3. Surface hardness

-- Resistance tp permanent indentation.

It is a measure of load capacity of the contact.

(1) Brinell hardness, H (indentation hardness)

H = max. average pressure a contact area can develop

For surface-hardened steel such as gear surfaces,

$$H \approx 6.0\ GPa$$

Finite element calculations show that the contact pressure in a fully plastic contact is fairly uniform. So, H is the max pressure a contact can develop.

Also, experiments of many metal materials show:

$$H \approx 3Y \approx 6K$$

Y = uniaxial tensile strength of the material
K = shear strength of the material (metal materials yield by shear stress)

Question: why the contact can develop a pressure or sustain a compressive stress much higher than *Y*?

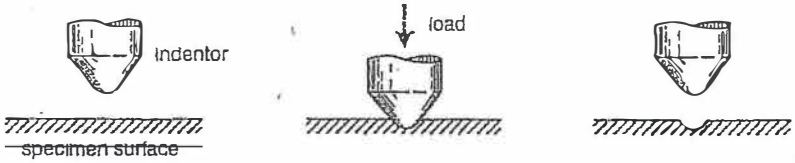
(2) Rockwell hardness, R_a, R_b, R_c

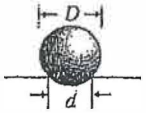
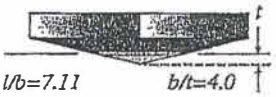
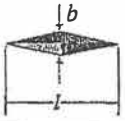
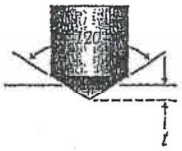
-- R_c is often used in machine industry for surface hardness of stressed components.

$R_c \sim 30$ for an annealed steel

$R_c \sim 60$ for surface-hardened steel surface such as gears and rolling bearings.

