

Precipitation in aluminum alloy 2024 under applied stress

Liwei Quan^{1,2}, Sam Gao¹, Barry Muddle¹

1, ARC Centre of Excellence for Design in Light Metals, Monash University, Australia
2, Northeastern University, Shenyang, China

Introduction

Aluminium alloy 2024 (Al-Cu-Mg) alloy is widely used on aircraft wings which is traditionally fabricated by cold forming of aged alloy sheets. Age forming, also called creep ageing or stress ageing, combining both the ageing treatment and forming process, with external stress applied on the alloy sheet during ageing process, has recently drawn much attention of researchers. It is found that an external elastic stress can promote the formation of θ' (Al₂Cu) precipitates preferentially in certain orientation in the age-formed Al-Cu binary alloys. However, there is almost no report of the study on the age forming of ternary Al-Cu-Mg alloys. This study is to investigate the effect of external stress on the microstructure and mechanical properties of a commercial 2024 alloy during isothermal ageing at 170°C by creep ageing method.

Experimental

Commercial alloy 2024 (Al-4.2Cu-1.5Mg-0.6Mn-0.3Fe-0.2Si-0.1Cr-0.05Zn, in wt.%) sheet with a thickness of 4 mm was used in the present study. Samples were solution heat treated in a salt bath at 495°C for 1 hour followed by water quench and then aged at room temperature to reach a T4 temper. Creep ageing of the T4 tempered alloy samples was carried out at 170°C under different stresses up to 310 MPa. Hardness, tensile tests and TEM were employed to study the mechanical property and microstructure of the creep aged alloy.

Key Results

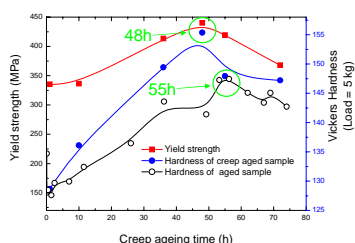


Fig. 1 Yield strengths and hardness curves of the alloy ageing for various time under 250 MPa at 170°C indicating that the applied stress can increase the hardening response and accelerate the hardening process.

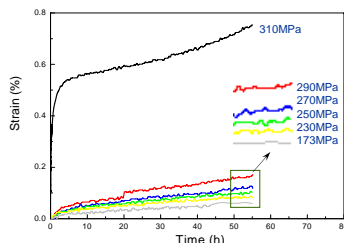


Fig. 2 Creep curves 170°C under different stresses showing that the strain rate increases with an increased stress applied during the stress ageing. This suggests that a higher applied stress can result in a better formability.

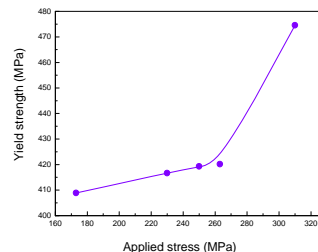


Fig. 3 Yield strengths of the alloy creep aged for 55 h at 170°C under various stresses showing that the yield strength increases with an increased stress applied. The yield strength is 383.6MPa of the alloy aged at 170°C without external stress.

310MPa is plastic stress over 289MPa the yield strength of the sample at 170°C.

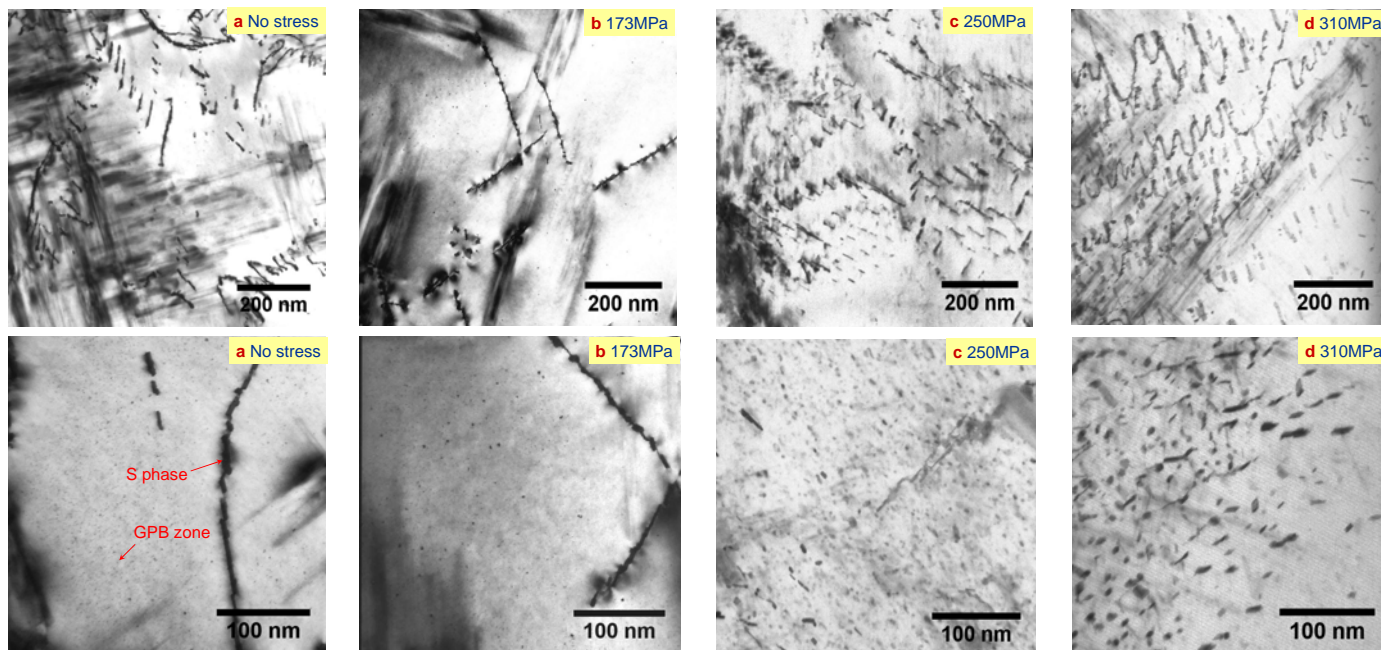


Fig. 4 $\langle 100 \rangle_{\alpha}$ bright field TEM images showing microstructures of the alloy samples creep-aged for 55 hours at 170°C under different stresses. The microstructure of stress-free aged alloy contains a dense and uniform distribution of fine GPB zones within the α -matrix and a heterogeneous formation of S phase on dislocations (4a). After creep ageing at 173 MPa, GPB zones grow in size (4b). After creep ageing at 250 MPa, the size of GPB zones grow further and some GPB zones are replaced by S phase within the α -matrix (4c). After creep ageing at 310 MPa, the GPB zones are almost completely replaced by S phase within the α -matrix (4d). It appears that an increased external stress can increase the density of dislocations while the stress has no obvious effect on promoting a preferential precipitation of either GPB zones or S phase along a certain orientation.

Conclusion

An external stress can accelerate the hardening response of 2024 alloy during creep ageing. The yield strength of the alloy can be improved by an external stress applied on the sample and also increased with larger stress. An increased external stress can increase the density of dislocations, however it has no obvious effect on promoting a preferential precipitation of either GPB zones or S phase along a certain orientation.