



INSPIRED . RELIABLE . GLOBAL

Bearing Failure Mechanisms



The Question

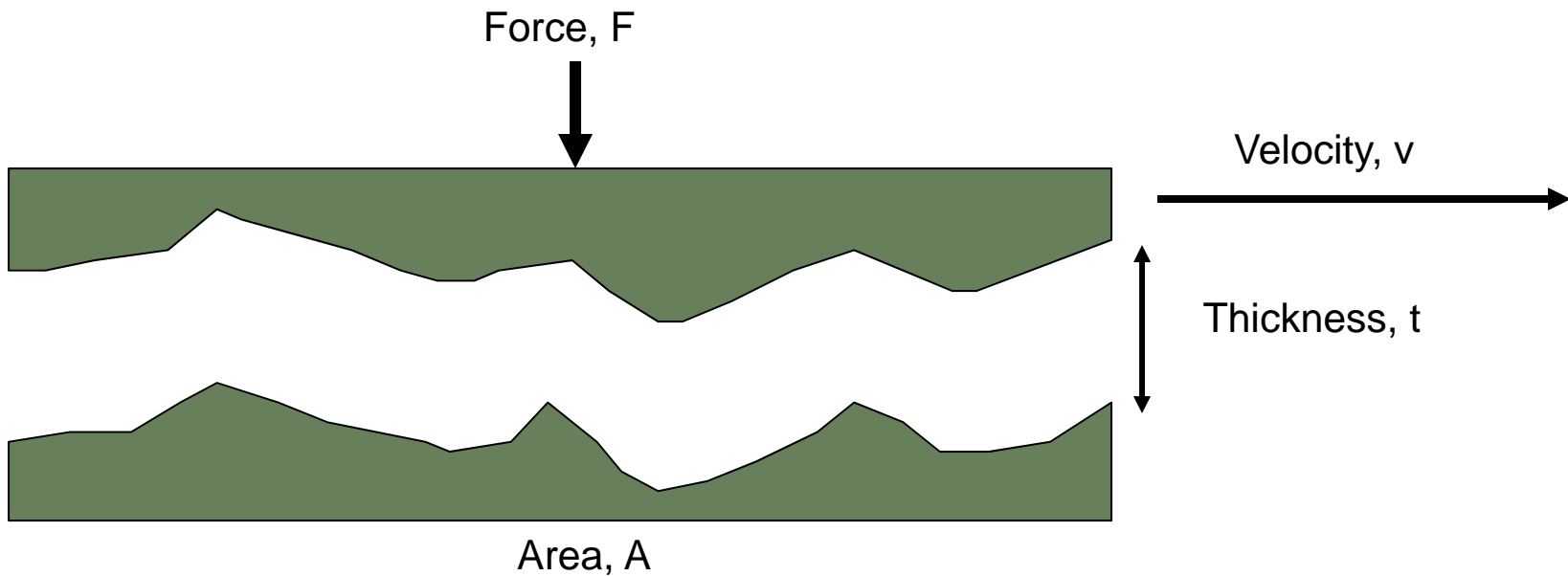
How long are bearings designed to last?

What is the L_{10} life?

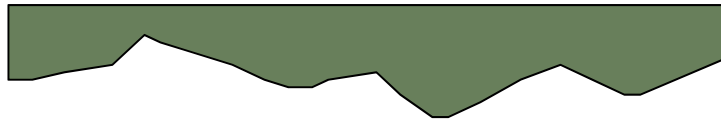
- The age to which at least 90% of a sufficiently large population of the same bearings under the same conditions can reasonably expect to survive.
- Predicted life is $\sim 5 \times L_{10}$

Friction and Lubrication Regimes

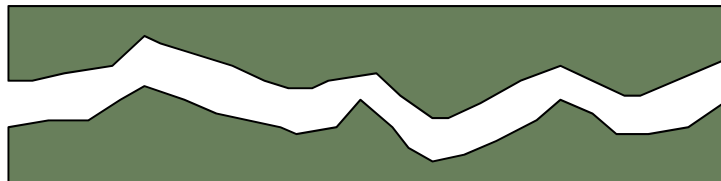
Lubricant Film Thickness



Lubricant Film Thickness



Mild Lubrication

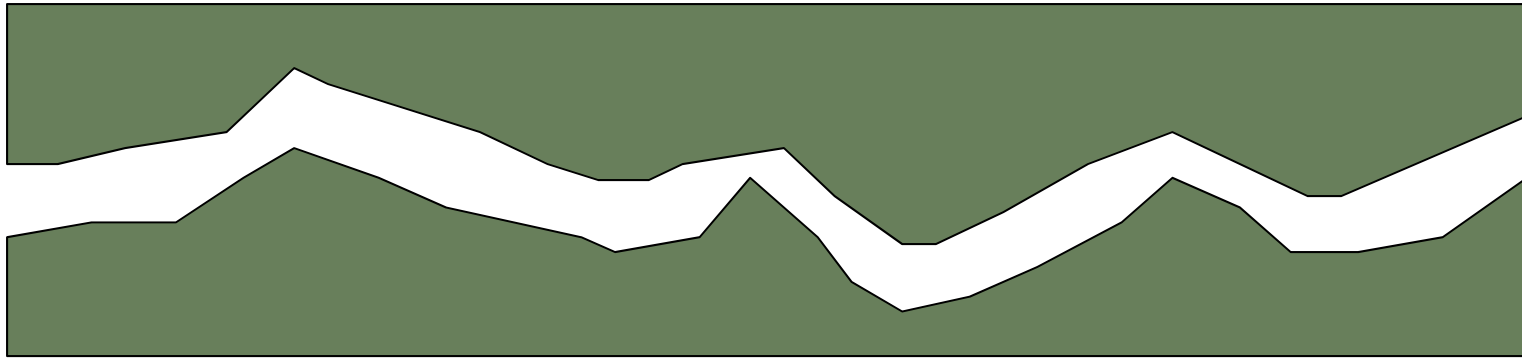


Severe Lubrication

Specific Film Thickness (λ)

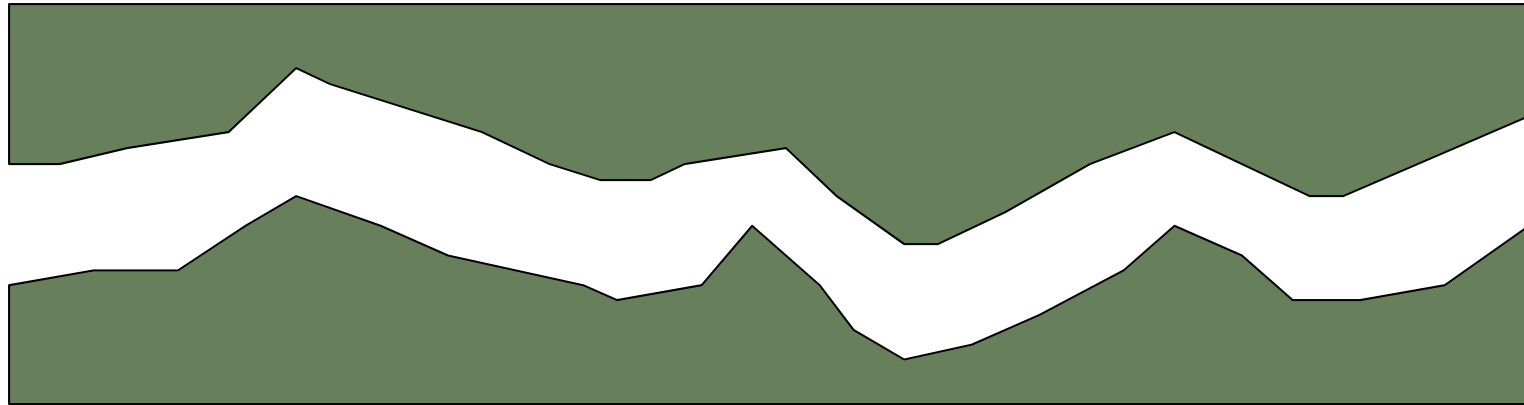
$$\lambda = \frac{\text{MeanFilmThickness}(t)}{\text{SurfaceRoughness}(\sigma)}$$

