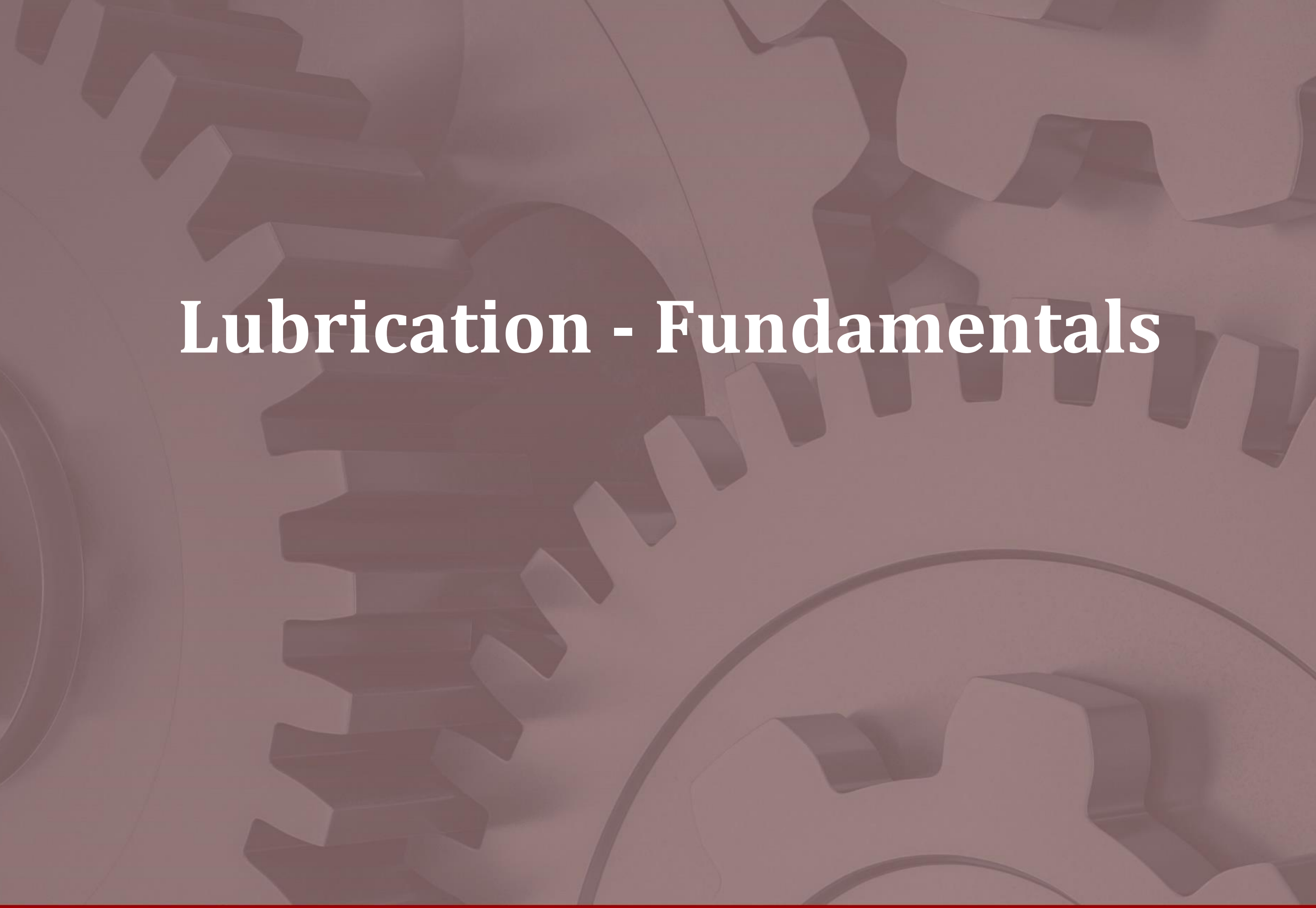


Lubrication - Fundamentals

An Online Continuing Education Course for Engineers

Course Number: MA-1005

Credit: 1 Hour / 1 PDH / 1 CPD

Lubrication-Fundamentals

Introduction

Friction is a good thing. Without it, we wouldn't be able to walk down the street or ride in a car or perform a thousand other tasks that we take for granted. But, friction has a dark side too. In rotating equipment, for example, excessive friction causes wearing of surfaces, heat buildup, lost energy and eventual failure of components.

