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THE PATH DEPENDENCE OF DEFORMATION TEXTURE DEVELOPMENT†

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It is demonstrated for the case of three different strain paths, all of which end up with the same, elongated specimen shape, that the texture developed during straining is path dependent. This is true both for experiments on aluminum polycrystals and for simulations using the LApp code.

Introduction

The rate of change of the orientation of any particular grain in a polycrystal at any particular time is proportional to the current rate of slip on its active slip systems. The distribution of slips at any one time depends on the current state of stress (or of straining). Thus, both the tensor character of the orientation change and its magnitude depend on the instantaneous boundary conditions. When the boundary conditions change during a test, the final texture should depend on the path taken, not only on the final 'finite strain' (or shape change) in the specimen: the strain, as usual, is not a state parameter.

While such a path dependence must exist in principle, it is not self-evident how sensitive a final texture may be to the path taken. For this reason, a series of test was undertaken to measure the effect quantitatively, and computer simulations of the same set of conditions were performed.[1] The general result was that, in very good agreement between experiment and theory, some paths turned out to give similar textures, some very different ones. The extreme case treated was a cube compressed many times in all three directions, with the result of zero net shape change at the end; it did exhibit a noticeable deformation texture (of cubic sample symmetry).

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In the present note, we summarize a single case: that of three different 'tension' paths. The experiments were performed on pure aluminum, machined by spark erosion to about 1 cm^3. The initial texture was a mild cross-rolling texture The calculations were based on a simulated but similar initial texture. They used the Los Alamos Polycrystal Plasticity code (LApp, version 4u), with a rate sensitivity of 0.03; relaxed constraints were not important at the strain levels used.

Overview

Figure 1(a) shows the geometry of a normal tensile tests, and the typical texture resulting after about 60% strain (in this case, by simulation, assuming a random initial texture). The texture is demonstrated on an 'inverse pole figure': it has a strong <111> and a mild <100> fiber component.

Figure 1(b) shows the geometry of repetitive channel-die test, where the specimen was rotated around the free direction between increments of straining. (Shims were inserted into the sides of the die, and the specimen was re-machined if necessary.) The inverse pole figure (again calculated using an initially random sample) is only a little different from the 'standard': the <111> fiber is weaker and more spread out.

Figure 1(c), finally, shows a specimen that underwent repeated unconstrained compression in two perpendicular directions, resulting in a net extension in the third direction. Here, the calculated texture is quite different: it appears virtually random, with a slight <u>absence</u> of orientations near <111>.

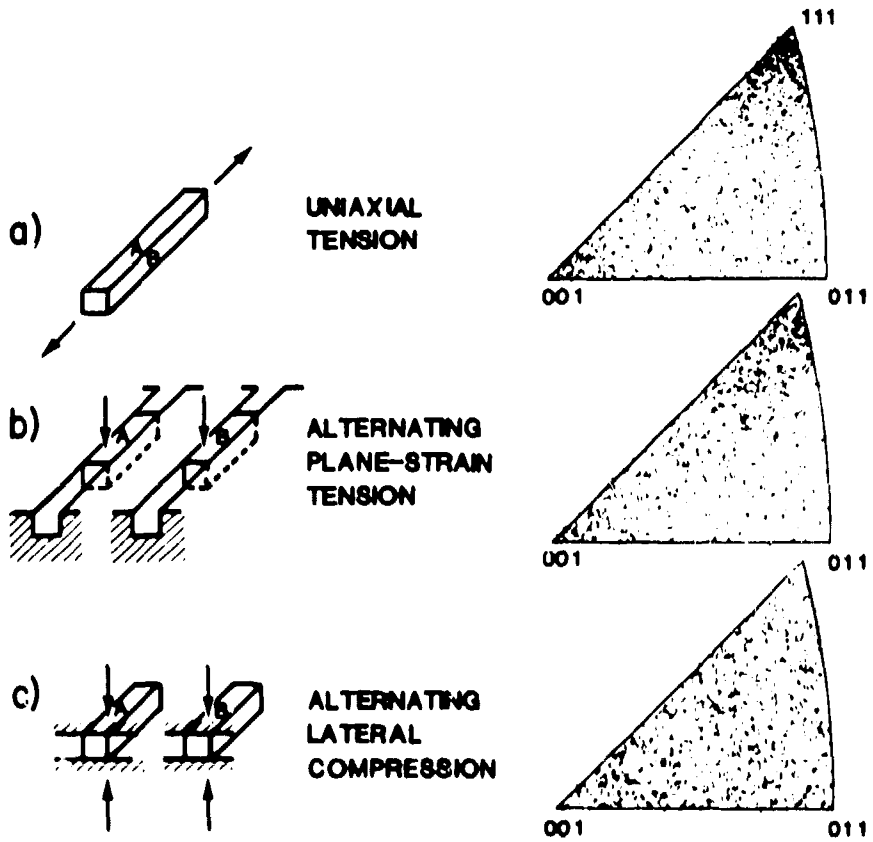

FIG. 1 – Three strain paths to achieve an eventual elongation perpendicular to the faces A and B. Inverse pole figures of the texture calculated after 60% extension.

