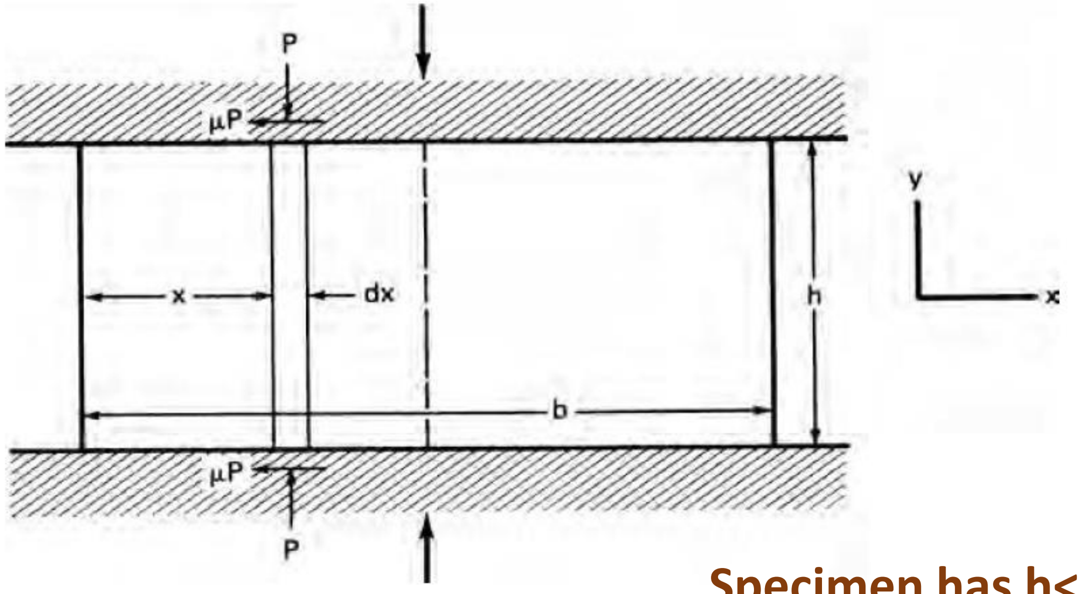
# Friction in Metal working

# Friction

- We have already seen that including friction in the calculations, reduces the mechanical efficiency of the system and it also changes the slip line fields
- In most of the calculations, we have neglected friction, which is not a realistic scenario
- **Coulomb Friction**
  - $\mu = \tau/p$
  - $\tau$ = shearing stress at the interface
  - $p$ = normal stress at the interface

