Lecture #31

ERDM

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Assignment

Given in class!!

Bulk Deformation & Sheet Working Operations

- **Rolling**
- **Forging**
- **Extrusion**
- **Wire Drawing**

- **Bending**
- **Deep Drawing**
- **Blanking**
- **Stamping**

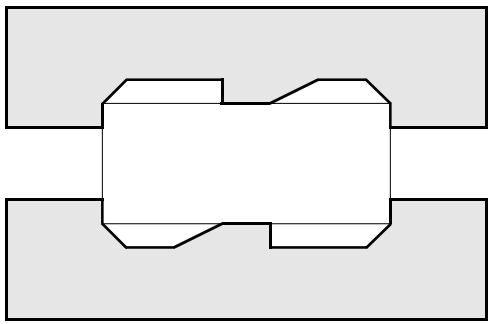
Environmental Considerations

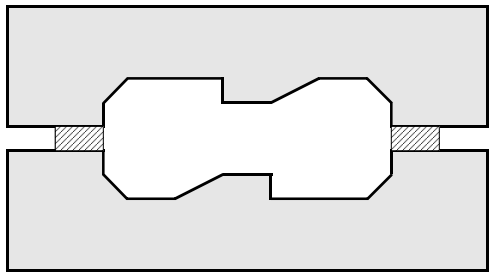
- **Flash**
- **Lubricant**
- **Worn dies**
- **Scrap parts**
- **Energy**

General Comments

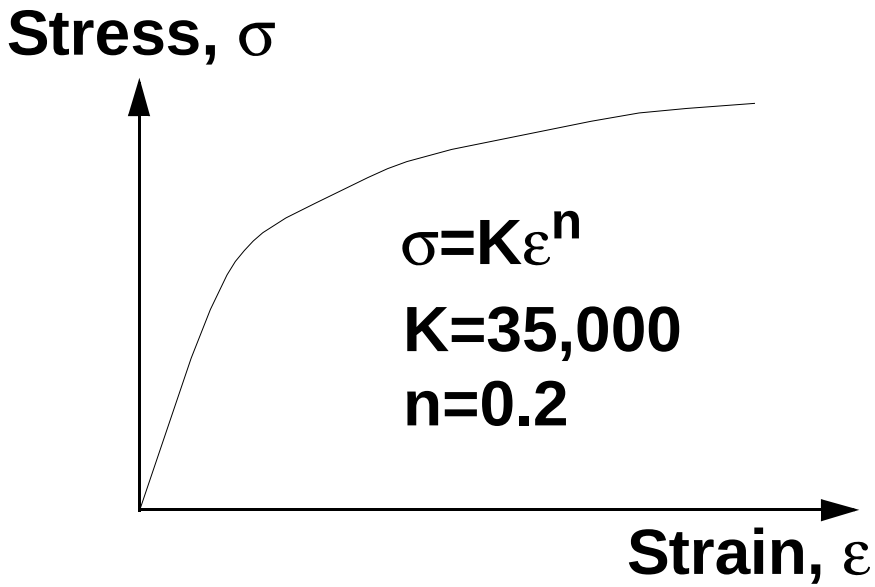
Develop mechanistic models to characterize waste streams and energy consumption.

