Sheet Metal Forming - 2

Georgia Institute of Technology

ME 4210: Manufacturing Processes & Engineering
Instructor: Ramesh Singh; Notes by Prof. S.N. Melkote

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Outline

- Deep Drawing Basics
- Limiting Drawing Ratio (LDR)
- Forming Limit Diagram

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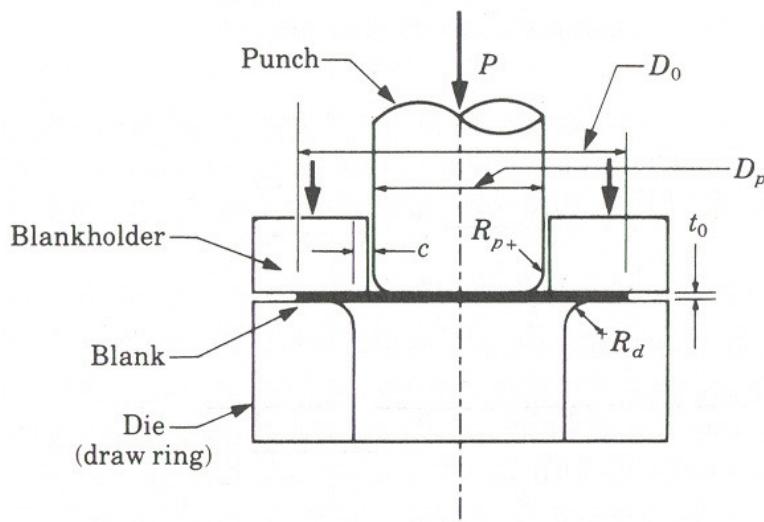
Deep Drawing Basics
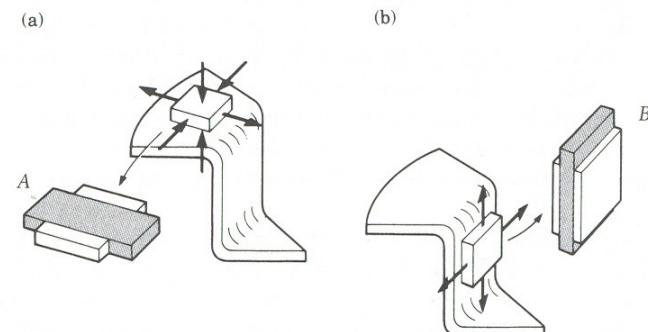
- Flat sheet-metal blank is formed into a cylindrical or box-shaped part by means of a punch that presses the blank into the die cavity
- Applications: beverage cans, utensils, sinks

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Deep Drawing Basics

- Basic deformation modes: bending and stretching
- Key variables: punch diameter (D_p), blank diameter (D_0), blank thickness (t), punch force (P), punch radius (R_p), die radius (R_d), punch-die clearance (c), blankholder force


Deep drawing

Stress States

Source: Kalpakjian & Schmidt, 4th Ed., 2003

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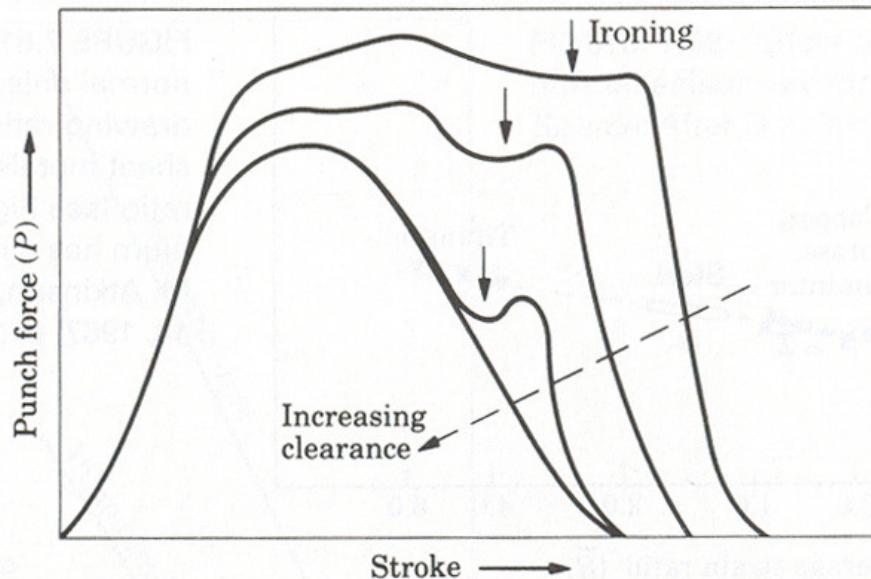
Deep Drawing

