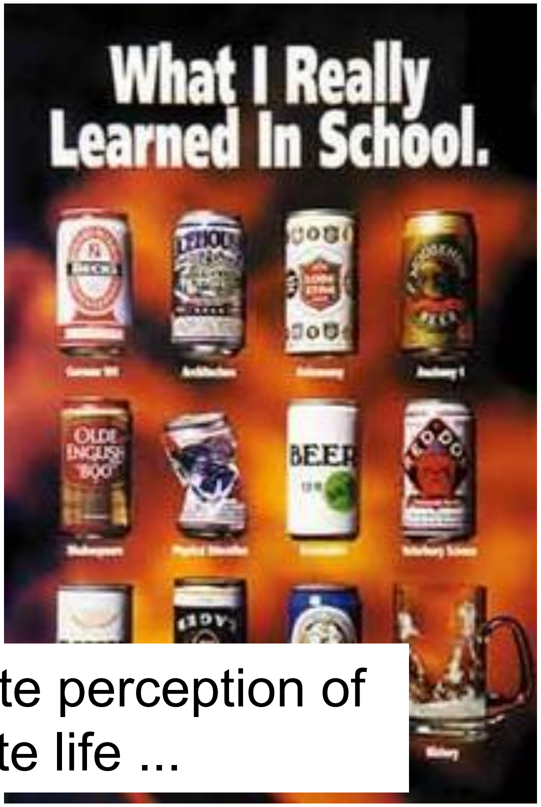
# *Texture, Anisotropy & Beer Cans*

27-750, Fall 2009

Advanced Characterization and Microstructural Analysis

A.D. Rollett, P. Kalu

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# *Beverage Can Making*

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

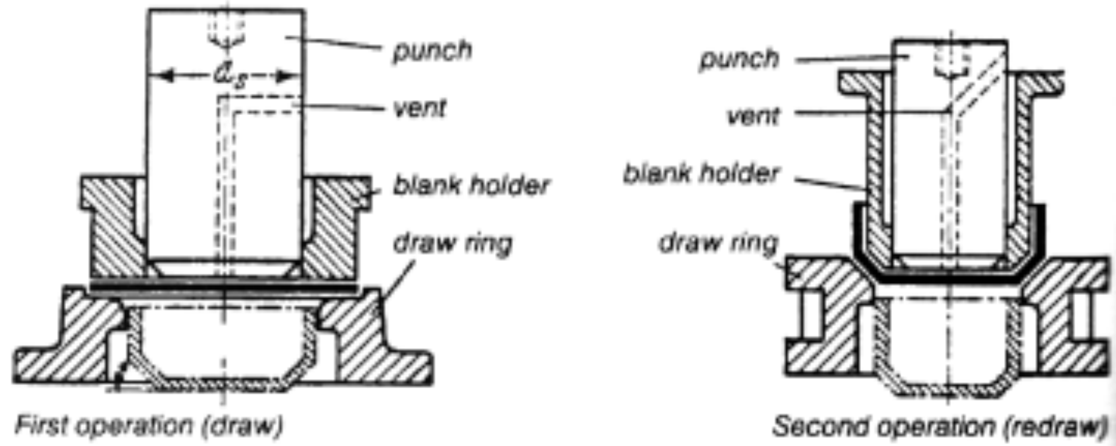



Fig. 9.33: Schematic illustration of deep drawing. For deep drawing, precision sheet (mostly circular blanks) is formed in a lubricated fixture. A blank holder prevents wrinkles from forming. For extra deep draws, the operation can be carried out in successive steps (possibly with an intermediate anneal).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

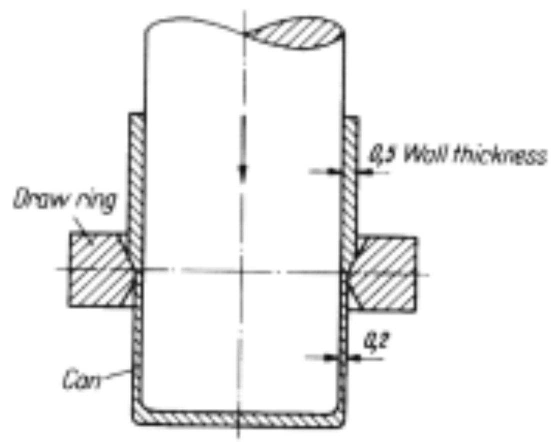



Fig. 9.34: Schematic showing wall ironing of an aluminum beverage can. Often a series of draw rings are used.

