CYCLIC HARDENING OF B.C.C. IRON ALLOYS SINGLE CRYSTALS

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Cyclic hardening of dislocation structures produced in Fe-Si single crystals by cyclic deformation at constant plastic strain amplitude is investigated by additional deformation under constant load amplitudes. At the load amplitudes corresponding to the "plateau-stress", the hardening was essentially absent, whereas at the lower load amplitudes there is a marked hardening with a tendency to saturation.

INTRODUCTION

The cyclic deformation of single crystals of Fe-Si (1) and Fe-Cr (2) alloys under plastic strain control has been studied recently. At present, the investigation of cyclic hardening of these alloys at constant load amplitudes is in progress. Preliminary results of this study are reported in this paper.

EXPERIMENTS

Cylindrical specimens with gauge diameter of 3.5 mm and gauge length of 10 mm were prepared from single crystals of Fe-Si alloys (0.5 to 3wt.%Si) and of Fe-13.6wt.%Cr, oriented for single slip, by the same manner as in (1,2). Symmetrical tension-compression tests were performed at constant plastic strain range $\Delta \varepsilon_{pl}$ (i.e. at plastic strain amplitude $\pm \Delta \varepsilon_{pl}/2$) and at constant load amplitude (CLA tests) in a screw-driven machine at room temperature and at frequency of 0.1 Hz.

SUMMARY OF EARLIER WORK

Cyclic hardening curves of the investigated alloys measured at constant plastic strain amplitudes and the dislocation arrangements show similarities to fcc metals (1-4). Examples of the cyclic hardening curves are shown in Fig.1. The stage of rapid hardening is followed by the saturation stage. The cyclic stress-strain curves

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exhibit plateau which is connected with localization of plastic deformation in persistent slip bands (PSBs). In the rapid hardening stage the dislocation structure consists of primary dislocations concentrated in loop patches with a low dislocation density between them (the vein structure).

In the saturation stage the slip is concentrated in PSBs. The saturation stress is constant for plastic strain amplitudes ranging from 10^{-4} to $5x10^{-3}$. The dislocation structure in PSBs typical of fcc metals namely the wall structure (or ladder structure) consisting only from primary dislocations occurs only at the beginning of saturation. Then the secondary dislocations are activated and the cell structure forms in PSBs. There are additional differences between the cyclic deformation of the bcc alloys and fcc metals, e.g. the morphology of extrusions and intrusions in PSBs, the changes of specimen cross section from circular to elliptical one.

RESULTS AND DISCUSSION

The stability of the dislocation structures formed during cyclic deformation was investigated on the Fe-Si alloys by CLA tests. The specimens were predeformed by cycling at constant $\Delta\varepsilon_{pl}$ on various stress levels. Then the deformation mode was changed to cycling at a constant load amplitude equal to the last tensile load peak and variations of the plastic strain amplitude were measured. A typical example of the obtained results is shown in Fig.2. This figure shows changes of the plastic strain amplitude in dependence on number of cycles during deformation at CLA test.

The work-hardening of the dislocation structure formed during the predeformation causes the decrease of . An inspection of Fig.2 indicates that the ability of the dislocation structure to work-hardening markedly decreases with increasing stress in the rapid hardening stage. Consequently, the work-hardening decreases and after sufficient number of cycles a steady state occurs at which an equilibrium between formation and annihilation of dislocations can be assumed at small $\Delta\varepsilon_{pl}$ (e.g. at $\Delta\varepsilon_{pl} \cong 1x10^{-5}$ and 80 MPa in Fig.2).

In the saturation stage the plastic strain amplitude remains constant during the CLA test. This result corroborates the onset of a dynamic equilibrium between formation and annihilation of dislocations in PSBs as it is manifested by the existence of the plateau-stress in the cyclic stress-strain curves.

CLA measurements suggest that during cyclic deformation of Fe-Si crystals at constant plastic strain amplitudes, small enough, the stress saturates to values which depend on $\Delta\varepsilon_{pl}$ and are smaller than the plateau stress, similarly, as in the so-called regime A in copper single crystals (4).

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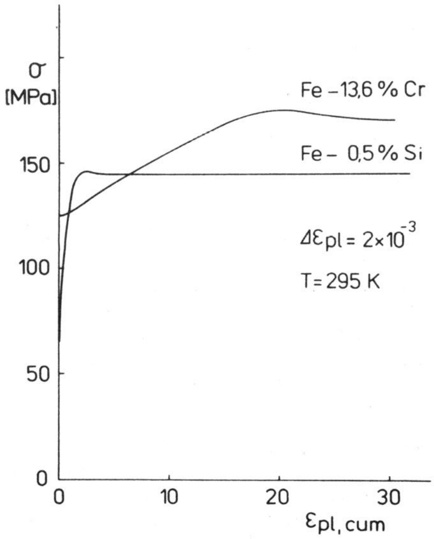

Figure 1 Examples of cyclic hardening curves

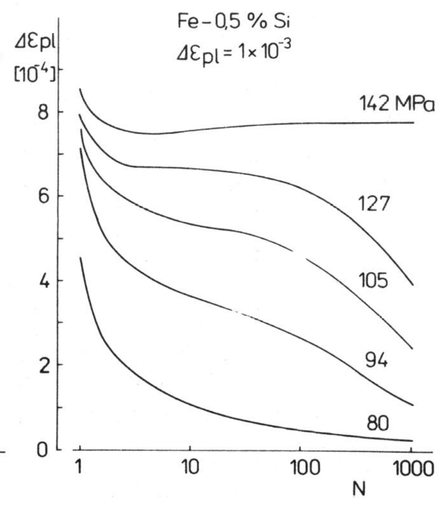

Figure 2 Dependence of on number of cycles at CLA