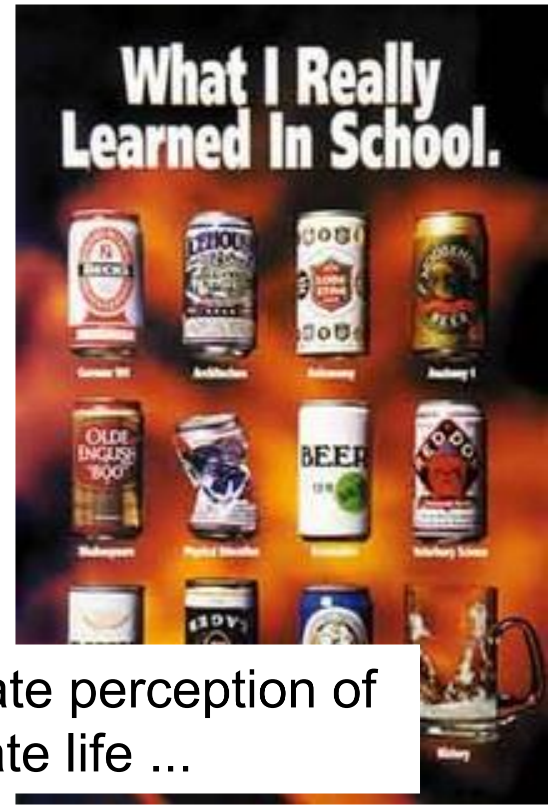
Carnegie Mellon

Texture, Anisotropy & Beer Cans

A.D. Rollett

27-750

Texture, Microstructure & Anisotropy



An unfortunate perception of undergraduate life ...

Updated 27th Jan. 2016

Example: beverage cans

MSE

Beverage Can Making

refs: Altenpohl, D. G. (1998). *Aluminum: technology, applications and environment*. TMS, the Aluminum Association; *Steels*. Llewellyn & Hudd, Butterworth & Heinemann.

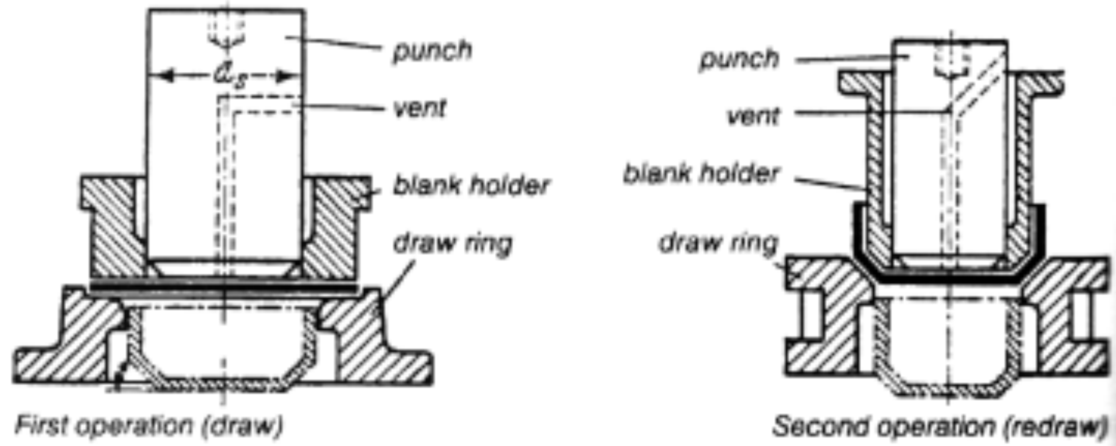


Fig. 9.33: Schematic illustration of deep drawing. For deep drawing, precision sheet (mostly circular blanks) is formed in a lubricated fixture. A blank holder prevents wrinkles from forming. For extra deep draws, the operation can be carried out in successive steps (possibly with an intermediate anneal). d_s = punch diameter. Shown in solid black are (left) the blank and (right) the semifinished deep-drawn part.

