Introduction to Wear

- Plastic deformation at the interface often leads to wear, i.e., deformation induced wear.
- Wear can also be caused by chemical processes.
- There are many different kinds of wear mechanisms
- We have to analyze these wear mechanisms using mechanics, thermodynamics, etc. Tribology is a multi-disciplinary subject.

Wear Mechanisms

Classification	Wear Mechanisms	Wear coefficient K (range)
Wear dominated by mechanical Behavior of Materials	1. Asperity deformation and removal 2. Wear caused by plowing 3. Delamination wear 4. Adhesive wear 5. Abrasive wear 6. Fretting wear 7. Wear by solid particle impingement	10^{-4} 10^{-4} 10^{-4} 10^{-4} 10^{-2} to 10^{-1} 10^{-6} to 10^{-4}
Wear dominated by chemical behavior of materials	1. Solution wear 2. Oxidation wear 3. Diffusion wear 4. Wear by melting of the surface layer 5. Adhesive wear at high temperatures	

Wear Coefficient

- **Definition of Wear Coefficient K**

$$K = \frac{\text{(Wear volume) (Hardness)}}{\text{(Normal load) (Sliding distance)}} = \frac{3VH}{NS}$$

- **K is dimensionless.**

Wear of metals

- Consider the case of two metal disks sliding against each other. Which metal will wear faster among the following pairs?

1. AISI 1020 steel against AISI 1020 steel
2. OFHC copper against OFHC copper
3. OFHC copper against AISI 1020 steel
4. Carbon/carbon composite and OFHC copper

Sliding Wear at Low Speeds

- **Wear by Asperity Removal**
  - **Initial surface asperities**
  - **Smooth/Rough transition during steady state wear**
  - **Particles are expected to be small**

Wear by Asperity Removal

1020 steel disk sliding against 52100 steel pin (normal load 0.3 kg)

Graph removed for copyright reasons.
See Figure 5.1 in [Suh 1986]: Suh, N. P. *Tribophysics*. Englewood Cliffs NJ: Prentice-Hall, 1986. ISBN: 0139309837.

Wear by Asperity Removal

1020 steel disk sliding against 52100 steel pin (normal load 0.0.075 kg)

Graph removed for copyright reasons.
See Figure 5.2 in [Suh 1986].

Plastic deformation of original asperities for 1018 steel

(a) 2 mm CLS A, normal = 0.91 kg (After 10 passes)
(b) 3.3 mm CLA, normal load of 0.35 kg after 0.25 m of sliding
(Testing done in argon at 1.8 m/min.)

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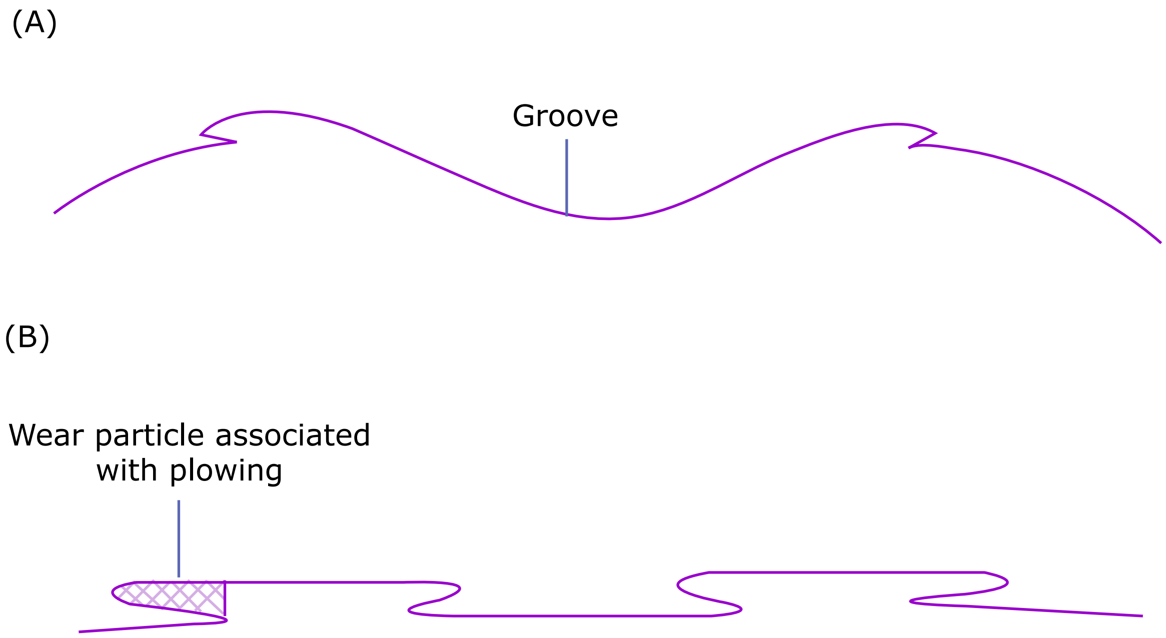
See Figure 5.3 in [Suh 1986].

Sliding Wear at Low Speeds

- **Wear by Plowing**
  - **Formation of grooves and furrows**
  - **Repeated deformation of the furrows**
  - **Removal of particles**
  - **Expected to be thin and small**

Plowing at Low Sliding Speeds



Schematic illustration of wear particle formation due to plowing.
(A) Ridges formed along the sides of the plowed grooves. (B) Flattened ridges.