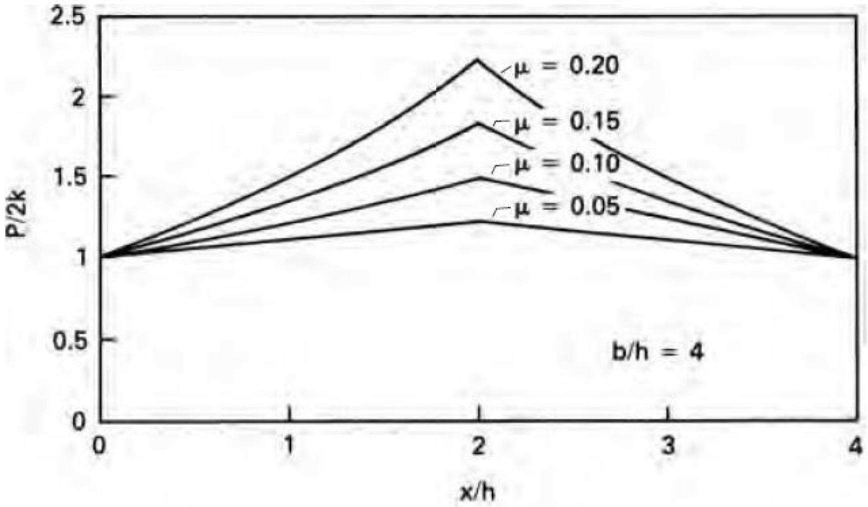
# FRICTION IN PLANE-STRAIN COMPRESSION

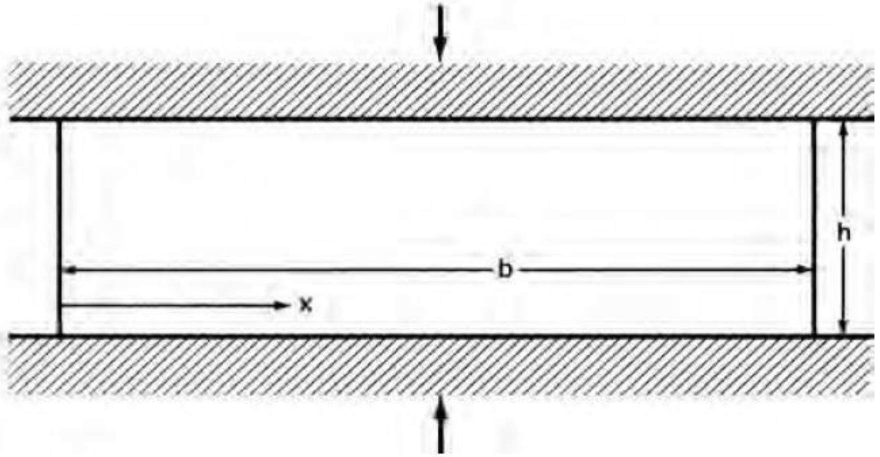
- **Class lecture**




**Specimen has h<b**

**Essentials for a slab analysis**




**Friction hill in plane-strain compression with a constant coefficient of friction**

# FRICTION IN PLANE-STRAIN COMPRESSION

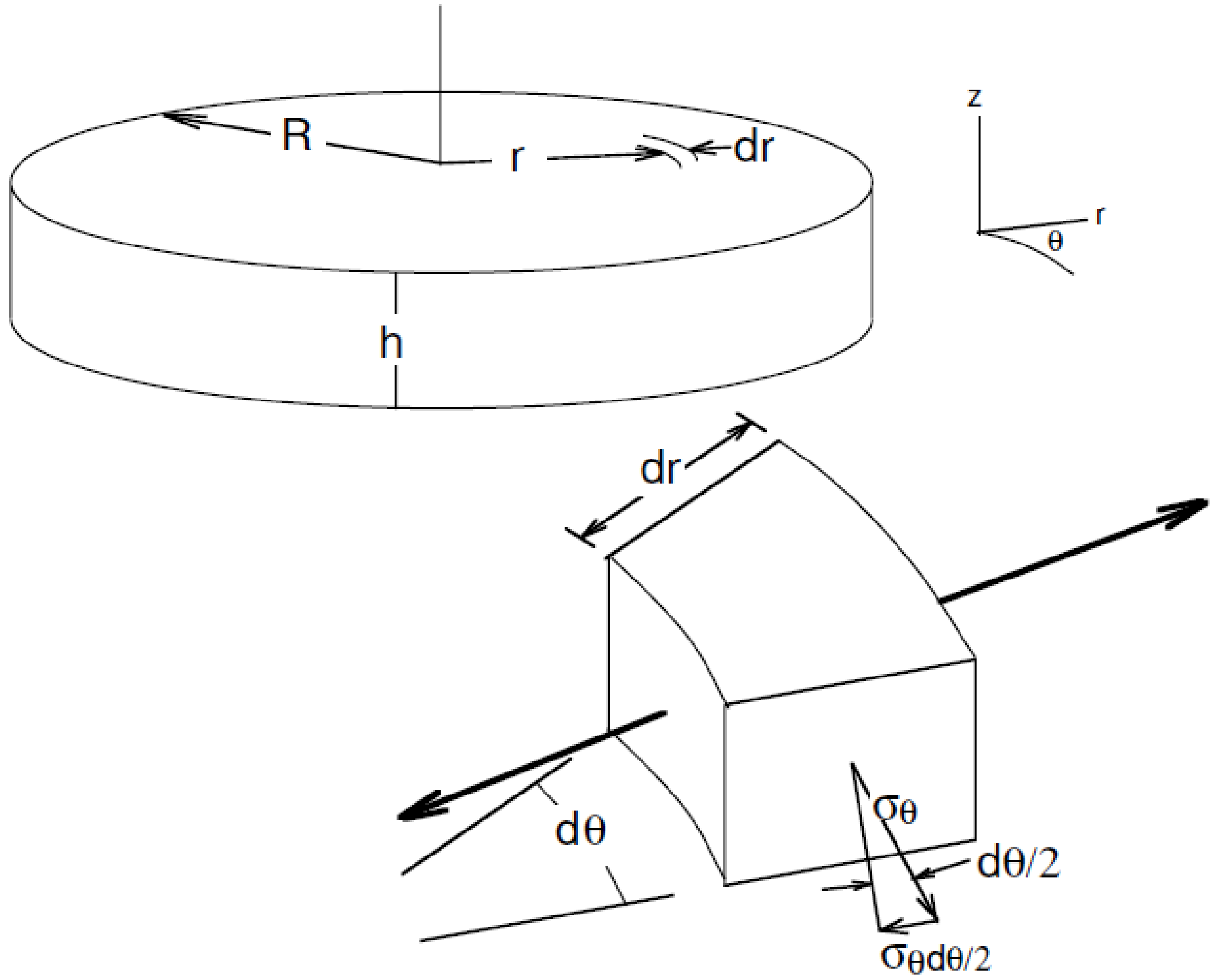
Plane-strain compression is conducted on a slab of metal 20 cm wide and 2.5 cm high, with a yield strength in shear of $k = 100$ MPa. Assuming a coefficient of friction of $\mu = 0.10$,

