Types of Wear & Lubricating Regimes

The primary purpose of a lubricant is to protect machine components from surface fatigue and wear. Ideally, the base oil separates surfaces such that there is minimal wear; on occasions, this is not possible, and the additive package will help minimize the wear.

There are six significant wear categories: fatigue, wear, corrosion, electrical erosion, plastic deformation, and fracture. Lubricants play a crucial role in reducing or eliminating the following three:

- Abrasive wear: Occurs when the asperities (surface roughness peaks) of a surface cut into the opposing surface. As they slide against each other, the harder elements of one surface plow into and deform the softer metal of the opposing surface. Abrasive wear should reduce with time because the resulting surfaces will conform after an initial break-in period.

- Adhesive wear: Occurs when the most pronounced asperities contact each other and cause friction. As the surfaces slide against each other under load, the friction and heat generated cause the asperities to weld together and tear and break off. This process wears down the metal surfaces and contaminates the lubricant with metal particles which circulate through the system and cause three-body abrasive wear. Adhesive wear is very undesirable because the deteriorating surface quality further disrupts the lubricant film, accelerating the failure mode.

- Surface-initiated fatigue: Results from insufficient lubricant film. As with adhesive wear, asperity high points contact each other. However, unlike adhesion, there is no welding event. Cyclic loading causes micro-cracks in the asperities, which eventually grow until some material flakes off the surface. This type of damage is typical of rolling contacts found in rolling bearings, cams, and gears at the pitch line.

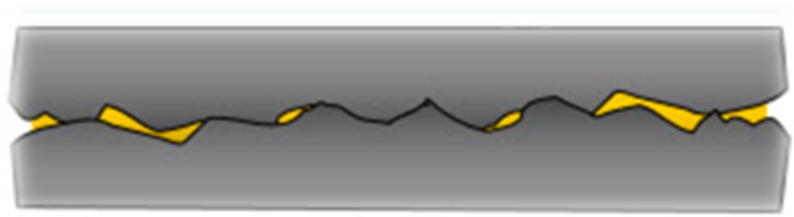
The benefits of a lubricant

Almost every modern hardware application requires a lubricant. Any relative motion of surfaces will result in friction, wear, and eventual component failure; the lubricant is the primary defense against all of these adverse outcomes. Lubricants:

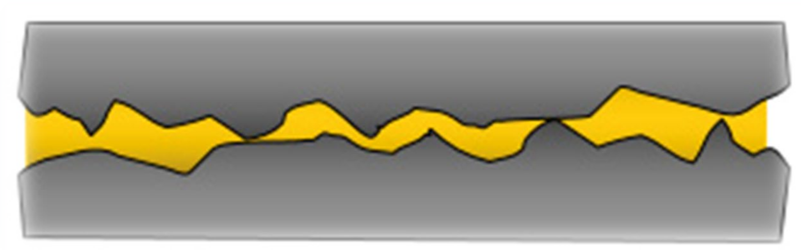
- Reduce friction, increasing equipment efficiency.
- Separate equipment surfaces, reducing component wear.
- Dissipate heat, which cools components and reduces heat-related failures.
- Suspend and remove contaminants, reducing abrasion and the buildup of sludge, varnish, and deposits.
- Prevent rust and corrosion by forming a protective barrier.

Lubricating Regimes

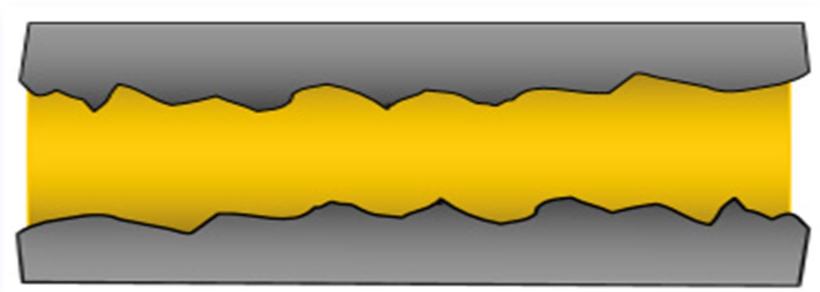
Tribologists (those who study friction and lubrication) and lubrication engineers define three different lubrication "regimes." While arbitrary, they help define different types of surface contact that occur under various operating conditions. Based on the likely lubrication regime, we may then select an appropriate lubricant.



Boundary Lubrication: Occurs when a lubricant film cannot prevent the asperities of two surfaces from making complete contact. This could be because there is no lubricant at the surface contact (as in at startup), the viscosity is too low (due to incorrect lubricant selection), or the speed is too low (as with the pins on an excavator bucket). During boundary lubrication, friction can decrease as the load decreases and viscosity and speed increase. Components experience boundary lubrication conditions at startup and shutdown, with the highest levels of friction and resulting wear.



