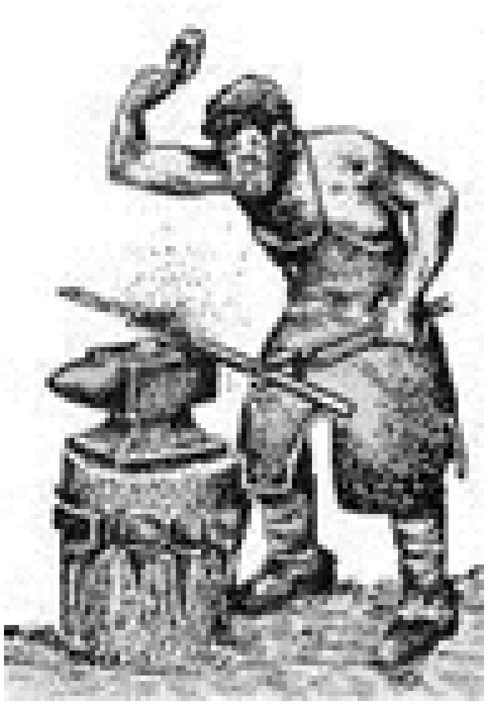
Mathematics and Science in Schools in Sub-Saharan Africa

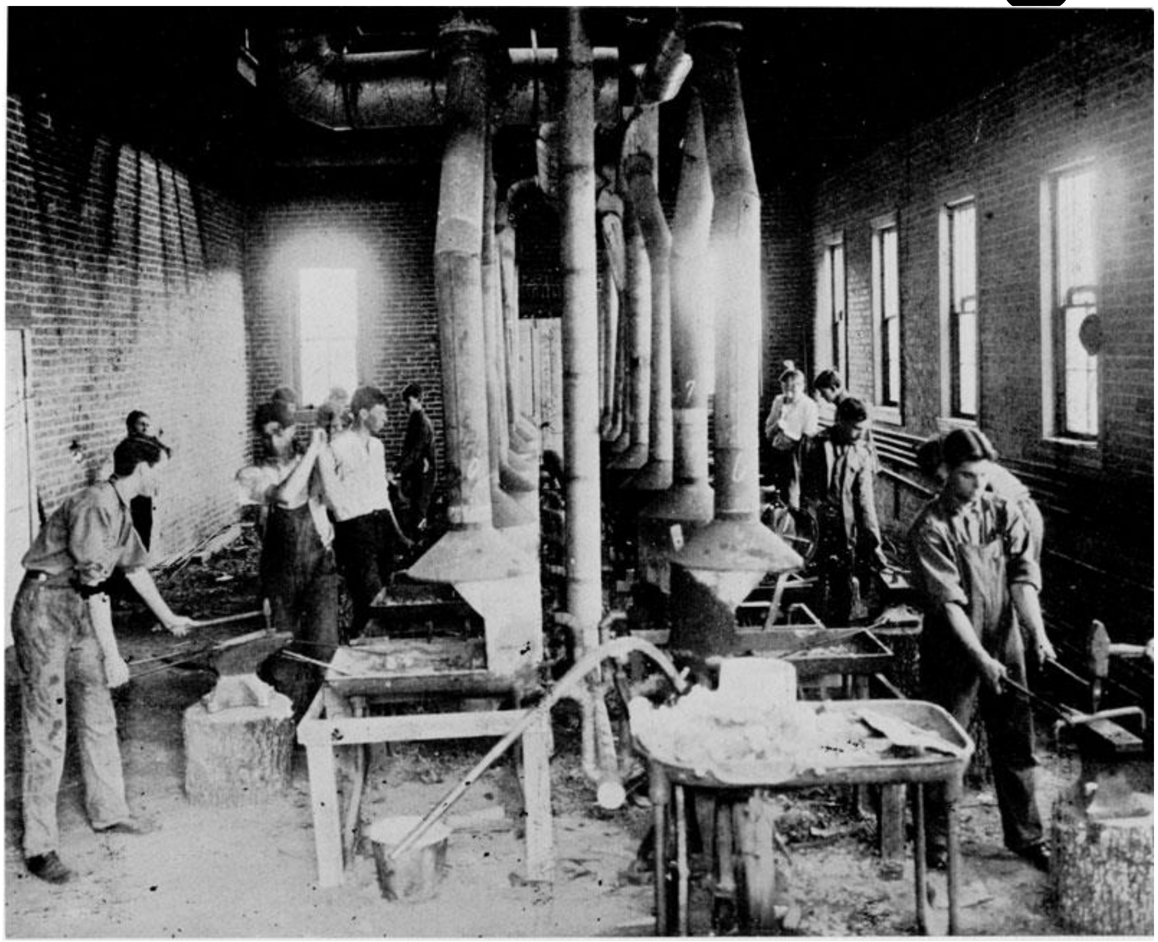
