Dependence of thermomechanical response on Cu content in a hardenable Al-Si-Mg alloy

Seyedmehdi Hosseini [a*], Chamini Mendis [a], Isaac Chang [a] and Zhongyun Fan [a]

[a] Brunel Centre for Advanced Solidification Technology (BCAST), Brunel University London, Uxbridge, UB8 3PH, UK

ABSTRACT
In this study, we investigated the effect of Cu content on the thermomechanical response of a precipitation-hardenable Al-Si-Mg alloy produced by the casting and rolling processes. The Cu content ranged from 0.35 to 0.95 wt.%, while the alloy maintained fixed amounts of Si and Mg. The thermomechanical process included pre-aging (PA), stretching by 4% (S), and post-aging (T6). The results were based on the yield strength (YS) and the thermomechanical response was defined as YS_PAST6 – YS_T6. The findings indicated that at low and medium levels of Cu, the YS of the samples in PA and PAS conditions remained mostly constant at 206 and 281 MPa, respectively. However, it increased from 334 (low Cu) to 351 MPa (medium Cu) when the PAST6 process was completed. At a high level of Cu content, the YS_PA and YS_PAS enhanced to 221 and 298 MPa, respectively. Nevertheless, the YS after complete PAST6 was 349 MPa, slightly lower than that of the alloy containing medium Cu level. It was observed that the thermomechanical response of the alloy is at its maximum (50 MPa) when the amount of Cu is around the middle of the defined range.

1. Introduction

Al-Si-Mg alloys represent a significant category of aluminum alloys, known for their excellent comprehensive properties including light weight, medium strength, good welding performance, and corrosion resistance. However, compared to Al-Zn-Mg alloys, they exhibit lower strength but superior corrosion resistance. Certain automotive components, such as bumpers, not only demand remarkable corrosion resistance but also require specific strength values [1].

One promising and applicable approach to address this issue involves strengthening Al-Si-Mg products using the thermomechanical processes such as PAST6 [2]. This research aims to investigate the correlation between each step of the thermomechanical possess and the Cu content added to the alloy, with the goal of achieving the maximum boost in YS through pre-aging and deformation processes.

2. Experimental procedures

An Al-Si-Mg alloy, containing more than 1.3 wt.% of Si+Mg and three different amounts of Cu ranging from 0.35 to 0.95 wt.%, was prepared using a book-shaped permanent mould.

Fig. 1 illustrates how the rolled samples were prepared and the thermomechanical processing was carried out.

The ASTM E8 standard sample and test method [3] were applied to perform the tensile test using an Instron machine.

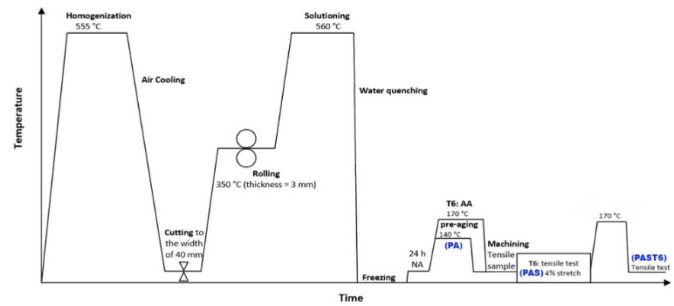

Fig.1 Schematic representation of the thermomechanical processing.

3. Results and discussion

According to Fig. 2, up to the medium level of Cu, the yield strength values are approximately 206 and 281 MPa in PA and PAS conditions, respectively. However, with an increase in Cu content to the high level, they increase to 221 and 298 MPa, respectively. This enhancement may be attributed to the higher driving force for producing an increased number density of PA precipitates due to higher chemical potential of the alloy. As the density of precipitates increases, their interaction with dislocations during plastic deformation becomes more significant, resulting in a higher YS in the PAS condition. Although the YS_T6 values are measured to be 296 (low Cu), 301 (med Cu), and 308 (high Cu), the highest YS_PAST6 is observed for the sample with medium level of Cu. Therefore, the maximum difference between YS in PAST6 and T6 conditions, named the thermomechanical response, is achieved in the medium Cu-bearing samples (50 MPa).

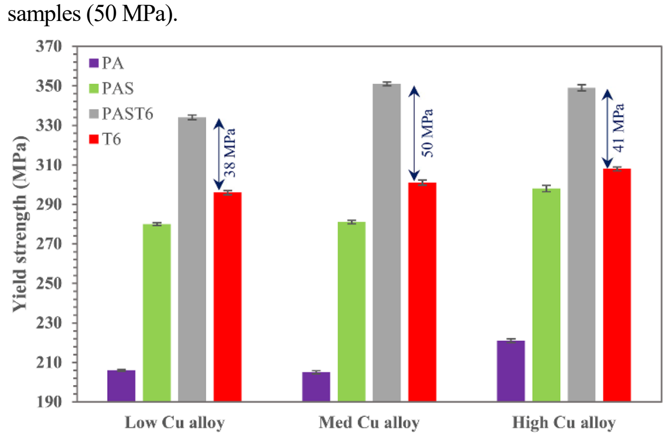

Fig. 2 Yield strength values of the alloys subjected to each step of thermomechanical processing.

It has been reported that the yield strength of heat-treated Al-Si-Mg-Cu shows a plateau in the range from 0.4 wt.% to 0.85 wt.% Cu, and then increases beyond this range of Cu. This behavior can be ascribed to the existence of various variants of precipitates in the alloy. With an increase in Cu Content, the metastable types of β-Mg_2Si is not the dominant dispersed phase and vanishes around 0.85 wt.% Cu. At a high level of Cu content, the dominant precipitate types are Q–$Al_5Cu_2Mg_8Si_6$ and θ–Al_2Cu in their metastable format (Q″ and θ″) [4]. It seems true that the Q-type precipitates represent better performance in the T6 heat treatment condition, while a better thermomechanical response is achieved once a mixture of β and Q-type precipitates contributes to the strengthening of the alloy.

Acknowledgments
The authors acknowledge the financial support by EPSRC (UK) through the STEP Al grant (EP/S036296/1).

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