- **Energy - use knowledge on energy -- plastic deformation work**
- **Flash**



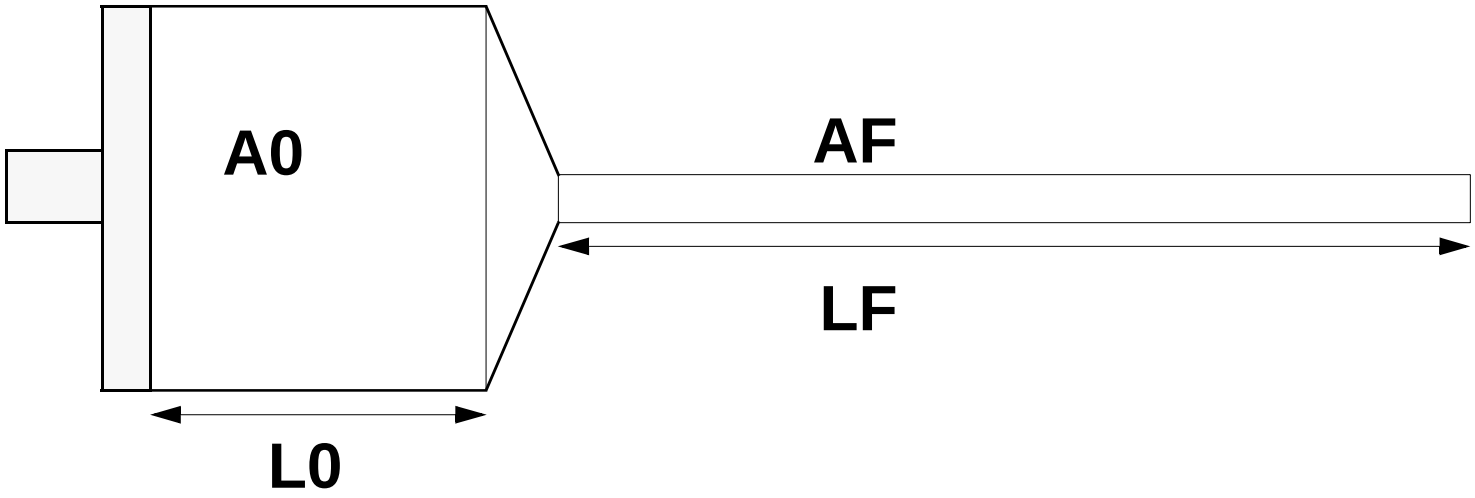


Summary - Plasticity Theory



$$\frac{Deformation\ Energy}{Unit\ Volume} = \frac{K\varepsilon^{n+1}}{n+1} = U \qquad Energy = U(Vol)$$

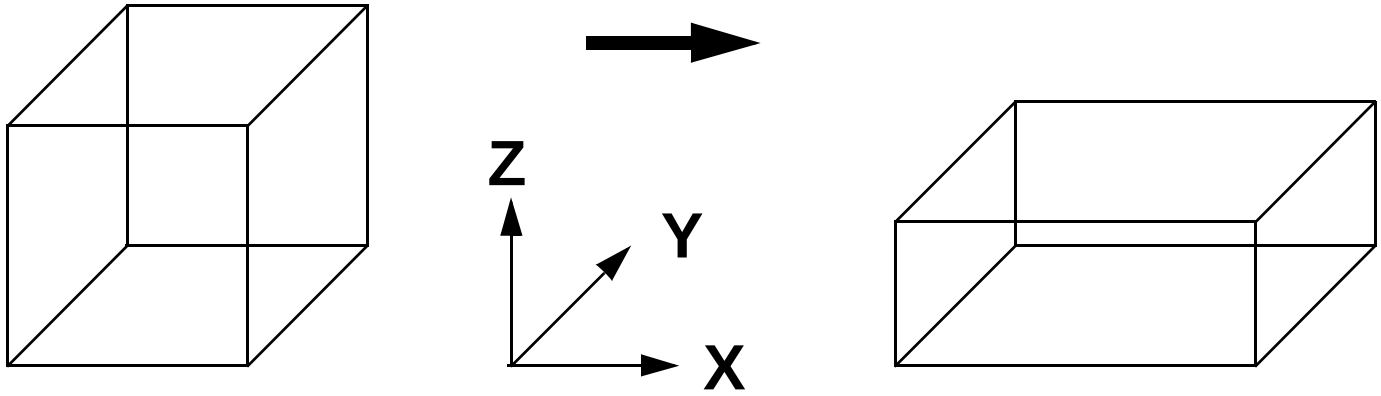
Extrusion (Drawing)