Boundary Lubrication



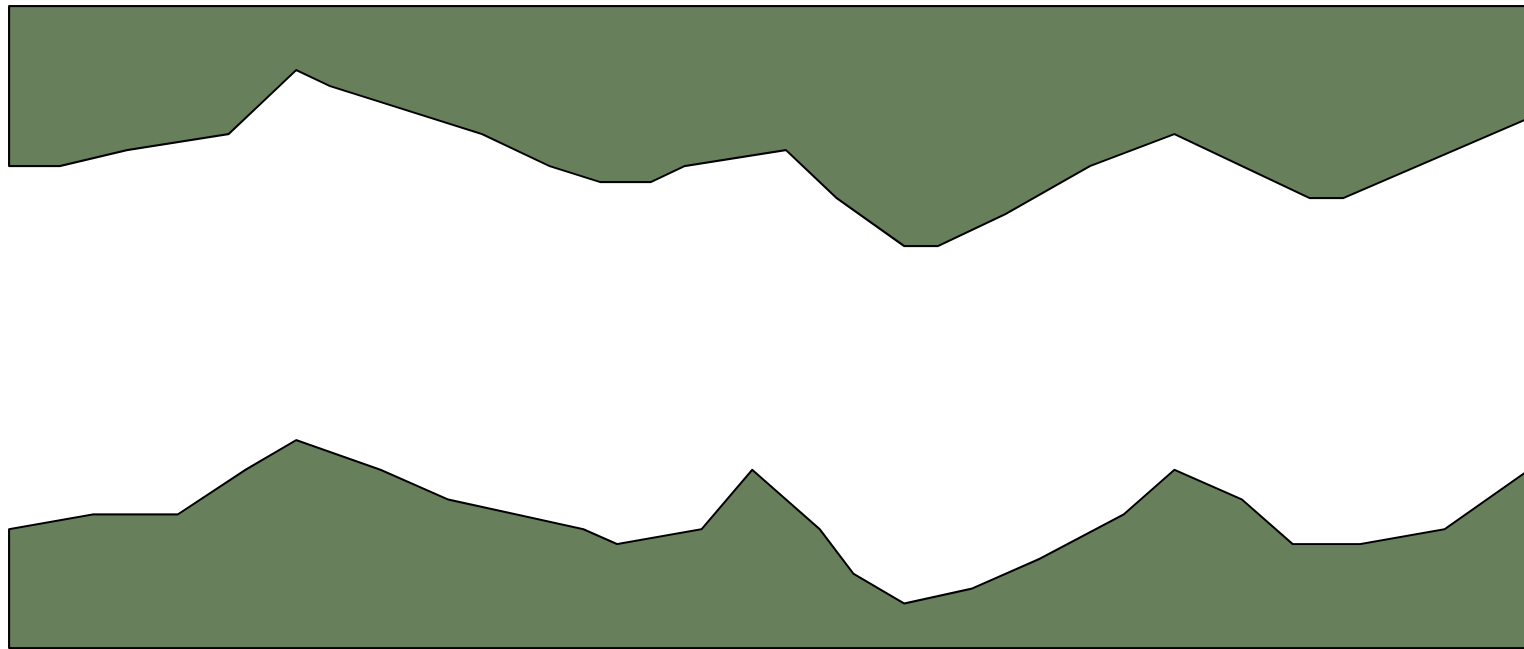
$$\lambda < 1$$

Mixed Lubrication



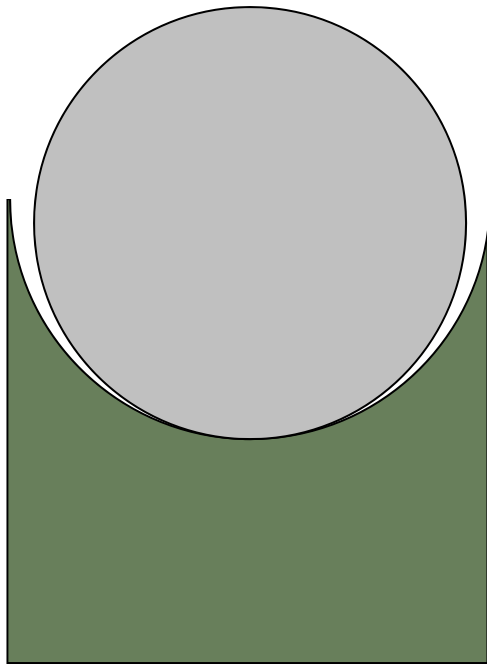
$$1 < \lambda < 4$$

Full Film Lubrication



$$\lambda > 4$$

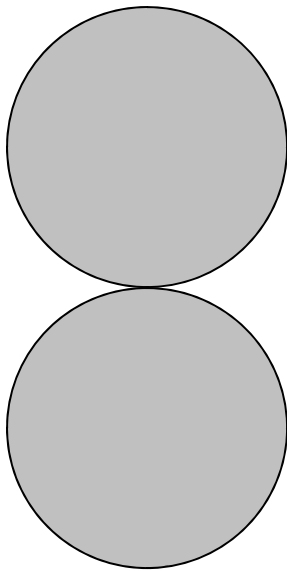
Hydrodynamic Lubrication



High Conformity

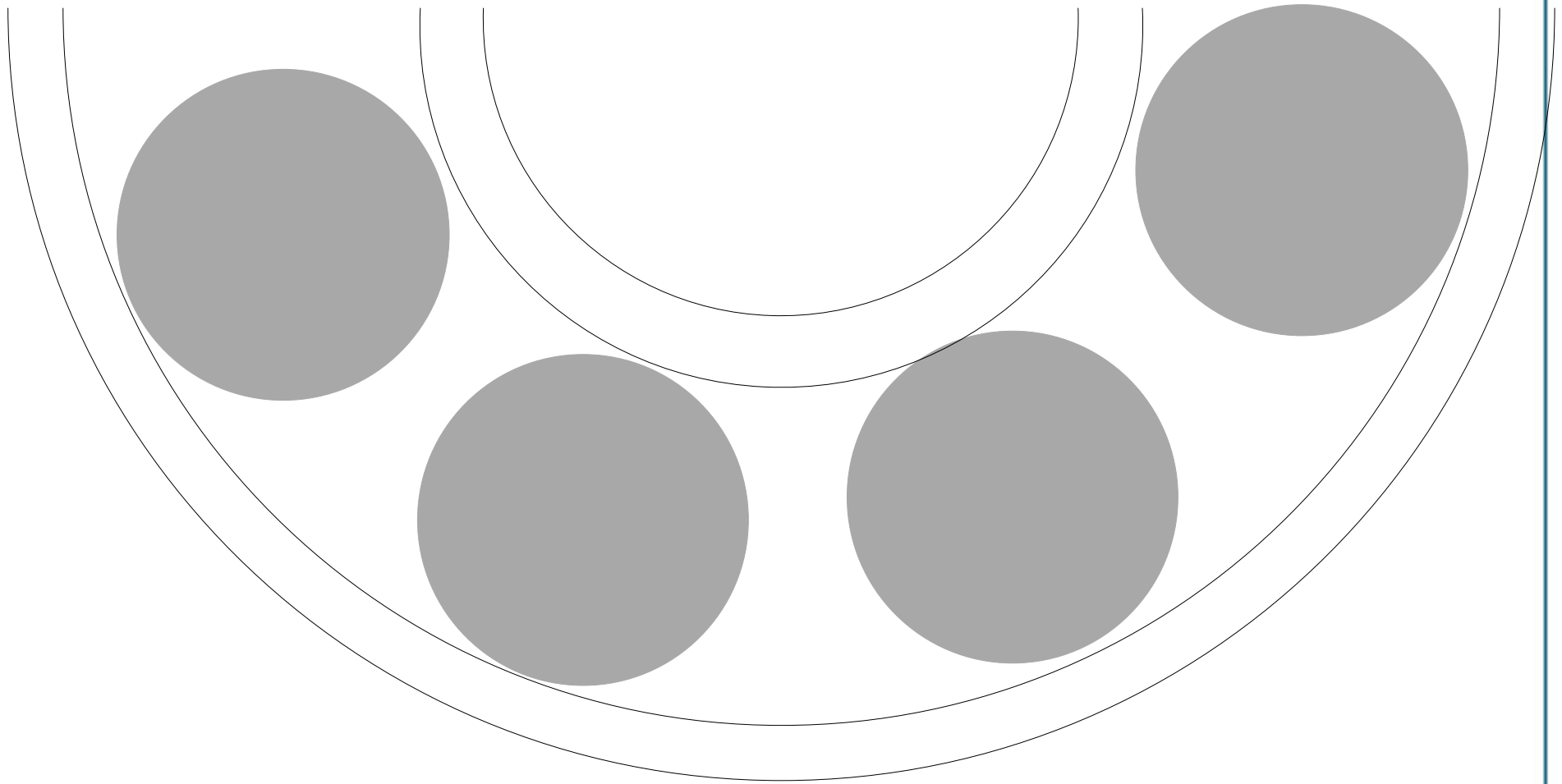
- large contact area
- low contact pressure
