**True Stress–True Strain Curves**

The slope n is the **strain-hardening exponent**, and K is the **strength coefficient.**

Diagram

Description automatically generated

**Flow Stress**Defined as the true stress required to continue plastic deformation at a particular true strain. For strain-hardening materials, the flow stress increases with increasing strain.

@ necking,

**Effect of temperature**

Chart, diagram

Description automatically generated

v = rate of deformation

The effect of strain rate on the strength of materials is generally expressed by  
C = strength coefficient  
m = strain-rate sensitivity exponent of the material

**Chart, diagram

Description automatically generated with medium confidence**

**Text

Description automatically generated**As the amount of cold work increases, the amount of strain on the material also increases.

**Hardness –** resistance to plastic deformation



**Diagram

Description automatically generated**

**Rule of thumb, c = 3**More practically, a relationship also has been observed between the ultimate tensile strength (expressed in MPa) and Brinell hardness number for steels:

Diagram

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A picture containing text, vegetable

Description automatically generated**Recovery** – occurs below the recrystallization temperature, the stresses in the highly deformed regions are relieved and the number of mobile dislocations is reduced. Subgrain boundaries begin to form, with no notable change in such mechanical properties as hardness and strength, although with some increase in ductility.  
**Recrystallization** - The process of replacing grains with new, equiaxed and stress-free grains at elevated temperature. Approximately between 0.3 and 0.5 Tm. The recrystallization temperature is defined as the temperature at which complete recrystallization occurs within approximately one hour. Recrystallization decreases the density of dislocations and lowers the strength of the metal but raises its ductility.

* For a constant amount of deformation by cold working, the time required for recrystallization decreases with increasing temperature.
* The more the prior cold work, the lower the temperature required for recrystallization.
* The higher the amount of deformation, the smaller the resulting grain size after recrystallization. Recrystallizing a deformed metal is a common method of converting a coarse-
* Anisotropy due to preferred orientation usually persists after recrystallization. To restore isotropy, a temperature higher than that required for recrystallization may be necessary. grained structure to one of fine grain, with improved properties.

Diagram

Description automatically generated  
**Grain growth -** Continued increase in the temperature, the grains begin to grow; their size may eventually exceed the original grain size. It has an adverse effect on hardness and strength. Large grains produce the orange-peel effect, resulting in a rough surface appearance, such as when sheet metal is stretched to form a part or when bulk metal is subjected to compression, such as in forging operations. Not desirable for engineering properties  
**Material Structure**In body-centered cubic crystals, there are 48 possible slip systems; thus, the probability is high that an externally applied shear stress will operate on one of the systems and cause slip. However, because of the relatively high b/a ratio, the required shear stress is high. Metals with bcc structures (such as titanium, molybdenum, and tungsten) have good strength and moderate ductility. Diagram

Description automatically generated

In face-centered cubic crystals, there are 12 slip systems. The probability of shear stress aligning with a slip system is moderate, and the required shear stress is low. Metals with fcc structures (such as aluminum, copper, gold, and silver) have moderate strength and good ductility. A picture containing diagram

Description automatically generated

The hexagonal close-packed crystal has three slip systems, and thus it has a low probability of slip; however, more systems become active at elevated temperatures. Metals with hcp structures (such as beryllium, magnesium, and zinc) are generally brittle.Diagram

Description automatically generated

Modulus – Structure independent  
Strength – Microstructure dependent

**Point defects.**

Diagram

Description automatically generated

**Grain** size significantly influences the mechanical properties of metals. Large grain size generally is associated with low strength, low hardness, and high ductility. **Hall—Petch equation**

Sy=yield strength  
Syi=basic yield strength  
k=constant related to the effectiveness of GB blocking (from table/graph)  
d=grain diameter **Line intercept and ASTM**

L=length of line  
N=# of intersections  
The ASTM grain-size number, n, is related to the number of grains, N, per square inch at a magnification of by the expression

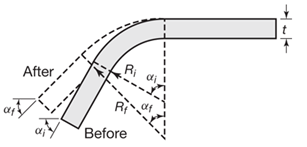
**Solidification**C=Mold constant  
Asurface=Surface area  
V=volume of casting  
**Lever rule**weight fraction of solid is proportional to the distance between Co and CL  
weight fraction of liquid is proportional to the distance between CS and Co

Diagram

Description automatically generated



**Bulk Deformation Processes  
Forging**

**Rolling  
low friction  
high friction**R=roll radius  
**Extrusion**=cross-sectional area of the billet  
=area of the extruded product  
Ideal force, no friction  
Ideal force, with friction  
Actual forces  
where a and b are experimentally determined constants. It has been determined that an approximate value for a is 0.8, and that b ranges from 1.2 to 1.5.  
**Hot Extrusion**=original billet area  
= extrusion constant (from plot)  
**Sheet Metal Processes  
Springback**  
Look up Ks from table.

Text

Description automatically generated  
 Can’t look up Ks from table. Need material properties.  
Diagram

Description automatically generated  
Limiting Drawing Ratio

Normal anisotropy/plastic anisotropy/strain ratio  
Diagram

Description automatically generated with medium confidence  
Planar anisotropy  
Text

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Want a high for good LDR.  
Text

Description automatically generated  
Low for good LDR  
Desirable to have a larger die and punch radii.  
Maximum punch force  
Text

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A picture containing graphical user interface

Description automatically generated**Map

Description automatically generated with low confidencePolymer Properties**

Composites  
A material system that is composed of two or more physically distinct phases that have different properties and constituents.  
Diagram

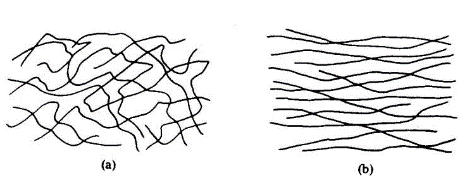
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Diagram, text

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Diagram

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**Shrink Rate**  
Polymers have high thermal expansion coefficients, so significant shrinkage occurs during solidification.

Diagram

Description automatically generatedDiagram

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Description automatically generatedThe higher the Dp the higher the polymer viscosity or resistance to flow

Diagram

Description automatically generatedA picture containing text, receipt, screenshot

Description automatically generatedDiagram

Description automatically generated

**Nasa paper**Diagram

Description automatically generated

Diagram, text, letter

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**Ceramics Properties**Some properties include hardness, thermal and electrical resistance. Grain size has a major influence on the properties of ceramics; the finer the size, the higher is the strength and the toughness (fine ceramics). The bonding between the atoms is generally covalent (electron sharing) and ionic (primary bonding between oppositely charged ions).  
P= volume fraction of pores in the solid  
= tensile strength at zero porosity  
n= ranges between 4 and 7  
= tensile strength at zero porosity  
= the conductivity at zero porosityChart

Description automatically generated