$$\varepsilon = \ln\left(\frac{LF}{L0}\right)$$

Assumes no redundant work or friction losses

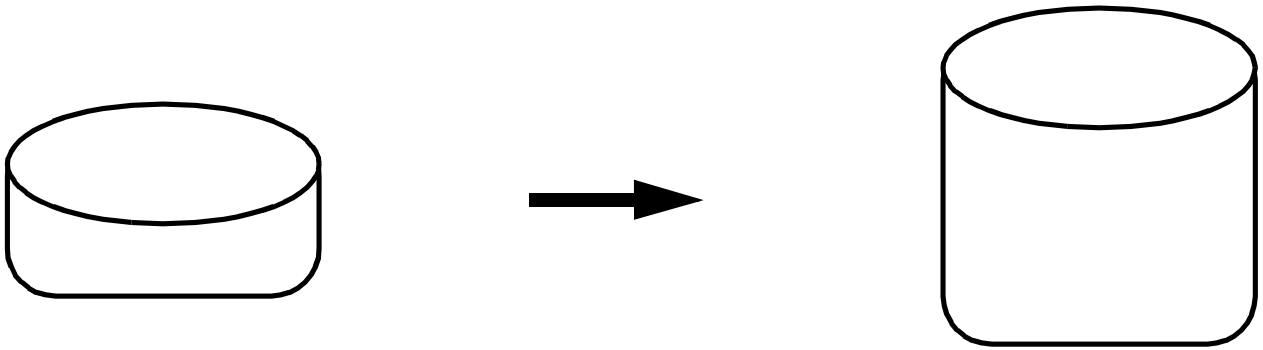
Forging



$$\varepsilon_x = \ln\left(\frac{X_f}{X_0}\right) \qquad \varepsilon_y = \ln\left(\frac{Y_f}{Y_0}\right) \qquad \varepsilon_z = \ln\left(\frac{Z_f}{Z_0}\right)$$ **Prin. Strains**

$$\bar{\varepsilon} = \frac{2}{3}(\varepsilon_1 - \varepsilon_3)$$

Deep Drawing



$$\varepsilon_{axial} = \ln\left(\frac{h_f}{h_0}\right) = \ln\left(\frac{t_0}{t_f}\right) = -\varepsilon_{radial}$$

$$\bar{\varepsilon} = \frac{2}{3}(\varepsilon_1 - \varepsilon_3)$$

Forging Competitive Issues

(Forging Industries Association)
http://www.forging.org/techno/Vision.htm
other good stuff at www.forging.com

- **Technology development and application**
- **find & deploy strategic technologies**
- **die design/modeling**

- **Cooperative efforts**
- **leverage resources/share knowledge/protect IPRs**
- **enlist suppliers/fair compensation at each stage**
- **information exchange/technology deployment**
- **Unify support for Industry Vision**

- **Energy and the environment**
- **energy efficient/environmentally responsible**
- **cooperate to make process environmental asset**
- **pollution prevention**
- **reduce or eliminate forging die lubrication**
- **reduce energy consumption**
- **induction heating/combustion advancements**
- **waste treatment/recycling**
- **renewable energy and environmental protection**

- **Competitiveness**
- **process improvement + productivity = profitability**
- **electronic product design/process technology**
- **net-shape/materials utilization**
- **decrease per-unit energy, die, and labor costs**

- **Education**
- **customers, workforce, politicians**
- **new technologies (education & process)**

- **Markets**
- **globalization/realistic projections for demand**
- **value-added services**
- **competing materials/processes**

- **Human resources**

Energy & Environment Needs

- **Eliminate aerosol emission within the plant through the use of advanced die systems. The development of cost-effective new production methods (such as net shape forging) will eliminate the need for post-forging removal of surface material.**

- **Establish a program that develops and deploys environmentally benign lubricants, or eliminates the requirement for die lubrication altogether. Develop new water-based synthetic die lubricants that eliminate graphite from the forging process.**

More Needs

- **Reduce energy consumption through advanced waste heat recovery systems that maximize furnace or induction heater efficiency. One such step is to develop closed-loop controls that minimize the heat wasted in the forging process when problems occur in forging systems.**

- **Increased use of induction heating and advances in combustion technology will significantly improve energy efficiency in forging facilities and reduce the environmental impact of today's fossil-fuel fired process heating systems--completely eliminating harmful products of gas combustion.**

Still More Needs

- **All fluids necessary to plant operation will be recycled, and ultimately replaced with environmentally benign materials.**

- **New ways to treat waste are needed to prevent damage to the environment. Improvements are needed in methods and technology to minimize forging scale and recycle other process materials and gasses that otherwise represent an environmental liability.**

- **Renewable energy, advanced technologies for energy and resource efficiency, cogeneration, and other waste reduction process improvements and other cost-effective environmental protection improvements must be developed.**

One Idea

- **Fluorochemical technology of 3M**

- **Effective lubricants which are fully volatile**
- **Non-Volatile Residues (NVR) of < 1 ppm**

- **Clean -- Workpiece is dry with no residue**

- **Environmentally friendly?**
- **Non-VOC**
- **non hazardous waste**
- **No ODP**
- **Low GWP**
- **Atmospheric Lifetime 4-5 years**
- **750 ppm PEL**
- **No Flash points**

