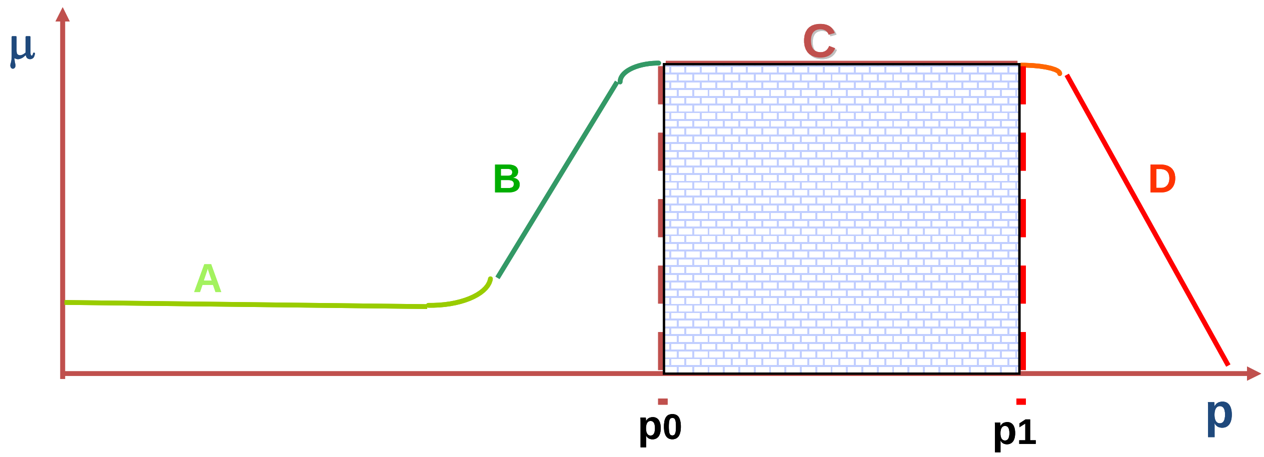
Technical Manual

Friction joint theory



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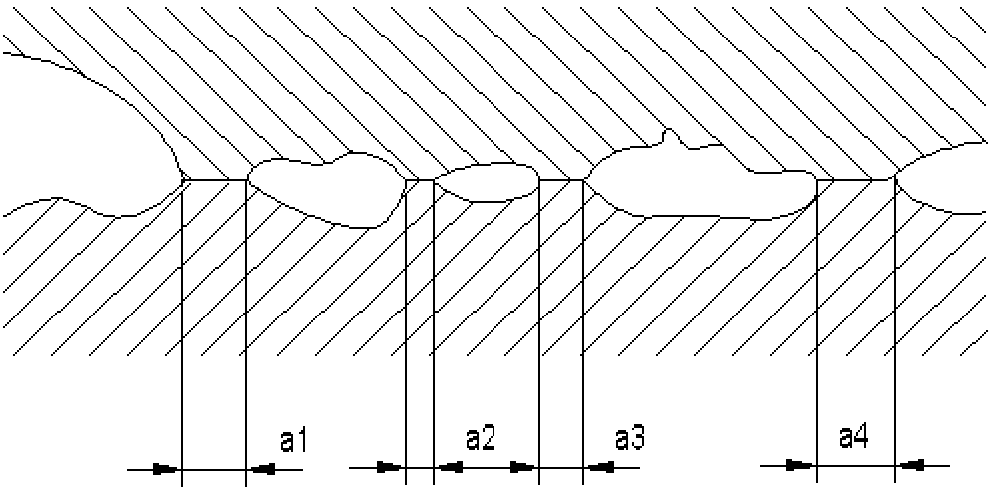
Friction theory

Friction is the resistance to motion which is experienced whenever a solid body slides over another. The resistive force which is parallell to the direction of motion is called the "friction force". If the solid bodies are pressed toward each other and a force is applied, then the value of the force which is required to initiate sliding is the "static friction force". The force required to maintain sliding is the "kinetic (or dynamic) friction force". Kinetic friction is generally lower than static friction.
A friction joint will be locked until the tangential force is bigger than the static friction.