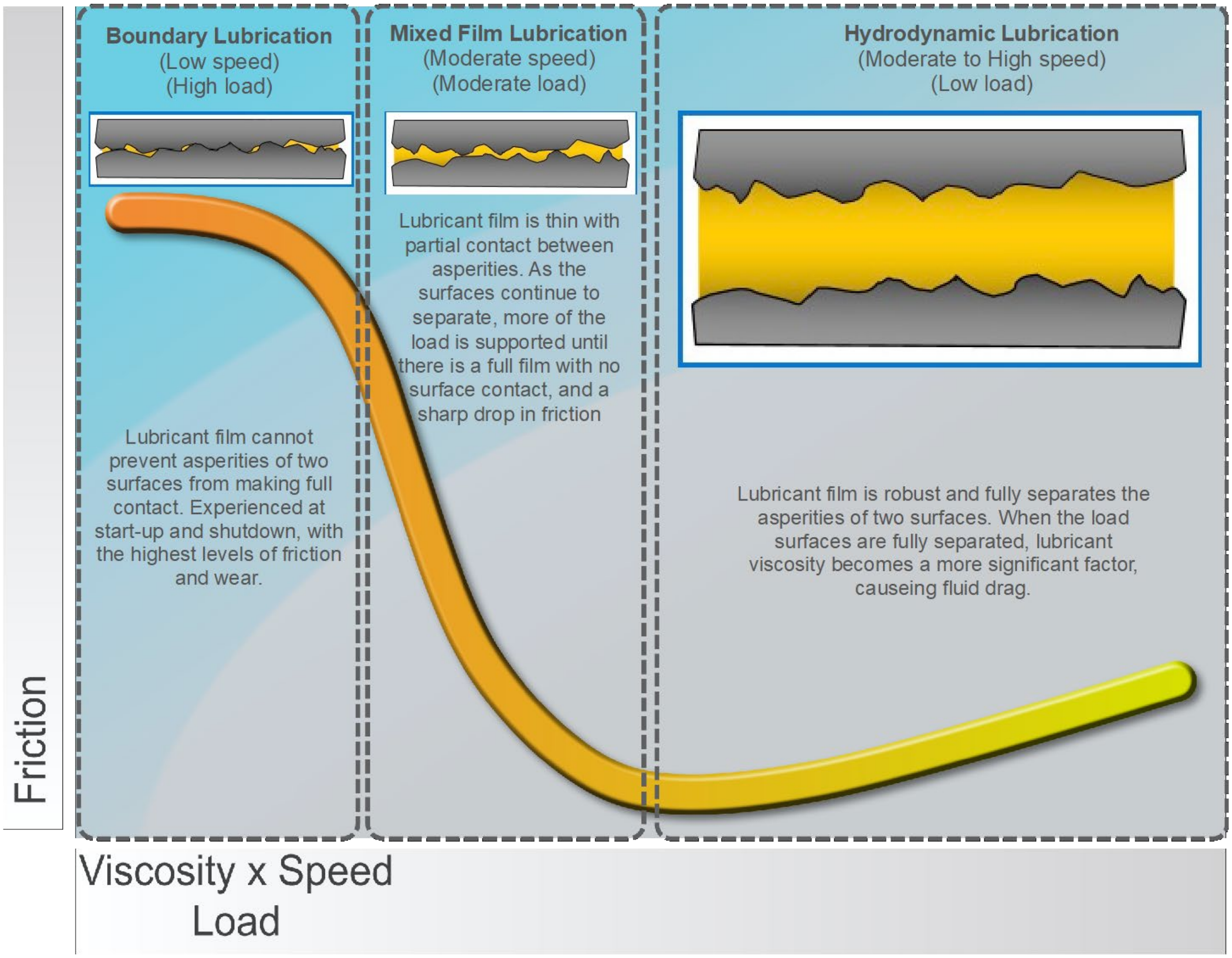
Mixed Film Lubrication: Occurs when components transition between boundary and hydrodynamic lubrication. A thin lubricant film between two surfaces leads to partial contact between asperities. The load is shared by both the lubricant and the surface contacts. As the speed increases or the load decreases, the surfaces begin to separate, and a fluid film forms. Initially, the film is very thin, but as the surfaces continue to separate, more load is supported by a full hydrodynamic lubricant film, no surface contact, and a sharp drop in friction.



Full Film Lubrication: Full film lubrication, also commonly called Hydrodynamic lubrication, occurs when a robust lubricant film entirely separates the asperities of two surfaces. During full film lubrication, friction slowly increases as the load decreases and speed increases. Because hydrodynamic lubrication is associated with the least amount of wear, it is the most desirable lubrication regime. However, when the loaded surfaces are fully separated, lubricant viscosity becomes a more significant factor, causing fluid drag.

Fluid Drag:
It takes energy to move a fluid. It takes more energy to move more fluid and even more to move a fluid with high viscosity. This is the concept of fluid drag. In boundary and mixed film lubrication, the surface friction dominates – once the surfaces are separated in full film lubrication, the friction is determined by fluid drag and the friction between the metal surface and the fluid.

As a result, once full film lubrication is achieved, any additional separation of surfaces comes at the penalty of increased friction. This separation could be due to increased speed (increasing the friction between the metal surface and fluid) or increased viscosity (increasing the energy required to move the fluid).



The Stribeck Curve

The Stribeck curve provides an overview of how friction changes with different lubrication scenarios. It takes the three lubrication regimes described above and compiles all the information into a single plot.

One axis of the Stribeck curve plots the coefficient of friction, while the other charts the product of viscosity and speed divided by the load. Viscosity and speed have an inverse relationship with load. This means if viscosity and speed increase, load decreases, and vice versa.