Lubrication reduces friction by forming a physical barrier between the surfaces of moving parts. In addition, lubrication provides many other benefits, such as:

- Keep moving parts apart
- Transfer heat
- Carry away contaminants & debris
- Transmit power
- Protect against wear
- Prevent corrosion

This course covers the basics of friction and wear, as well as how lubricants are used to reduce friction in common applications.

Lubrication Principles

Friction

a. Definition of friction.

(1) Friction is a force that resists relative motion between two surfaces in contact. Depending on the application, friction may be desirable or undesirable. Certain applications, such as tire traction on pavement and braking, or when feet are firmly planted to move a heavy object, rely on the beneficial effects of friction for their effectiveness. In other applications, such as operation of engines or equipment with bearings and gears, friction is undesirable because it causes wear and generates heat, which frequently leads to premature failure.

(2) For purposes of this course, the energy expended in overcoming friction is dispersed as heat and is considered to be wasted because useful work is not accomplished. This waste heat is a major cause of excessive wear and premature failure of equipment. Two general cases of friction occur: sliding friction and rolling friction.

b. Sliding friction.

(1) To visualize sliding friction, imagine a steel block lying on a steel table. Initially a force F (action) is applied horizontally in an attempt to move the block. If the applied force F is not high enough, the block will not move because the friction between the block and table resists movement. If the applied force is increased, eventually it will be sufficient to overcome the frictional resistance force f and the block will begin to move. At this precise instant, the applied force F is equal to the resisting friction force f and is referred to as the force of friction.

(2) In mathematical terms, the relation between the normal load L (weight of the block) and the friction force f is given by the coefficient of friction denoted by the Greek symbol μ. Note that in the present context, "normal" has a different connotation than commonly used. When discussing friction problems, the normal load refers to a load that is perpendicular to the contacting surfaces. For the example used here, the normal load is equal to the weight of the block because the block is resting on a horizontal table. However, if the block were resting on an inclined plane or ramp, the normal load would not equal the weight of the block, but would depend on the angle of the ramp. Since the intent here is to provide a means of visualizing friction, the example has been simplified to avoid confusing readers not familiar with statics.

c. Laws of sliding friction. The following friction laws are extracted from the Machinery Handbook, 23rd Revised Edition.

(1) Dry or unlubricated surfaces. Three laws govern the relationship between the frictional force f and the load or weight L of the sliding object for unlubricated or dry surfaces:

(a) "For low pressures (normal force per unit area) the friction force is directly proportional to the normal load between the two surfaces. As the pressure increases, the friction does not rise proportionally; but when the pressure become abnormally high, the friction increases at a rapid rate until seizing takes place."

(b) The value of f/L is defined as the coefficient of friction μ."The friction both in its total amount and its coefficient is independent of the area of contact, so long as the normal force remains the same. This is true for moderate pressures only. For high pressures, this law is modified in the same way as the first case."

(c) "At very low velocities, the friction force is independent of the velocity of rubbing. As the velocities increase, the friction decreases."

The third law (c) implies that the force required to set a body in motion is the same as the force required to keep it in motion, but this is not true. Once a body is in motion, the force required to maintain motion is less than the force required to initiate motion and there is some dependency on velocity. These facts reveal two categories of friction: static and kinetic. Static friction is the force required to initiate motion (F_s). Kinetic or dynamic friction is the force required to maintain motion (F_k).

(2) Lubricated surfaces. The friction laws for well lubricated surfaces are considerably different than those for dry surfaces, as follows:

(a) "The frictional resistance is almost independent of the pressure (normal force per unit area) if the surfaces are flooded with oil."

(b) "The friction varies directly as the speed, at low pressures; but for high pressures the friction is very great at low velocities, approaching a minimum at about 2 ft/sec linear velocity, and afterwards increasing approximately as the square root of the speed."

(c) "For well lubricated surfaces the frictional resistance depends, to a very great extent, on the temperature, partly because of the change in viscosity of the oil and partly because, for journal bearings, the diameter of the bearing increases with the rise in temperature more rapidly than the diameter of the shaft, thus relieving the bearing of side pressure."

(d) "If the bearing surfaces are flooded with oil, the friction is almost independent of the nature of the material of the surfaces in contact. As the lubrication becomes less ample, the coefficient of friction becomes more dependent upon the material of the surfaces."