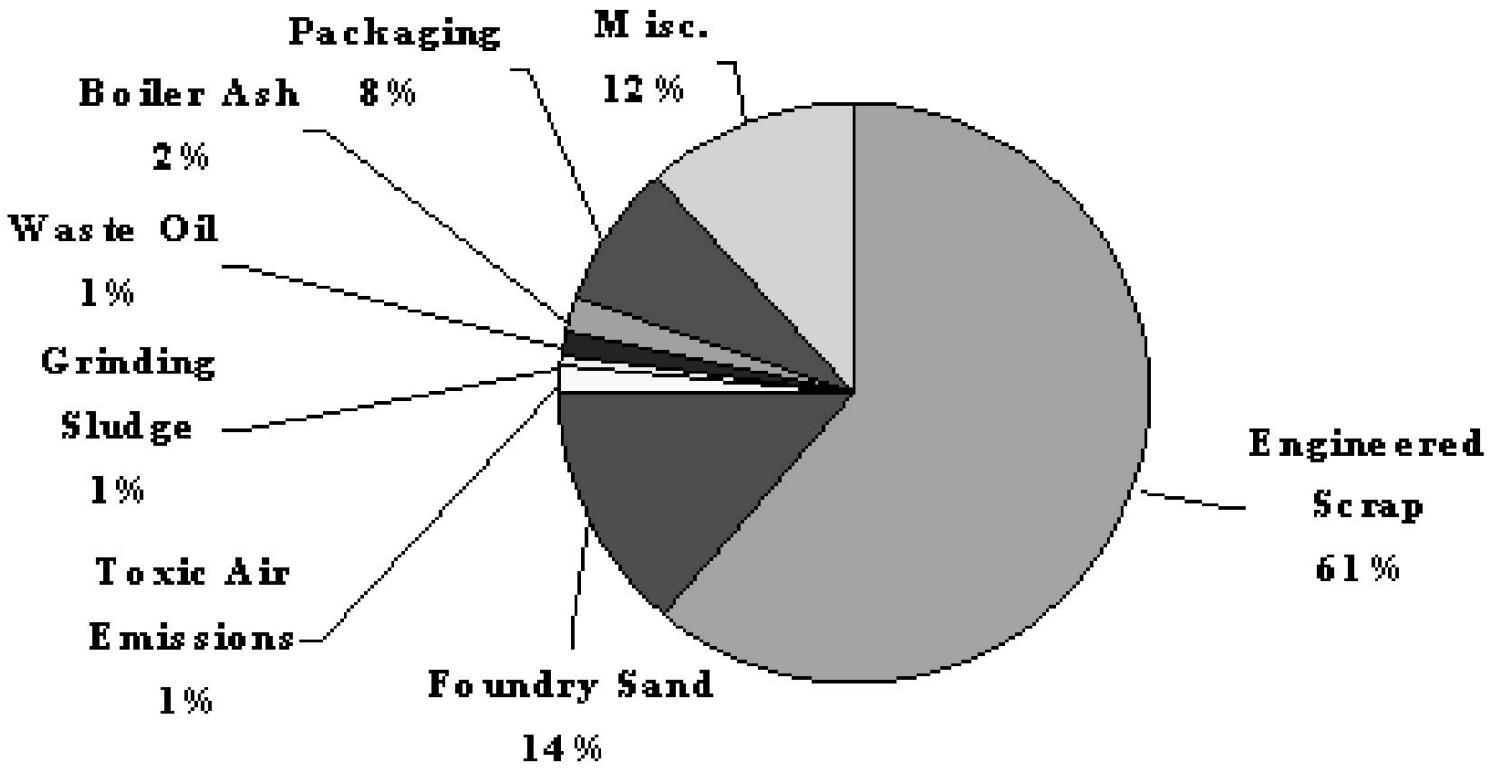
Toyo Seikan Can Company

- **Traditional**
  - **Use lubricant for forming**
  - **Cleaning**
  - **Coating -- printing and for beverage protection**
  - **Impact on Design**

- **Avoid lubrication -- use pre-coated steel in the manufacture of beverage cans.**