(a) Estimate the maximum pressure at the onset of plastic flow;

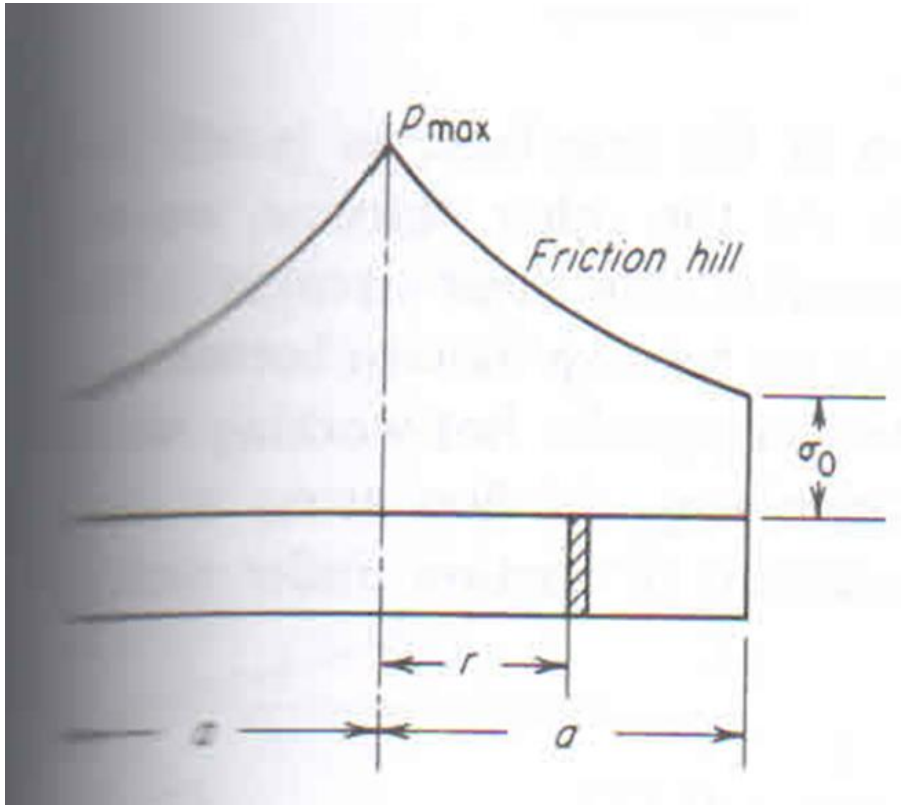
(b) Estimate the average pressure at the onset of plastic flow.