- Punch force can be estimated by:

$$P_{max} = \pi D_p t_o (UTS) \left(\frac{D_o}{D_p} - 0.7 \right)$$
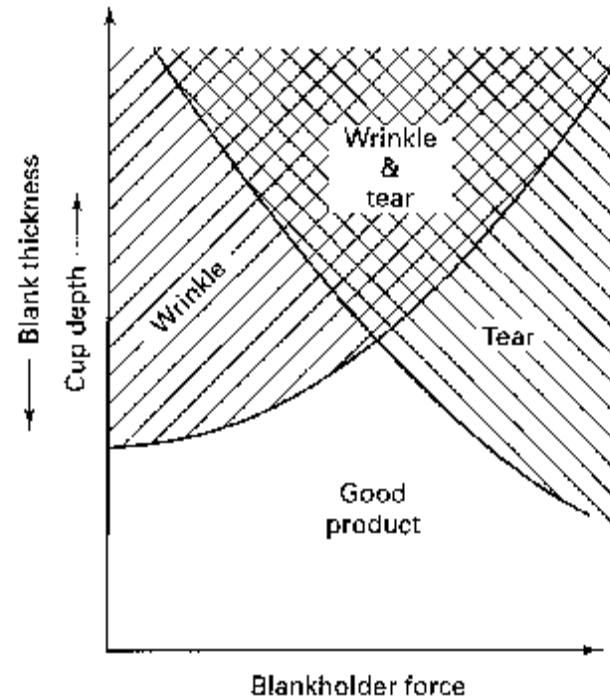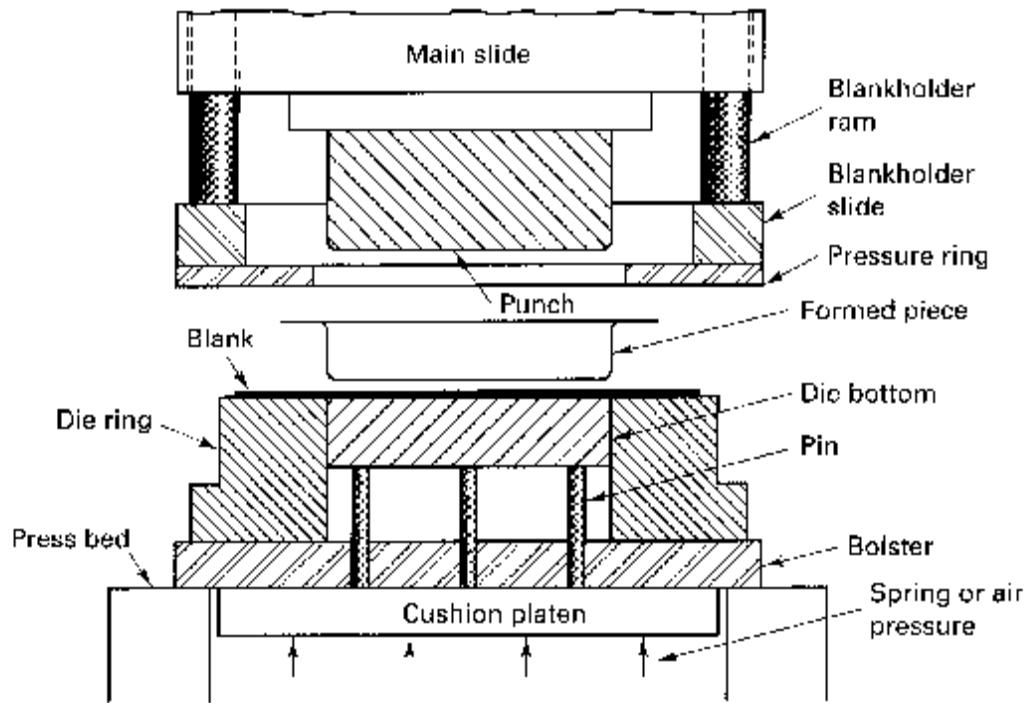
- Punch-die clearance affects "ironing"