MATERIAL SCIENCE



CUSTOMIZING METALS

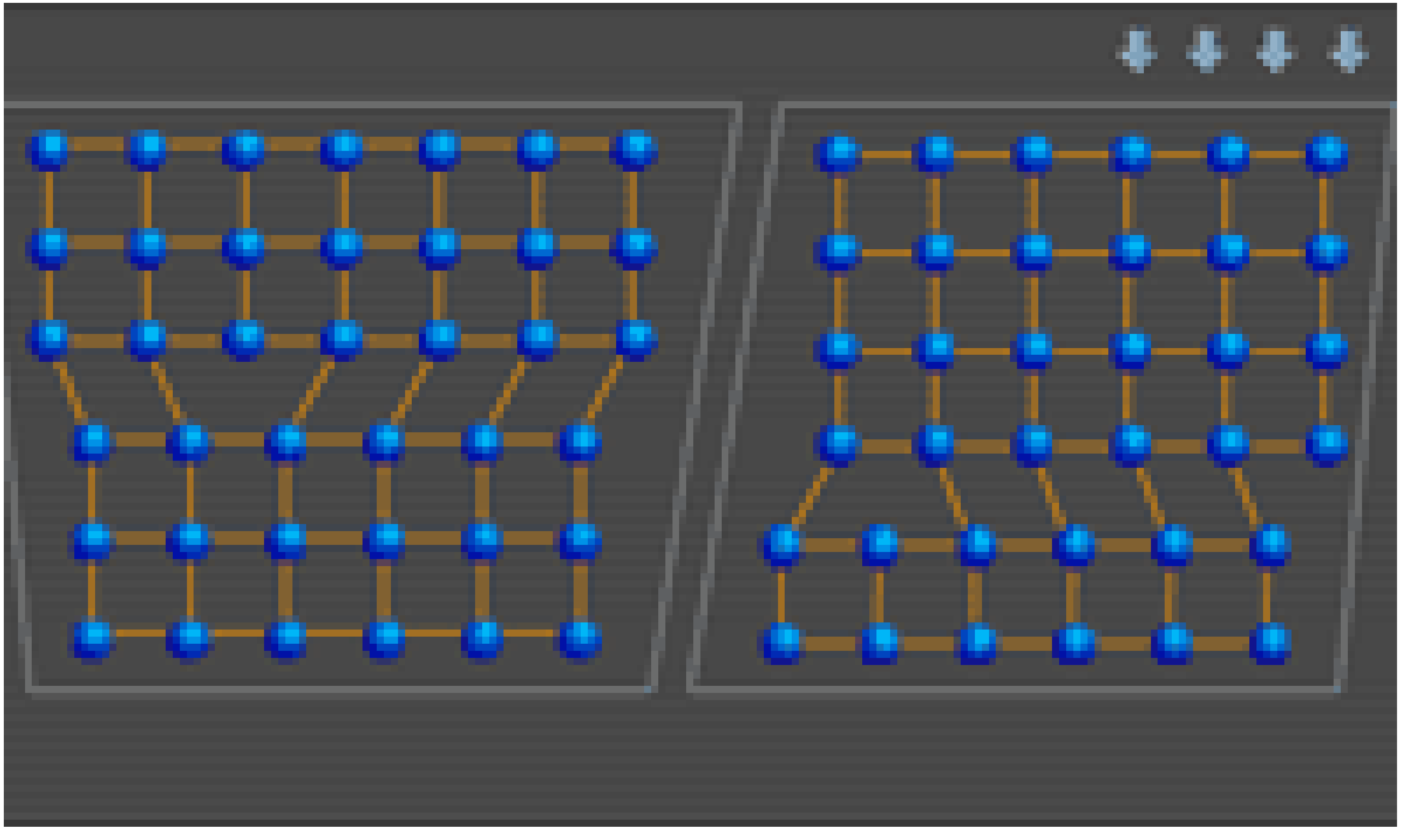
What is Cold Working?