- Oil wedge between surfaces
- Oil film supports the load
- Contact pressure may be 58,000 psi
 - typically only several hundred psi
- Journal Bearing

Elastohydrodynamic Lubrication

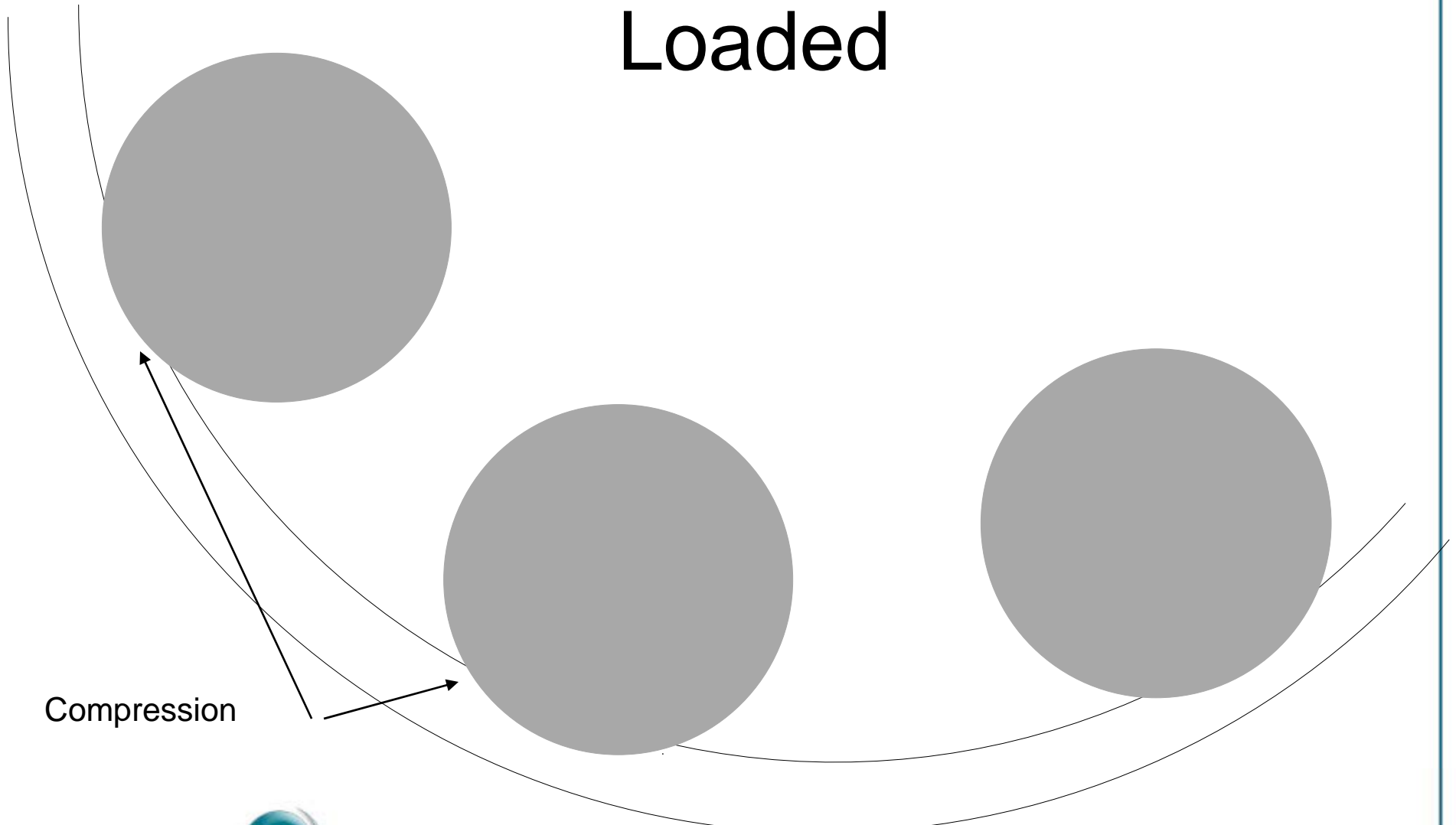


Low Conformity

- small contact area
- high contact pressure
- Oil wedge between surfaces
- Oil film supports the load
- Contact pressure 450,000 psi
- Rolling Element Bearing

