

DEFORMATION TEXTURES : CONNECTION BETWEEN MODELLING AND EXPERIENCE IN ELASTOPLASTIC BEHAVIOUR OF POLYCRYSTALS.

F. ROYER⁽¹⁾, T. BAUDIN⁽²⁾, D. CECCALDI⁽²⁾, R. PENELLE⁽²⁾,
C. PEYRAC⁽³⁾, C. VIAL⁽⁴⁾

(1) Université de Metz, IPER, CMSR/LPMC, 1 bld Arago,
57070 METZ.

(2) Laboratoire de Métallurgie Structurale, UA 1107,
bat. 413, 91405 ORSAY.

(3) IRSID, 185 rue du Président Roosevelt,
72105 SAINT GERMAIN EN LAYE.

(4) Pontifica Universidad Catolica de Chile, Departamento
de Eng. Meca. i Metallurgica, vicuna Mackenna,
48060 SANTIAGO, CHILI.

Two materials of industrial interest are studied, an α -brass and an aluminium 1050 sheet, either from an experimental point of view (results of classical mechanical tests, complex loading pathes, measurement of the poles figures) as from a theoretical approach based on the modelling of the elastoplastic behaviour of the polycrystal.

1' INTRODUCTION

The general framework of this contribution can be described as follow :

a) α -brass : the classical mechanical tests such as uniaxial tension along the transverse and rolling direction, biaxial tension and close to plane-strain deformation are performed.

b) aluminium : the influence of a prestrain is studied in the case of complex loading pathes.

c) quantitative measurements of the initial and deformation textures are realized using either X-rays or neutron diffraction.

d) an attempt is made to reproduce the deformation textures by modelling the anisotropic behaviour of polycrystalline materials in the framework of a self consistent scheme.

2' INITIAL STATE, MECHANICAL TESTS AND TEXTURES

a) α -brass specimen :

the sample is a cold rolled strip with intermediate and final annealing. The grains are approximatively equiaxed but with mixed grain sizes (diameters between 25 and 50 μm).

The yield locus of the α -brass has been determined using the uni-

axial tensile test, biaxial expansion (bulge test) and a specific geometry of the sample which allows to involve simultaneously close to plane-strain deformation and uniaxial tension [1,2]. The principal results obtained are the following :

- the biaxial flow stress appears greater than the average uniaxial stress even though the Lankford's coefficient is less than one ;

- plane-strain flow stresses either in rolling or transverse directions are greater than in uniaxial tension at low strains. Increasing strain implies that flow stresses under uniaxial or plane-strain become very similar ;

- under uniaxial tension the flow stress along the transverse direction has a greater rate of hardening then along the rolling direction.

In figure 1 are plotted experimental and predicted strain curves with Hill's yield criterion [3].

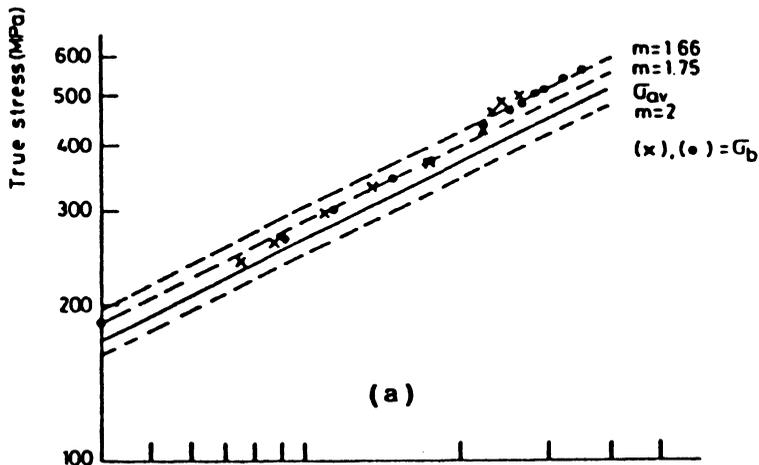


figure 1 : experimental and predicted stress/strain curves.
Hill's yield criterion (1979) : biaxial expansion.

