Typical Textures, part 2
FCC Torsion, BCC textures

A. D. Rollett
27-750
Texture, Microstructure & Anisotropy

Last revised: 26th Apr. ‘14
Objectives

• Part 1 of the slides covers shear (torsion) and rolling textures; part 2 covers some aspects of textures in BCC metals.
Shear Texture

• Shear strain means that displacements are tangential to the direction in which they increase.

• Shear direction=1, Shear Plane $\perp$ 2-axis

Note the definition of strain, $\varepsilon_{ij}$, as the derivative of the displacement $u_i$ with respect to coordinate $x_j$. 

$2 = Torsion Axis = \{hkl\}$

$1 = Shear Direction = <uvw>$

$\varepsilon_{12} = \tan \theta$

$d\varepsilon = \begin{pmatrix} 0 & +\Delta & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$
Torsion Textures: twisting of a hollow cylinder specimen

Sense of shear:

Torsion Axis
Shear Textures: idealized texture components for FCC metals

A partial fiber \{111\}<uvw>
B partial fiber \{hkl\}<110>
C component: \{001\}<110>
Shear Texture Components

• Why study shear textures? Shear strain is common near the surface of rolled parts, for example.

• Partial Fibers:  
A/D \{111\}<uvw>…<110>  
B \{hkl\}<110> … \{112\}  
Components C \{001\}<110>  
D \{112\}<111>  
E \{011\}<111>  
F \{110\}<001>
{100} Pole figures
Montheiliet et al.,
Acta metall., 33, 705, 1985

Table 1. Notation and Miller indices used for the different ideal orientations

<table>
<thead>
<tr>
<th>A</th>
<th>[111]&lt;110&gt;</th>
<th>C</th>
<th>[001]&lt;110&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>A†</td>
<td>[111]&lt;112&gt;</td>
<td>D₁</td>
<td>[111]&lt;111&gt;</td>
</tr>
<tr>
<td>A†</td>
<td>[111]&lt;112&gt;</td>
<td>D₁</td>
<td>[111]&lt;111&gt;</td>
</tr>
<tr>
<td>B</td>
<td>[110]&lt;110&gt;</td>
<td>E</td>
<td>[111]&lt;111&gt;</td>
</tr>
<tr>
<td>B</td>
<td>[110]&lt;110&gt;</td>
<td>E</td>
<td>[111]&lt;111&gt;</td>
</tr>
</tbody>
</table>

Fig. 4. Stereographic plots of the ideal orientations listed in Table 1. (a) and (c): inverse pole figures showing the orientations of the j and k unit vectors for the f.c.c. (a) and b.c.c. (c) components. The angle \( \psi \) is defined in Section 5. When \( \phi = 0 \), j and k coincide with the \( \theta \) and z axes of the specimen, respectively. (b) and (d): \{100\} pole figures associated with the f.c.c. (b) and b.c.c. (d) ideal orientations.
FCC Torsion Textures

Plots of \{111\} and \{200\} pole figures (equal area projection; torsion axis vertical) for the following materials deformed in torsion; the shear direction points to the left in these figures.

a) Nickel at $\gamma=3.6$

b) Copper at $\gamma=3.5$

c) Silver at $\gamma=3.5$

d) Cu-30Zn at $\gamma=3.5$

e) Ni-60Co at $\gamma=3.2$

Note that the partial "A" fiber is present in Ni and Cu, but is absent in the other materials. Silver, brass and Ni-60Co show instead a "D" fiber which is similar to the A fiber but rotated approximately 90° about the torsion axis. The B fiber is present to varying degrees in all the materials.

Kocks, Ch. 5
**BCC uniaxial textures**

92% rolled Ta
Tensile test in original RD to strain of 0.6: <110> fiber

(a) Normal and rolling direction inverse pole figures (equal area projection) of 92% rolled Ta and (b) Prior normal and rolling direction inverse pole figures for (a) tested in tension to a strain of 0.6 (tensile direction coincident to prior rolling direction).

Kocks, Ch. 5
BCC torsion textures: Fe

Ideal \{|100\} pole figures

\[
\begin{array}{c}
\text{D_1} \\
\text{D_2} \\
\text{E_1} \\
\text{E_2} \\
\text{F}^* \\
\end{array}
\]

Fig. 18. Experimental 200 and 110 pole figures for Armco iron sheared to \(\gamma=2.1\) (\(e_M=1.2\)) [WILLIAMS 1962] (Stereographic projection.) The shear direction points right on top.
**BCC torsion textures: Ta**

(a) initial texture from swaged rod;  
(b) torsion texture

---

**Ideal \{100\} pole figures**

Fig. 19. Recalculated 111, 100 and 110 pole figures for tantalum: (a) initial texture; (b) tested in torsion to \( r_{\text{VM}} = 1.4 \). Equal-area projection.

Kocks, Ch. 5
Rolling Textures BCC

\{110\} and \{100\} pole figures (equal area projection; rolling direction vertical) for (a) low-carbon steel cold rolled to a reduction in thickness of 80\% (approximate equivalent strain of 2); (b) tantalum, unidirectionally rolled at room temperature to a reduction in thickness of 91\%.

Kocks, Ch. 5
\{100\} Pole figure for certain components of rolled BCC metals

Note how very different components tend to overlap in a pole figure.

Kocks, Ch. 5
BCC fibers: the $\phi_2 = 45^\circ$ section

Fig. 6. Exact positions of important orientations in the $\phi_2 = 45^\circ$ section.
Ta, Fe rolling textures

Note: Euler angles are Roe angles: axes transposed with $\Theta$ horiz., $\psi$ vertical.

Fig. 15. Plot of the 45° sections ($\phi=45°$, Roe angles) for the same steel and tantalum textures shown in Fig. 13: (a) low-carbon steel prior to cold rolling; (b) low-carbon steel cold rolled to a reduction in thickness of 80% (approximate equivalent strain of 2); (c) tantalum, unidirectionally rolled at room temperature to a reduction of 91%. The contours are drawn at multiples of the random intensity of 1, 2, 3...7. Note the weaker intensities in the tantalum, and the stronger $\alpha$ fiber in the steel.

Fig. 16. Plot of the 45° sections ($\phi=45°$, Roe angles, origin in lower left corner) for steels with 0% and 2% Si, both as hot-rolled (initial condition) and after 75% reduction cold rolling. The strongest intensity is at the (112)(110) position in the 0% Si-steel, whereas it is at the (111)(110) position in the 2% Si-steel. Note that a weak RD||(110) fiber is already present in the hot rolled 2% Si-steel.
Note the marked alloy dependence in the alpha fiber; smaller variations in the gamma fiber.

Fig. 17. Plot of the $\alpha$ and $\gamma$ fibers for a range of iron-Si alloys, including 0, 1, 2, & 3% Si. Increasing silicon leads to stronger $\alpha$ fibers in both the hot-rolled (initial) condition and the cold-rolled condition.
Summary: part 2

• Typical textures illustrated for shear textures and for $bcc$ metals.
• Pole figures are recognizable for standard deformation histories but orientation distributions provide much more detailed information.