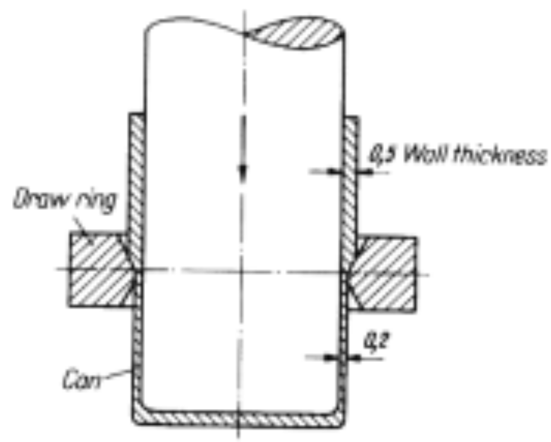


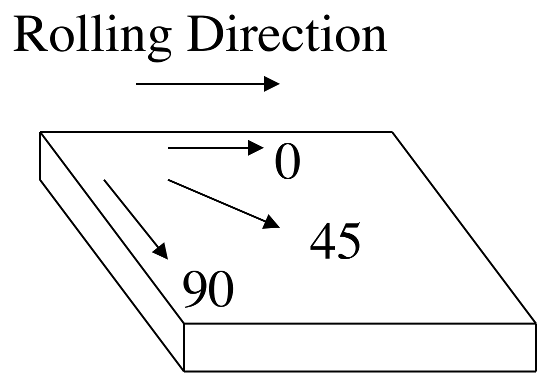
Fig. 9.34: Schematic showing wall ironing of an aluminum beverage can. Often a series of draw rings are used.

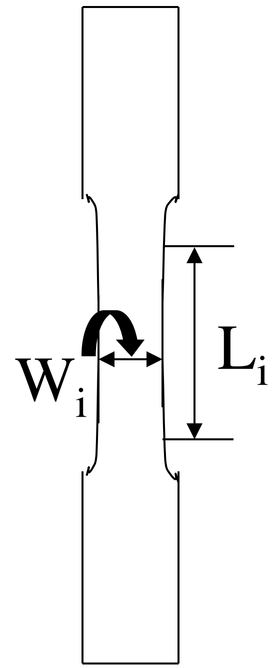
Strain Ratio in Tensile Test

Plastic Strain Ratio (r-value, or Lankford parameter)