All surfaces are rough looked on in a microscopic scale and true contact is obtained over a small fraction of the apparent contact area. Furthermore the real area of contact is independent of the apparent area of contact.



The real area = a1+ a2+ a3+ a4 ... +an.

The real area is often only a few percentages of the apparent area.

A very thin oil film or other minor impurities do not effect the friction if only the peaks canbreak through the film. Then the real area and the friction force will not be affected. If however the impurities are too big, compared to the roughness of the surface, the friction force will drop drastically. The roughness of the surface and the degree of purity are two of the most important parameters to control to be able to control the friction force.

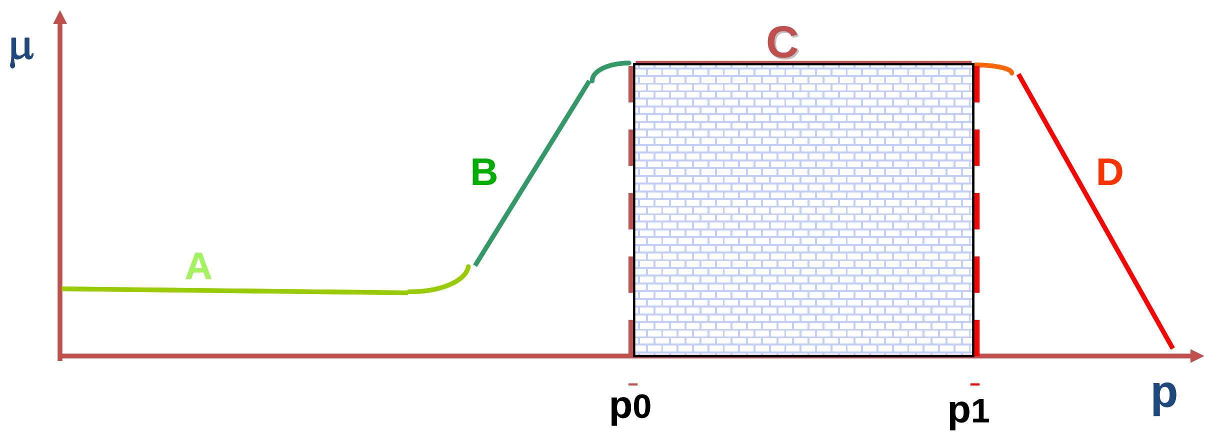
The friction force F is proportional to the normal load N

$$F = \mu * N$$

μ is a constant known as the coefficient of friction. It is a constant only for a given pair of materials, under a given set of ambient conditions and varies for different materials and conditions.

In a friction joint N is equal to the surface pressure p multiplied by the contact area.

From the literature the following relation is known between μ and the surface pressure p.



P_0 = (approx. 30 MPa) P_1 = (approx. 400 MPa)

Part A.
The surface pressure p is very low and there is no real contact area built up. The film of impurities compared to the roughness of the surface are too thick. μ is independent of p.

Part B.
The surface peaks break through the film.

Part C.
Some stable parts of real contact area have been built up and within this area μ is independent of p again.

Part D.
The surface pressure will be close to what the material can stand, the yield point. When the material collapses then $\mu = 0$.

A friction joint should be designed to work within part C. The surface pressure is high enough to break through the film of impurities, but not too high.

The following values have been well tested.

Material	μ	**Surfaces**
Steel/Steel	0.12	A thin film of oil
Steel/Steel	0.17	Cleaned with a solvent
Steel/Cast iron	0.10	A thin film of oil
Steel/Cast iron	0.15	Cleaned with a solvent

Steel/Aluminium and steel/stainless steel give similar values as for steel/cast iron.

In the tests the surface roughness has been between Ra 1.0 μm to Ra 3.0 μm.
The surface pressure is 90 MPa.