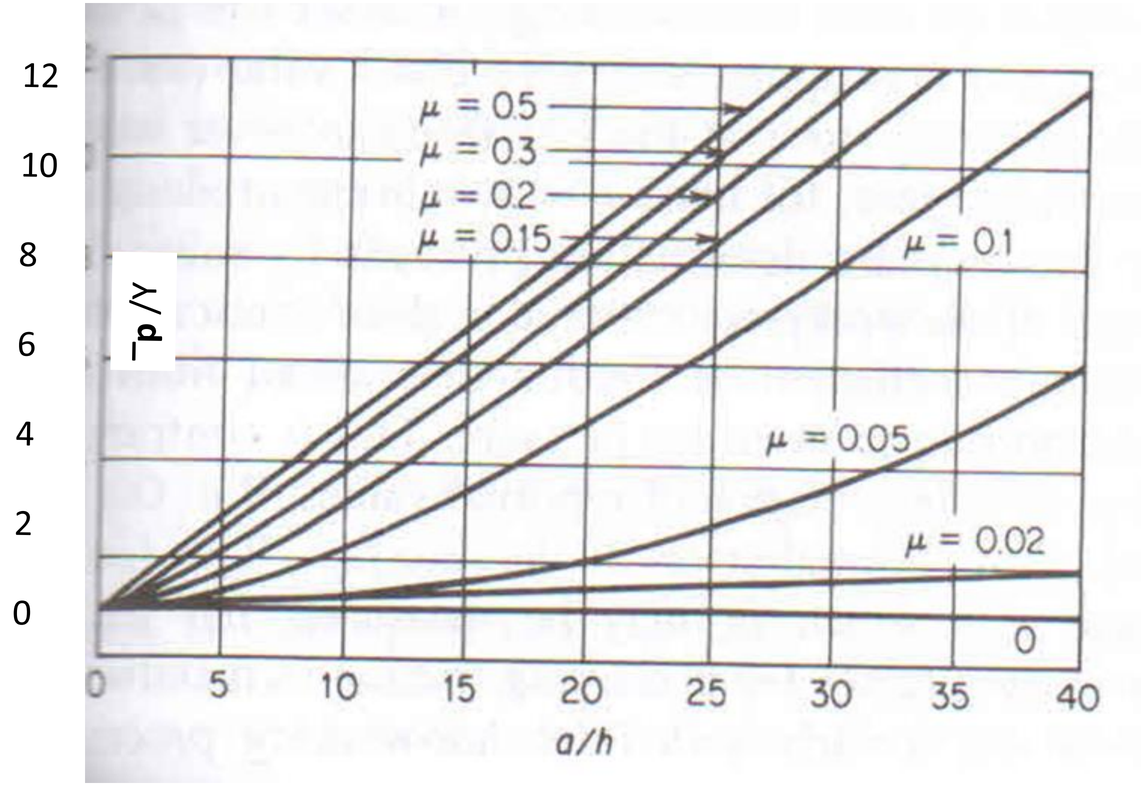
# AXIALLY SYMMETRIC COMPRESSION

**Dieter: 15.7 + class lecture**



# Columbic Friction for a compressed circular disk




- When μ increases, avg. pressure increases
- Role of friction becomes important at large values of *a/h*

# Sticking Friction

Interface has constant film shear strength ‘$\tau$’

No relative motion possible

This is often seen in hot-working where lubrication may be difficult

Here $\tau_i$ = k (Y.S. in shear)

With the von Mises’ yield criteria, C.O.F. under sticking condition:

$$\mu = \frac{\tau_i}{p} = \frac{k}{\sigma_0} = \frac{\sigma_0 / \sqrt{3}}{\sigma_0} = \frac{1}{\sqrt{3}} = 0.577$$

# Interface friction factor

- New way of looking at friction
- m= $\tau_i/k$
  - $\tau_i$ = Interface shear stress
  - $k$ = yield shear strength
- *m* varies from 0 (perfect sliding) to 1 (sticking)
- In columbic friction, we use p, which can exceed Y, but $\tau_i$ can never exceed $k$
- Once $\tau_i = k$, sliding ceases and only deformation starts to take place
- Hence, *m* seems a better suited parameter particularly for deformation

# Ring Compression Test

Useful for measuring *m* or µ.