W: width
T: thickness
L: length

i: initial
f: final





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

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

$$\Delta r(planar - anisotropy) = \frac{1}{2}(r_0 - 2r_{45} + r_{90})$$

Large r_m and small Δr required for deep drawing

Example: beverage cans

Correlation of Earing with ΔR

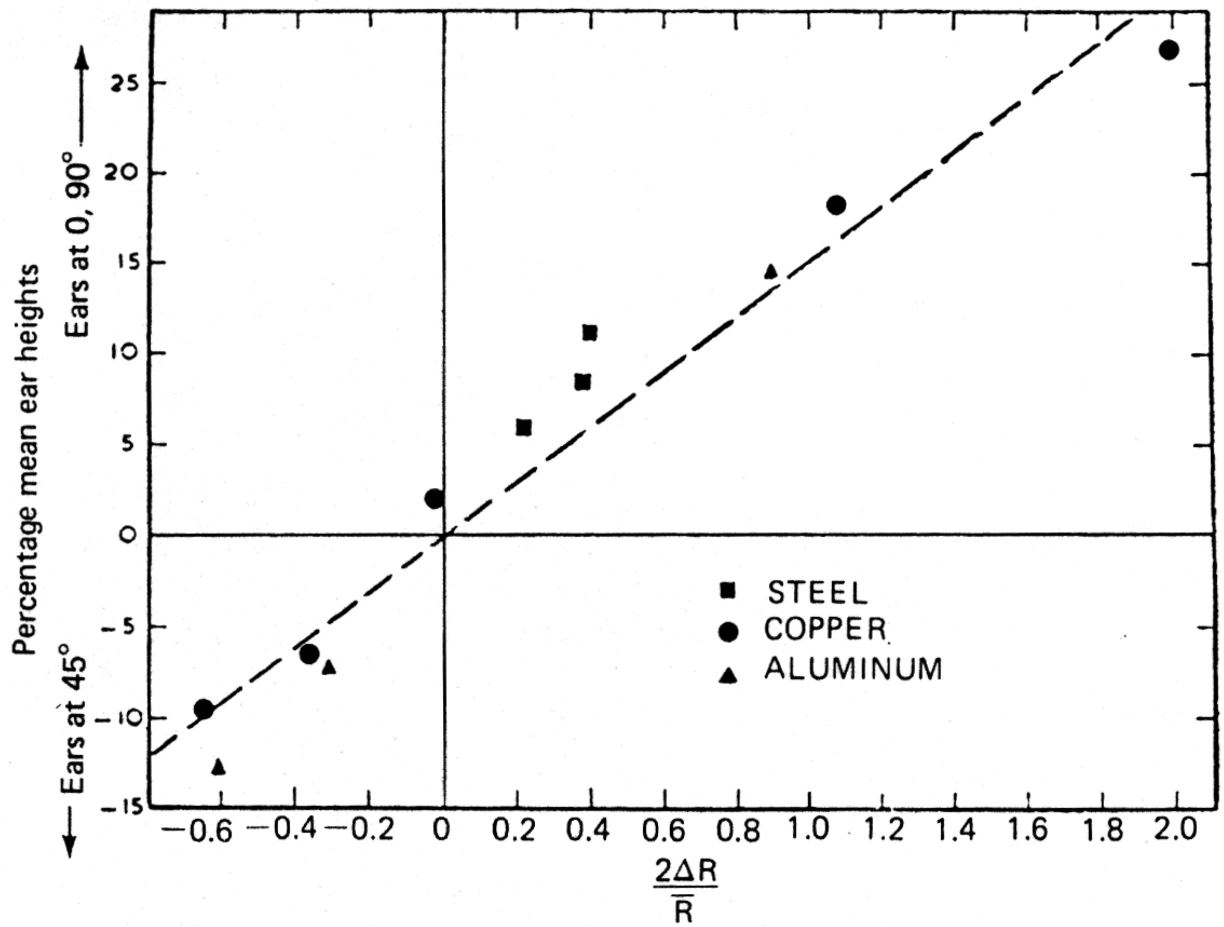


Figure 14-12 Correlation of extent of earing with ΔR. From D. V. Wilson, and R. D. Butler, *ibid.*

Example: beverage cans

Relation of Earing to Deformation, Annealing texture

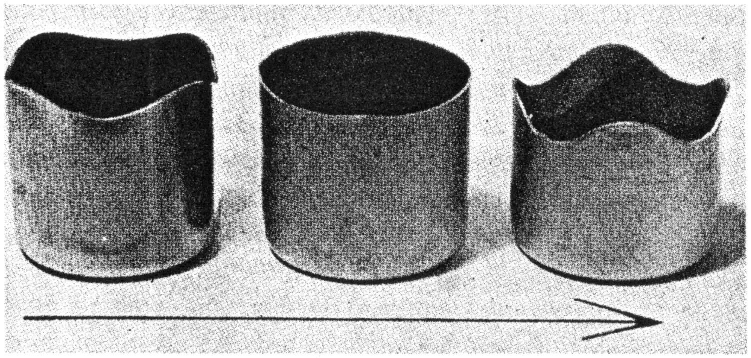


Figure 14-10 Earing behavior of cups made from three different copper sheets. Arrow indicates rolling direction of the sheets. From D. V. Wilson and R. D. Butler, *J. Inst. Met.*, 90 (1961–2), pp. 473–83.