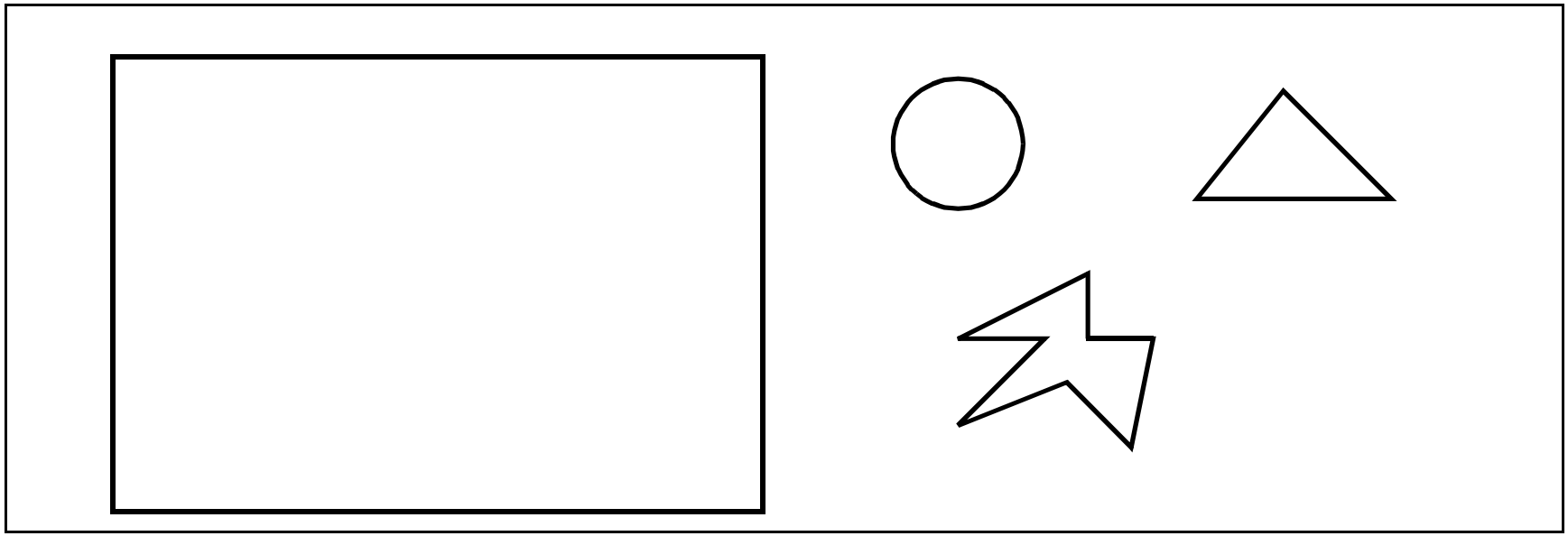
- **Bottling Plant**

Sources of Solid Waste



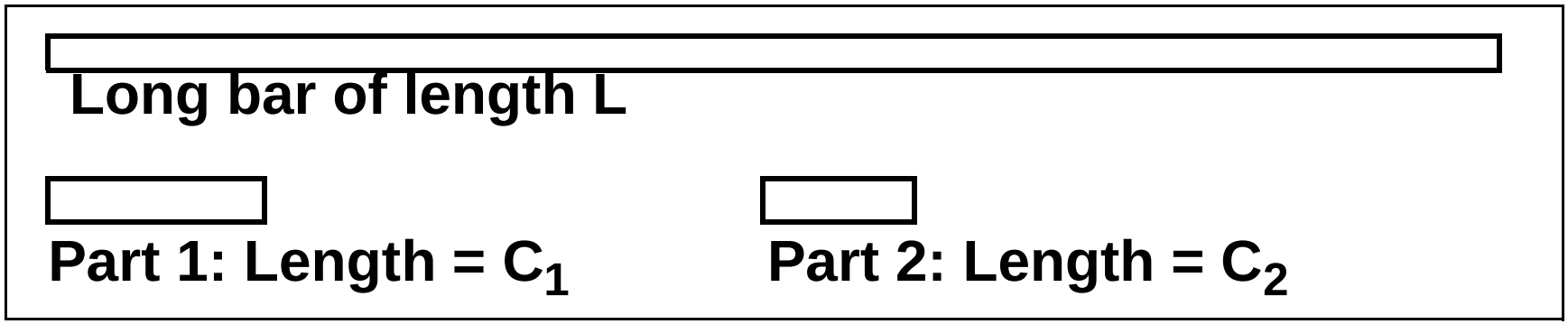
Minimizing Waste

http://techreports.isr.umd.edu/reports/1998/TR_98-8.pdf
See also web refs to Gilmore/Gomory Stock problem



How can we perform this blanking process so as to minimize scrap?

One-Dimensional Version



Let x_1 be number we cut of part 1 type (integer)

Let x_2 be number we cut of part 2 type (integer)

Max: $z = C_1*x_1 + C_2*x_2$

st: x_1 & x_2 non-negative

$C_1*x_1 + C_2*x_2 <= L$

Relax integer requirement -- linear programming solution