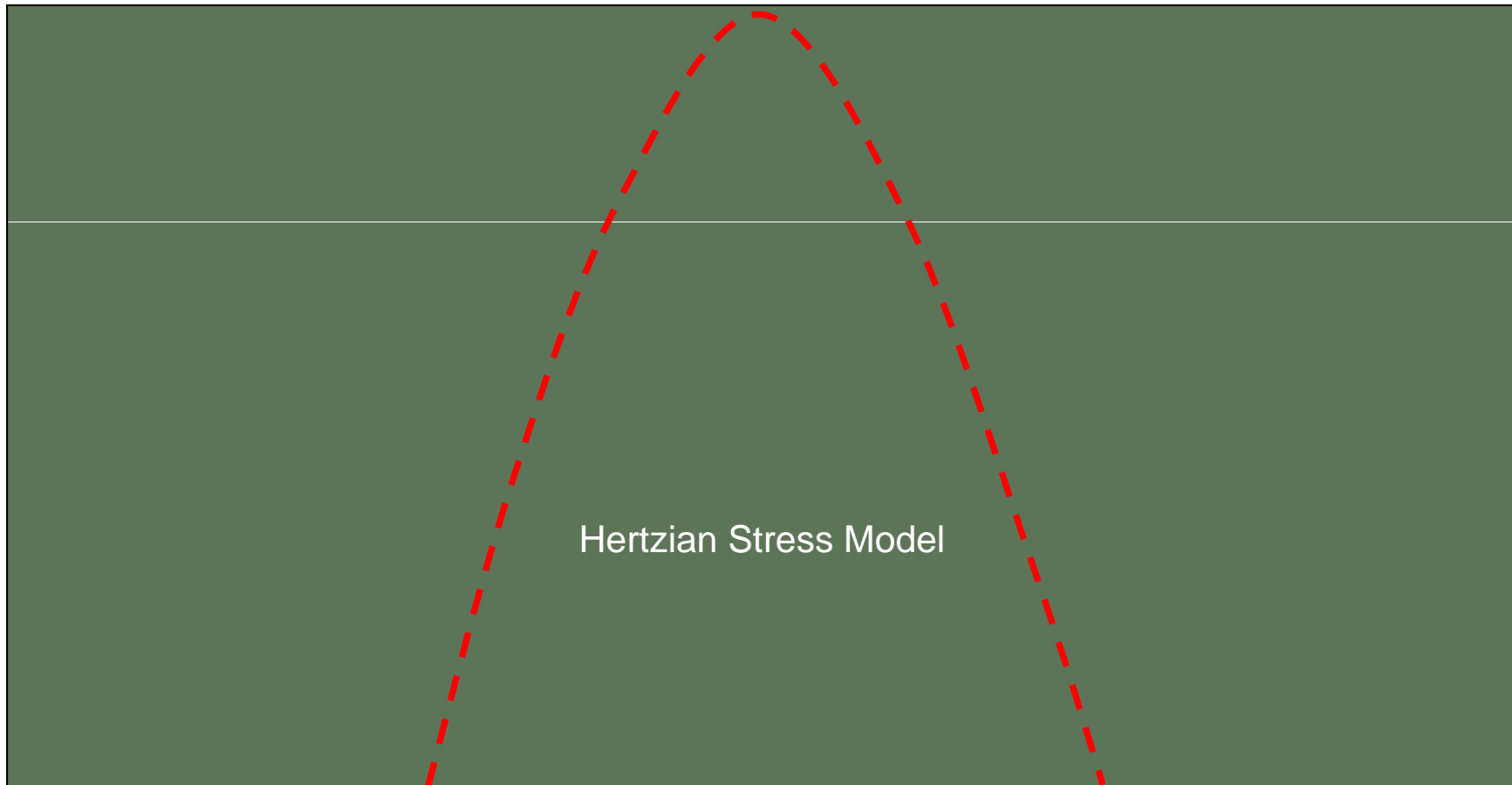


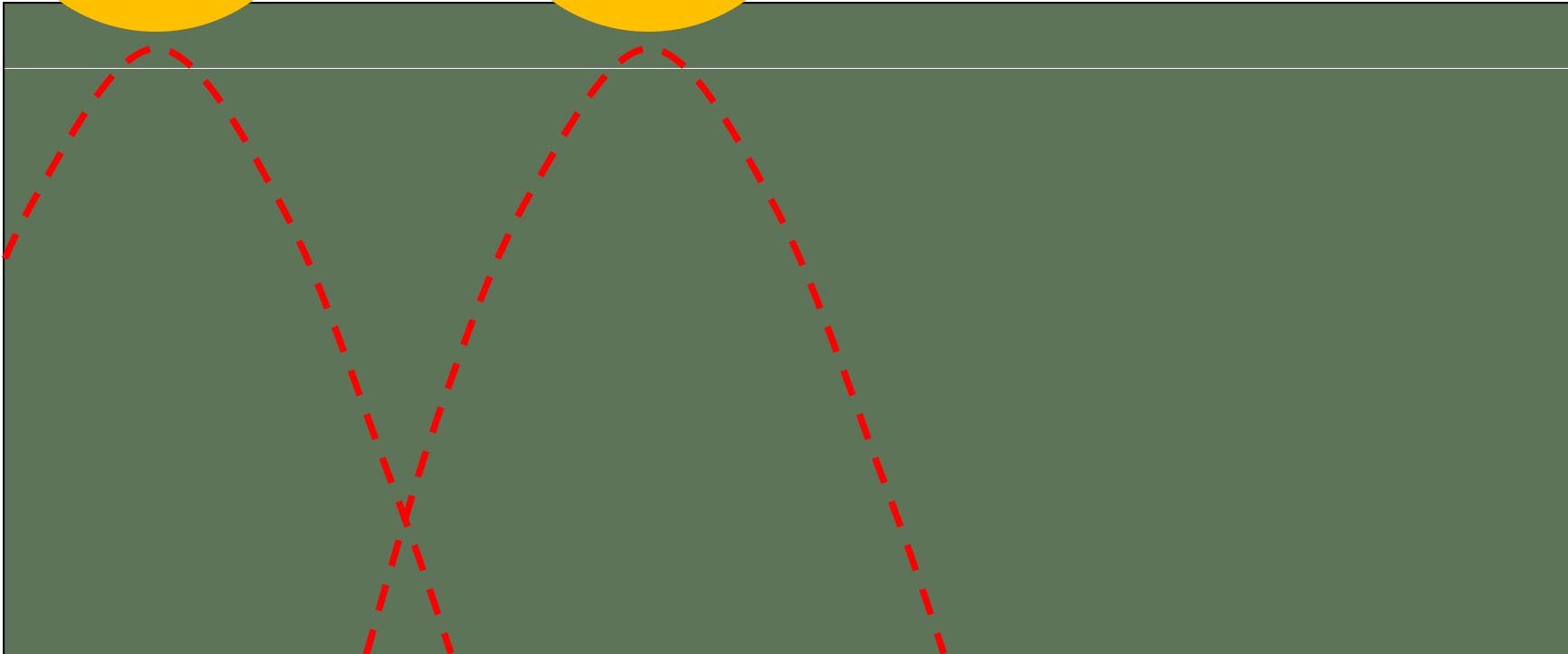
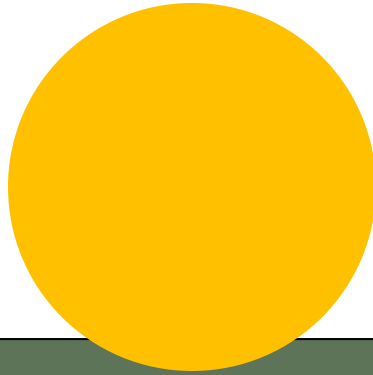
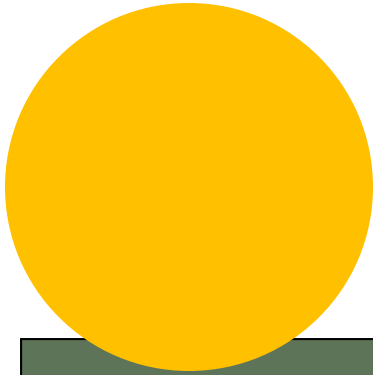
Loaded



Compression

Normal Race





How often does this happen in 1 day?