Source: Kalpakjian & Schmidt, 4th Ed., 2003

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Deep Drawing

- Effect of blankholder force
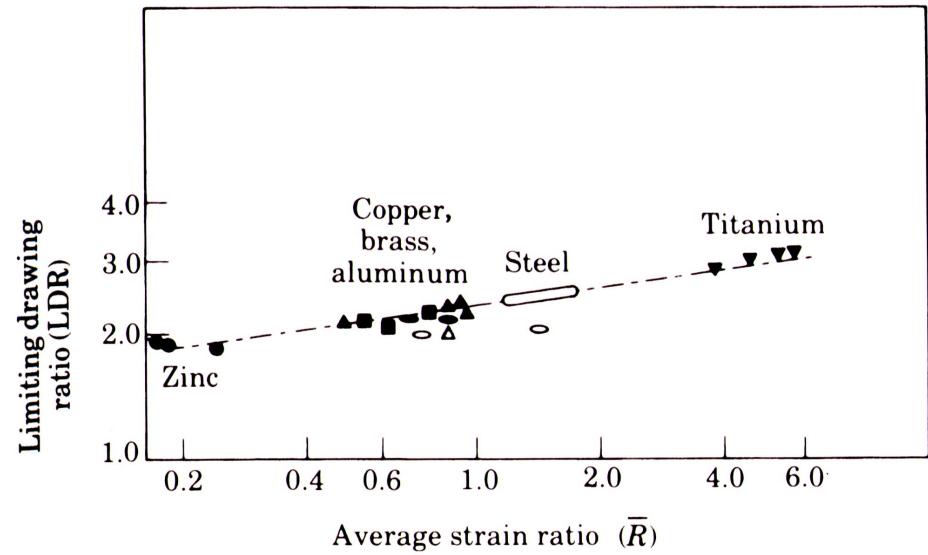
Source: DeGarmo, Black, Kohser, 9th Ed., 2003

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Limiting Drawing Ratio (LDR)

- **LDR** - the maximum ratio of blank diameter to punch diameter that can be drawn without failure (=D_o/D_p)