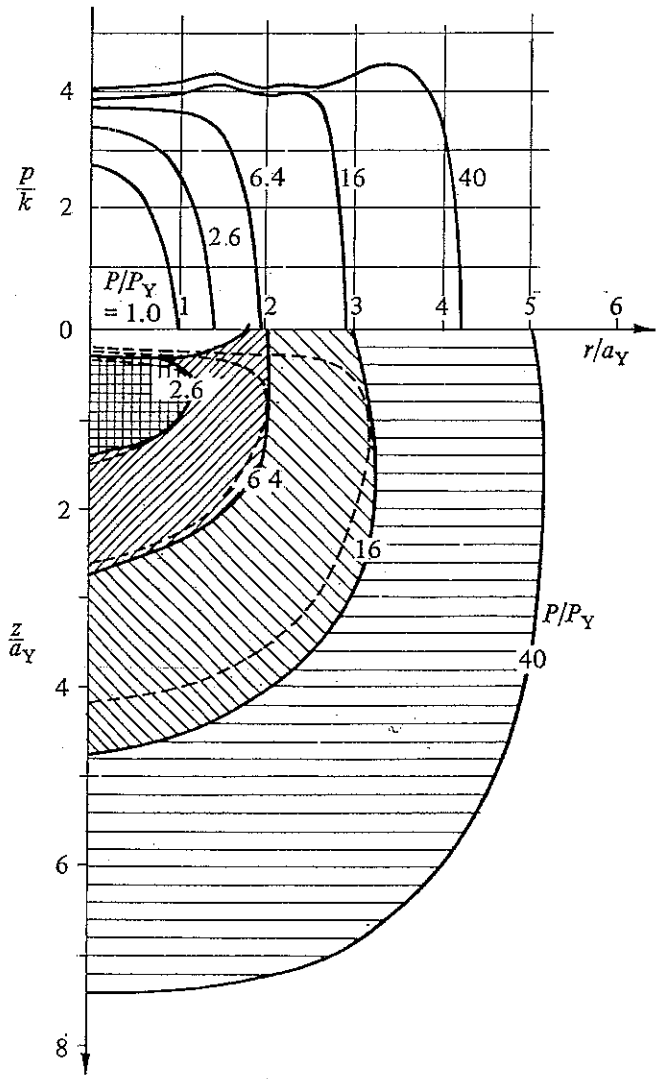
Hardness measurements



test	indenter	shape of indentation: side view	shape of indentation: top view	load	formula for hardness number
Brinell	10 mm sphere			P *(variable)*	$BHN = \pi D[D - \sqrt{D^2 - d^2}]\frac{2P}{}$
Vickers	diamond pyramid			P *(variable)*	$VHN = 1.72P/w^2$
Knoop microhardness	diamond pyramid			P *(variable)*	$KHN = 14.2P/l^2$
Rockwell A C	diamond cone			60 kg 150 kg	HRA = 100-500 t HRC = 100-500 t
B	1.6 mm diameter sphere			100 kg	HRB = 130-500 t

Contact Mechanics by Johnson

Fig. 6.11. Indentation of an elastic-plastic half-space by a rigid sphere, Hardy *et al.* (1971): development of the plastic zone. Broken line - contours of J_2.



FRICTION AND WEAR OF MATERIALS

Second Edition

ERNEST RABINOWICZ

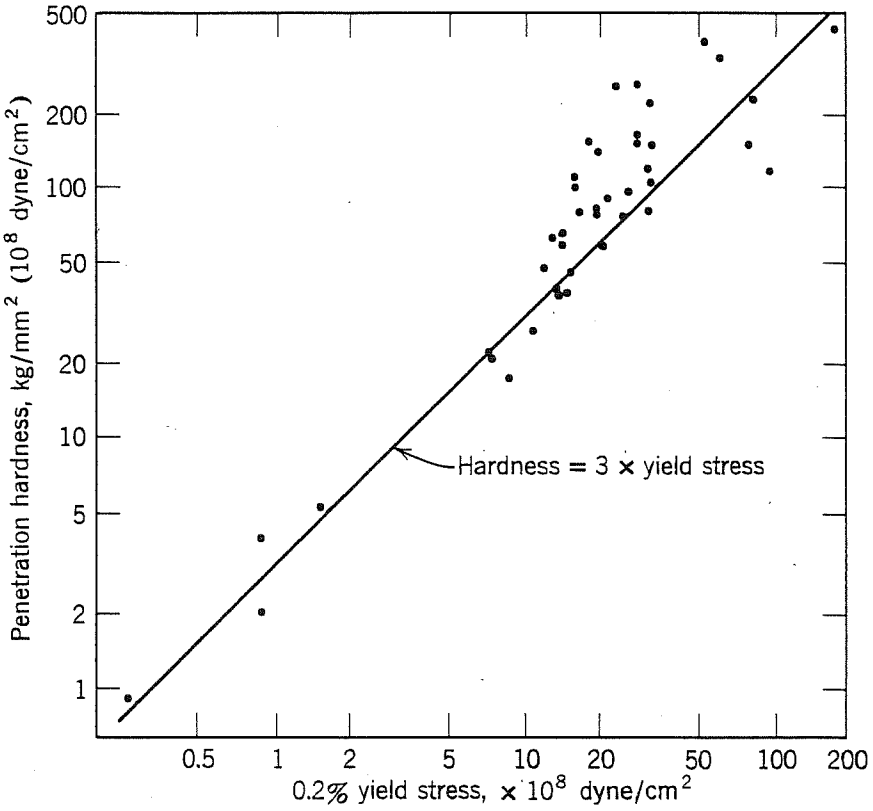
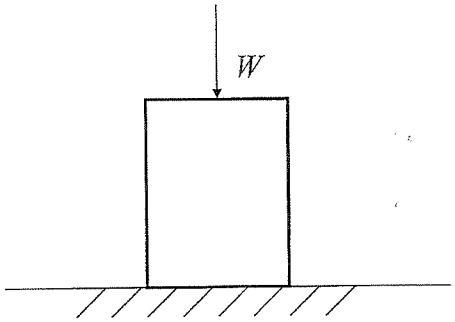
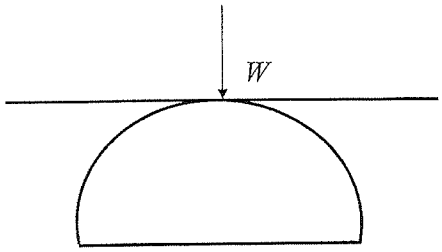


Fig. 2.10 Comparison of yield stress and hardness for elemental metals.