- 1775 rpm (29.583 cycles per second)
- 8.193 Ball Pass Frequency Inner Race

24 hours
x 60 minutes per hour
x 60 seconds per minute
x 29.583 cycles per second
x 8.193 BPF
20,941,072 cycles per day
628,232,161 cycles per month
7,538,784,934 cycles per year

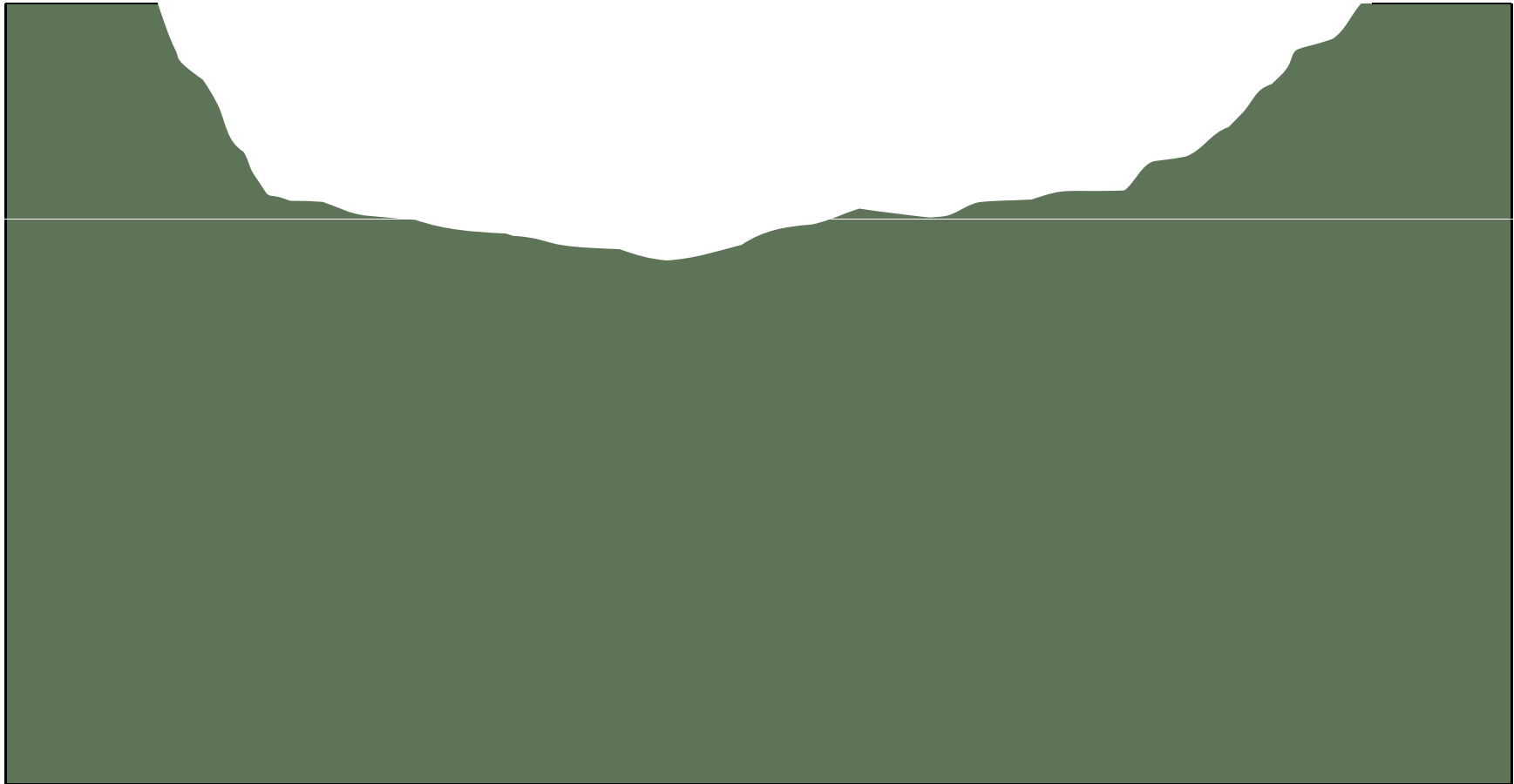
Subsurface Fatigue



Subsurface Fatigue - Advanced



