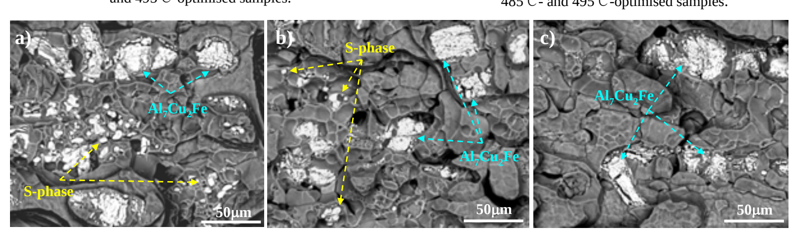

Fig. 10: Backscattered electron images of the tensile fracture surfaces of RRA-treated : a) 475℃-, b) 485℃- and c) 495℃-optimised samples. The phases labeled in the images were identified by EDS analysis.

Conclusions

1. The 495℃-optimised solution treatment can successfully dissolve the S-phase particles, resulting in a lower volume fraction of remaining particles (mainly Al_7Cu_2Fe and Mg_2Si) in the samples. Meanwhile, the recrystallised fraction of 495℃-optimised samples is about 45±5%.
2. For the RRA-treated samples, two competing mechanisms, i.e. precipitation strengthening and recrystallisation softening exist in determining the strength.
3. Due to the dissolution of the S-phase and the resulting higher density of η′ strengthening precipitates, the RRA-treated 495℃-optimised samples exhibit superior tensile strength and better corrosion resistance than samples solution treated in the AMS2772E-specified range of 471-482℃.