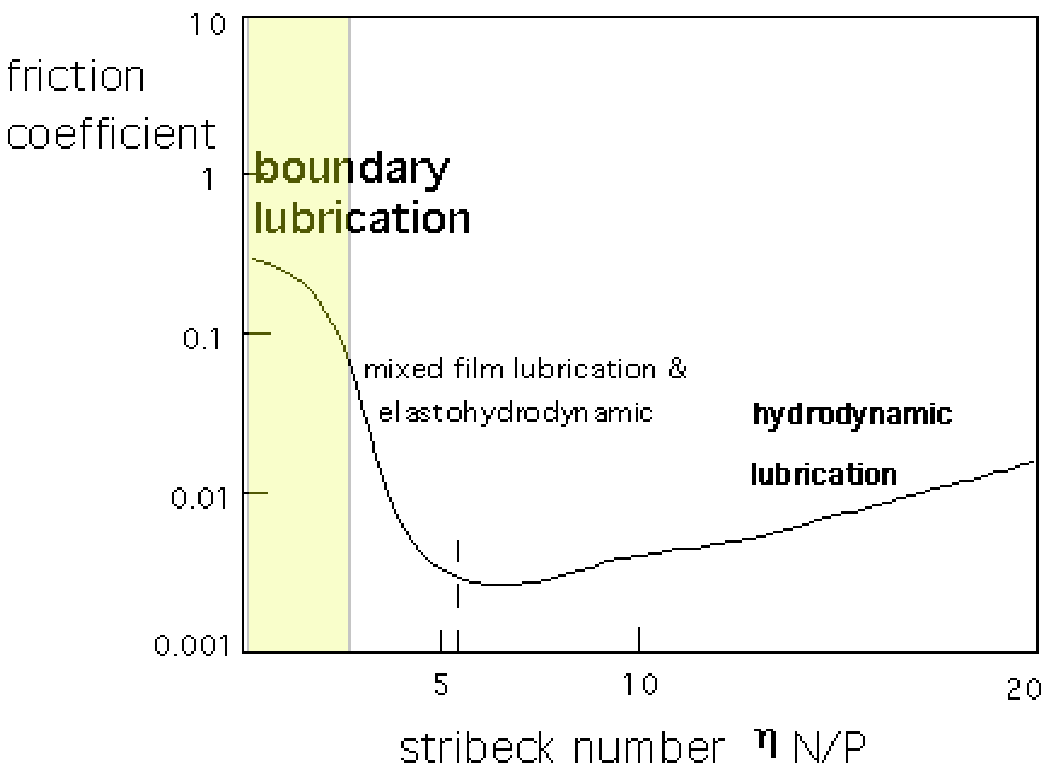
Boundary Lubrication

Definition: Campbell [1]

"Boundary lubrication is lubrication by a liquid under conditions where the solid surfaces are so close together that appreciable contact between opposing asperities is possible. The friction and wear in boundary lubrication are determined predominantly by interaction between the solids and between the solids and the liquid. The bulk flow properties of the liquid play little or no part in the friction and wear behavior. "

Stribeck Curve



Characteristics

- Liquid-solid interactions

- Contact between asperities
  - Increased friction
  - Wear

- Friction & wear determined by properties of solid surfaces as well as properties of lubricant

- Shear of thin surface films
  - Lubricant films < 100 nm thick
  - Several to hundreds of molecules thick
  - Solid or liquid
  - "Lubricant starved" contact

- Load sharing
  - Asperity-asperity contacts
  - Lubricant pressures generated by
    - Squeeze films
    - Sliding

- "Oiliness" of surfaces determines friction
  - Lubricant film thickness < 100 nm thick

Examples

- Engines: Piston rings & liner @ TDC & BDC

- Biological
  - Synovial joints, e.g., knee with synovial fluid
  - Teeth/saliva during chewing