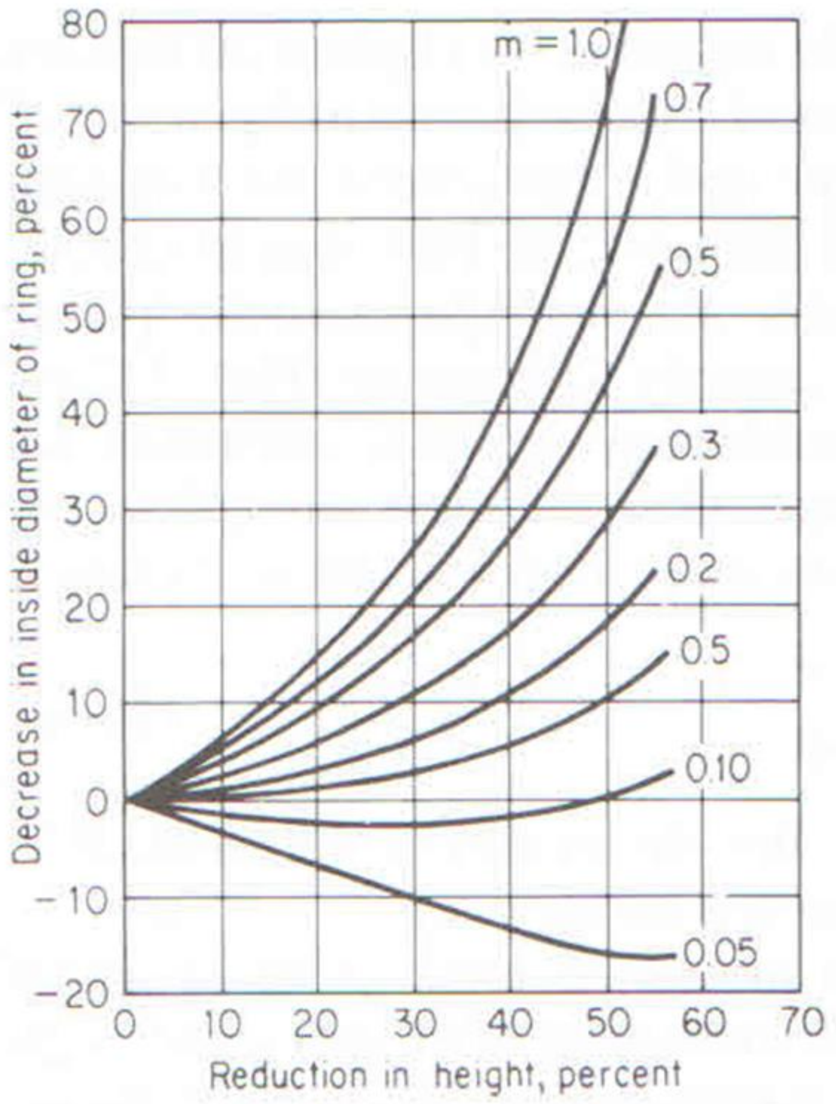
Take a ring with OD:ID: thickness as 6:3:1

Friction factor is determined by measuring the percentage change in the ID of the ring.

For low values of m the ID increases while for higher values of m the ID of the ring decreases.

Use calibration curve between ΔID and percent reduction to obtain m.

Conventionally m measured for high temp. and strain rate of typical hot working processes.