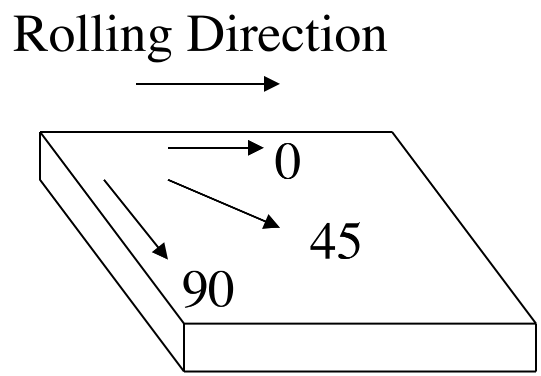
# *Strain Ratio in Tensile Test*

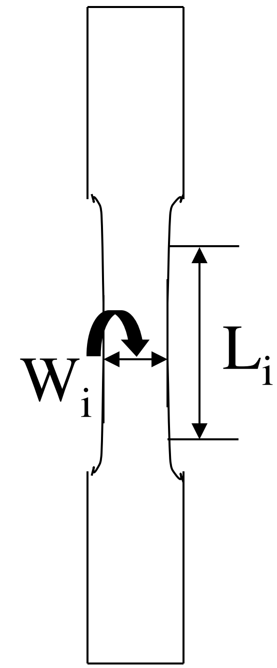
## Plastic Strain Ratio (r-value)