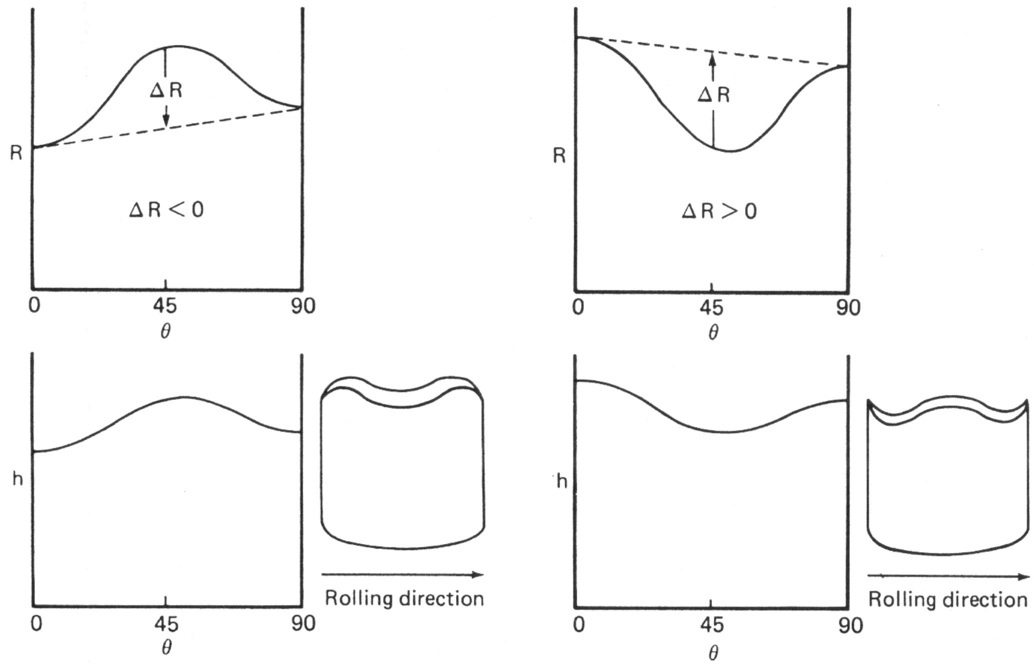
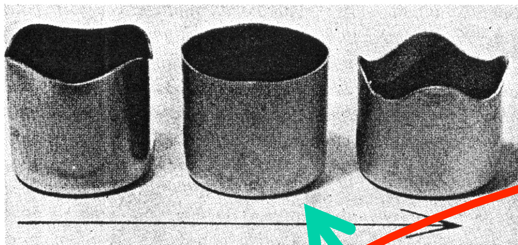


Figure 14-11 Relation of earing to angular variations of *R*. Here, *h* is the wall height.

Example: beverage cans

Earing-Texture Correlation

deformation texture ⇒ 45° ears



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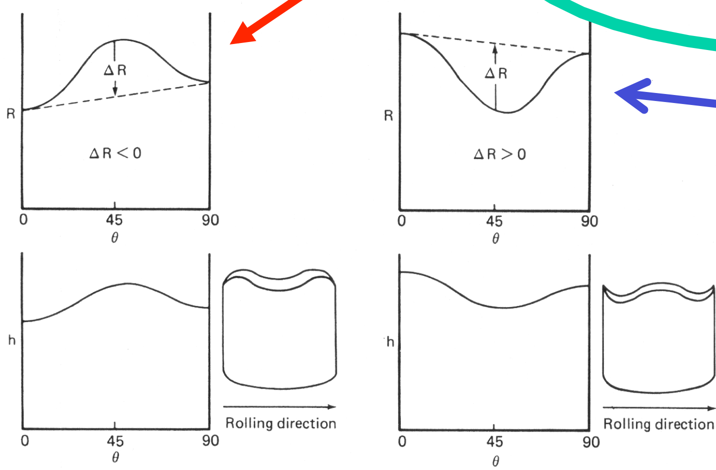
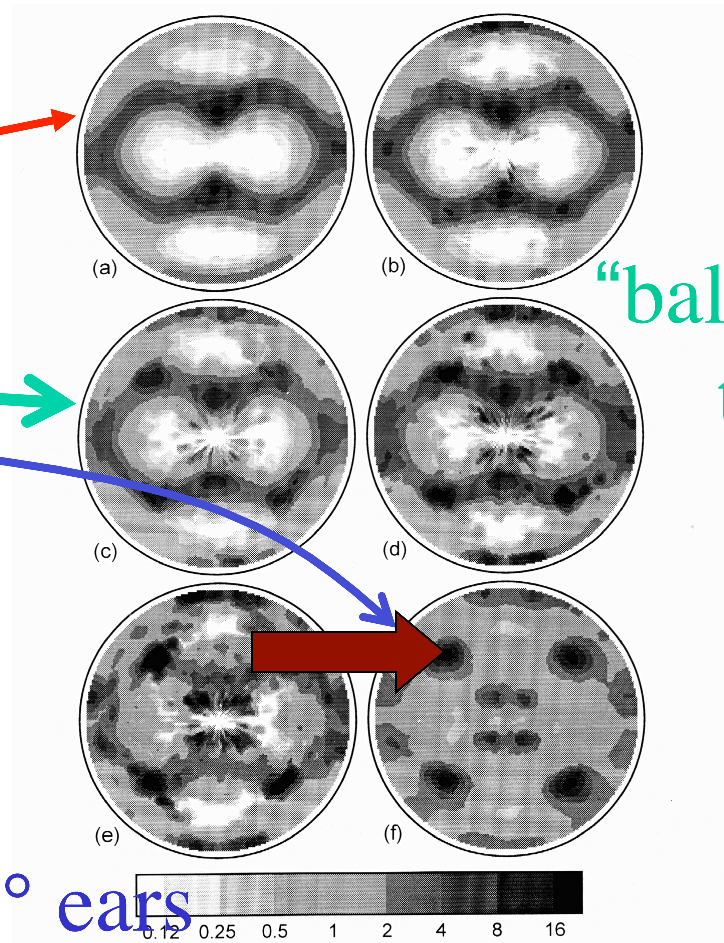