- LDR is affected by normal anisotropy, $\overline{R}$

$$R = \frac{\varepsilon_w}{\varepsilon_t} = \frac{\ln\left(\dfrac{w_o}{w_f}\right)}{\ln\left(\dfrac{t_o}{t_f}\right)} = \frac{\ln\left(\dfrac{w_o}{w_f}\right)}{\ln\left(\dfrac{w_f l_f}{w_o l_o}\right)}$$
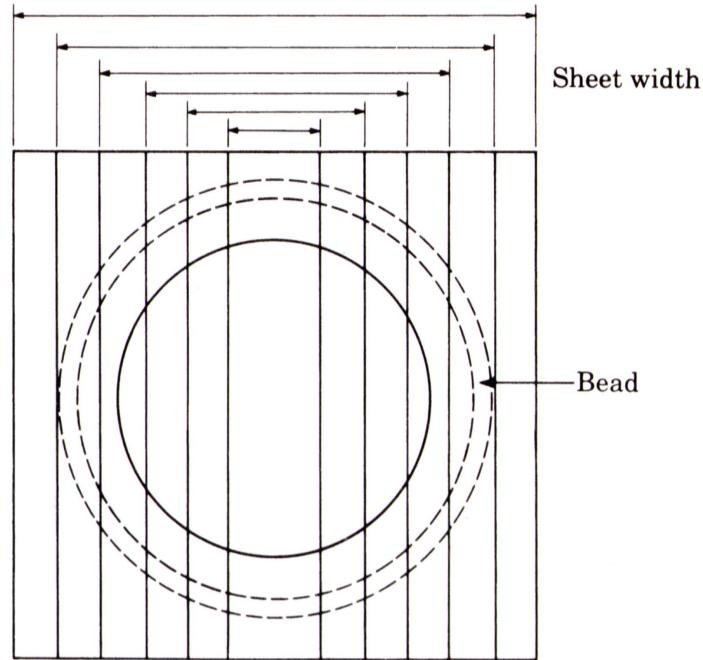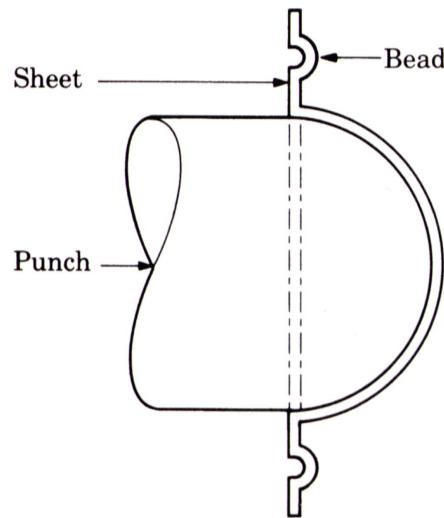
$$\overline{R} = \frac{R_o + 2R_{45} + R_{90}}{4}$$

Source: Kalpakjian & Schmidt, 4th Ed., 2003

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Forming Limit Diagram (FLD)

- Formability: ability of sheet metal to undergo the desired deformation without failures such as necking and tearing
- FLD used to estimate formability of sheet metal in deep drawing

Source: Kalpakjian & Schmidt, 4th Ed., 2003

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Forming Limit Diagram (FLD)

