

# Hardness

## Advanced

All people, without exception, have a pretty good idea of what "hardness" means in the context of materials properties. Extremely few people, however, have a decent notion of what the terms "yield stress" or "maximum elongation" tells us about materials properties.

- Ironically, while the two latter properties are well-defined, hardness is not!
- Yield stress**, as we know, can be measured in precisely defined ways, and can be expressed in terms of basic material properties.
- Hardness** is different. It is not uniquely defined, and that means there is no unambiguous way of measuring it. There are only some *recipes* - that's why we have several hardness scales in parallel.

Essentially, there are two types of basic hardness measurement set-ups (plus some more unusual principles).

1. Measure the **size** of an indentation made by some indenter under a known load. The following hardness tests use this principle:
    - Vickers**
    - Brinell**
    - Knoop
  2. Measure the **depth** to which an indenter penetrates under specified conditions. The following hardness tests use this principle:
    - Rockwell B**
    - Rockwell C**
    - Shore A**
- More unusual or outdated are
- Mohs** hardness scale (the first one), defined via "what scratches what".
  - Shore scleroscope principle: measure the rebound of a ball or hammer.

In the "[Materials in Action](#)" series, "Structural Materials", page 100, the scales are compared (which is not easy).

- Here we usually use the **Vickers scale**. It runs from 0 to about 3000; the unit is essentially that of stress (**Pa**); but the numbers are given in outdated units:
- In the "Materials in Action" series you will find an unusual unit: "**kgf**", which is *kilogram-force*, which is something different from a "**kg**", because that was and is a mass. Nevertheless, the unit for the hardness is **kg/mm<sup>2</sup>**; what is meant is the force that a mass of one **kg** experiences in the gravitational field of the earth. In German the unit "kilopond" (**kp**) was used; it's the same thing. Of course [we have](#)  $1\text{kg/mm}^2 \approx 10\text{N}/10^{-6}\text{m}^2 = 10^{-5}\text{Pa}$

Here is a table with some **Vickers hardness** data:

Material	Vickers hardness	Material	Vickers hardness	Material	Vickers hardness
Sn	5	Limestone	250	Polypropylene	7
Al	25	MgO	500	Polycarbonate	14
Au	35	Window glas	550	PVC	16
Cu	40	granite	850	Epoxy	45
Fe	80	quartz	1200		
Mild steel	140	Al <sub>2</sub> O <sub>3</sub>	2500		
Hardened steel	900	WC	2500		

Hardness measures in some lumped way a combination of elastic, plastic, and fracture properties, i.e. it combines somehow Yield stress, Youngs modulus and fracture parameters.

- There is, however, no unique formula giving the hardness number as a function of the primary parameters.

The best one can do is to provide some approximate relations for certain classes of materials.

- For relatively soft metals and for steel, respectively, there is a very simple relation between the Vickers Hardness  $H_V$  and the yield stress  $R_p$  or the tensile strength  $R_M$

$H_V \approx \begin{matrix} 3 R_p & \text{"soft" metals} \\ 3.2 R_M & \text{steel} \end{matrix}$
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- Of course, you have to express the strength parameters in  $\text{kg/mm}^2$ , too

▶ This makes life easier and explains why we have not much dealt with hardness here: For our materials of interest, it is essentially the same as the much better defined parameters governing plastic deformation.

- Life would be even more easier, if most scientists would use the same hardness scale. Of course, they don't, so here is an approximate conversion, adopted from the "Materials in Action " Series [already mentioned](#).