These results and the summary of all the results concerning other loading paths lead to the fact that a description of anisotropy by currently proposed yield criteria [3,4] is not sufficient for α -brass. So the question can be asked on the nature of the informations that can be put out from texture measurements. Because of the geometry of some deformed samples and for the precision of the measurements, textures have been determined by neutron diffraction on a channel of the nuclear reactor of Saclay. Figure 2 shows how the initial texture $\{ 112 \} \langle 110 \rangle$ associated with the cubic component $\{ 001 \} \langle 100 \rangle$ transforms in significant textures (and peaks intensities) in regards to the loading path.

b) aluminium 1050 sheet :

in a second set of experiences, uniaxial tensile tests along the rolling and transverse directions are performed on a material with a sharper texture as the previous one. Furthermore the influence of a predeformation is studied in the framework of a combination of tensile tests in the rolling direction plus transverse direction and vice-versa. In this study too a particular geometry of the test sample [5] is used. Once more the importance of the crystallographic texture evolutions can be pointed out : [6]

- the initial texture is described by two components, one near $\{ 123 \} \langle 112 \rangle$ and the $\{ 100 \} \langle 001 \rangle$ one ;

- tension $\not\parallel$ RD : widening of the peak around $\langle 111 \rangle$. No rotation of the peaks at 25° from ND. Decrease of the cubic component without vanishing ;

- tension $\not\parallel$ TD : reinforcement of the $\{ 111 \}$ poles in their initial position. At 20 % of deformation the $\{ 112 \} \langle 123 \rangle$ component moves to $\{ 112 \} \langle 110 \rangle$;

- prestrain $\not\parallel$ RD + tension $\not\parallel$ TD : a "memory effect" of the first deformation is displayed at the earlier stage strain $\not\parallel$ TD.

For higher strains, the peculiarities of a RD tension appears.

- prestrain $\not\parallel$ TD + tension $\not\parallel$ RD : the texture obtained is typically the one developed during the second path on and after the first RD strain.

Some of these important modifications of the crystallographic textures during the complex loading pathes are plotted in the figure 2. Such results are of fundamental interest in an attempt of controlling the texture development.

3') MODELLING OF THE PLASTIC BEHAVIOUR.

The results of two classes of models are referred :

- full constraint Taylor models [7],

- self consistent code based on the integration of the dislocation densities in an elastoplastic behaviour [8].

Table 1 presents the Taylor's factors for the α -brass sample. From a textural point of view one may conclude that the flow stress in uniaxial tension along TD is greater than the corresponding one along RD in deformed states.

The hardening strain rate in plane-strain is lower (slightly higher in biaxial expansion) than in uniaxial deformation. Always in the framework of the Taylor's model, a qualitative analysis of the yield loci obtained for the aluminium sample does not show drastic differences.