ETP Transmission AB

Friction theory for a friction joint

A friction joint is usually a tubular component placed between a shaft and hub. Its main function is to create a surface pressure between the shaft and hub, joining the two parts together by friction. Using this method both torque and axial forces can be transmitted at the same time.

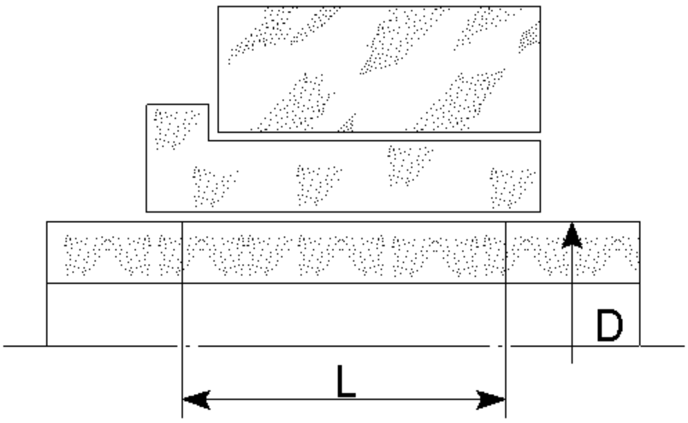
The friction force is calculated from:

$F_{fric.} = A*p*\mu$

A = contact area (mm^2)

p= surface pressure (N/mm^2)

$F_{fric.}$ = friction force (N)



$A = \pi*D*L$

L = Length of the contact area (mm)

D = Shaft diameter (mm)

If no axial force, Fa = 0 then:

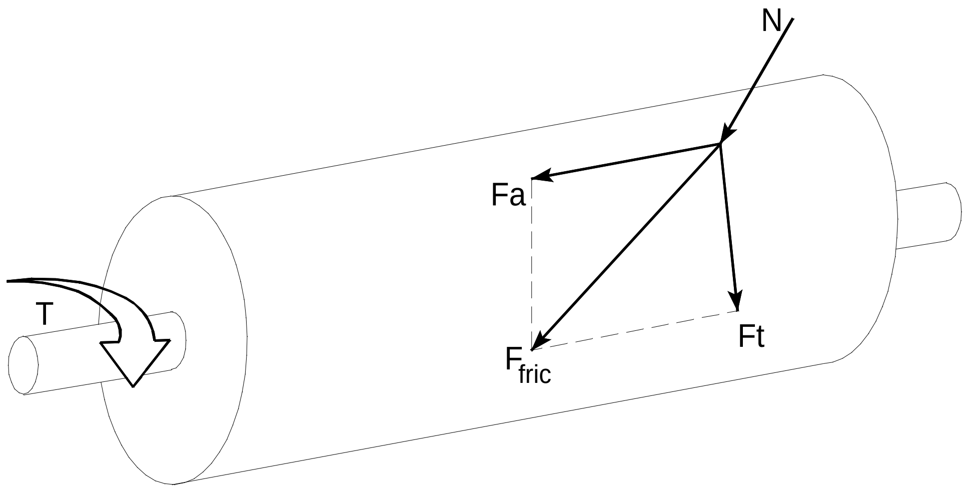
$$T = F_{fric.} * \frac{D}{2} * 10^{-3}$$

T = The transmittable torque (Nm)

This can also be written:

$$T = \frac{\pi}{2} * D^2 * L * p * \mu * 10^{-3}$$

The friction force can be used to transmit either a torque, an axial force or some of each at the same time.



The friction force can be split in two components, one in the axial direction and one in the tangential direction.

$$F_{fric} = \sqrt{F_t^2 + F_a^2}$$

T depends on the tangential friction force.