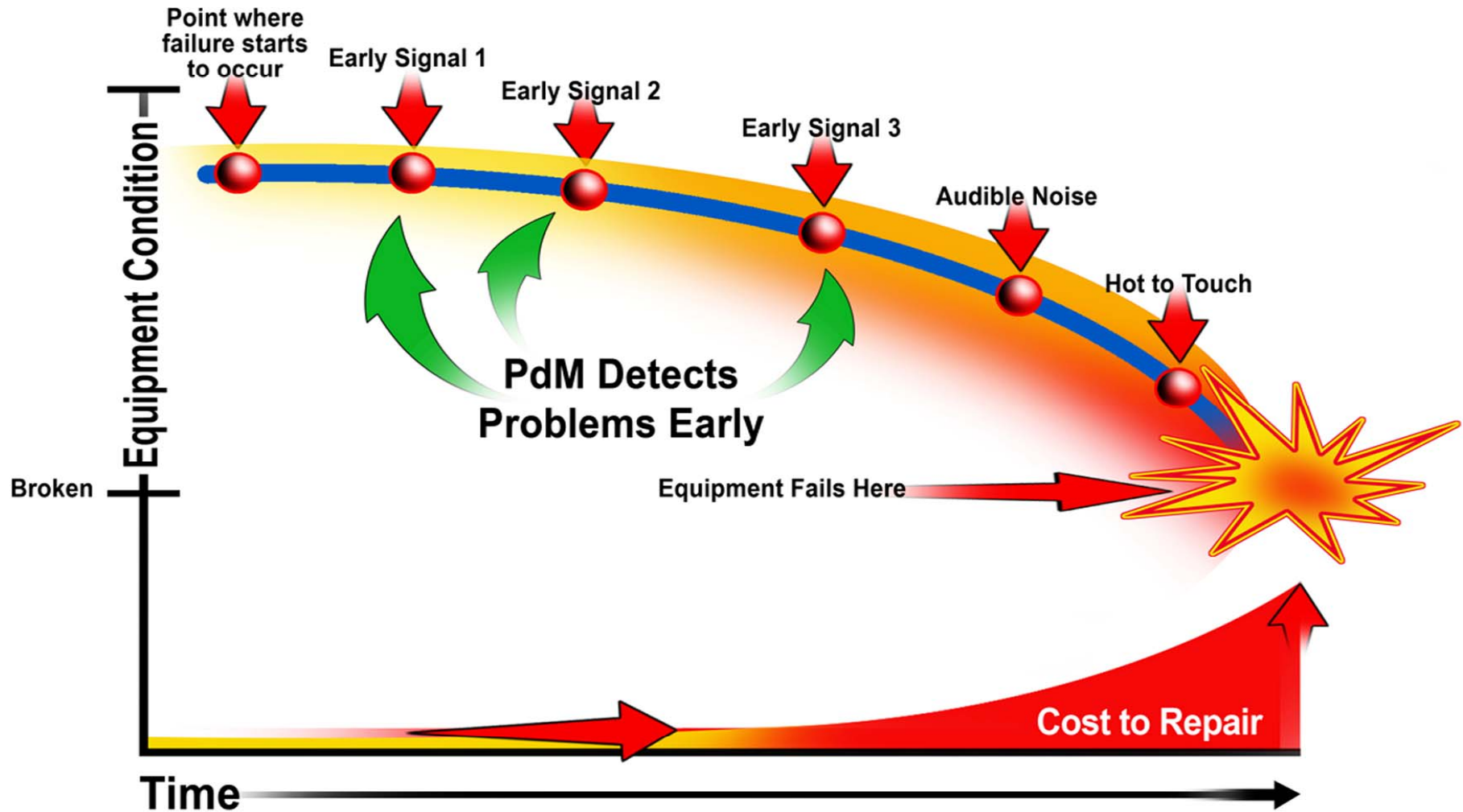
Spalling



First Sign of Trouble



The P-F Curve



Lubrication Dynamics

For any lubricant -

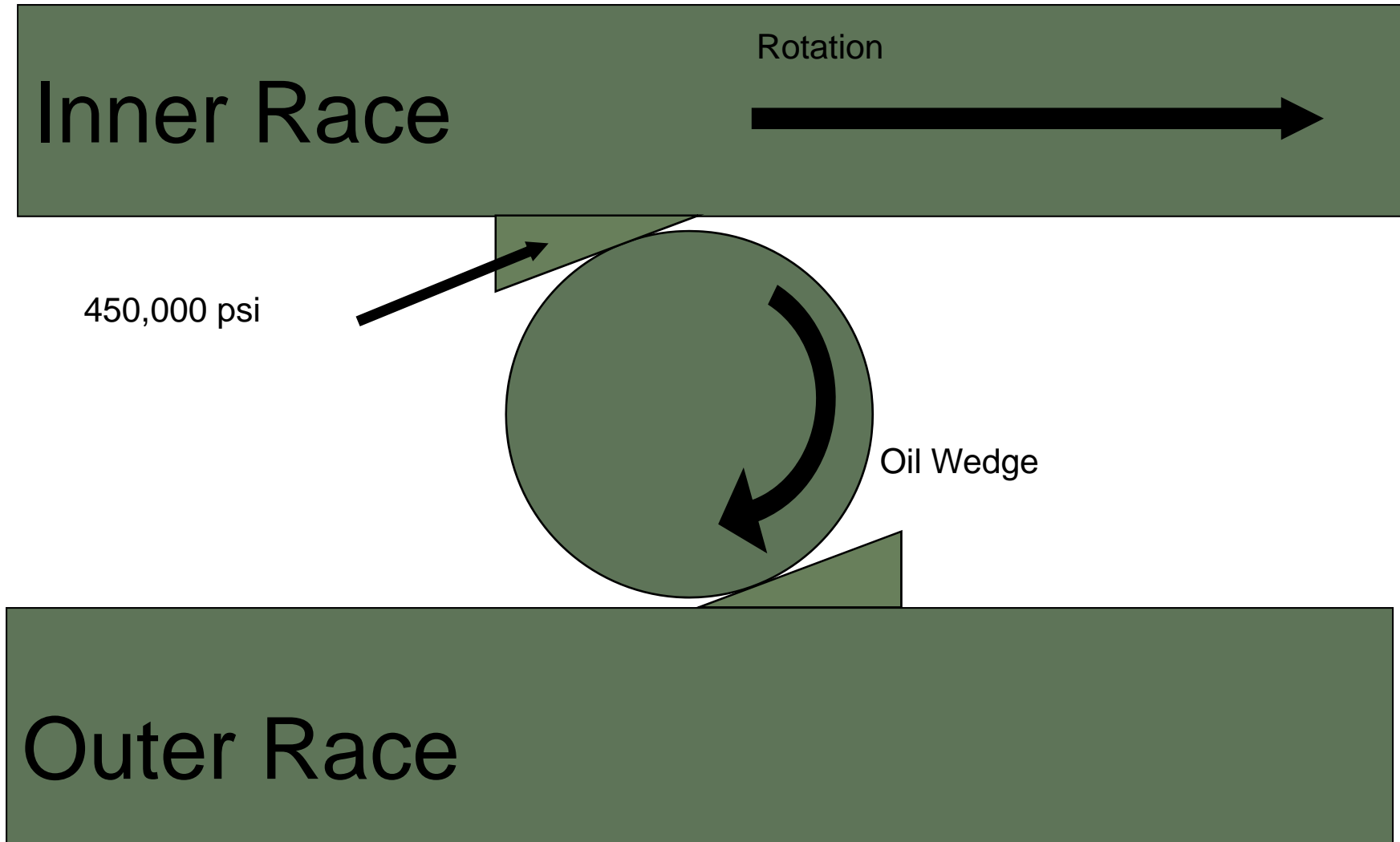
As pressure goes up...

Viscosity goes up exponentially.

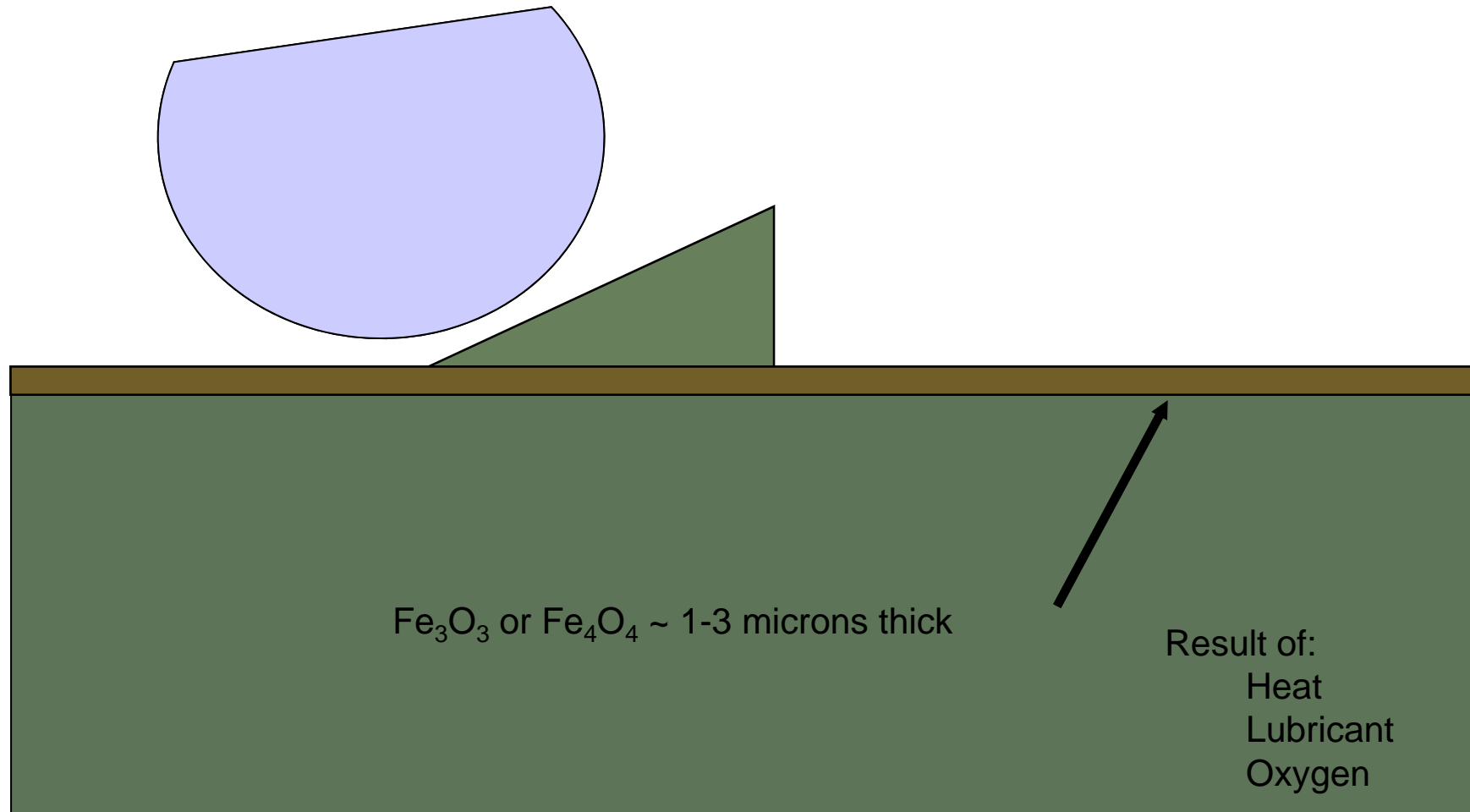
At 200,000 psi the lubricant becomes harder than the metal.