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

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

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




Large $r_m$ and small $\Delta r$ required for deep drawing

Example: beverage cans

# *Correlation of Earing with ΔR*

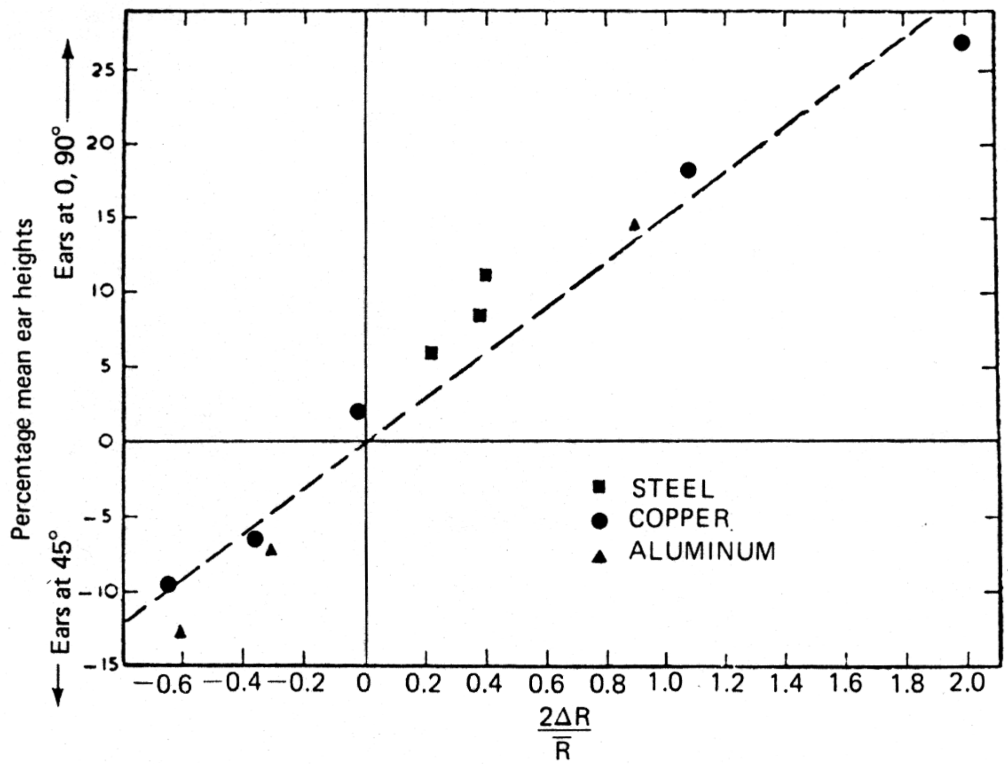



**Figure 14-12** Correlation of extent of earing with $\Delta R$. From D. V. Wilson, and R. D. Butler, *ibid.*

Example: beverage cans

# *Relation of Earing to Deformation, Annealing texture*

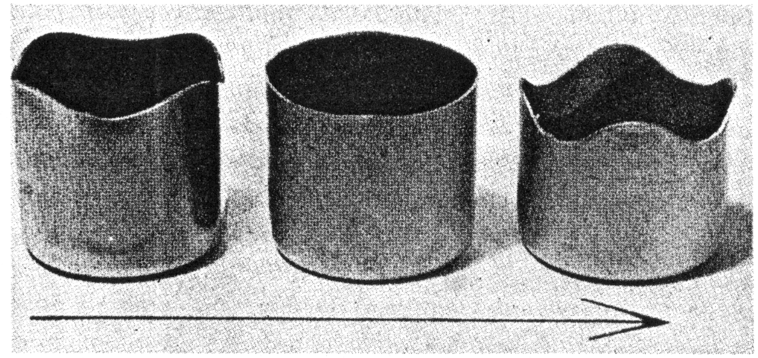


**Figure 14-10** Earing behavior of cups made from three different copper sheets. Arrow indicates rolling direction of the sheets. From D. V. Wilson and R. D. Butler, *J. Inst. Met.*, 90 (1961–2), pp. 473–83.

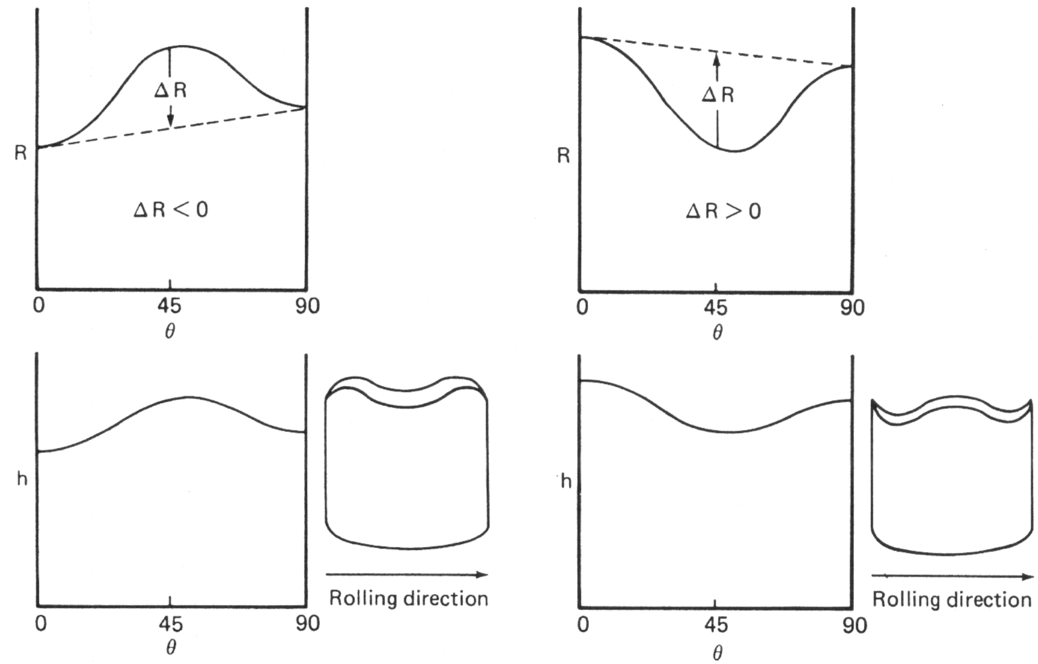
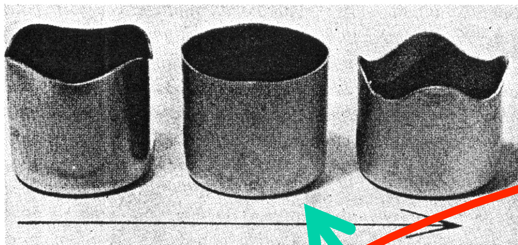