Cold-Working



Altering the size or shape of a metal by plastic deformation.

Cold-Working



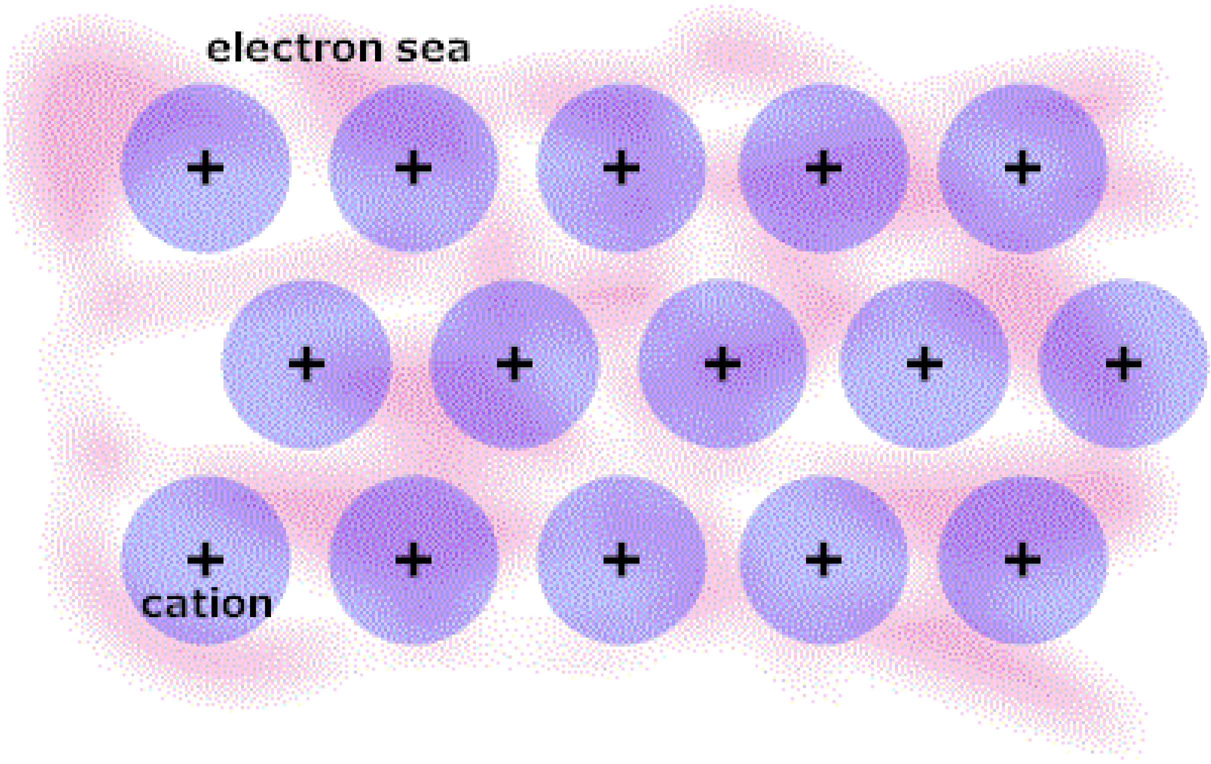
. ***Cold working produces additional dislocations within the metal structure.***

