Friction and lubrication in metal forming

The relative motion between two touching surfaces create resistance to this motion called **friction.** The mechanics of friction are complex.

1*. Coulomb Friction*. It is assumed that the shear stress is proportional to the pressure (p) between the workpiece and the die. Then (***=μp***) where the proportionality factor (μ) is called the Coulomb coefficient of friction or friction factor.

2*. Constant friction*. It is assumed that the shear stress is proportional to the strength of the workpiece material. Then = m√ 3, where the proportionality factor (m) is called the shear factor, with 0 < m < 1. The factors (μ and m) are assumed constant for a given die, workpiece and lubricant.

As is illustrated in the linear relationship defined by Coulomb's law is not validating all normal stress (pressure) levels because the shear stress cannot exceed the shear strength of the material. Thus, a second law named the interface shear friction law has been developed

The interface shear friction law uses a friction factor or a shear factor to quantify the interface. Friction equation shows that the frictional shear stress is dependent on the flow stress of the deforming material, and the friction factor or the shear factor (m). Thus, for a frictionless condition, (m=0), and for a sticking friction condition,(m=1). Sticking friction is the case where sliding at the interface is preempted by shearing of the bulk material.

Types of friction force

1. ***Static friction force*** using to start moves the move body.
2. ***Dynamic friction force*** using to keep in the body moving.

What is friction force causes?

1. Elastic and plastic deformation in surface metal forming.
2. Thermal energy from redundant work.
3. Increases the work done to produce the metal forming.

Factor effecting on friction force

1) Environment
2) Velocity load In high velocity the friction factor less than 0.1 and in low velocity the friction factor more than 0.1
3) Type of forming

In coulomb friction depend on friction factor ($\boldsymbol{\mu}$) its value between $0 < (\boldsymbol{\mu}) < 0.5$ where (0) Represent sliding friction and (0.5) its high value of friction factor that let to obtain a sticking friction.

Beneficial effect of friction

Some operation require a certain frication

1. It's necessary in rolling operation to obtain the greatest possible reduction in area per pass
2. It's necessary in wire drawing operation to obtain the greatest possible reduction in area per pass without fracture.
3. It's necessary in punch of deep drawing operation.

Lubrication in metal forming

The major function of lubrication in metal forming is to prevent pick up. It is reduce wear and reduce friction.

In metal forming different lubrication mechanisms may be present

- Dry condition
- Boundary lubrication
- Mixed-film lubrication
- Hydrodynamic lubrication

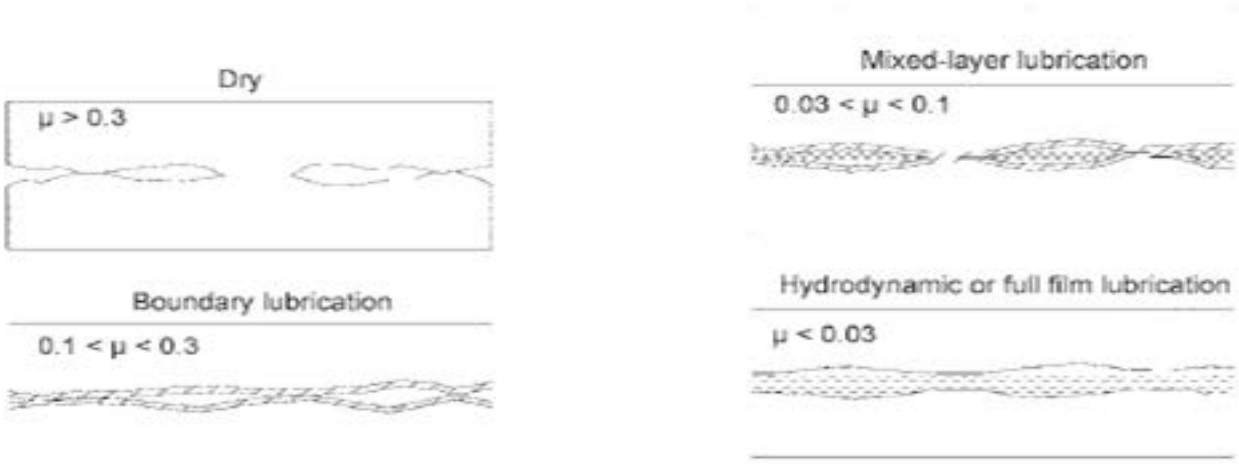
A ***dry condition*** means no lubrication is present at the mating surfaces; thus, friction is high. This condition is often used when the material formability is large enough to form a part with simple geometry without lubricants or when the frictional condition does not significantly influence the part quality, for instance, air bending, V-die bending, and U-die bending without stretching. A dry condition is desirable in only a few selected forming operations, such as hot rolling of plates or slabs and non-lubricated extrusion of aluminum alloys.

Boundary lubrication is defined as a condition where the solid surfaces are so close together that surface interaction between single or multi molecular films of lubricants and the solid asperities dominates the contact Boundary lubrication is the most widely encountered lubrication condition in metal forming.

Mixed-layer lubrication is also frequently encountered in sheet metal forming. In this case, the micro peaks of the metal surface experience boundary lubrication conditions and the micro valleys of the metal surface become filled with the lubricant.