**Figure 14-11** Relation of earing to angular variations of *R*. Here, *h* is the wall height.

Example: beverage cans

# *Earing-Texture Correlation*

deformation texture ⇒ 45° ears



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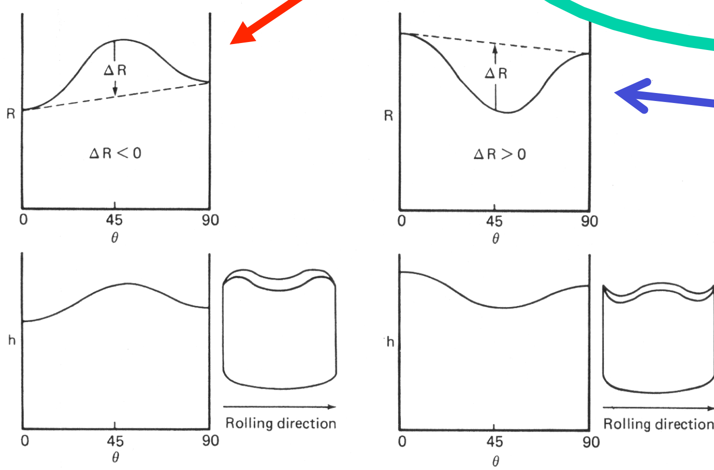


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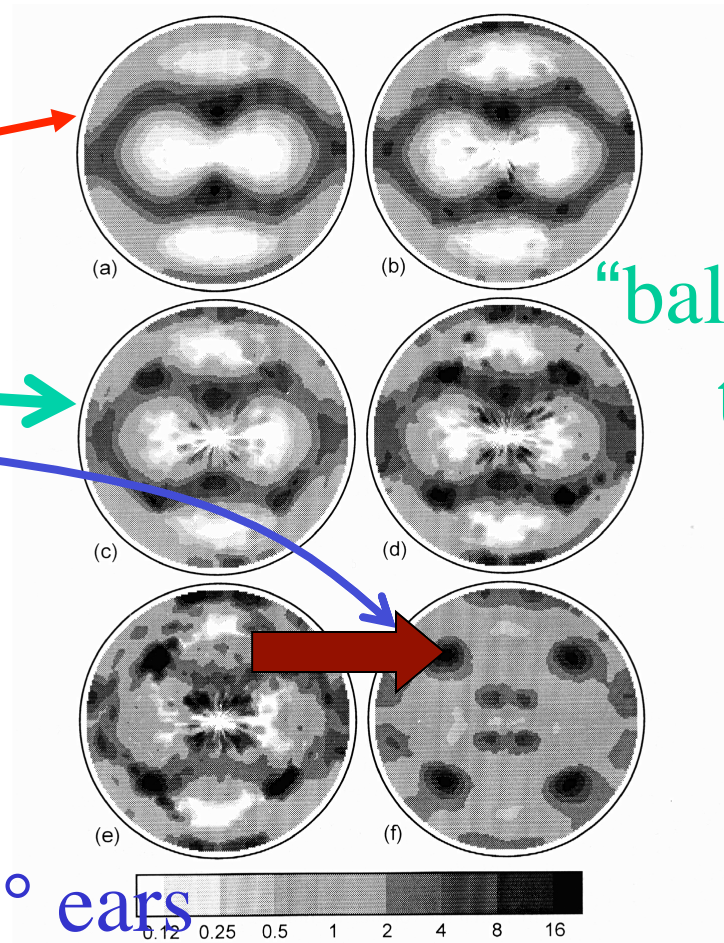


"balanced" texture

annealing texture ⇒ 0,90° ears

Example: beverage cans

# *Texture-Formability in Steels*

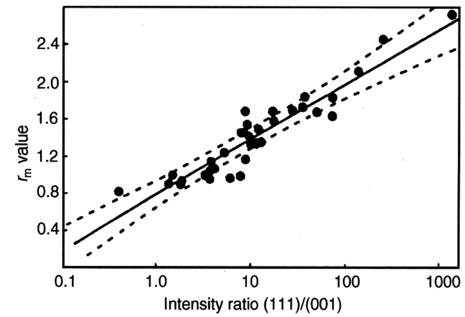


**Figure 1.18** *Relation between the ratio of the intensity of the (111) component to the intensity of the (001) component and the $r_m$ value of low-carbon steel sheets (After Held[39])*

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

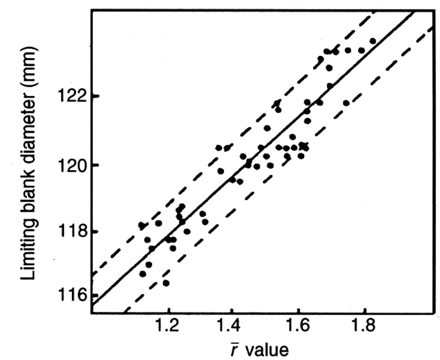


**Figure 1.19** *Effect of $\bar{r}$ on limiting blank diameter for a range of low-carbon steels for Swift cups drawn using polythene sheet lubrication (After Atkinson and Maclean[40])*