Cold-Working

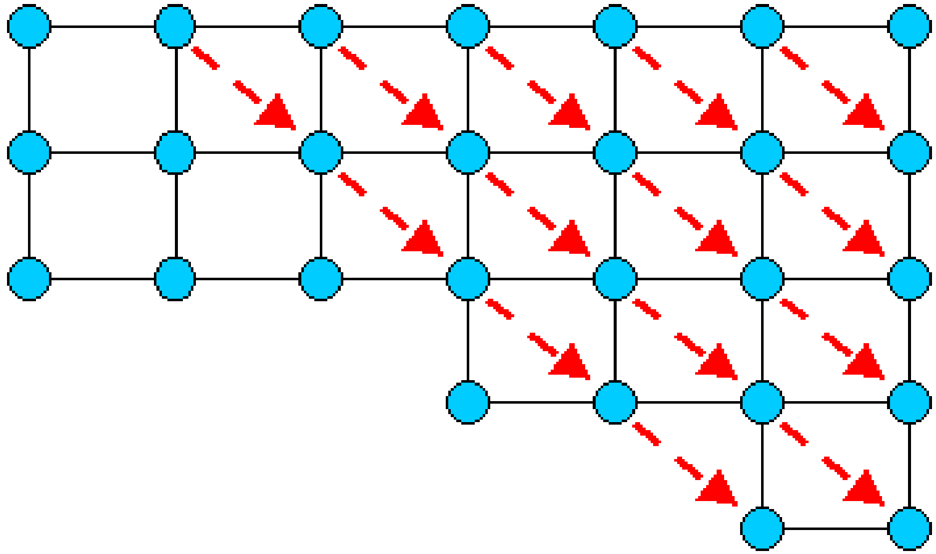
Cold working is often referred to as work hardening.

Metals are Malleable

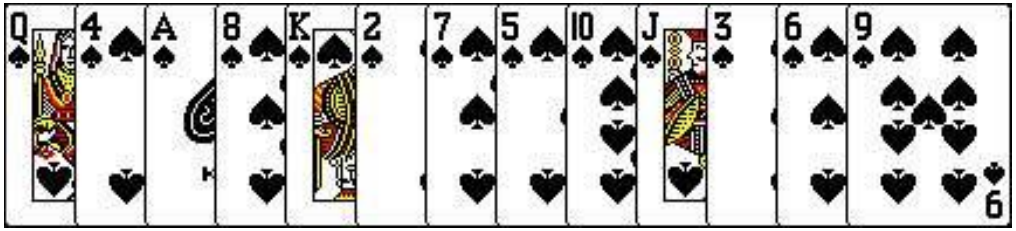
Metals are Flexible!



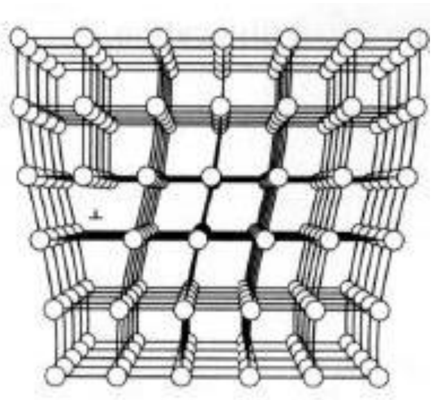
If a metal is stressed in tension beyond its elastic limit, it elongates slightly.

