An unfortunate perception of undergraduate life ...

Example: beverage cans
Beverage Can Making


Example: beverage cans
Strain Ratio in Tensile Test

Plastic Strain Ratio (r-value)

\[ r = \frac{\ln(W_i / W_f)}{\ln(T_i / T_f)} = \frac{\ln(W_i / W_f)}{\ln(L_f W_f / L_i W_i)} \]

\[ r_m (r - value) = \frac{1}{4} (r_0 + 2r_{45} + r_{90}) \]

\[ \Delta r \text{(planar – anisotropy)} = \frac{1}{2} (r_0 - 2r_{45} + r_{90}) \]

Large \( r_m \) and small \( \Delta r \) required for deep drawing

Example: beverage cans
Correlation of Earing with $\Delta R$

![Graph showing the correlation of earing with $\Delta R$.](image)

**Figure 14-12** Correlation of extent of earing with $\Delta R$. From D. V. Wilson, and R. D. Butler, *ibid.*

Example: beverage cans
Relation of Earing to Deformation, Annealing texture

Example: beverage cans
Earing-Texture Correlation

- Deformation texture $\Rightarrow 45^\circ$ ears
- "Balanced" texture
- Annealing texture $\Rightarrow 0,90^\circ$ ears

Example: beverage cans
Texture-Formability in Steels

Fig. 1.18 shows the relationship between r-value and the ratio of intensities of the 001 and 111 components in a sheet.

Fig. 1.19 shows the relationship between limiting blank diameter and r-value for low carbon steels.

Fig. 1.20 shows the relationship between the mean fractional increase in thickness at the top rim of a Swift cup for low-carbon steels.

Example: bev
Swift Cup Test

Another common method to test sheet formability is the swift cupping test (standard: IDDRG guidelines). Circular blanks with increasing diameter $D_o$ are deep drawn into a cylindrical cup and the maximum diameter $D_{o\text{ max}}$ is determined. Dividing by the punch diameter it gives the limiting draw ratio:

$$\beta_{o\text{ max}} = \frac{D_{o\text{ max}}}{d_o}$$
**Nb Sheet Example**

- Two different areas of a Nb sheet, “upper” and “lower” were scanned with EBSD to evaluate variability in formability.
- The pole figures and inverse pole figures showed strong differences.
**Nb Sheet Example: IPFs**

- Note the differences in intensity in the 001 and 111 locations in the ND/001 inverse pole figure for the two samples.
  - Upper 111: 7.5
  - Upper 001: 0.0
  - Lower 111: 0.8
  - Lower 001: 10.0
- These numbers suggest significant differences in r-value and formability.

Example: beverage cans
**Nb sheet example, contd.**

- The two samples are, in fact, at opposite ends of the chart of r-value versus 111:001 intensity ratio!
- The yield surfaces (calculated with the Lapp code) for the two samples also show marked differences, consistent with the other information.