Figure 14-11 Relation of earing to angular variations of *R*. Here, *h* is the wall height.



"balanced" texture

annealing texture ⇒ 0,90° ears

Texture-Formability in Steels

Llewellyn

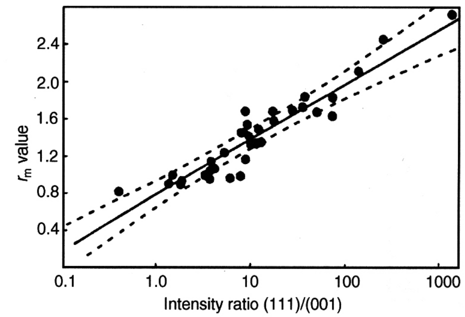


Figure 1.18 *Relation between the ratio of the intensity of the (111) component to the intensity of the (001) component and the r_m value of low-carbon steel sheets (After Held[39])*

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

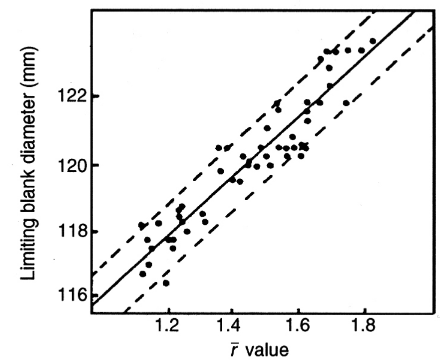


Figure 1.19 *Effect of $\bar{r}$ on limiting blank diameter for a range of low-carbon steels for Swift cups drawn using polythene sheet lubrication (After Atkinson and Maclean[40])*

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

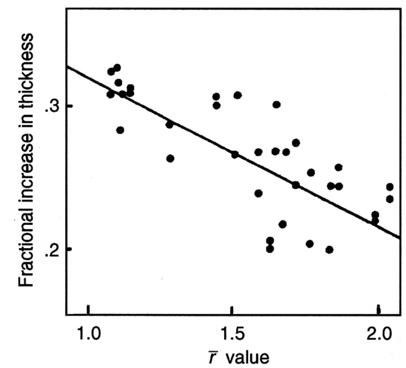


Figure 1.20 *Relationship between mean fractional increase in thickness at the top rim of a Swift cup and $\bar{r}$ value, for a range of low-carbon steels, Blank diameter 63.5 mm – Punch diameter 32 mm (After Hudd and Lyons[41])*

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

aluMATTER:Testing Methods

http://aluminium.matter.org.uk/content/html/eng/default.asp?catid=175&pageid=214

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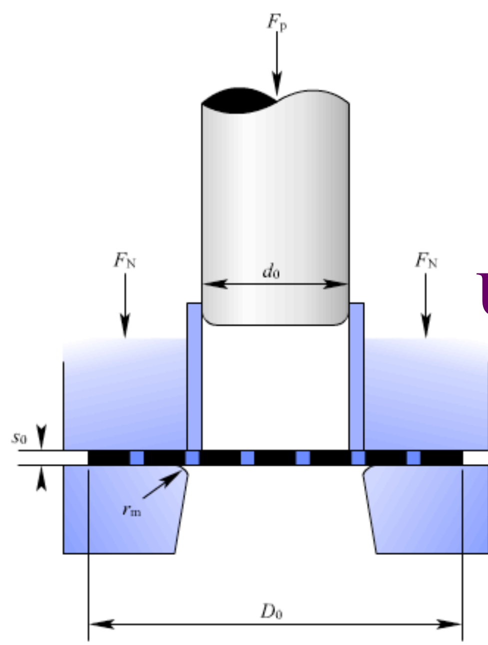
Swift Cup Test