- Oiled gun barrel & bullet

- Start up & shut down of equipment:
  - Engines
  - Bearings
  - Cams

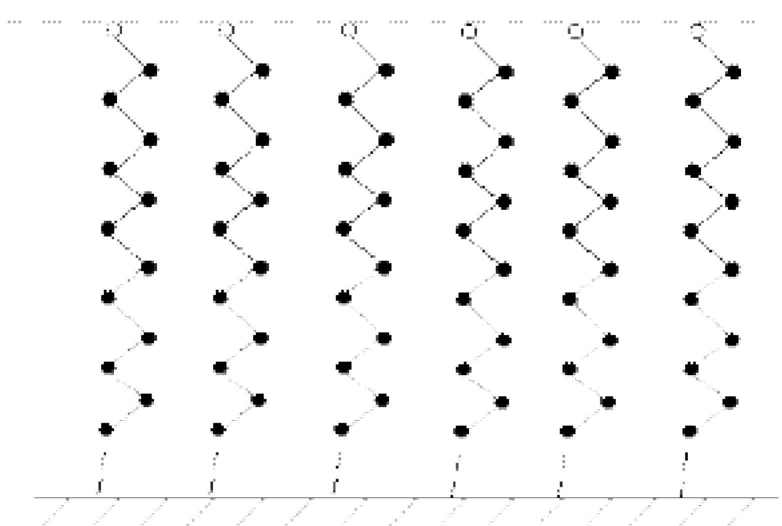
- Lubricated metal cutting or machining

Protective Films

- Chemical interactions form (protective) films
  - Surface absorption
  - Surface reactions

- Diamond like (protective) films
  - Very low (dry) friction $\mu \approx 0.001$
  - Chemically inert, very hard
  - Ali Erdemir: "Near-Frictionless Carbon…….ultra-hard coating many times slicker than Teflon."
  - Hydrogenated carbon bonded to surface, unreactive.

- Design of protective boundary films (hydrocarbons)
  - Film absorbs to surface
  - Bodies don't touch
  - Class of oil additives for bonding to surfaces (surfactants)



GREASES

MOLECULAR DYNAMICS OF FILMS

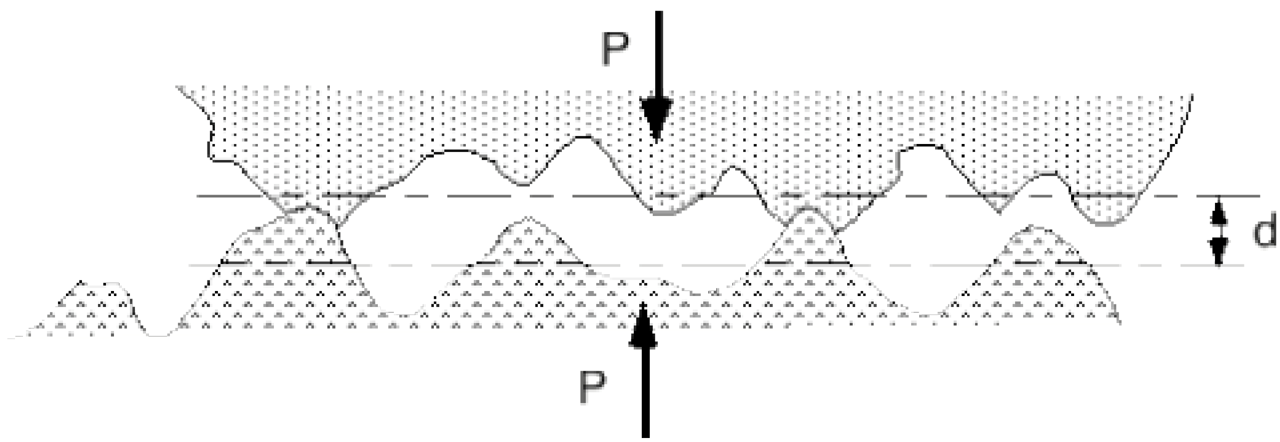
FLOW THROUGH ROUGH SURFACES

ADHESION OF LUBRICANT

GOOD BOUNDARY LUBRICANTS

BOUNDARY LUBRICATED CONTACT MODELS

- Rough surfaces contact:



- Asperity forces P_i support load @ discrete points
- Hydrodynamic fluid pressures p_{fluid} support load elsewhere

- Total load support

$$P = \Sigma_{asperities} P_i + \int_{area} p_{fluid}\, dA$$

$$\approx N \int_d^\infty P_i(z)\, F(z)\, dz + \int_A p_{fluid}\, dA$$

Notes:

- Real contact area $A_{real} << A$, apparent contact area. Thus

$$\int_{(A - A_{real})} p_{fluid}\, dA \approx \int_A p_{fluid}\, dA$$

- Many asperities of many heights, thus

$$\Sigma_{asperities} P_i \approx N \int_d^\infty P_i(z)\, F(z)\, dz$$

- References

1. W.E. Campbell, Boundary Lubrication, Boundary Lubrication, an Appraisal of World Literature, ASME, 1969, pp. 87-117..

2. N.K Myshkin, Chung Kyun Kim, Mark I Petrokovets, Introduction to Tribology, Cheong Moon Gak, 1997.