

## **FINITE-ELEMENT SIMULATION OF TEXTURE DEVELOPMENT IN POLYCRYSTALLINE METALS**

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### **Abstract**

Texture simulations are performed by the Representative Volume Element technique. An aggregate of grains with isotropic initial orientation distribution is subjected to large standard deformations. Within the grains, slip system theory with Voce-type hardening is implemented. The results are compared with experimental data.

Keywords: Finite Inelastic Deformations, Texture Induced Anisotropy

### **1. Introduction**

In Bronkhorst et al. (1992) experimental results of texture development of polycrystalline copper under different standard deformations have been reported, which clearly show the induction of anisotropy into an initially isotropic specimen.

The present simulation of this process has been performed by the Representative Volume Element technique (RVE). For that purpose, a cubic specimen has been implemented with 512 grains, each of them consisting of 5 constant strain tetrahedral elements. In the interior and on the boundaries of the RVE, a displacement split of the deformation into a homogeneous global one and a fluctuation part is assumed, such that the mean deformations equals the global one, and that the fluctuations on the boundaries fulfill periodic boundary conditions. In that way compatibility on the boundaries is gained, whereas equilibrium of the boundary tractions results from the finite element solution of the initial and boundary value problem. The initial ODF, assumed as isotropic, has been generated randomly, selected by a filter technique, and finally optimized by means of an appropriate isotropy measure.

Within the grains, the material is modelled by a slip system model taking into account the 12 octahedral slip systems of an FCC crystal. On each of them, a slightly rate dependent law with Voce-type hardening has been applied. The ration between latent and self hardening has been taken as 1.4.

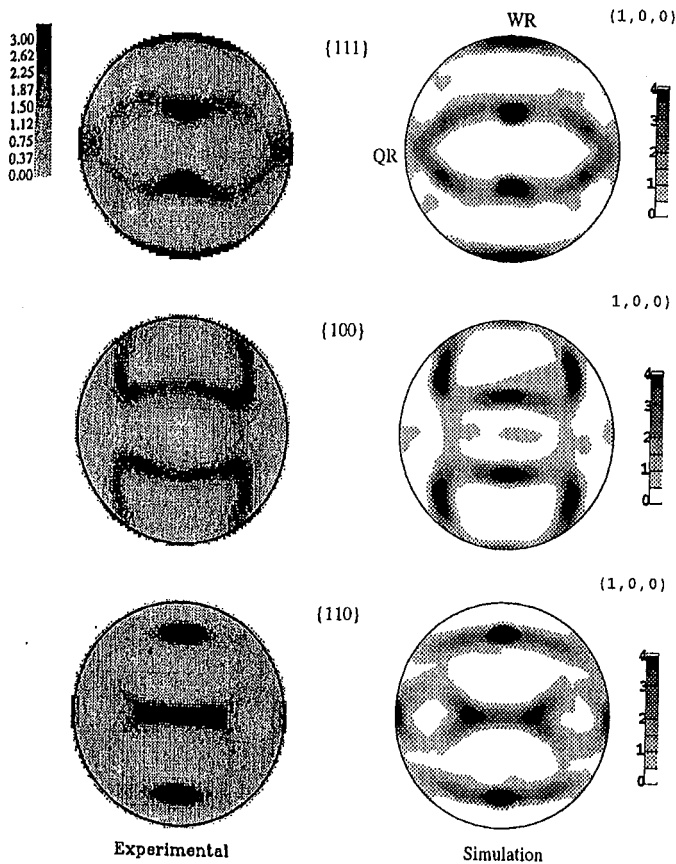


Fig. 1: Rolling texture

The specimen has been submitted to the following standard deformations, (A) uniaxial compression to 21% of the initial length, (B) uniaxial extension to 145%, (C) plane strain compression to 21%, and (D) simple shear up to a shear number of 1.5. All these tests imply large deformations, such that a fully nonlinear analysis had to be applied.