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

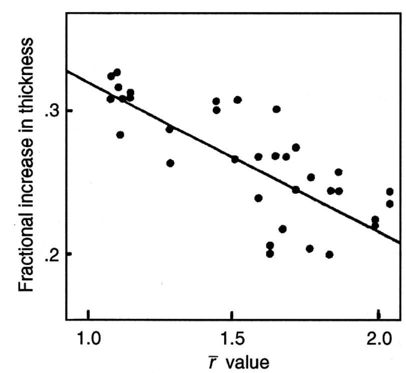


**Figure 1.20** *Relationship between mean fractional increase in thickness at the top rim of a Swift cup and $\bar{r}$ value, for a range of low-carbon steels, Blank diameter 63.5 mm – Punch diameter 32 mm (After Hudd and Lyons[41])*

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

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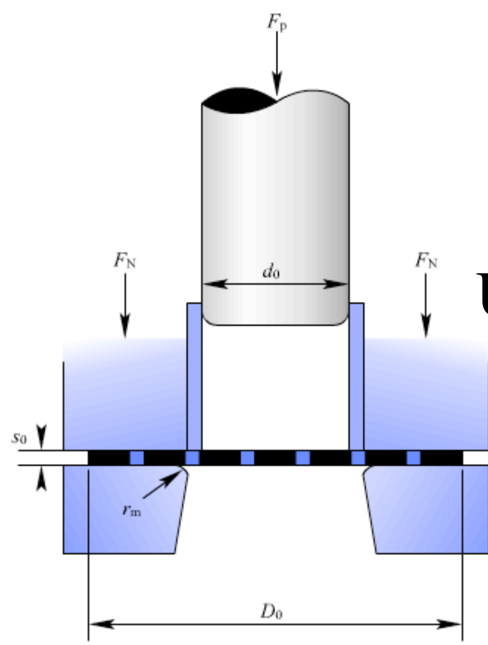
## Swift Cup Test

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:

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

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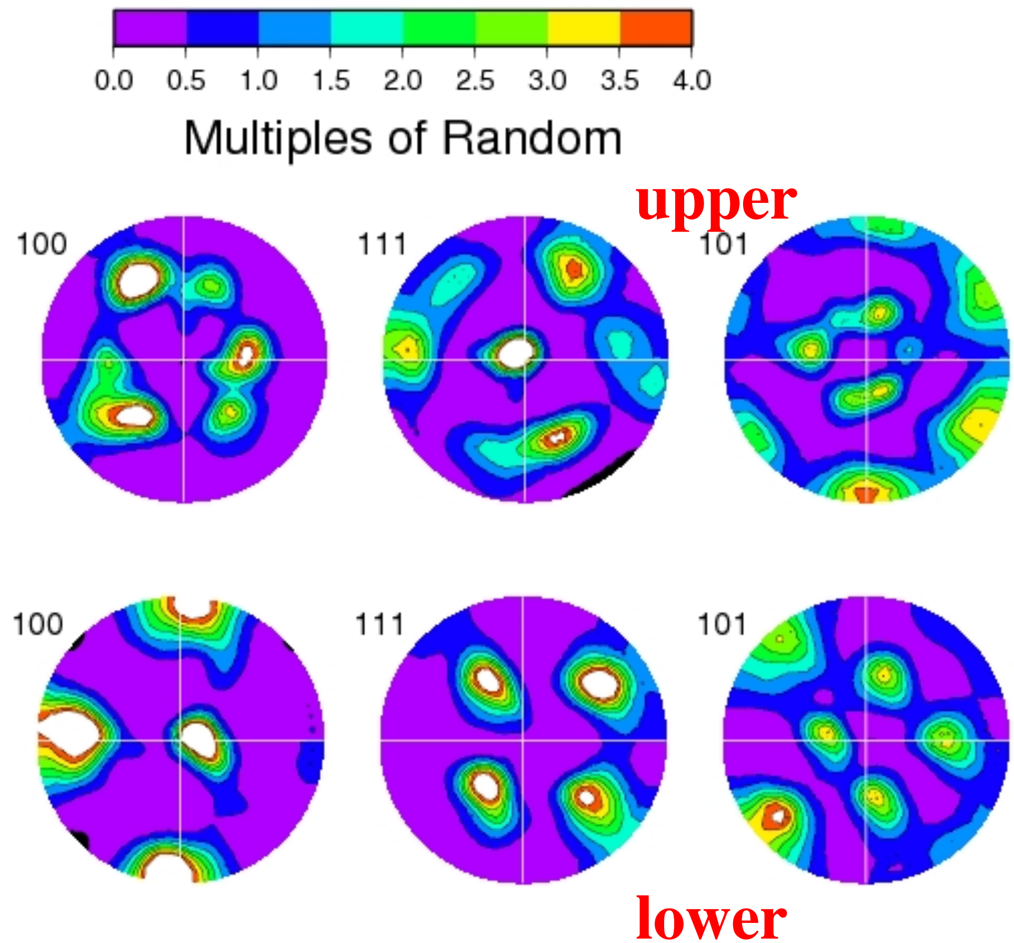
# *Nb Sheet Example*