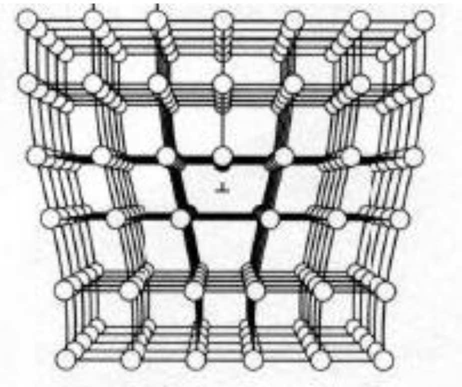


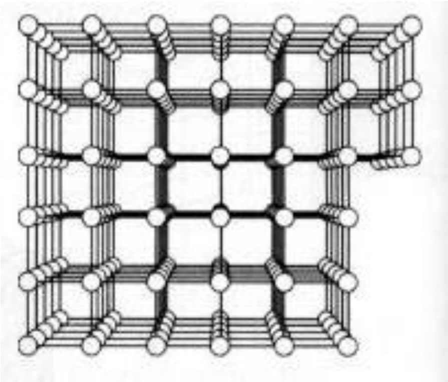
This elongation (slip) occurs in the direction which atoms are the most closely packed since it requires the least amount of energy.

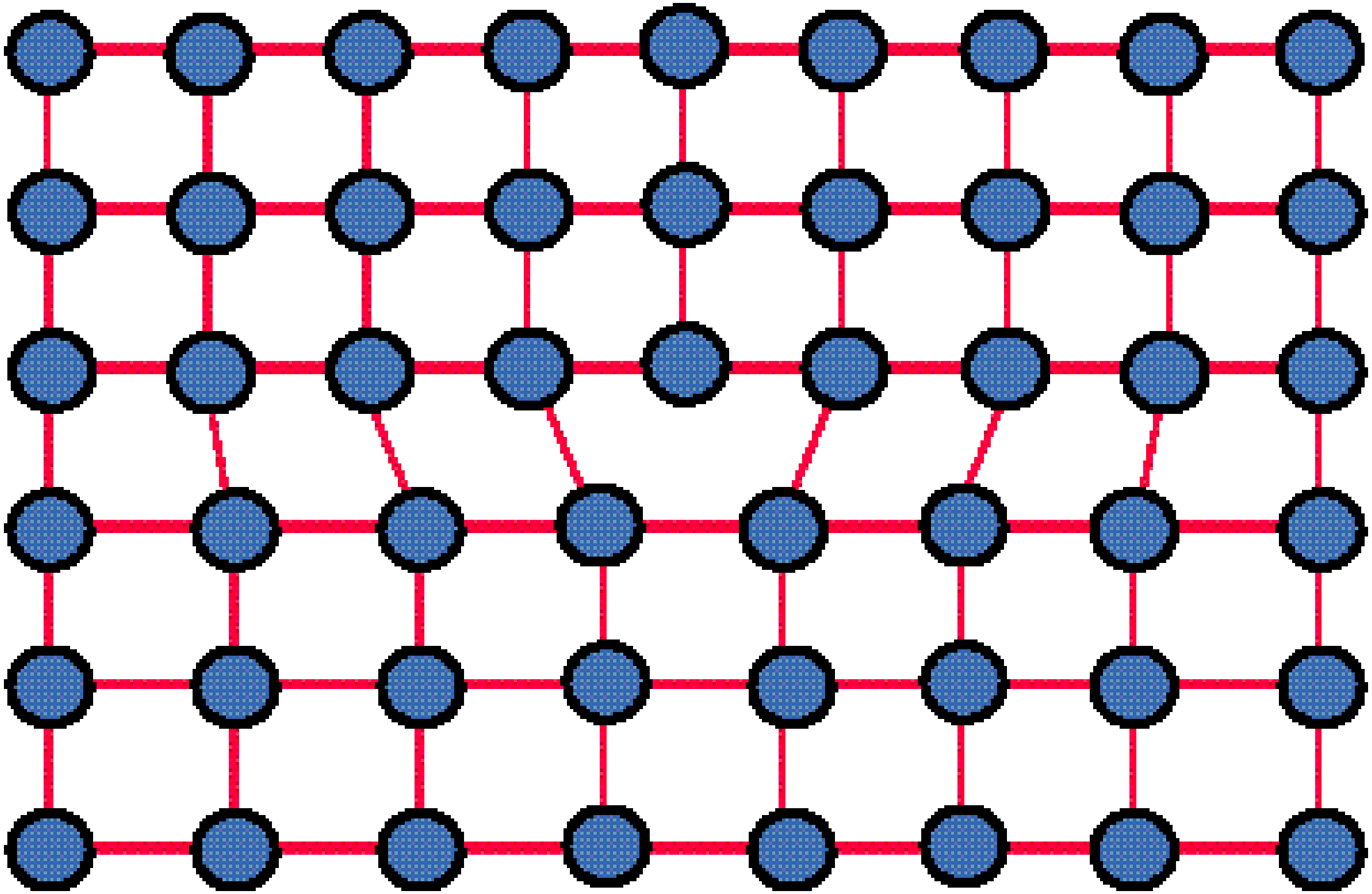


All the slip that occurs in a metal is caused by the movement of dislocations in its crystal structure.