- Bulge tests performed for various sheet widths
- Each sheet has circular grid marks etched on it
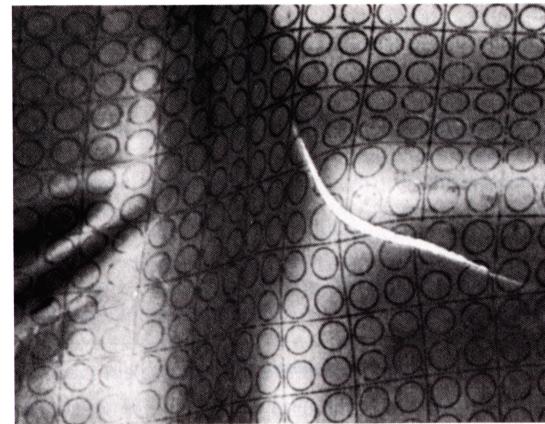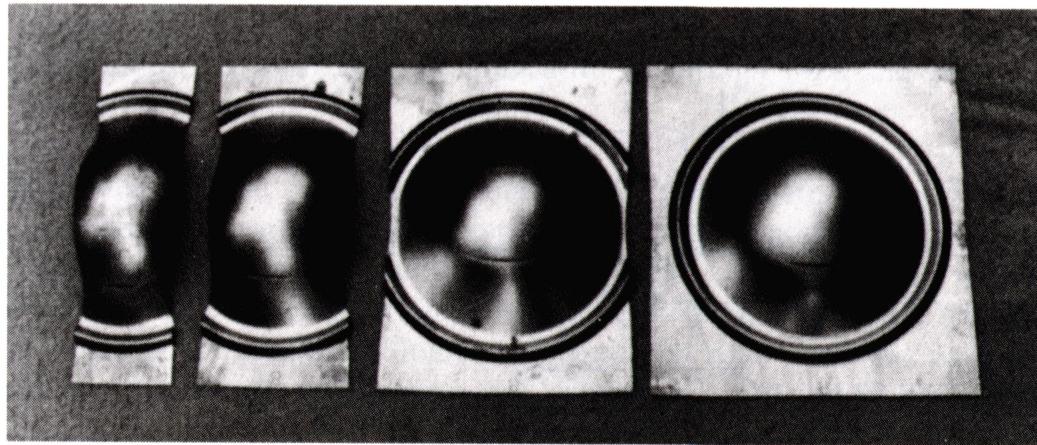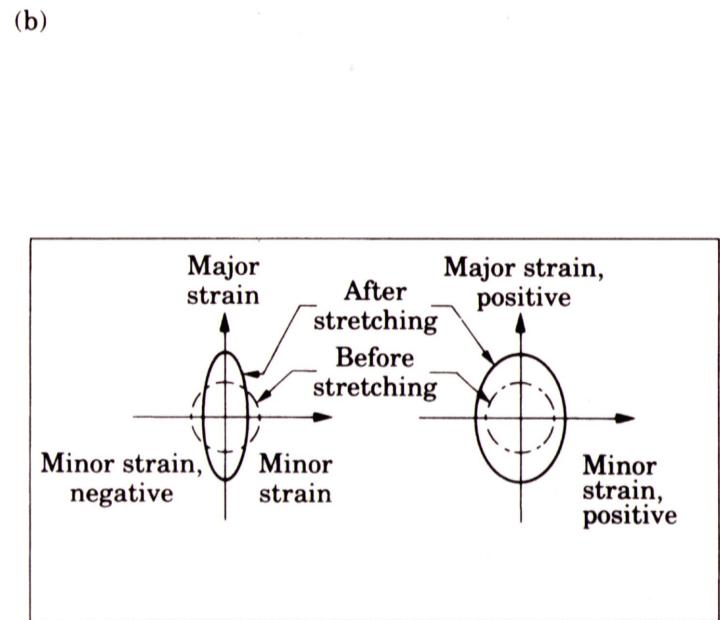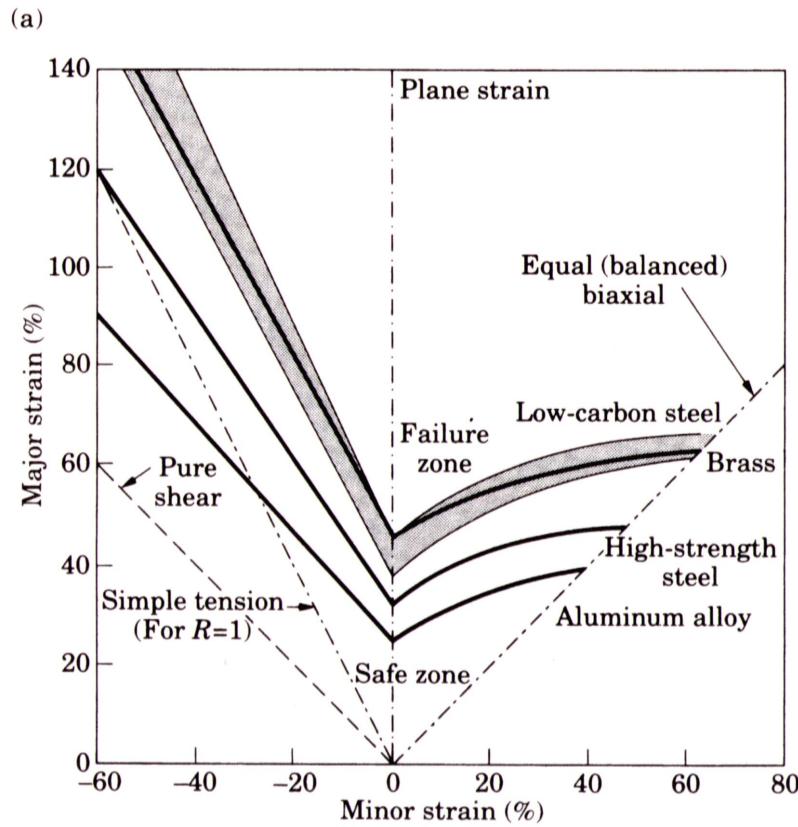
FIGURE 7.71 An example of using grid marks (circular and square) to determine the magnitude and direction of surface strains in sheet-metal forming. Note that the crack (tear) is generally perpendicular to the major (positive) strain. *Source:* After S.P. Keeler.