(3) The coefficient of friction. The coefficient of friction depends on the type of material. Tables showing the coefficient of friction of various materials and combinations of materials are available. Common sources for these tables are Marks Mechanical Engineering Handbooks and Machinery's Handbook. The tables show the coefficient of friction for clean dry surfaces and lubricated surfaces. It is important to note that the coefficients shown in these tables can vary.

(4) Asperities. Regardless of how smooth a surface may appear, it has many small irregularities called asperities. In cases where a surface is extremely rough, the contacting points are significant, but when the surface is fairly smooth, the contacting points have a very modest effect. The real or true surface area refers to the area of the points in direct contact. This area is considerably less than the apparent geometric area.

(5) Adhesion. Adhesion occurs at the points of contact and refers to the welding effect that occurs when two bodies are compressed against each other. This effect is more commonly referred to as "cold welding" and is attributed to pressure rather than heat, which is associated with welding in the more familiar sense. A shearing force is required to separate cold-welded surfaces.

(6) Shear strength and pressure. As previously noted, the primary objective of lubrication is to reduce friction and wear of sliding surfaces. This objective is achieved by introducing a material with a low shear strength or coefficient of friction between the wearing surfaces. Although nature

provides such materials in the form of oxides and other contaminants, the reduction in friction due to their presence is insufficient for machinery operation. For these conditions, a second relationship is used to define the coefficient of friction: $\mu = S/P$, where S is the shear strength of the material and P is pressure (or force) contributing to compression. This relationship shows that the coefficient of friction is a function of the force required to shear a material.

(7) Stick-slip. To the unaided eye the motion of sliding objects appears steady. In reality this motion is jerky or intermittent because the objects slow during shear periods and accelerate following the shear. This process is continuously repeated while the objects are sliding. During shear periods, the static friction force F_s controls the speed. Once shearing is completed, the kinetic friction force F_k controls the speed and the object accelerates. This effect is known as stick-slip. In well lubricated machinery operated at the proper speed, stick-slip is insignificant, but it is responsible for the squeaking or chatter sometimes heard in machine operation. Machines that operate over long sliding surfaces, such as the ways of a lathe, are subject to stick-slip. To prevent stick-slip, lubricants are provided with additives to make F_s less than F_k.

d. Rolling friction.

(1) When a body rolls on a surface, the force resisting the motion is termed rolling friction or rolling resistance. Experience shows that much less force is required to roll an object than to slide or drag it. Because force is required to initiate and maintain rolling motion, there must be a definite but small amount of friction involved. Unlike the coefficient of sliding friction, the coefficient of rolling friction varies with conditions and has a dimension expressed in units of length.

(2) Ideally, a rolling sphere or cylinder will make contact with a flat surface at a single point or along a line (in the case of a cylinder). In reality, the area of contact is slightly larger than a point or line due to elastic deformation of either the rolling object or the flat surface, or both. Much of the friction is attributed to elastic hysteresis. A perfectly elastic object will spring back immediately after relaxation of the deformation. In reality, a small but definite amount of time is required to restore the object to original shape. As a result, energy is not entirely returned to the object or surface but is retained and converted to heat. The source of this energy is, in part, the rolling frictional force.

(3) A certain amount of slippage (which is the equivalent of sliding friction) occurs in rolling friction. If the friction of an unhoused rolling object is measured, slippage effects are minimal. However, in practical applications such as a housed ball or roller bearing, slippage occurs and contributes to rolling friction. Neglecting slippage, rolling friction is very small compared to sliding friction.

e. Laws of rolling friction. The laws for sliding friction cannot be applied to rolling bodies in equally quantitative terms, but the following generalities can be given:

(1) The rolling friction force F is proportional to the load L and inversely proportional to the radius of curvature r, or $F = \mu_r L/r$, where μ_r is the coefficient of rolling resistance, in meters

(inches). As the radius increases, the frictional force decreases.

(2) The rolling friction force F can be expressed as a fractional power of the load L times a constant k, or $F = kL^n$ where the constant k and the power n must be determined experimentally.

(3) The friction force F decreases as the smoothness of the rolling element improves.