Results

The actual experimental results, as well as the computer simulations based on the initial texture of the experimental samples, are displayed in detail in Fig. 2. All results are shown as Sample Orientation Distributions (SODs); i.e. as plots of the tensile axis in terms of a crystal reference frame, for different values of the azimuth and (at the far right) for all azimuths together: this is equivalent to the inverse pole figure already shown in Fig. 1. For a true fiber texture, there should be no dependence on the azimuth, and this is evident for the pure tension case (c, which was only done by simulation). The other two exhibit significant differences between the sections, as well they should. Note as a particular curiosity that the sample that underwent alternating lateral (free) compression (b) does exhibit a rather random projection (except for the hole near <111>), but is far from random in the sections.

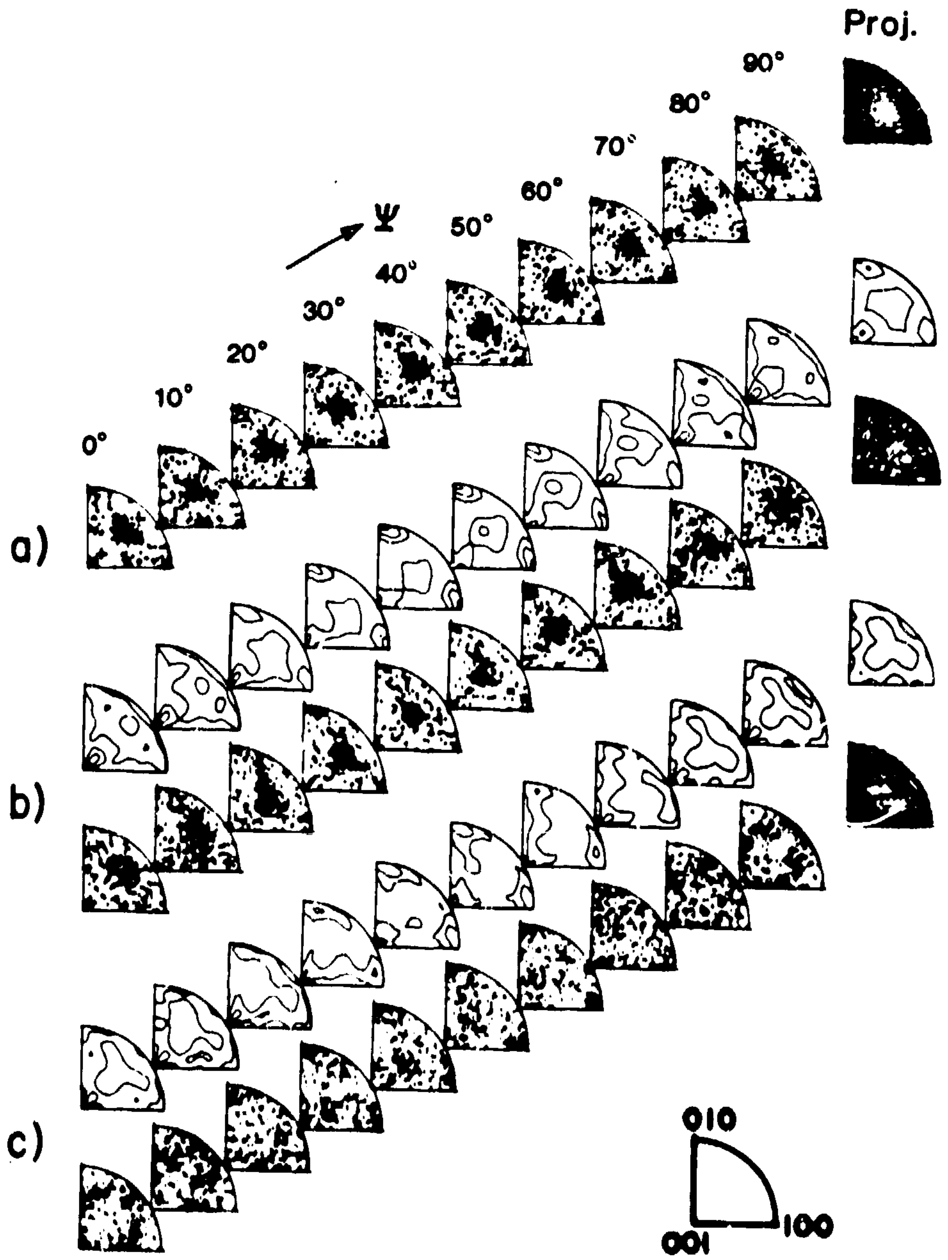

FIG. 2 – The same tests as in Fig. 1: experiments (contour lines) and simulations based on the initial texture (points), displayed as SODs.

Reference

1. T. Takeshita, U.F. Kocks and H.-R. Wenk: Acta Metall., submitted.