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BAUSCHINGER- AND X-Y TESTS ON Cu SPECIMENS

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INTRODUCTION

The effects of a change in the strain direction by 90° (x-y tests) or 180° (Bauschinger tests) [1,2] on strain hardening in polycrystalline copper at room temperature was investigated. Earlier, we calculated the shear stresses in the material for x-y tests, from which it was deduced that many of the mobile dislocations reverse their paths upon the 90° change in strain direction. The prediction was verified by *in situ* tests in the HVEM [3]. We now carried out macroscopic x-y tests, in which the specimen was first strained in the x-direction, then unloaded, then strained in the y-direction. The results are compared to the outcome of a simple phenomenological model.

THE SAMPLES

Specimens were prepared from one sheet of commercial copper (thickness 10 mm), in such a way that the strain direction in the experiments is at 45° to the rolling direction of the material. The specimens for compression-tension tests are cylindrical, with gauge diameter 4 mm (cross section 12.6 mm²) and gauge length 17 mm. Those for the x-y tests are lozenge-shaped plates with gauge thickness 2 mm (cross section 1st test ≈ 112 mm², 2nd test ≈ 52 mm²) and gauge length 28.3 mm². These samples are pre-machined, annealed for one hour in vacuum at 550 °C, finished, and again annealed in the same way.

In the x-y tests, the angle between the grips and the strain direction is 45°. Thus the presence of the grips has little influence on the lateral contraction, which makes for a homogeneous strain throughout the gauge section of the sample. After finishing the first part of an x-y test, the sample is carefully machined to the smaller size required for the second tensile test in transverse direction.

RESULTS

The experiments were performed at a strain rate $\dot{\epsilon} = 2 \times 10^{-4} \text{ s}^{-1}$. Figure 1 shows some results for specimens that were pre-strained to a stress $\sigma_p = 80, 100, 120 \text{ MPa}$ respectively. We found that the differences in strain hardening behaviour are indicated most sensitively by the quantity $d\epsilon/d\sigma$ ($= \theta^{-1}$). Here ϵ is the true plastic strain and σ the true stress MPa. The curves were obtained in tensile straining. Curves A are for a sample monotonically strained to $\epsilon = .12$. Curves B are for samples that were previously strained in compression, and curves C for samples previously strained in transverse tension. Measurements like these indicate that the 'Bauschinger effect' in x-y tests is about half as strong as in compression-tension tests.

Figure 1. $d\epsilon/d\sigma$ vs. σ for copper specimens in tensile strain. A) monotonic strain to $\epsilon = .12$. B) after pre-strain in compression. C) after pre-strain in transverse tension and unloading. Vertical lines indicate pre-stress σ_p .

MODEL

We devised a phenomenological computer model based on a few simple considerations, similar to those employed by several other investigators [4,5,6], which can account for the observed partial reversibility of strain hardening.

The sample is considered as a composite (Masing model) with a continuous dislocation-density distribution. Everywhere in the material the total (elastic + plastic) strain is the same. The local critical tensile stress σ_c at which the material deforms plastically is given by:

$$\sigma_c = \sqrt{s}$$

where s is proportional to the local dislocation density. Initially we have $s(v) = s_0(v)$, where v is the volume fraction, $0 \leq v \leq 1$. For $s_0(v)$ we take the simple expression:

$$s_0(v) = b + m \cdot v^p$$

b , m and p being adaptable parameters. The dislocation density increases linearly with the plastic strain $\epsilon_p l$

$$\Delta s = h \cdot \Delta \epsilon_p l$$

where h is a constant hardening parameter. The additional dislocations are taken to be reversible up to a certain limit. After strain reversal, the new dislocations annihilate the reversible fraction, so that the density and hence σ_c first decrease, and then increase while a new surplus of dislocations of opposite sign is built up. It seems likely [6] that reversible dislocations tend to pile up near walls, i.e. in regions with high gradients in dislocation density. Our model cannot take care of such gradients, therefore we use the slope of the $s(v)$ curve, and assume the maximum reversible dislocation density to be

$$r \cdot \frac{ds}{dv}$$

where r is a constant.

In x-y tests the sample is first strained in the x-direction, then unloaded, then strained in the y-direction. In our model we make the assumption that the set of potential glide systems activated in x-strain and the set of those activated in y-strain overlap for 50%. Therefore we assume that only half of the above mentioned reversible dislocations can be reversed in transverse straining. Figure 2 shows some results computed with:

Young's modulus

$$E = 1.1 \times 10^5 \text{ MPa}$$

for $s_0(v)$

$$\begin{cases} b = 100 \text{ MPa}^2 \\ m = 10^5 \text{ MPa}^2 \\ p = 20 \end{cases}$$

hardening parameter

$$h = 3.3 \times 10^5 \text{ MPa}^2$$

reversible parameter

$$r = 0.04$$

Our simple model yields some qualitative agreement with the experiments. For better results, however, the model should be extended to deal explicitly with the various slip systems in differently orientated grains [7].

Figure 2. Model computation of $d\epsilon/d\sigma$ vs. σ A) to $\sigma = \sigma_p$ ($\sigma_p = 100$ MPa), B) after compression to $\sigma = \sigma_p$, C) after transverse tension to $\sigma = \sigma_p$ and unloading.

REFERENCES

- [1] Sleeswyk, A.W., Kemerink, G.J., *Scripta Metall.* **19** (1985) 471.
- [2] Christodoulou, N., Woo, O.T., MacEwan, S.R., *Acta Metall.* **34** (1986) 1553.
- [3] Kassner, M.E., Sleeswyk, A.W., Echer, C.J., *J. Electron Microscopy Technique* **5** (1987) 189.
- [4] Mughrabi, H., *Acta Metall.* **31** (1983) 1367.
- [5] Bate, P.S., Wilson, D.V., *Acta Metall.* **34** (1986) 1097.
- [6] Hasegawa, T., Yakou, T., Kocks, U.F., *Mater. Sci. Engng.* **81** (1986) 189.
- [7] Cailletaud, G., *this issue*