- 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.

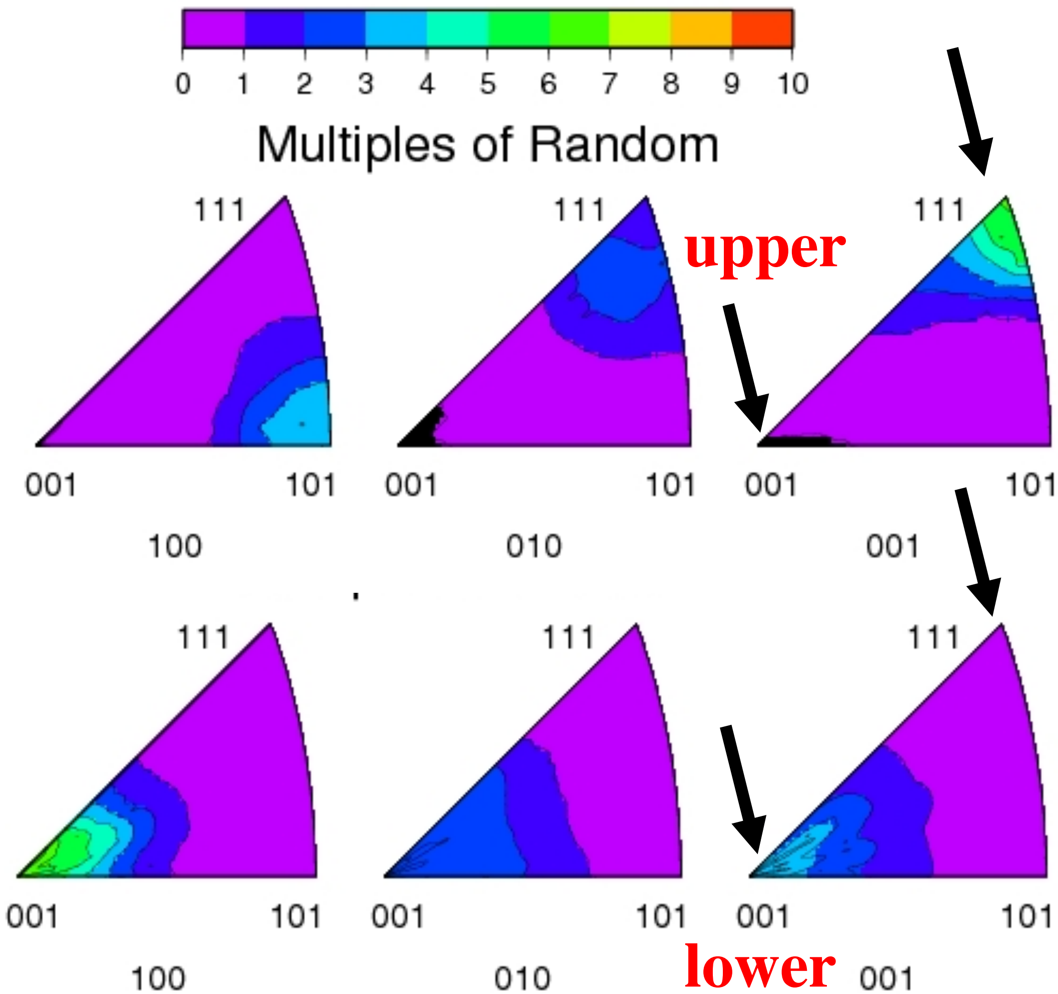



Example: beverage cans

# *Nb Sheet Example: IPFs*

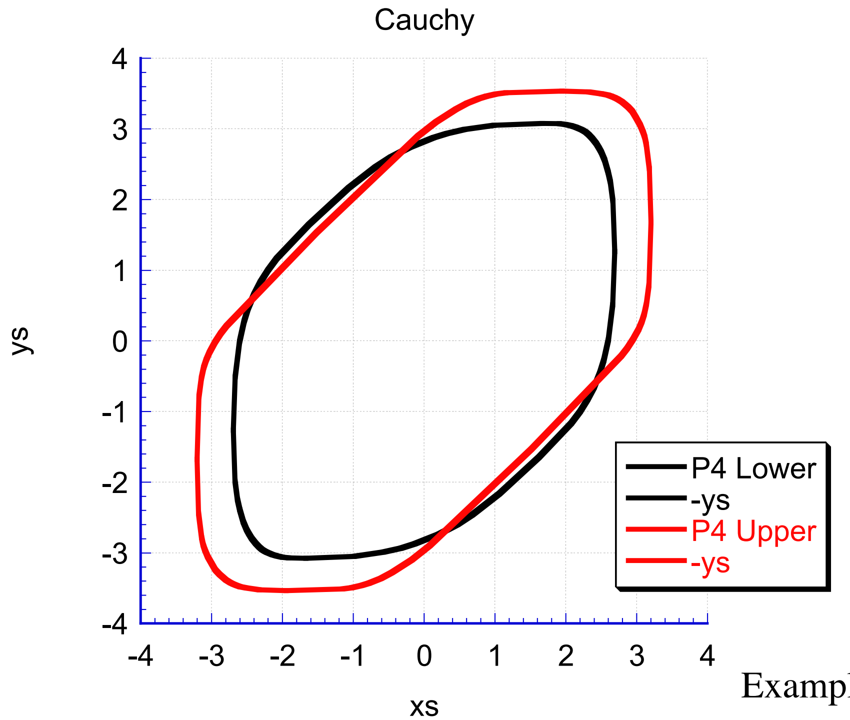
- Note the differences in intensity in the 001 and 111 locations in the ND/ 001 inverse pole figure for the two samples.