Maximum contact pressure in a frictionless contact



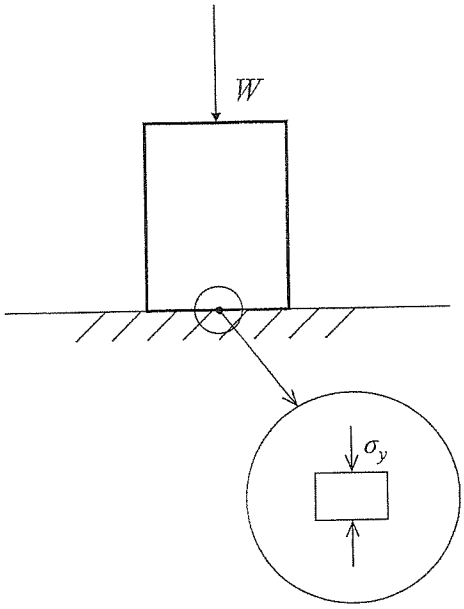


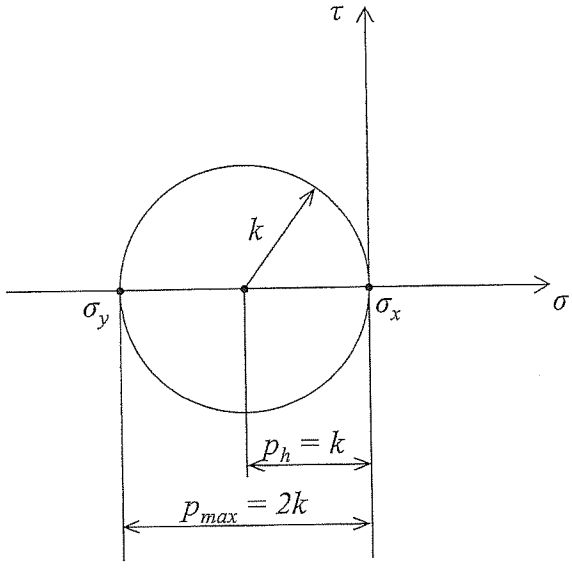
$p_{max} = 2k$

$p_{max} = H = 6k$

k = *material shear strength*

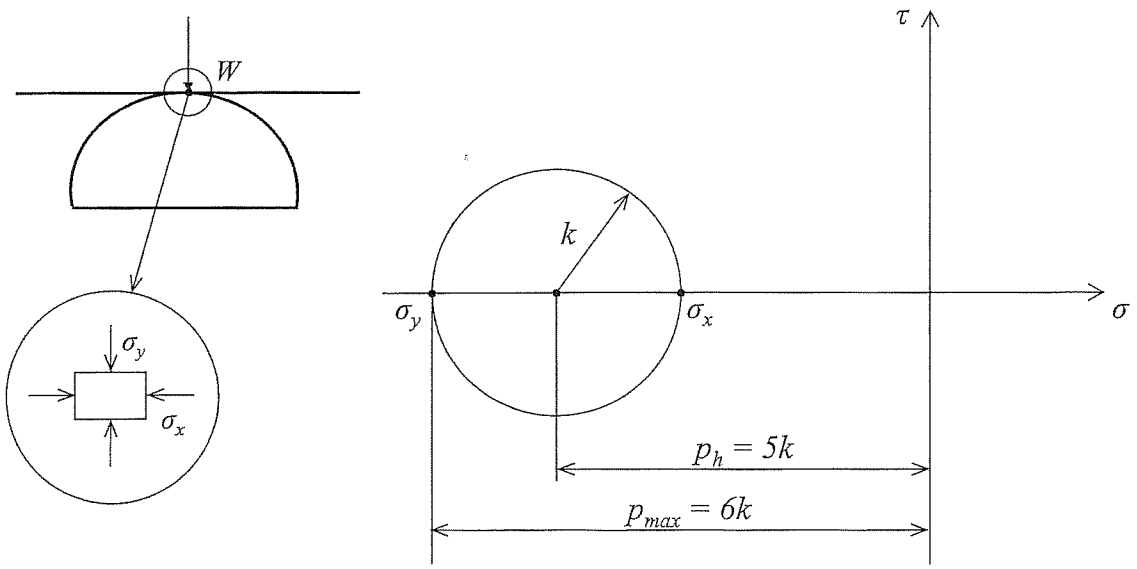
Contact hydrostatic pressure – flat surface