Sub Topics: Tensile 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 $D_{o\,max}$ is determined. Dividing by the punch diameter it gives the limiting draw ratio:

$$\beta_{o\,max} = D_{o\,max} / d_o$$

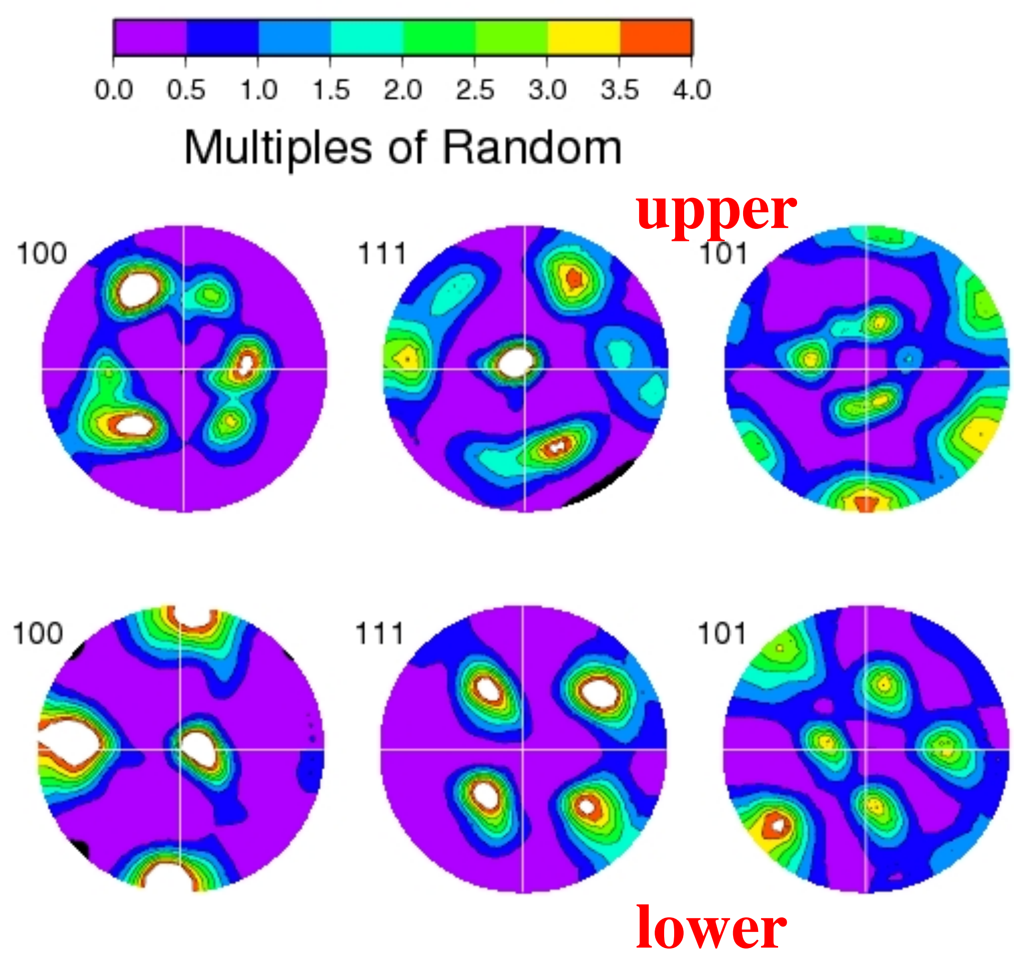


Transferring data from aluminium.matter.org.uk...

