HIGH TEMPERATURE DEFORMATION OF DISPERSION STRENGTHENED Al-Al$_4$C$_3$ COMPOSITE

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Abstract

The mutual relationship between mechanical properties and microstructure changes in Al-Al$_4$C$_3$ composite system is characterised by tensile test in wide range of testing temperatures. The dominant mechanism of plastic deformation at the deformation temperatures up to 300°C regardless of used strain rate was dislocation glide. In temperature region from 300 to 450°C and for lower strain rates the grain boundary glide participates in deformation process. The phenomenon of superplasticlike behaviour was observed at deformation temperature of 450°C and the strain rate $\dot{\varepsilon} = 10^{-4}$ s$^{-1}$. The dispersion strengthened system has been tested at 400°C by creep and fatigue superimposed on creep stress as well. The different loading schedules were defined by the stress ratio R. The criteria used to analyse the resistance to creep, or creep-fatigue, were the life to fracture and the strain to fracture.

1. Introduction

The mechanism of dispersion hardening is based on the presence of a small amount (up to 10 vol.%) of fine secondary particles in the matrix which prevent the movement of dislocations and affect the formation of microstructure and substructure during subsequent treatment. From several possible methods of preparation, the technology of mechanical alloying has shown considerable development in recent years.
A wide range of alloys and superalloys has been produced by this technology. Considerable attention has been paid to the Al-C system [1]. In this system an intensive dry milling of Al powder and graphite results in deformation, disintegration and welding of crushed powder particles with an incorporated phase C, which after subsequent thermal processing, forms the Al₄C₃ dispersoid as a result of a chemical reaction. Several studies [2,3,4] were devoted to preparation conditions, analyses of the microstructure and mechanical properties determination. The stability of mechanical properties at elevated temperatures is one of the basic demands of the relevant materials. However, a general quantitative theory describing the influence of particle on mechanical properties at short-term loads and elevated temperatures is missing. Real dispersion hardened system exhibits a β-distribution of dispersion particles, located along grain boundaries as well as in grain interiors, which affects the deformation processes to a different degree under the conditions of thermal exposure. Previous study [5] paid attention to analysis of the creep like behaviour of these dispersoid system. The strain rate at creep reached a maximum at 300°C, where dynamic polygonization processes made the maximum creep deformation possible.

The aim of the present study was to analyse the influence of the test temperature and the strain rate on resulting mechanical properties and correlate them with microstructure changes in the Al-Al₄C₃ dispersion strengthened system. The strengthened system was also subjected to creep and cyclic creep loading at 400°C, where different stress range R and stress amplitude Q defined individual cyclic regime.

2. Material and experimental procedures

The tested material was manufactured of aluminium powder dispersion strengthened by 8 vol.% of Al₄C₃ particles. The milling process of matrix powder with KS 2.5 graphite lasted 90 minutes. The powder was compacted under pressure of 600 MPa and annealed at temperature of 550°C/3 h. Extrusion was performed at 550 °C with 94 % reduction. The static mechanical tests were carried out on the Tiratest 2300 universal testing machine with a thermal chamber (± 2 °C). The mechanical tests were carried out at three different strain rate in range of \( \varepsilon = 10^{-1} - 10^{-5} \text{s}^{-1} \).

Creep test and load control cyclic creep test were performed at 400 °C. The strain and the life to fracture were tested at different loading schedules defined by various cyclic stress proportions

\[
Q = \frac{(\sigma_{\text{max}} - \sigma_{\text{min}})}{\sigma_{\text{mean}}}
\]

(1)

The cyclic stress ranged from 0 for pure creep to 1.67 for low cycle fatigue in tension. The character of loading stress and amplitude is expressed also by the stress ratio.

\[
R = \frac{\sigma_{\text{min}}}{\sigma_{\text{max}}}
\]

(2)

Various values of R from range 1 to 0.089 were chosen. The aim was to maintain the conditions of the continuous creep with superimposed fatigue stress component having a constant \( \sigma_{\text{max}} \) level of the stress at different amplitudes of cycles.

Since the selected temperature at tensile testing had manifested a strong dependence of the elongation on strain rate and onset of recovery process it had been supposed of interest also for creep-fatigue testing.