## 2. Texture

In Fig. 1 and Fig. 2 the resulting pole figures of test (C) and (D) are shown for the  $\{111\}$ ,  $\{100\}$ , and  $\{110\}$  orientations. Comparison of the experimental and simulated textures show good agreement in all cases. The analogue results for the other tests are shown in Kraska (1999).

Besides of these results the RVE-technique gives much more information on the resulting material, such that one can consider the RVE as "numerical laboratory" (C. Miehe). Indeed, by the results of the FEM calculation, we can among other

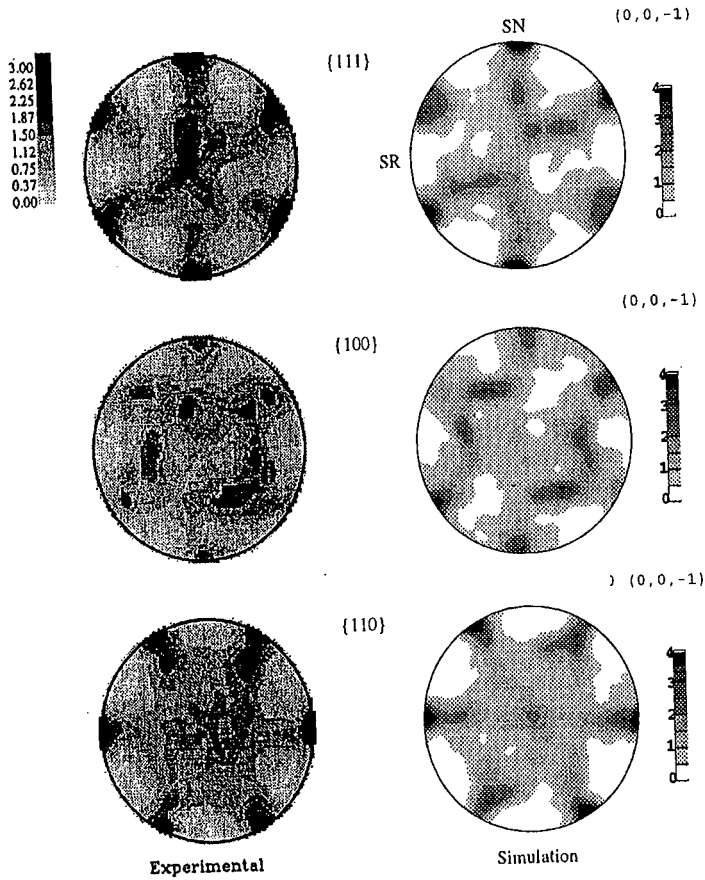


Fig. 2: Shear texture

features determine the induced elastic and inelastic anisotropy.

### 3. Elastic anisotropy

The induced elastic anisotropy can easily be investigated by the following procedure. By 5 independent shear tests and one compression test the elastic stiffnesses are identified. Their deviation from the initial (isotropic) ones indicates the texture induced anisotropy. The bulk moduli under all deformations remain the same, whereas the shear moduli vary up to 2.3% under compression. For many applications this effect is negligible. However, it is not unexpected and in accordance to experimental findings.

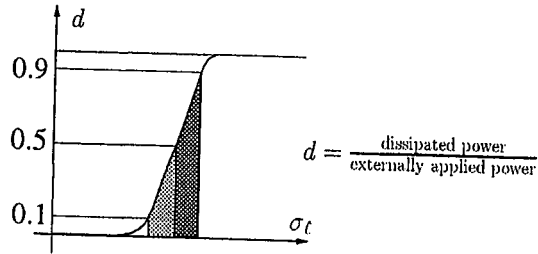


Fig. 3: The energy based yield indicator for different  $d$ -values

### 3. Inelastic anisotropy

The induced inelastic anisotropy is much more apparent and important. It can be investigated and demonstrated in different ways. One is to determine the yield loci with respect to different definitions. We are free to apply the usual offset criteria with different offset strains. However, we can also introduce energy based criteria, which can be easily evaluated by our RVE. One of them is the ratio  $d$  of the dissipated energy per unit time over the entire energy supply. In Fig. 3 this has been depicted for three different values of  $d$ . In Fig. 4 samples of the sheet after test (B) have been (computationally) strained in different directions within the three planes. In the three radiograms, the yield loci for the three  $d$ -values have been plotted for the three planes. When  $x$  indicates the tensile axis, the plots for the  $x$ - $z$ -plane are expected to equal those of the  $x$ - $y$ -plane. This can be observed, as well as a strong distortion of the yield loci due to texture development.