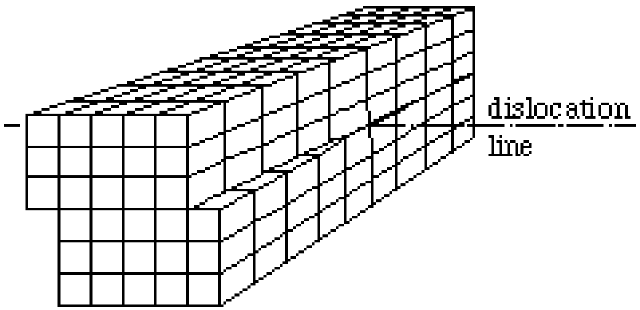


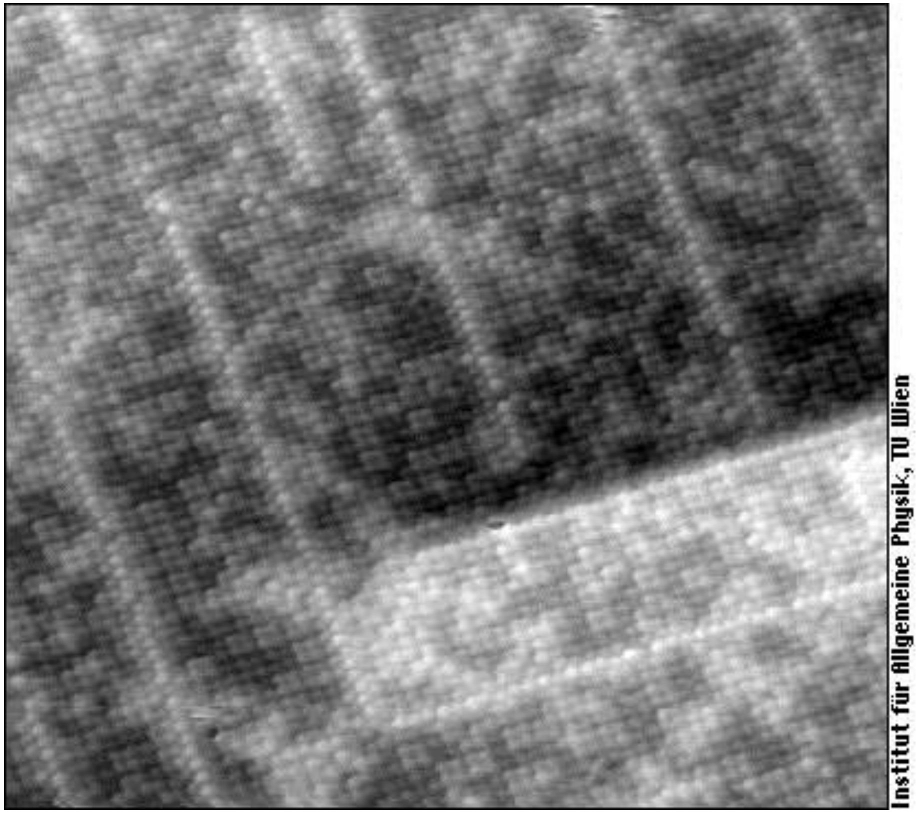




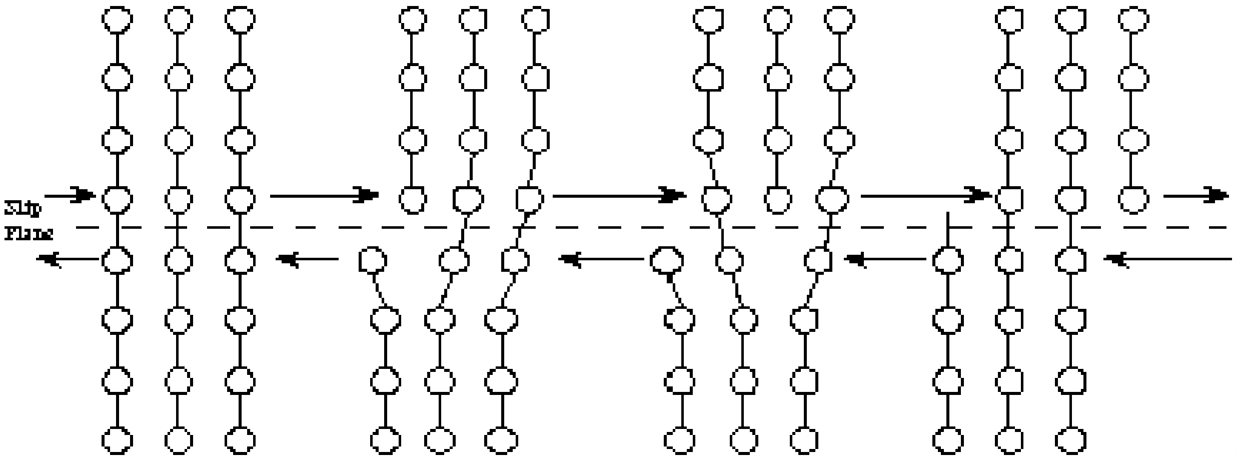