Wear

Wear is defined as the pr… o relative contact
betwee… ed during normal
oper… reates significant
econ… me. Friction and
wear… In other words,
wear…

a. … s defined as the
volum… is expressed in
units o… ormal load, the
relative… ical properties
of the m…

(1) … es. Surface
damage …

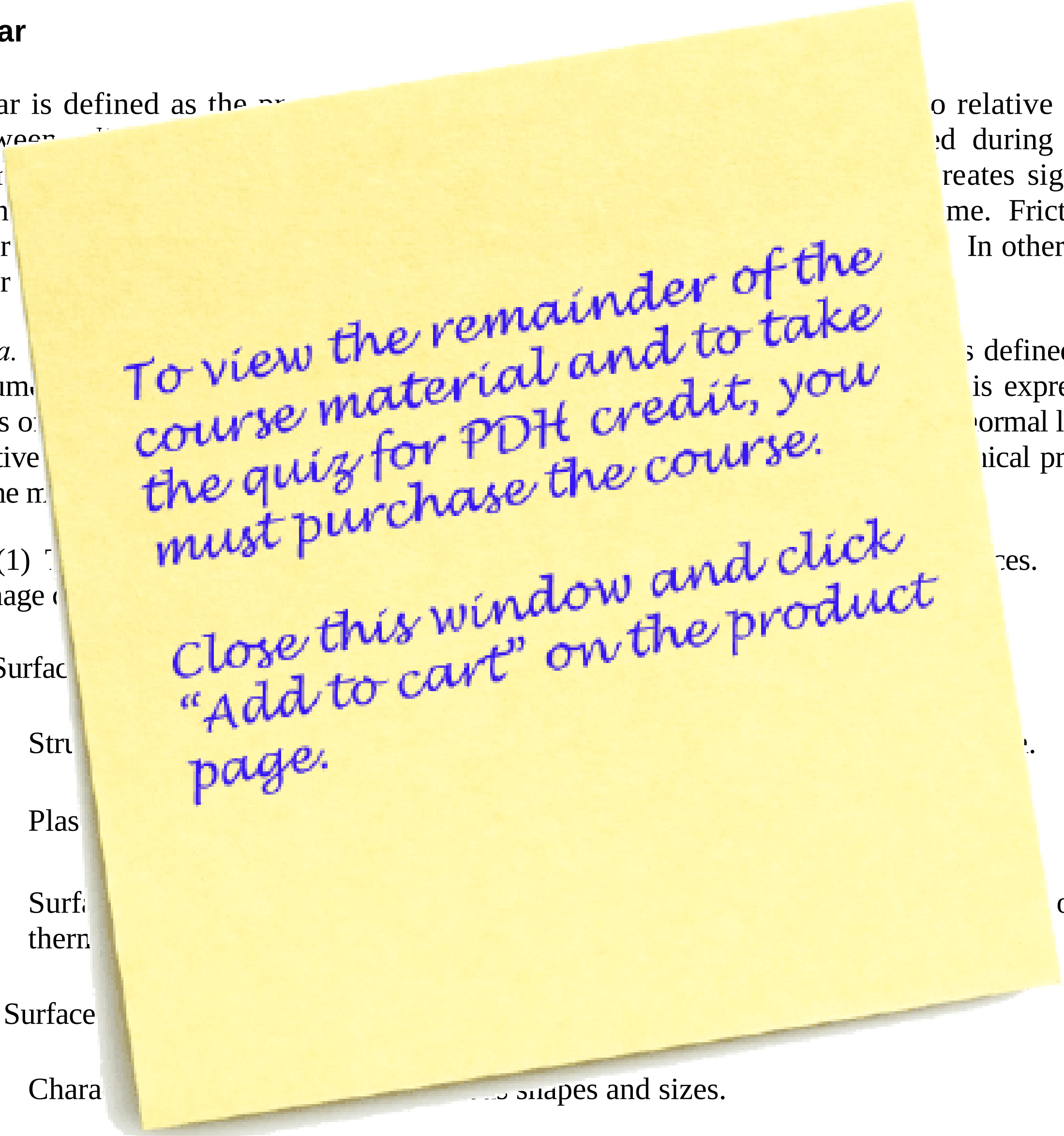
(a) Surfac…

- Stru… .
- Plas…
- Surf… of
  therm…

(b) Surface…

- Chara… shapes and sizes.
- Can be shear fracture, extrusion, chip formation, tearing, brittle fracture, fatigue fracture, chemical dissolution, and diffusion.

(c) Surface damage with gain of material:



To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.

Close this window and click "Add to cart" on the product page.