Hydrodynamic lubrication Hydrostatic, and Thick Film Lubrication

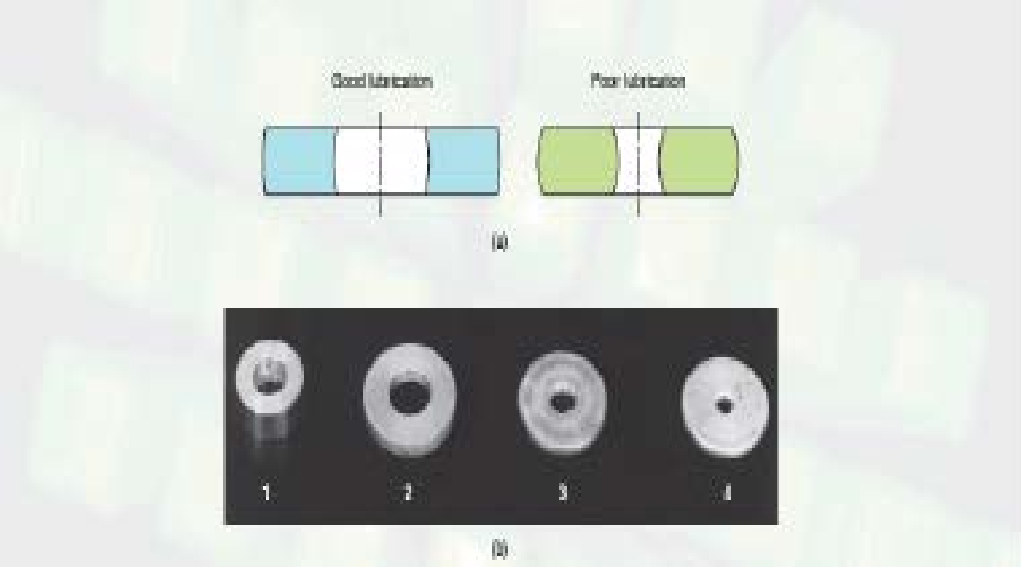
When a lubricant film separates the workpiece from contact with the die, is experienced in a few sheet metal forming processes, such as high-speed sheet rolling operations, where large velocities at the material-tool interface create hydrodynamic conditions.

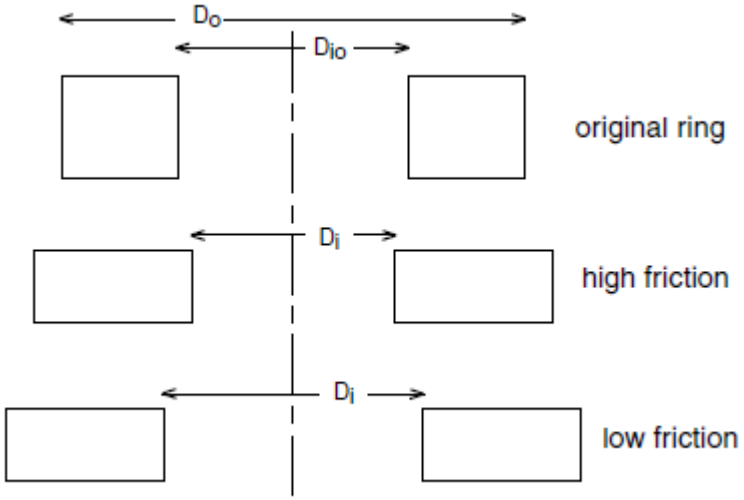


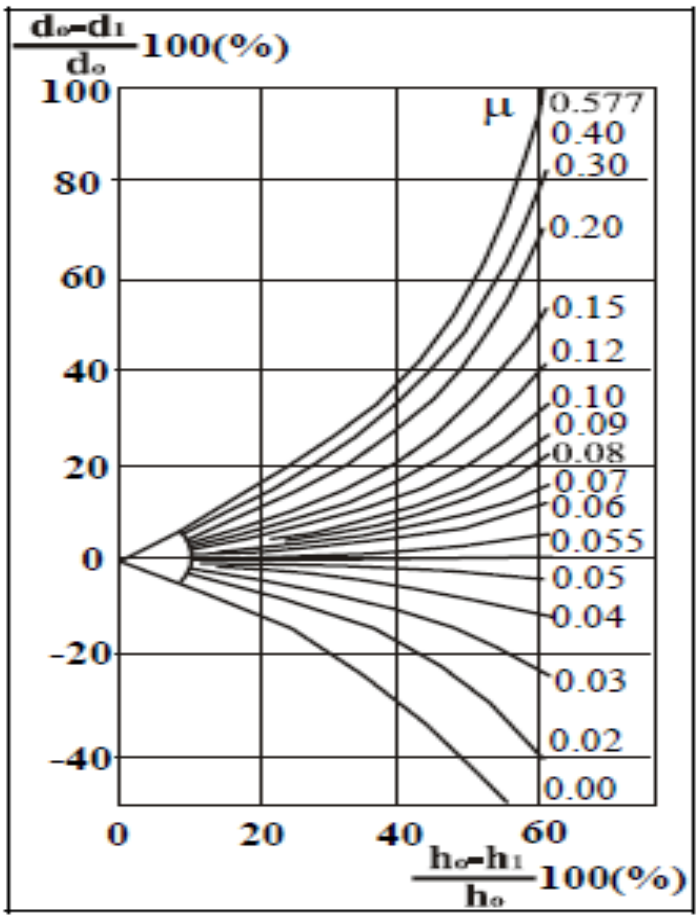
Measurement of friction factor

- **Ring Friction Test**

A simple test for friction in compression involves compressing a ring . If there were no friction the inner diameter would increase by the samepercentage as the outer diameter.With high friction, there is a no-slip location betweenthe inner and outer diameters so the inner diameter must decrease during compression.




D_o
D_{io}
original ring
D_i
high friction
D_i
low friction


$\frac{d_o-d_1}{d_o}$100(%)
100
80
60
40
20
0
-20
-40
μ
0.577
0.40
0.30
0.20
0.15
0.12
0.10
0.09
0.08
0.07
0.06
0.055
0.05
0.04
0.03
0.02
0.00
0
20
40
60
$\frac{h_o-h_1}{h_o}$100(%)