Source: Kalpakjian & Schmidt, 4th Ed., 2003

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Forming Limit Diagram (FLD)
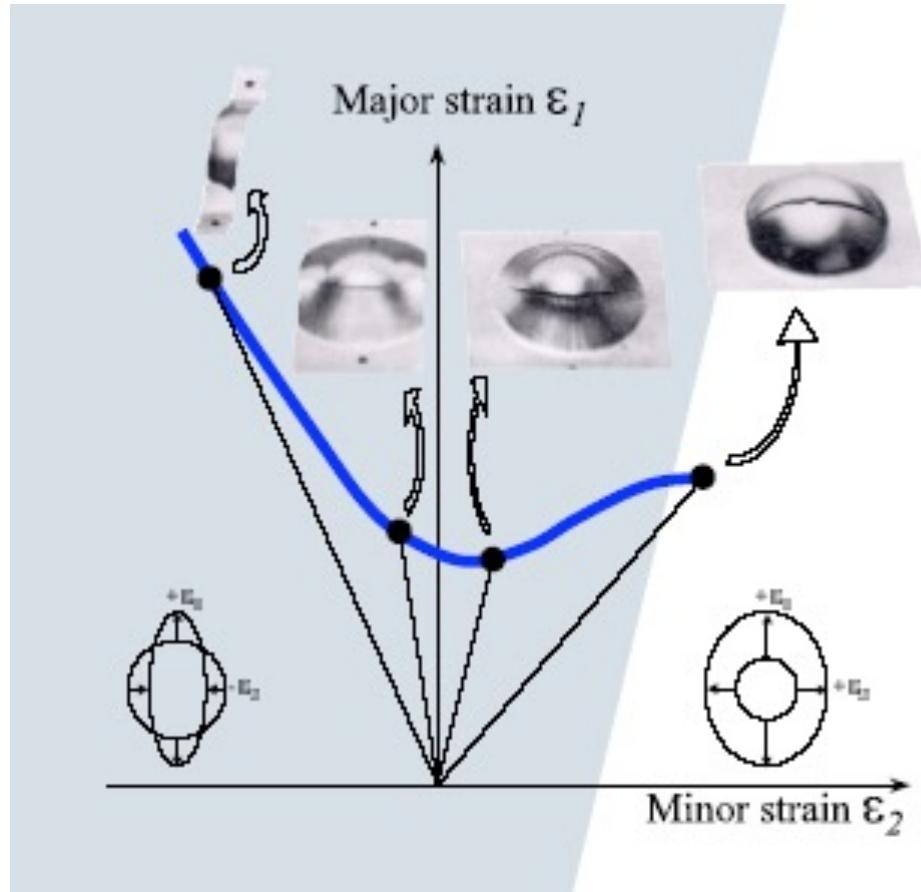
- Major and minor strains of deformed grid marks plotted

Source: Kalpakjian & Schmidt, 4th Ed., 2003

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Forming Limit Diagram (FLD)

- Failure occurs above a forming limit line; material is safe below the line

Source: http://www.mate.tue.nl/mate/pdfs/959.pdf

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Summary

- Deep Drawing Basics
- LDR
- FLD

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