ARC Centre of Excellence Design in Light Metals

Australian Government Australian Research Council

Tensile Properties and Work Hardening Behaviour of Alloy 6016 in Various T4 Conditions

Hao Zhong[1,2], Paul A. Rometsch[2], Lingfei Cao[2], Fuan Guo[1], Barry C. Muddle[2]
[1] Suzhou Nonferrous Metals Research Institute, Chalco, Suzhou 215026, China
[2] ARC Centre of Excellence for Design in Light Metals, Monash University, VIC 3800, Australia

1. Background

6xxx series aluminium alloys possess high strength-to-weight ratios and are therefore promising materials for the transport industry. Forming of cold rolled alloy sheets is typically carried out in the naturally-aged (T4) or pre-aged (T4P) conditions. Such pre-treatments influence the formability. Since the formability is associated with both the tensile properties and the work hardening behaviour, it is essential to study the effects of T4 and/or T4P treatments on these properties.

In the present study, the tensile flow behavior of alloy 6016 in the T4 and T4P conditions is examined and modeled in order to give guidance for further formability investigations.

2. Experimental

Alloy 6016 samples were solution treated at 550ºC for 30 min, water quenched, then
- naturally aged for 0 min, 3 h, 24 h and 1 week, or
- immediately pre-aged at 150, 200 or 250ºC for 20 s, then naturally aged for 24h.

Tensile data analysis:
- Hollomon relationship $\sigma = K\varepsilon^n$ (n: strain hardening exponent; K: strength coefficient)
- KME approach

$$\begin{cases} \theta = \theta_1\left(1-\dfrac{\sigma-\sigma_0}{\sigma_s-\sigma_0}\right) \\ \sigma = \sigma_0 + \sigma_\perp \\ \sigma_\perp = \alpha_\perp G b M\sqrt{\rho} \\ \dfrac{\partial \rho}{\partial \varepsilon^P} = k_1\rho^{1/2} - f_s k_2 \rho \end{cases}$$

(θ_1: initial work hardening rate; σ_s: saturation stress; σ_0: yield stress; $\sigma_\perp$: flow stress contribution from dislocation hardening; G: shear modulus, b: magnitude of the Burgers vector; M: Taylor factor; ρ: dislocation density; ε_p: plastic strain; k_1, k_2, f, $\alpha_\perp$: constants)

3. Tensile properties

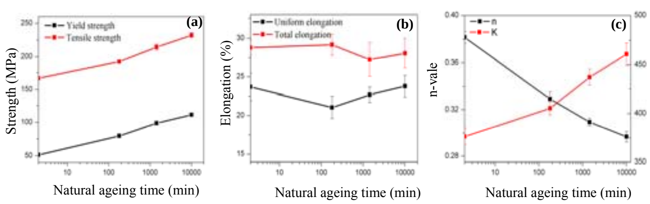

Fig.1 Effect of natural ageing on (a) strength, (b) elongation and (c) n and K values of 6016

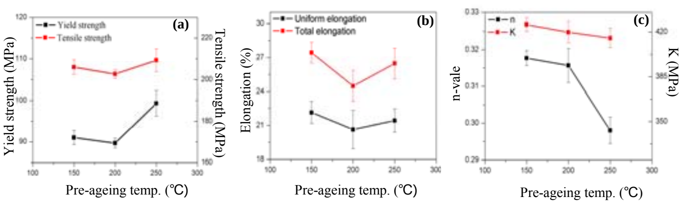

Fig.2 Effect of pre-ageing temp. on (a) strength, (b) elongation and (c) n and K values of 6016

4. Work hardening behaviour

(1) Work hardening rate

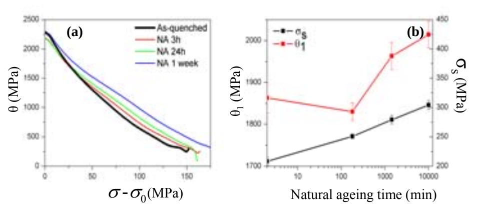

Fig.3 (a) KM plots and (b) work hardening parameters for naturally aged samples

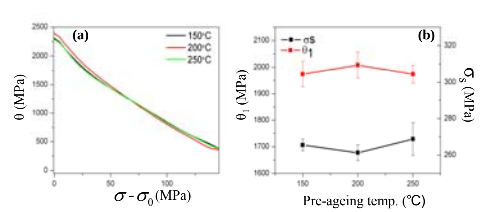

Fig.4 (a) KM plots and (b) work hardening parameters for pre-aged samples

(2) Modeling

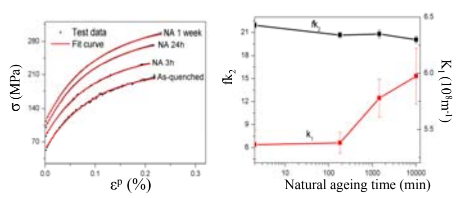

Fig.5 Strain-stress curves and model parameters for T4 alloys

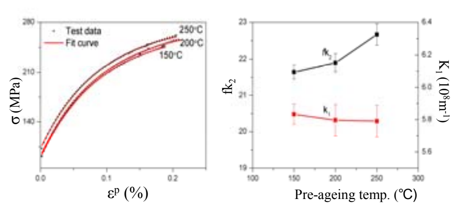

Fig.6 Strain-stress curves and model parameters for T4P alloys

5. Summary

Tensile properties
- Natural ageing increases the strength, and decreases the strain hardening exponent, but has little influence on the elongation.
- Pre-ageing at 250ºC results in a slightly higher strength and lower n-value than pre-ageing at lower temperatures. This could slightly decrease the formability.

Work hardening rate
- Naturally aged samples have a higher work hardening rate and therefore probably a better formability than as-quenched samples.
- Pre-ageing treatments in this study do not have a significant influence on the work hardening rate of alloy 6016.

MONASH University