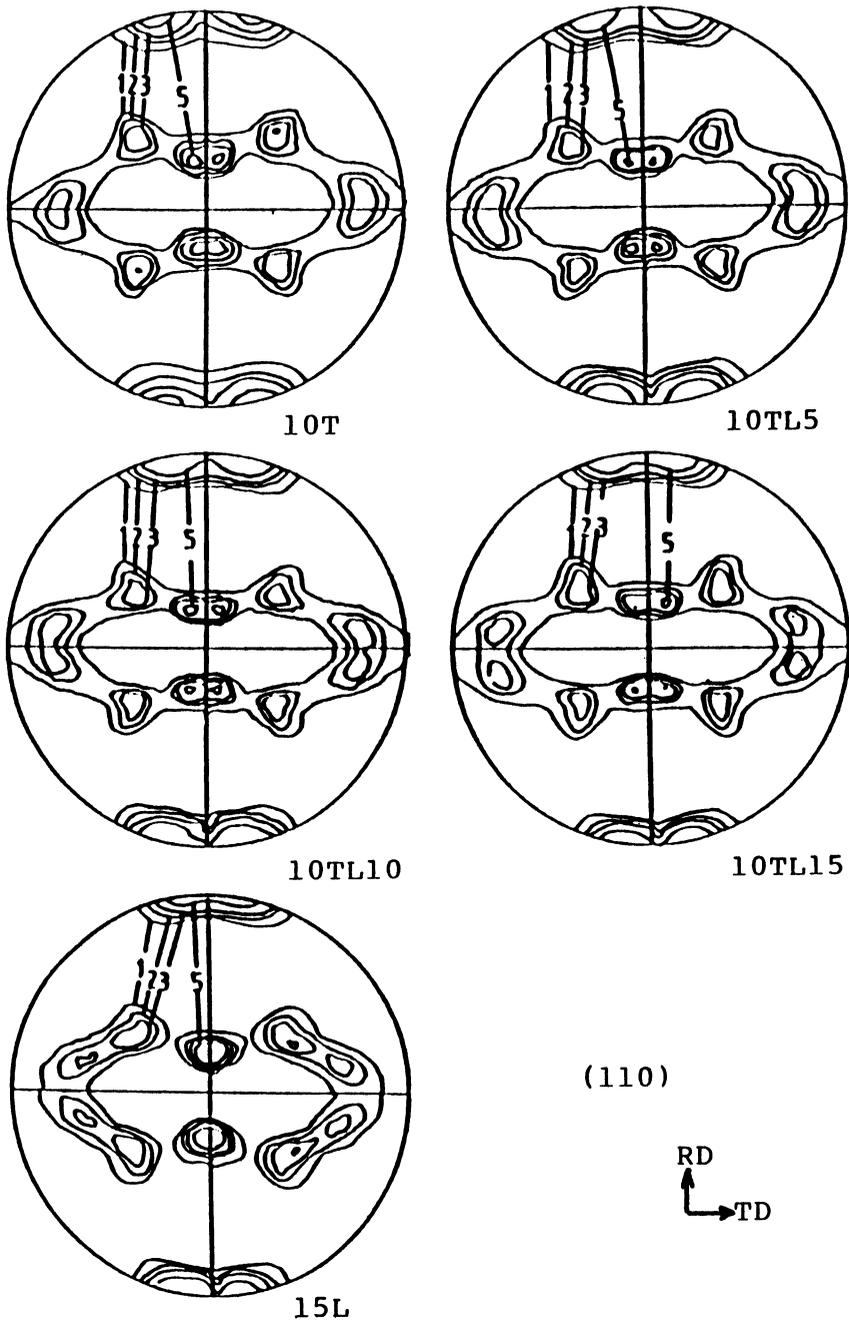


figure 2 : influence of a prestrain :
 10T : 10 % deformation along TD
 15L : 15 % deformation along RD
 10TL5 : 10 % / TD + 5 % / RD
 10TL10 : 10 % / TD + 10 % / RD
 10TL15 : 10 % / TD + 15 % / RD

Table 1 : variations of the Taylor's factors.

LIR (initial state) ; BI22 (biaxial tension - 22% in the plane of the sheet) ; LL24 and LT26 (respectively 24 and 26% uniaxial tension along RD and TD) ; PL22R and PL22T plane strain along RD and TD) ; X, Y : RD and TD ; PLX, PLY : plane strain along RD and TD ; B : biaxial expansion.

	LIR	BI22	LL24	LT26	PL22R	PL22T
X	3.044	3.070	3.059	3.116	3.113	3.025
Y	3.023	3.052	3.134	3.037	3.065	3.136
PLX	3.362	3.395	3.290	3.383	3.344	3.378
PLY	3.240	3.275	3.355	3.246	3.281	3.256
B	3.066	3.142	3.110	3.090	3.111	3.110
Y45	3.100	3.068	3.058	3.051		
$X_{av}=(X+Y)/2$	3.034	3.061	3.097	3.077		

This means that the crystallographic hardening is small but nothing allows to say that it is non-existent. The deformation textures obtained with an orientation set of 216 grains are plotted in figure 3. If the preliminary calculations lead to some interesting results, it appears that the basis set does not contains enough informations to describe with a good accuracy the initial texture.

4') CONCLUSION.

The importance of the crystallographic texture in the description of the anisotropy of polycrystals is clearly pointed out is this contribution. The fundamental interest for complex loading pathes has to be seriously developed because of the large amounts of results that can be obtained concerning the development of textures during industrial processes. The choice of a basis set including all the informations of the initial texture has to be discussed.

REFERENCES.

- (1) C. VIAL, J. Mech. Sci., 29, 29 (1987).
- (2) A. Pochettino, C. Vial and R. Penelle, this conference.
- (3) R.Hill, "Theoretical plasticity of textured aggregates", Math. Proc. Phil. Soc., 85, 179 (1979).
- (4) C. Vial, W. Hosford and R.M. Caddell, "Yield loci of anisotropic sheet metals", Int. J. Mech. Sci., 25, 899 (1983).
- (5) J. P. Boehler, L. El Aoufi and J Raclin, Res. Mechanica, 21, 73 (1987)
- (6) C. Peyrac, "Contribution à l'étude de l'anisotropie cristallographique induite", thèse de docteur-ingénieur, (1988), Orsay.