- Upper 111: 7.5
  Upper 001: 0.0

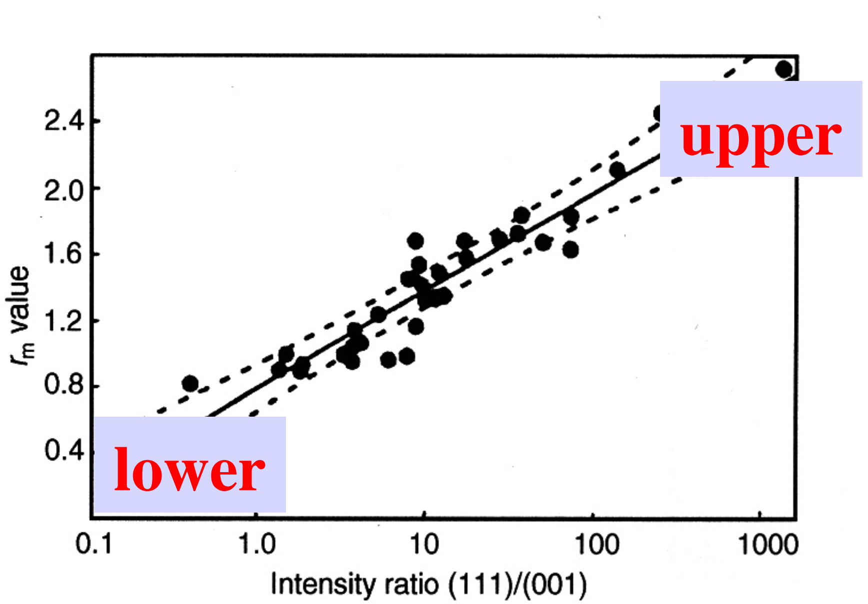
  Lower 111: 0.8
  Lower 001: 10.0
- These numbers suggest significant differences in r-value and formability.



# *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