Another measure for the texture influence on further deformations is the Lankford coefficient or  $r$ -value. In Fig. 4 it is plotted versus the angle to the rolling direction and compared with experimental results of Fundenberger (1993) for an aluminum sample submitted to the same channel die test. Although these data stem from different materials, the qualitative similarity gives rise for another promising applications of the RVE results.

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### 4. Conclusions

The RVE technique with periodic boundary conditions and FEM solutions is shown to be a "numerical laboratory" for investigations of various aspects and details of texture evolution in polycrystalline materials. Comparison with experimental results give good agreement with the numerical simulation. For further results the reader is referred to Bertram et al. (1999) and Kraska (1999).

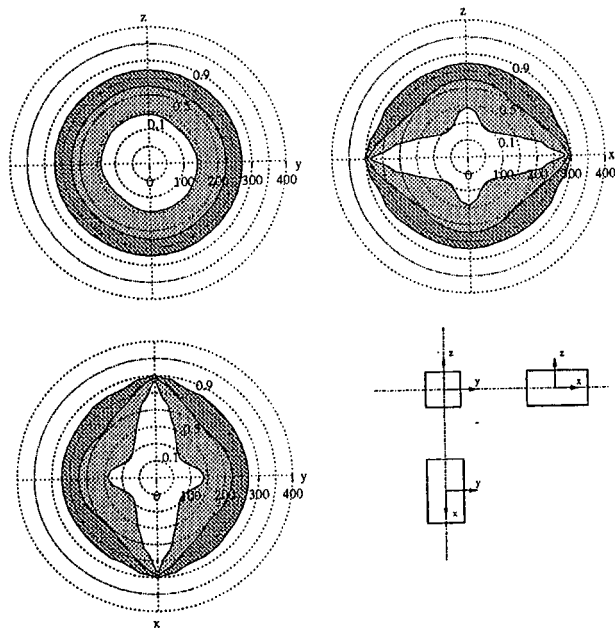


Fig. 4: Yield loci for tensile tests with different inplane directions

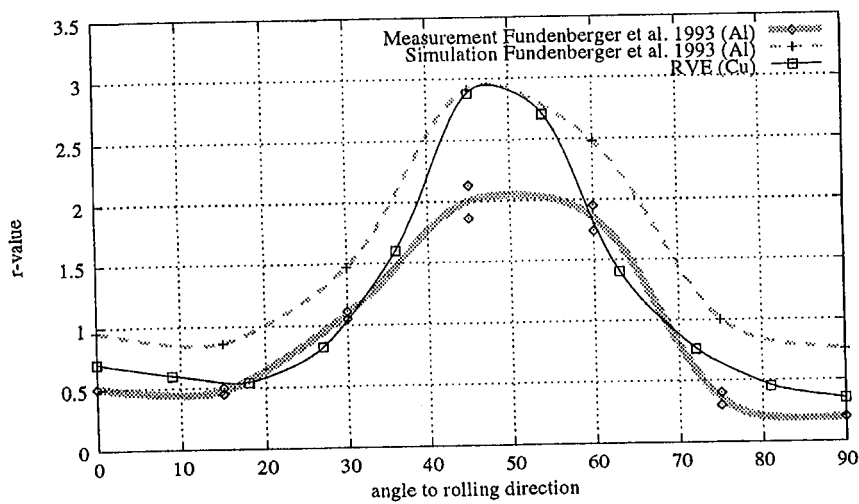


Fig. 5:  $r$ -values in simulation and experiment

## 5. References

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