URL: aluminium.matter.org.uk

Nb Sheet Example

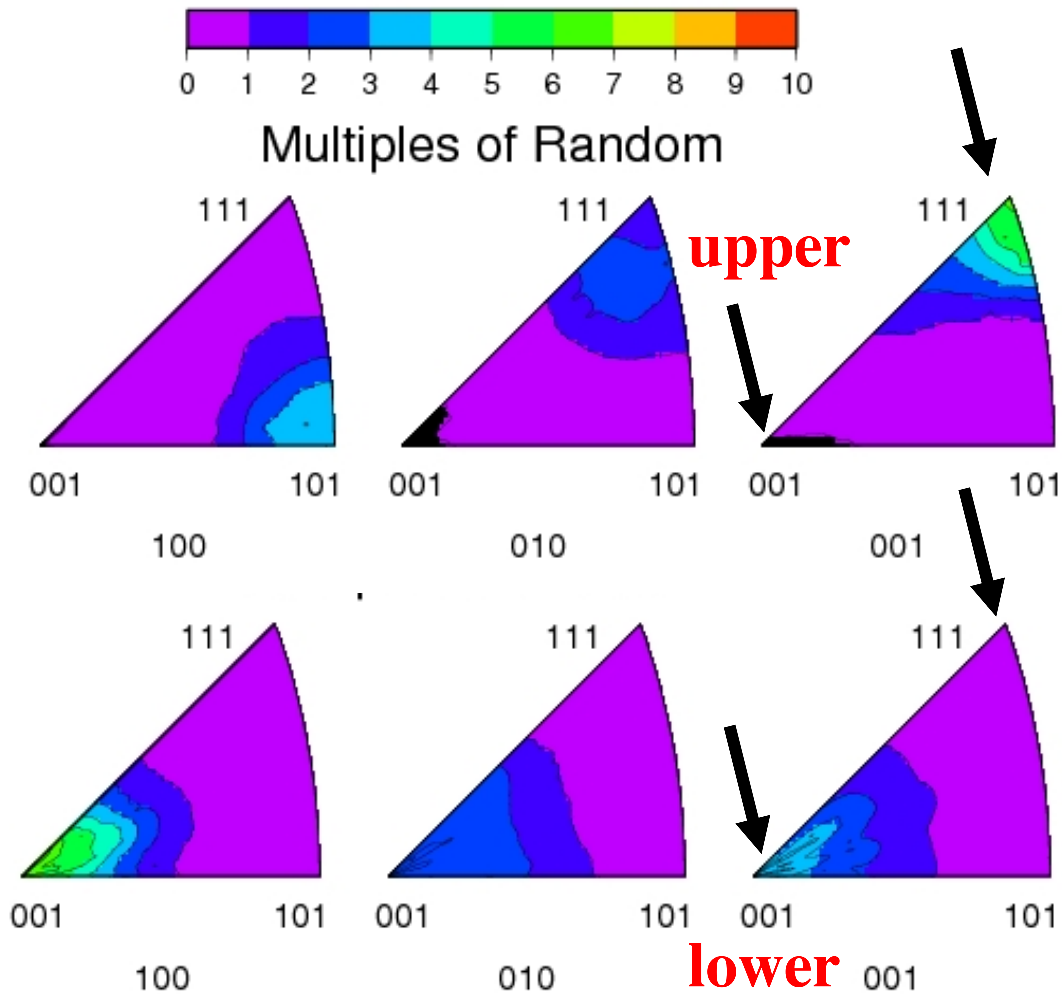
- Two different areas of a Nb sheet, “upper” and “lower” were scanned with EBSD to evaluate variability in formability.
- The pole figures and inverse pole figures showed strong differences.
- Data courtesy of R. Crooks