$T = F_t * \frac{D}{2}$ which means

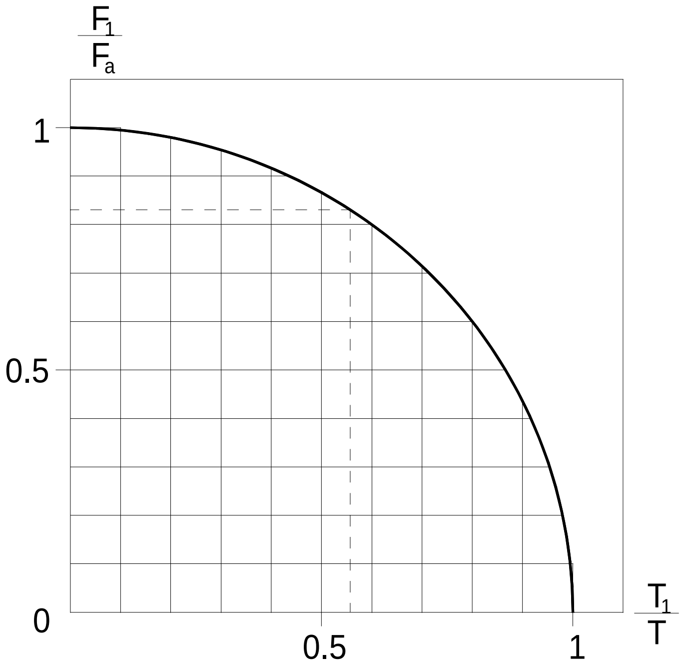
$F_t = F_{fric.}$ when no axial forces.

If simultaneously an axial force F_1, and a torque T1, are going to be transmitted, then the factors F_1/F_a and T_1/T must both be less than 1.0 and the formula below is valid. Otherwise the joint will slip.

$$\left(\frac{F_1}{F_a}\right)^2 + \left(\frac{T_1}{T}\right)^2 < 1$$

This is the formula for the inside of a circle.

If one of F_1 or T_1, is known the other can be determined. Either direct from the formula or from the diagram.


F1
Fa
1
0.5
0
0.5
1
T1
T

PT formulas, conversion factors

Some conversion factors

Length	1 m	=	1 000 mm
	1 inch	=	25.4 mm
	1 ft (foot)	=	0,305 m
Area	1 m^2	=	10^6 mm^2
	1 $inch^2$	=	645 mm^2
	1 ft^2	=	0.093 m^2
Volume	1 m^3	=	10^9 mm^3
	1 l	=	10^{-3} m^3
	1 gallon (UK)	=	4.55 l
	1 gallon (US)	=	3.79 l
Weight	1 lb (pound)	=	0.454 kg
Force	1 kp	=	9.807 N
	1 lb	=	4.448 N
Torque	1 kpm	=	9.807 Nm
	1 in lb	=	0.113 Nm
	1 ft lb	=	1,356 Nm
Surface Pressure (stress)	1 Pascal	=	1 N/m^2
	1 MPa	=	1 N/mm^2
	1 bar	=	0.1 N/mm^2
	1 bar	=	14.5 lbs/in^2 (psi)
Power	1 W	=	1 Nm/s (J/s)
	1 hk	=	735 W
	1 hp (UK, US)	=	745 W
	1 ft lb/s	=	1.36 W
Temperature	Farenheit	=	1.8 (Celsius) + 32
	Celsius	=	5/9 (Farenheit - 32)

Power - Speed – Torque

$P = T*\omega$

P	=	power (W)
T	=	torque (Nm)
ω	=	speed (rad/s)
n rpm	=	9.55 rad/s

P in hp , n in rpm

$$T = \frac{p}{n} * 7042\,\mathrm{Nm}$$

P in kW , n in rpm

$$T = \frac{p}{n} * 9550$$

Torque - Shaft diameter - shear stress

In a shaft subjected to pure twisting torque the maximum shear stress occurs at the surface.

$$\tau = \frac{T_v}{W_v}$$

τ	=	shear stress (N/mm^2)
T_V	=	twisting torque
W_V	=	the modulus for torsion
D	=	shaft diameter

$$W_v = \frac{\pi * D^3}{16}$$