And thus, the metal surfaces never touch.

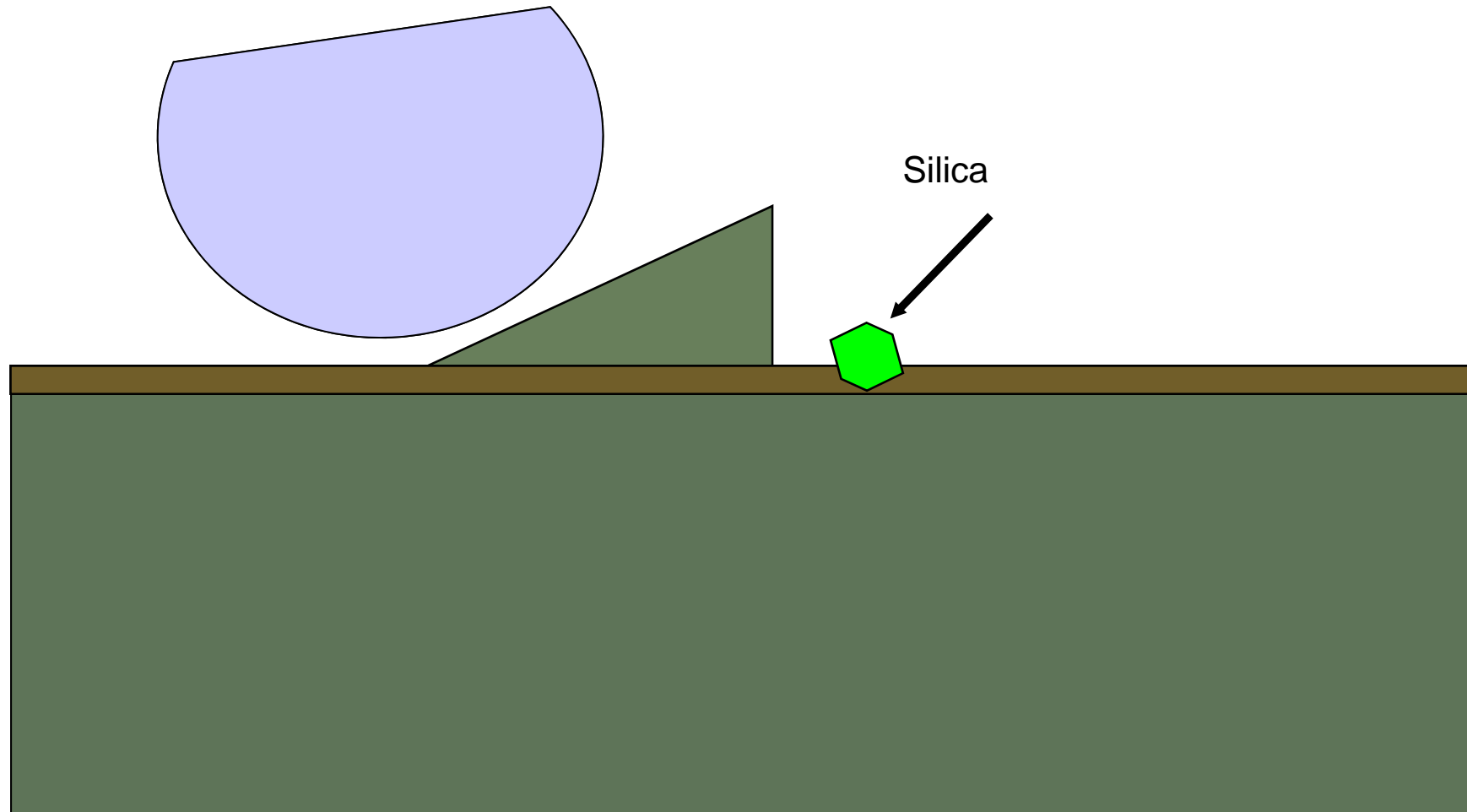
Lubrication Dynamics - Bearings



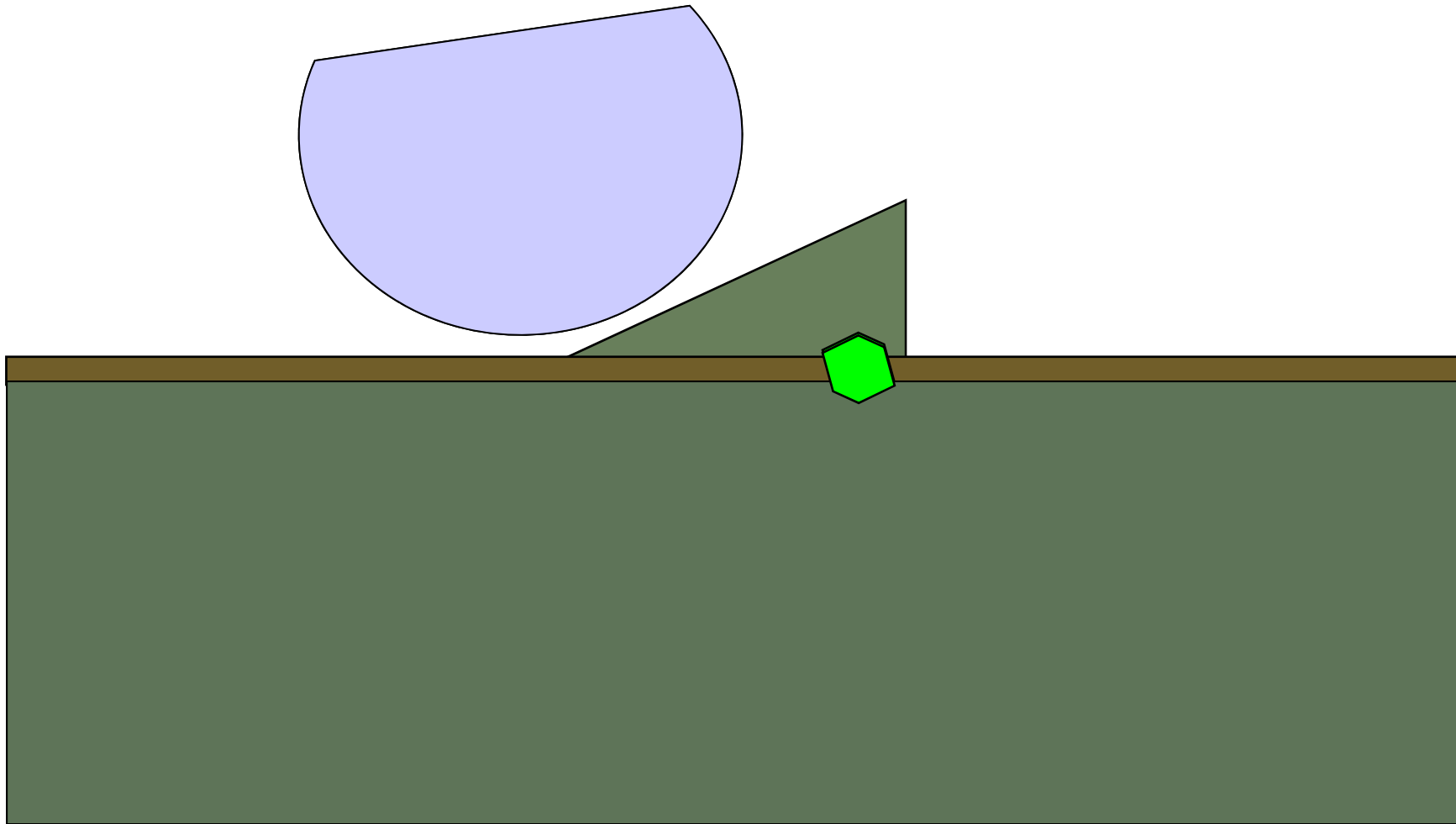
Lubrication Dynamics - Bearings



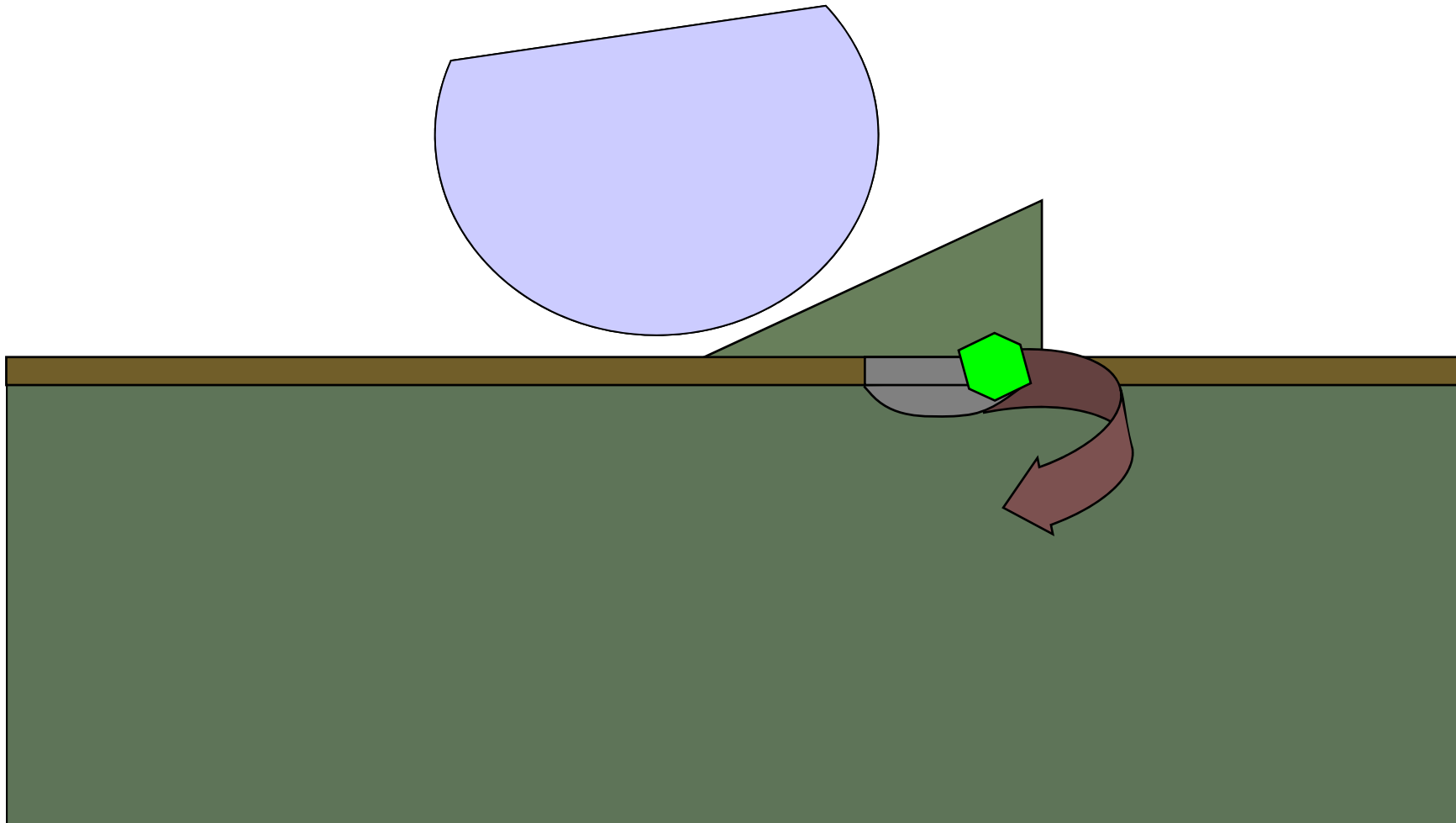
Lubrication Dynamics - Bearings



Lubrication Dynamics - Bearings

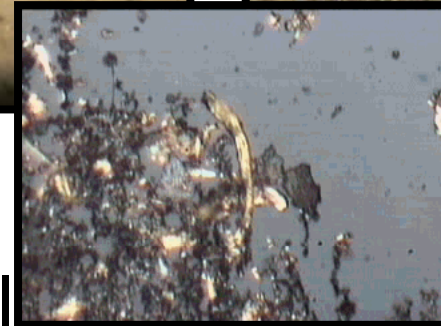
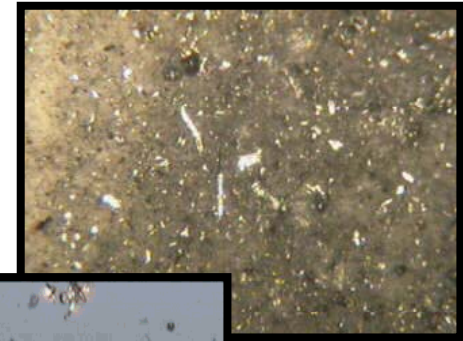


Lubrication Dynamics - Bearings



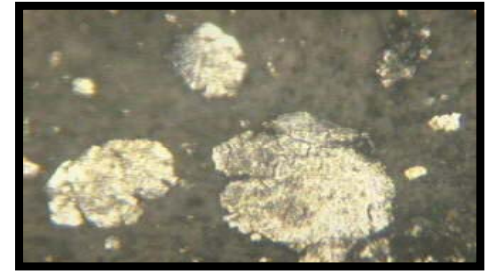
Abrasive Wear

- Looks like:
 - Curls
 - Corkscrew
 - Long needles
- Edges serrated
- 5-100 microns
- Results from abrasive particles
- Also called: plowing, cutting, gouging
- Caused from 2 or 3 body abrasions with sliding contacts



Surface Fatigue

- Looks like:
 - Contact Fatigue
 - Spalling
 - Pitting
 - Brinnelling
 - Fretting



- Begins by denting due to particles or shock loads
- Causes surface imperfections that with repeat high loading will cause a pop-out of surface material

Often Misquoted

“Bearings have an infinite life when particles larger than the lubricant film are removed”

