Erosive Wear

• Several different kinds of erosive wear
  – Solid particle impingement
  – Impingement of liquid droplets
  – Flow of hot gases
  – Cavitation of liquid media due to collapsing bubbles
Erosive Wear Due to Solid Particle Impingement

• Useful Applications
  – Grit blasting
  – Abrasive cutting (typically with water)
  – Water jet cutting (demo in the lab)
Erosive Wear Due to Solid Particle Impingement

• Applications adversely affected by erosion
  – Polymer processing machines and others
  – Coal plants (transport of pulverized coal)
  – Gas turbines
  – Power plants
  – Pipelines
  – Ship propellers
  – Aircraft
    • Windshield
    • Wings
    • Propellers
    • Rotors
• Erosion as a function of the following variables:
  Ductility of material being eroded
  Microstructure
  Velocity of particles
  Impingement angle
  Particle size
  Hardness of particles
  Strength of particles
  Temperature
Erosive Wear Due to Solid Particle Impingement

- Roughly proportional to $V^n$, where $n$ can be 1.7 to 2.8 for ductile metals and 1.4 to 5.1 for brittle materials
- Erosion rate -- (1/250) to (1/1000) by weight of abrasives
- Angle dependence -- around 20$^\circ$ for ductile materials and around 90$^\circ$ for brittle materials
- Particle size dependence -- Once it exceeds a certain size, it is independent of the particle size, similar to abrasive wear.
- Temperature dependence is different as a function of material properties. In general, the erosion rate of ductile metals decreases with increase in temperature.
- Erosion rate, in general, decreases with increase in hardness and toughness.
Model of Erosive Wear of Metals

- Cutting model of Finnie

\[ m\ddot{x} + p\psi bx = 0 \]
\[ m\ddot{y} + pJ\psi by = 0 \]
\[ I\ddot{\phi} + p\psi b\phi = 0 \]

\[ \psi = \frac{\ell}{y_t} \]

\( J \) – ratio of vertical to horizontal force component
\( p \) - constant horizontal component of contact stress
Erosion of Ductile Materials

• Erosive Wear Volume vs Velocity (Finnie Model)

\[ W = \left( \frac{\rho}{p \psi} \frac{M U^2}{J} \right) \frac{J \cos^2 \alpha}{6} \]
Erosion of Brittle Materials

• Transition from ring cracking to plastic indentation cracking
  – Yielding
    
    \[ a = \left( \frac{4kLR}{3E} \right)^{1/3} \]
    
    \[ \sigma_o = \frac{3L}{2\pi a^2} \]
    
    \[ L_y = B_2 \left( \frac{k}{E} \right)^2 H^3 R^2 \]
  – Hertzian fracture load for large indentation
    \[ L_f = B_1 R_n \]
Erosion of Brittle Materials

• Critical Radius

\[ R_c = B \left( \frac{E}{k} \right)^2 \frac{1}{H^3} \]
Erosion of Brittle Materials

• Loading due to Impact of Sphere