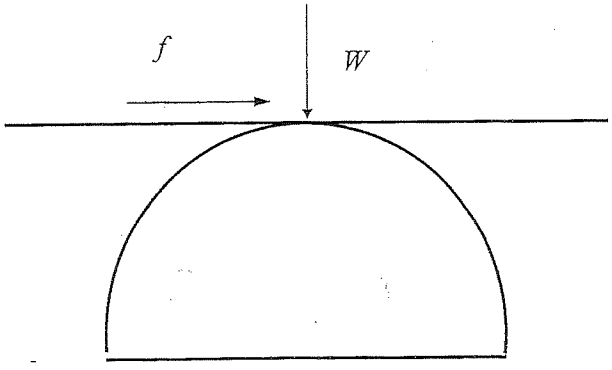


Stress Mohr circle

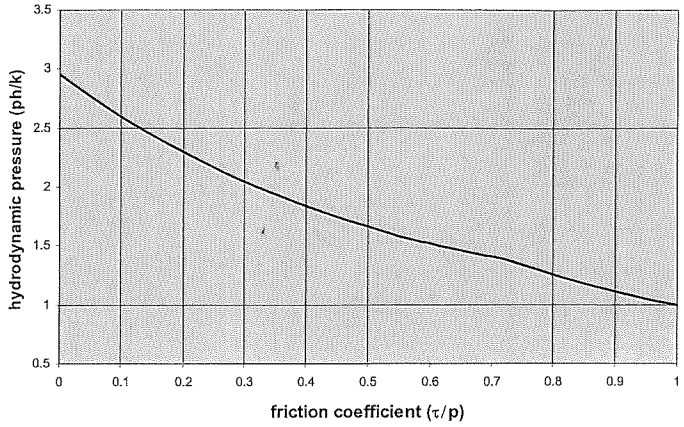
Contact hydrostatic pressure – curved surface



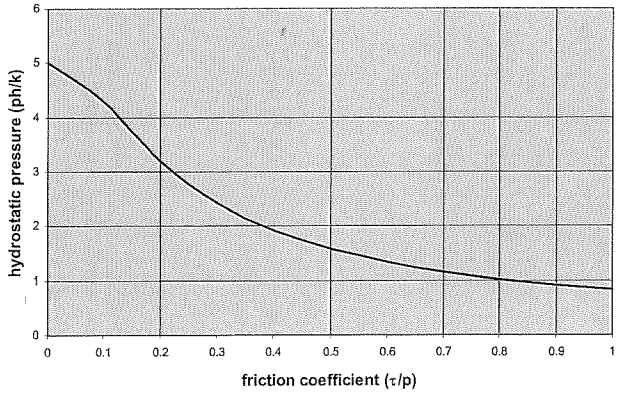
Would friction change hydrostatic pressure?



Hydrostatic pressure vs. friction coefficient – Johnson's results



Hydrostatic pressure vs. friction coefficient – Tabor equation ($p^2+\alpha\tau^2=H^2$)



Hydrostatic pressure vs. friction coefficient – our finite-element results