TEMPERATURE AND GRAIN SIZE DEPENDENCE OF YIELDING AND FRACTURE IN Zn-Al ALLOY

F. Abd El-Salam
Faculty of Education, Physics Department,
Ain Shams University, Cairo, Egypt.

S.A. Khairy
Faculty of Science, Physics Department,
Cairo University, Cairo, Egypt.

Abstract:

Quenched samples of eutectoid Zn-Al alloy having different grain diameters were aged at room temperature for 24 hours then subjected to tensile testing at different temperatures in the range 200-300°C. The resoftening which took place during the transformation of the dual precipitated phase into the single phase, was found to depend on grain diameter and was associated with a decrease in the grain boundary fracture surface energy to a minimum of about 10 erg/cm^2.

The resulsts were discussed in terms of the dislocation mechanisms and the phase boundary sliding resulting from a phase boundary diffusion.

Introduction

Increasing grain size was found(1) to shift the maximum value of the coefficient of the strain-rate sensitivity of the flow stress and plasticity towards slow strain rates. Also, the deformation induced grain growth became intensified with decreasing strain rate. The stress strain rate behaviour of fine grained Zn-Al eutectoid alloy was determined(2) at different temperatures from which it was shown that the diffusion of Zn rich phase plays a significant role in the deformation mechanism of this alloy. There are more experimental observations of mechanical weakening of the materials at the phase transformation temperature(3).

The present work aims at studying the effect of grain diameter on the mechanism controlling the mechanical yielding and fracture of Zn-22 wt% Al alloy in the temperature range 200-300°C including the phase transformation temperature.

with σ_0 representing the friction stress to be overcome by the moving dislocations and obtained as the intercept with the stress axis k is a constant related to the unpinning of dislocation source that was locked by interaction with solute atoms and is given as the slope of the straight line relating σ_y and $d^{-1/2}$. The variations of the friction stress σ_0 with temperature are given in figure 3.

On the basis of the relation(5)

$$\sigma_f = (B \gamma_f G / k) d^{-1/2} \tag{2}$$

where B = 1 for tensile stress, G = 2.7 x 10^{11} dyne/cm², the temperature dependence of grain boundary fracture surface energy, which is defined as: $\gamma_f = \sigma_y \sigma_f d / B G$, is given in figure 4.

Discussions

The precipitation of quenched Zn-Al alloy samples produced decomposition at room temperature and exhibited an entirely different fine grained equiaxed structure which is not typical of an eutectoid decomposition(6). Maintaining the quenched samples for large periods of time at a lower precipitation temperature allowed atomic diffusion, predominating the precipitation process to proceed towards dislocations, thus increasing the friction stress. As the applied stress was increased, dislocation segments were free from their pinning atmospheres. The stress increased the force on the freed dislocations which became able to glide on their slip planes. Grain boundaries act as effective barriers to dislocation motion towards annihilation sites(7). The increase in the dislocation density behind these barriers causes hardening. Accordingly, fine grained samples with high density of barriers need higher values of yield stress to release the locked dislocations eitherby a break down of the dislocation barriers or by prismatic slip. The resoftening associating the high temperature deformation could be related to the structural variations of one of the phases existing in the tested samples by increasing temperature towards the one phase transformation temperature. This leads to a dissolution process at one of the interphases and precipitation process at the other phase. This change in composition required moving the dislocations at the interphase boundary(8). Also, a diffusion process takes place in the temperature range of transformation such that a reasonable current of diffused atoms gives rise to an anomalous transformation plasticity expressed through the minima of yield stress seen in figure 1. This agrees with the superplastic behaviour observed during phase transformation in Zn-Al alloys(9).

The data of figure 2, which indicate that dislocation slip distances increased with increasing temperature and reached maxima during phase transformation agree with the theory(10) of work hardening in polycrystalline metals and the effect of grain size which limits the dislocations from any one source within the grains. The large amounts of heat treatment initially given to the large grained samples during the course of their preparation caused the slip planes to be relatively clean of

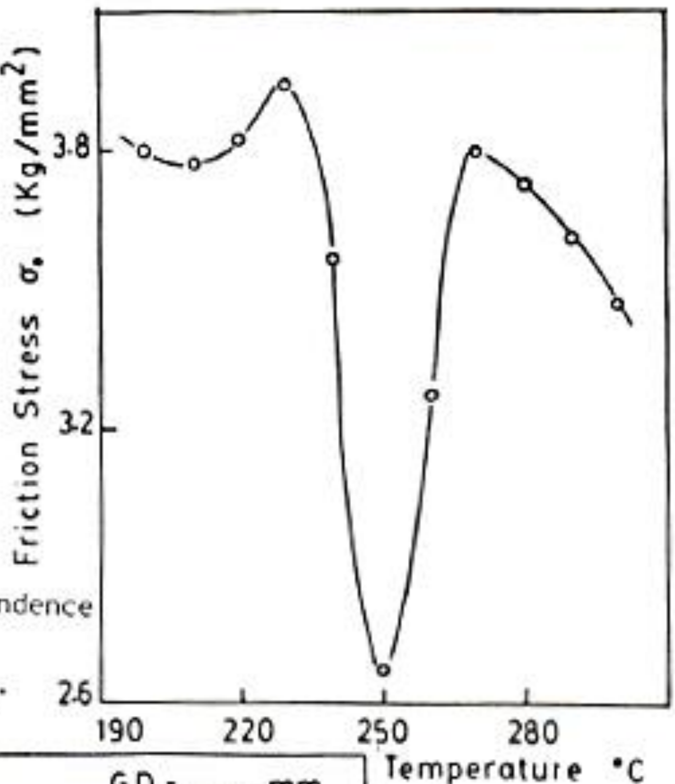

Figure 3: Temperature dependence of friction stress σ_o.

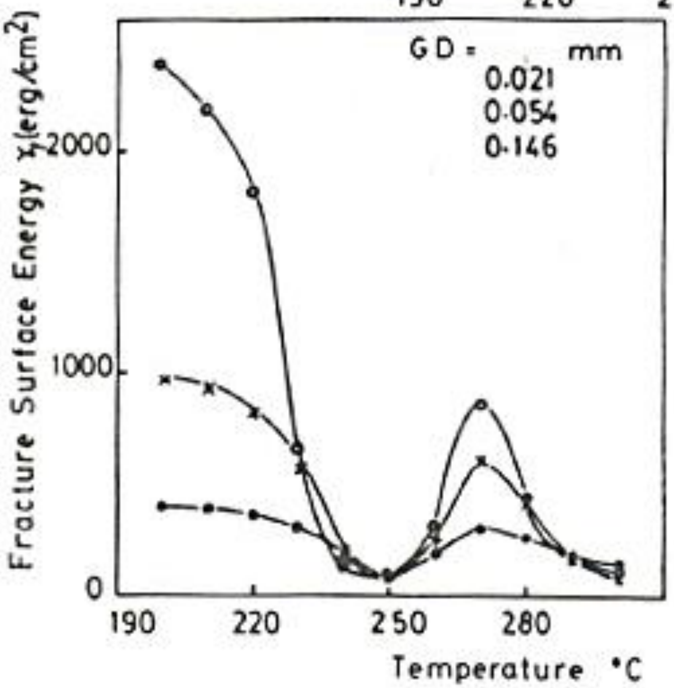

Figure 4: Variations of grain boundary fracture surface energy γ_f of Zn-Al alloy with grain diameter and with tempera-