Figure by MIT OCW. After Suh, N. P., and H. C. Sin. "The Genesis of Friction." *Wear* 69 (1981): 91-114.

Sliding Wear at Low Speeds

- **Delamination Wear**
  - **Subsurface crack nucleation and propagation**

- **Basic steps of delamination wear**
  - **Plastic deformation of the surface layer**
  - **Subsurface crack nucleation**
  - **Subsurface crack propagation**
  - **Creation of loose wear sheets**

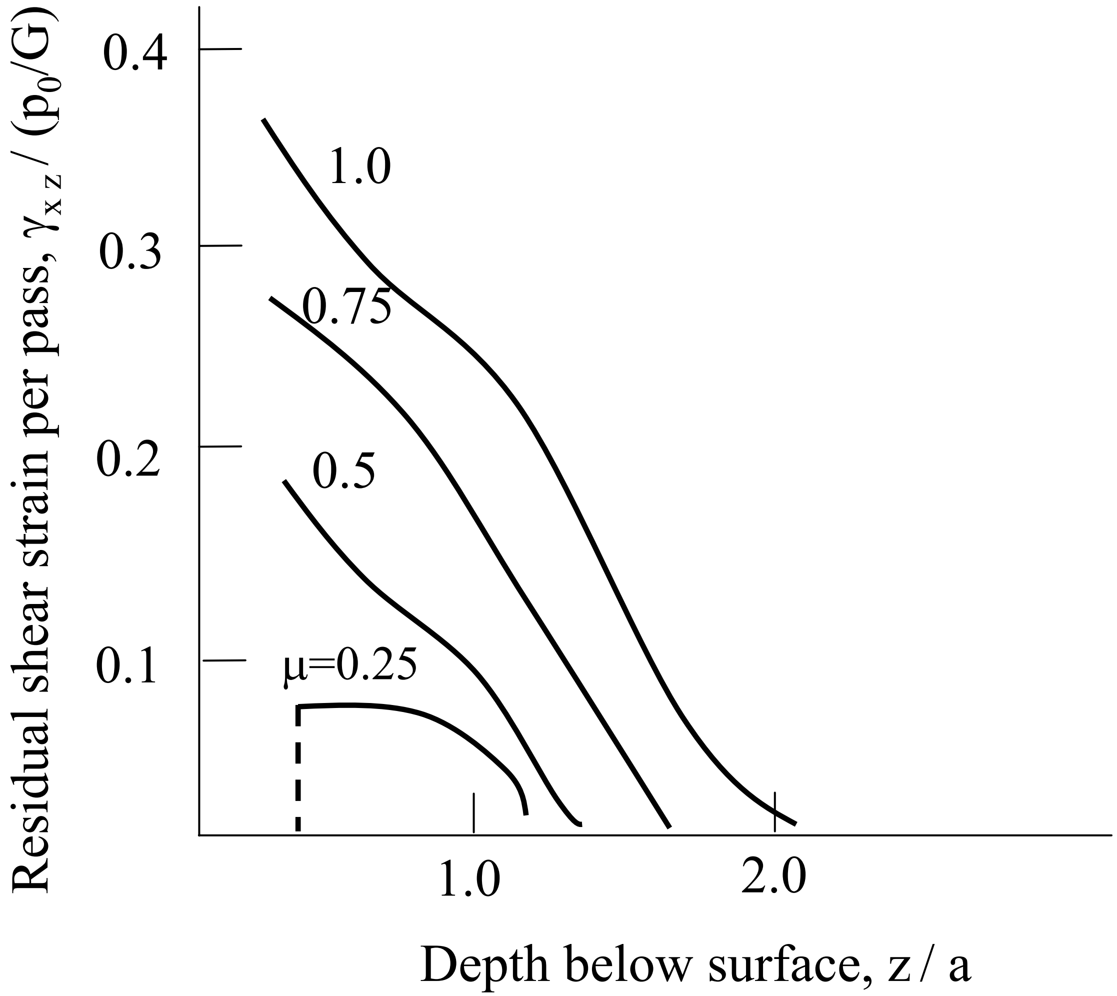
- **Large particles -- thickness > 1 μm, length~10 to 100 μm**

Deformation of the Surface Layer

Experimental Results: (a) copper, (b) 1020 steel

Graphs removed for copyright reasons.

Deformation of the Surface Layer
Analytical Results



Crack Nucleation -- Experimental Observation

Annealed iron with 1.3% Mo

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See Figure 4.33 in [Suh 1986].

Subsurface Cracks (annealed 1020 steel)

Photos removed for copyright reasons.
See Figure 4.34 in [Suh 1986].

Precipitation Hardened Cu-0.81 at% Cr alloy

(a) after 5 min (b) 10,000 min of aging

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See Figure 4.35 in [Suh 1986].

Subsurface deformation, void elongation, and crack formation in steel:

(a) doped 1020 steel, (b) commercial 1020 steel

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See Figure 5.5 in [Suh 1986].

Wear sheet formation in iron solid solution.

The sliding direction is always from right left since the only crack tip behind the slider can be subjected to tensile stress field which propagates the crack along the direction 70 degrees away from the surface.

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See Figure 5.6 in [Suh 1986].