EFFECT OF ELECTRIC CURRENT PULSE ON SUPERPLASTICITY OF ALUMINIUM ALLOY 7475①

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ABSTRACT The superplastic deformation of aluminium alloy 7475 applied electric current pulse has been studied. The results presented that applying a high density current pulse raises both the elongation rate and the m value, and makes supperior superplastic properties at high strain rate of $10^{-2}\,s^{-1}$, the optimum deformation temperature could move from 530 ℃ to 480～510 ℃, TEM observation showed the superplastic deformation of the alloy is the results of grain boundary slips and dislocation slips in grains under function of the electron wind; the intergranular tear is a main behavior of fracture of the alloy.

Key wards aluminium alloy 7475 superplasticity electric current pulse

1 INTRODUCTION

Previous studies showed that superplasticity of metallic material could be only obtained at high temperature and with relatively low strain rate, these conditions restrict its applying. Since electroplasticity effect was found in 1963, it was much attented widely[1-3]. Electroplastic effect termed enhances plasticity of an alloy and reduces its flow stress due to the interaction of drift electrons with dislocations under electric current[4]. At present, there are also some studies which show that the drift eletrons can influence fatigue, fracture, phase transformation of metallic materials and metal working. Only a few studies involving the effect of temperature on electroplastic effect have been conducted. Most works were performed in the range from 77 K～room temperture. However, studies on electrosuperplastic effect have been relatively few. Present work was therefore undertaken to observe effect of electrosuper plastic effect of aluminium alloy. High current densities were here employed to enhance the effects of the drift electron and short pluse times to reduce Joule heating.

2 EXPREIMENTAL

The sheet of aluminium alloy 7475(1.65 mm thick) employed in this investigation was directly supplied by Northeast Light Metal Factory. The elemental composition of the alloy is 5.48%Zn, 1.98%Mg, 1.52%Cu, 0.22%Cr, 0.06%Fe, 0.03%Si, 0.06%Mn, 0.06%Ti, and other is Al. All the superplastic tension tests of the specimens were run on an Instron machine model AG-10TA and were conducted at constant crosshead speed. In the present tests, electric current pulse density up to 7.4×10^{2} A/mm^{2} and 50 μs duration at a frequency of 10 Hz were produced for the specimens. Values of m can be determined by the Backofen's method. Thin foils were prepared from the sliced pieces by electrolytic jet polishing and were examined by a transmission electron microscope(JEM-100CX Ⅱ).

3 RESULT AND DISCUSSION

Fig. 1 gives the curves of the relation be-

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tween elongation rate(δ) and strain rate($\dot{\varepsilon}_0$) in the specimens superplastically deformed without and with the electric current pulse. It is here evident that applying electric current pulse significantly enhances the elongation rate of the specimens.

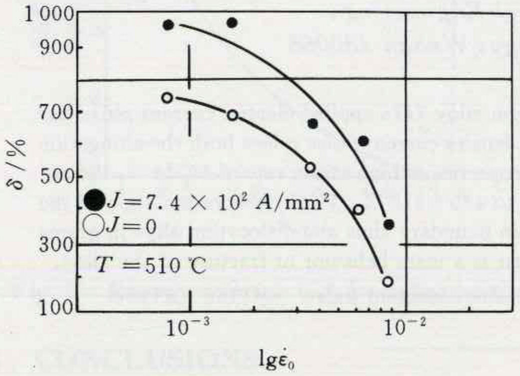

Fig. 1 Elongation rate *vs* strain rate for specimens tested without and with electric current

At 510 ℃ and with strain rate range from 8.3×10^{-4} s^{-1} to 1.67×10^{-3} s^{-1}, the δ is over 900%. One difference is noted in the specimens with the electric current pulse compared with specimens without, namely the δ was more than 260% with the electric current. Morever, at high strain rate, the elongation rate was still high, such as, $\dot{\varepsilon} = 8.3\times10^{-3}$ s^{-1}, $\delta\approx320\%$. It is very important for the commercial aluminium alloy 7475. Fig. 2 shows relation of the elongation rate with the temperature of the superplastic deformation. It is here seen the elongation rate of the specimens is maxmum at 530 ℃(i. e δ = 740%) without the electric current, but this value could be obtained at 480 ℃(δ =710%) with the electric current. Therefore, the temperature superplastically deformed is reduced. At same time, if deformation temperature of the specimens is over 450 ℃ and strain rate is below 3.33×10^{-3} s^{-1} with the electric current, the elongation rate is over 500%, and values of m are over 0.4(Fig. 3). These results show that applying an electric current pulse enhances anti-necking of the alloy. It is confirmed that there is a true effect of electric current on superplastic deformation of the metallic material.

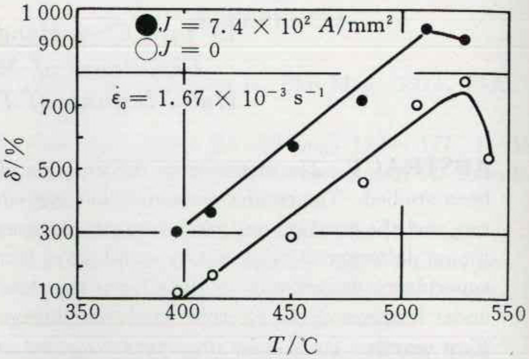

Fig. 2 Elongation rate *vs* temperature of deformation for specimens tested without and with electric current