(7) G. I. Taylor, *J. Inst. Metal*, 62, (1938)

(8) P. Macheto, J. J. Engel, M. Pernot and R. Penelle, *International Colloquium CNRS n°319 "Comportement plastique des solides anisotropes"*, editions du CNRS, eds J.P. Boehler, (1985), 157.

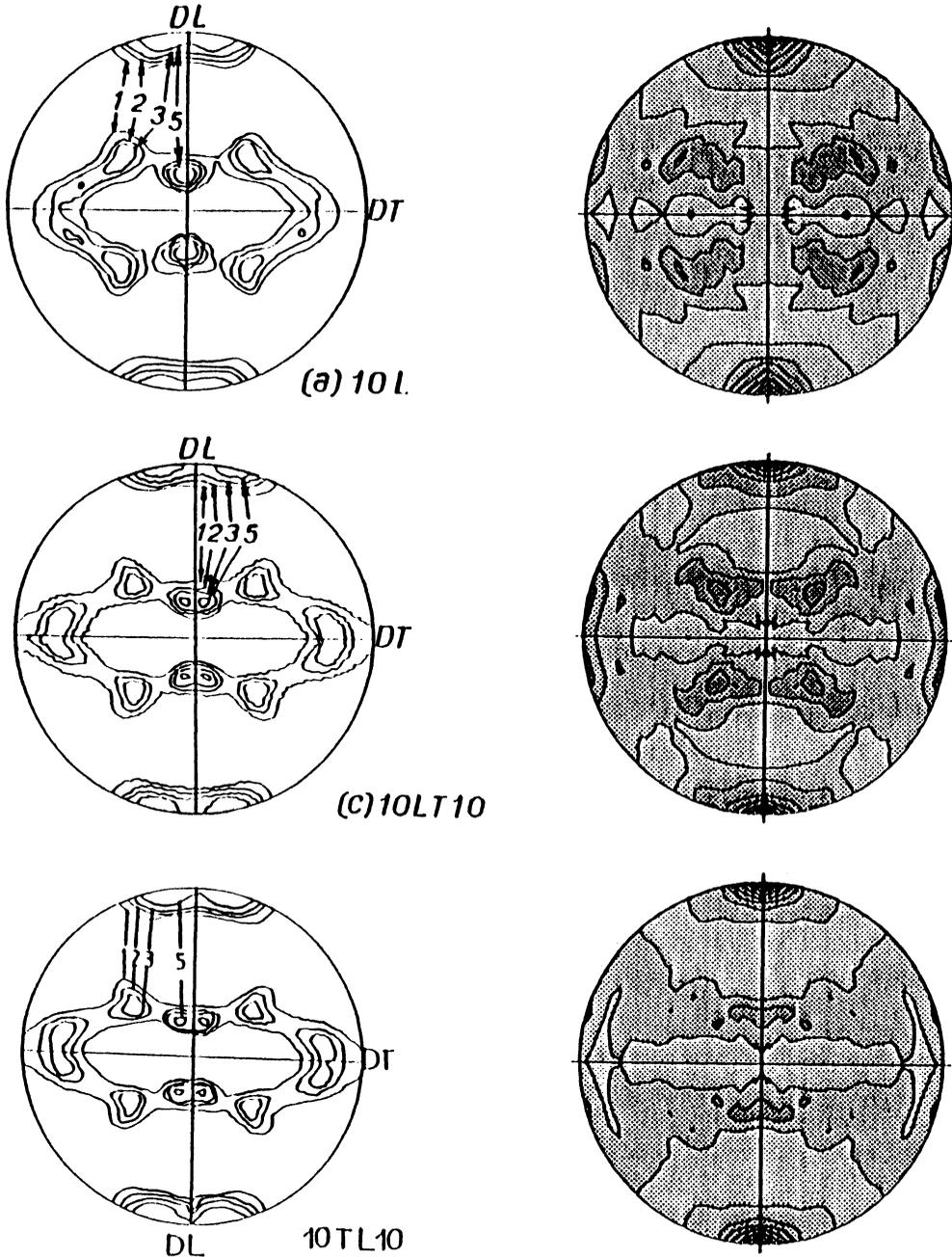


figure 3 : comparison between experimental and calculated textures of the Al 1050 sample.