# Functions of metalworking lubricant

Reduces deformation load

Increases limit of deformation before fracture

Controls surface finish

Minimizes metal pickup on tools

Minimizes tool wear

Thermally insulate the workpiece and the tool

Cools the workpiece and/or the tools

# Workability of metals

Workability is defined as the extent to which a material be deformed in a specific metal working process without the formation of cracks.

If ductility of the material is high the material can be mechanically worked with ease.

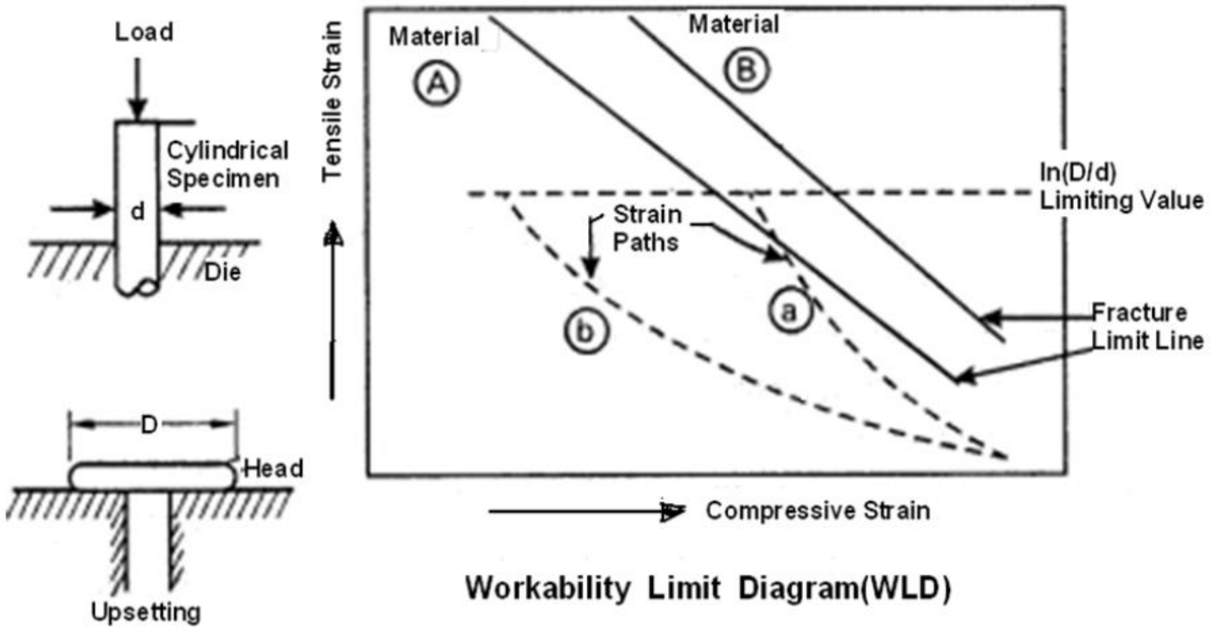
It is a complex technological concept that depends *not only* on the fracture resistance (ductility) of the material *but also* on the specific details of the deformation process.

**Workability may be considered to be a function of**

i) Fracture resistance viz., ductility of the material.

ii) Parameters if deformation –friction, temperature, strain rate.

# Workability Limit Diagram(WLD)




Workability Limit Diagram(WLD)

The strain path (a) meets the fracture limit line before reaching the limiting value. Fracture will take place in the material.
By improving the lubrication the stress path can be shifted to (b) and the deformation can be achieved without fracture.
Alternately, deformation can be made with strain path (a) by changing the material from A to the more workable material B with fracture limit line as shown in the figure.

Strain Paths and Fracture Limit Line for a given material is plotted .
For different values of compression strain at fracture the corresponding tensile strain is obtained and is plotted for different materials to get the WLD.

Consider cold upsetting of a cylinder into a blot head. A cylindrical specimen of dia. ‘d’ is upset to a head of diameter ’D’.
To form a head of diameter ‘D’ from diameter ‘d’ requires the material to withstand a circumferential surface strain of In(D/d).
For workability of the material, the strain path must reach this limiting value of strain without crossing the fracture limit line.

# Residual stresses

- Class lecture