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

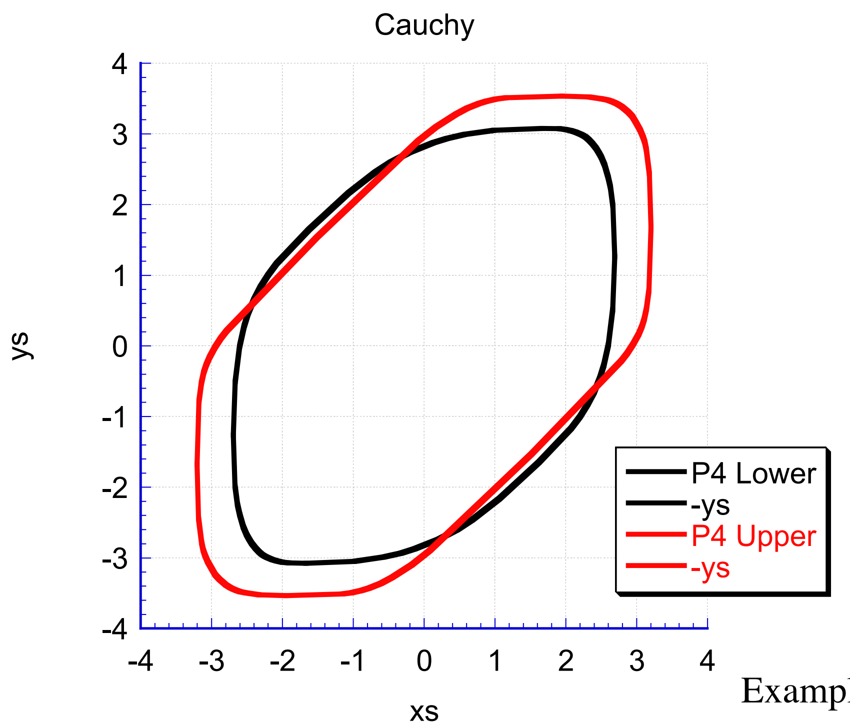
  Lower 111: 0.8
  Lower 001: 10.0
- These numbers suggest significant differences in r-value and formability.

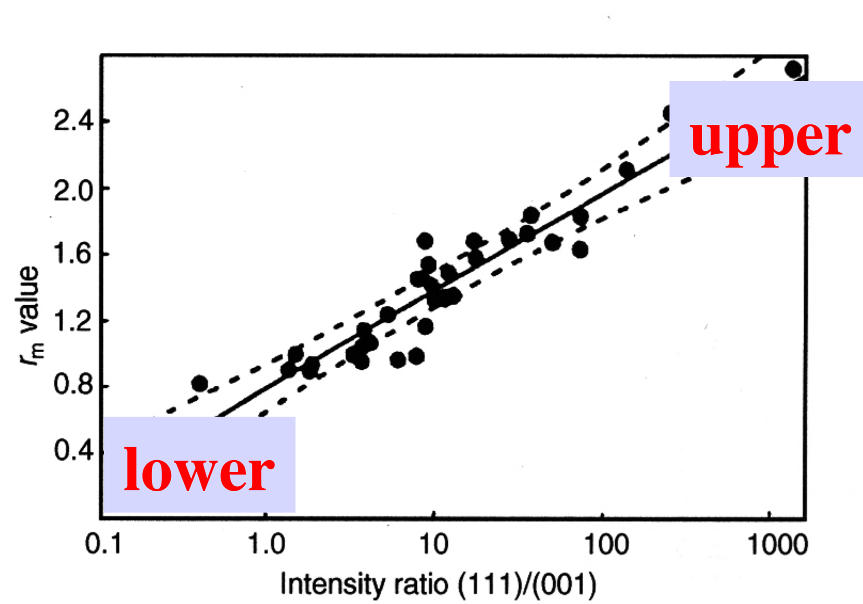


Example: beverage cans

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.





Example: beverage cans

r-value vs. q-value

- Bunge introduced the concept of the q-value in 1970:

$$q = r / (r-1)$$

- The major advantage of the transformed quantity is that its range is 0-1, instead of 0-∞, such that differences at large values of r are not exaggerated.
- Bunge, H.-J. (1970). "Some applications of Taylor's theory of polycrystal plasticity." *Kristall und Technik* **5** 145-175.
- Abstract: The Taylor theory of polycrystal plasticity was applied to three-axial deformation accomplished by glide on (111) [110] or (110) [111] glide systems. The orientation dependence of the Taylor factor was used to calculate the angular dependence of the relative strength of a textured material. The angular dependence of the strain ratio R — calculated from the minimum value of the Taylor factor — was compared with the measured strain ratio. The orientation changes of the crystallites of a polycrystalline aggregate after 1% plastic deformation were calculated and compared with experimental values. The orientations which are deformed without orientation changes were calculated and compared with those of maximum orientation density found by a three-dimensional texture analysis of cold rolled copper and iron. The dependence of the rotationless orientations on the axis ratio of the deformation tensor was calculated. This allows suggestions to be made on the dependence of the rolling textures on the lateral broadening of the sheet during rolling.