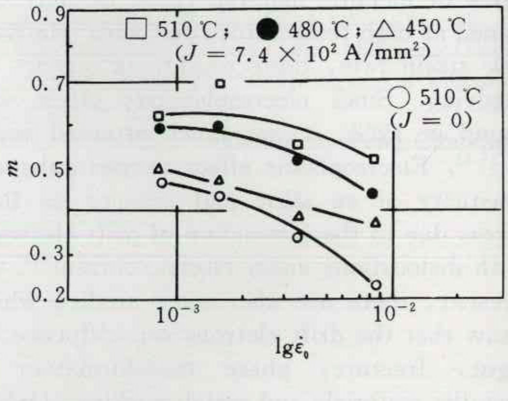

Fig. 3 *m* value *vs* strain rate for specimens tested without and with electric current

On the electroplastic effect of metallic material, less well know is the idea that drift electrons in a metal may assist dislocations in overcoming obstacles to their motion; i. e. that drift electrons can exert a push or "wind" on dislocation. The moving electrons in a metal crystal may interact with the dislocations. The idea that drift electrons can influence the generation and motion of dislocations led Troiskii and other scientists to conduct an extensive investigation into the influence of direct current pulse of the order of 10^3 A/mm^2 for $\sim 50\,\mu$s duration on the mechanical properties of metal, including dislocation generation and mobility[5].

While alloy was deformed, with high density electric current, drift electrons in the alloy crystal form electron wind. Additional force on dislocations due to an electron wind is similar to external applied force on dislocation. The additional force makes dislocations in the grains take part in slips (see Fig. 4(a), (b)) and may assist the dislocations in overcoming obstacles to their motion and even cross through second phase particles (see Fig. 4(c)). Meantime, the drift electrons can also influence the generation and arrangment of dislocations. The TEM micrographs in Fig. 4 (b), (c) shows the dislocations in grains are more parallel with the direction of electric current. These results present superplastic deformation of alloy is composed of the grain boundary slips and the dislocation slips in the grains. On the other hand, the drift electron-dislocation interaction co-ordinate the micro mechanism and delay the fracture of tension

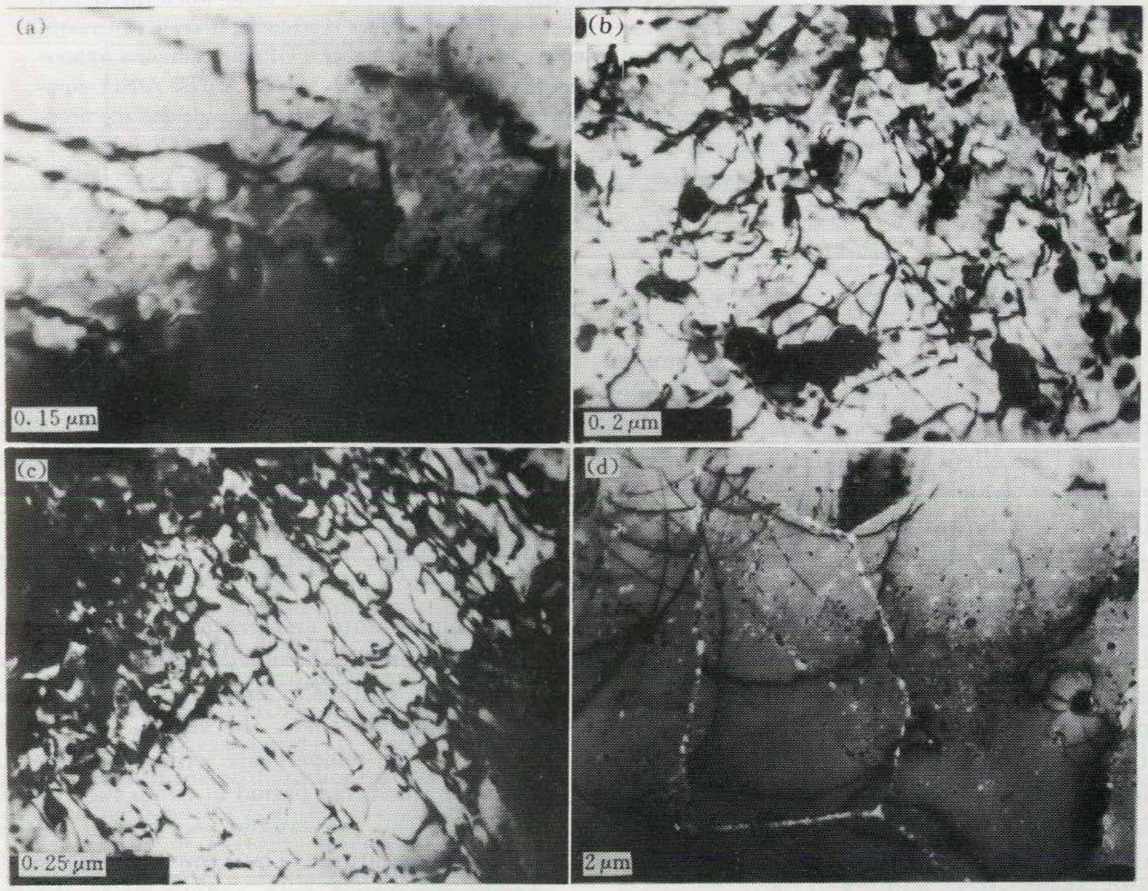

Fig. 4 Dislocation in grain and grain boundary fracture in superplastic deformation with
$J = 7.4\times10^2$ A/mm^2 ($\dot{\varepsilon}_0 = 8.3\times10^{-3}$ s^{-1}, $T = 480$ ℃)
(a), (b)—second-phase particles crossed by dislocation;
(c)—dislocation structure in grain; (d)—grain boundary fracture (*to page 84*)