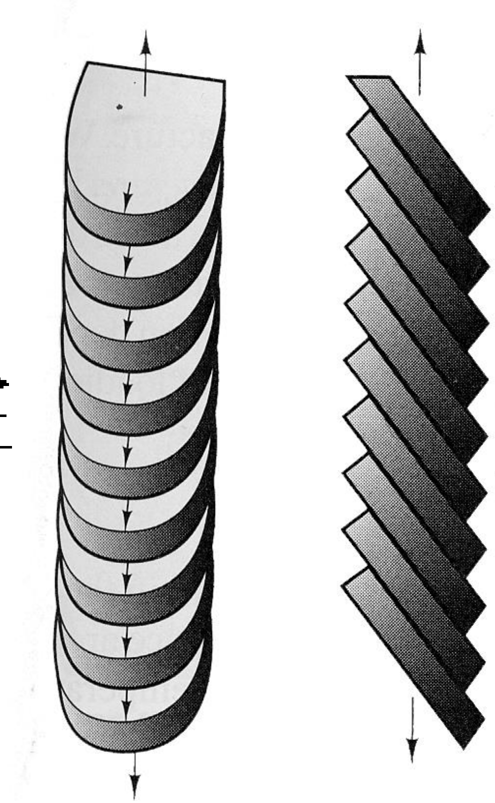
Dislocations are lines of defective bonding.



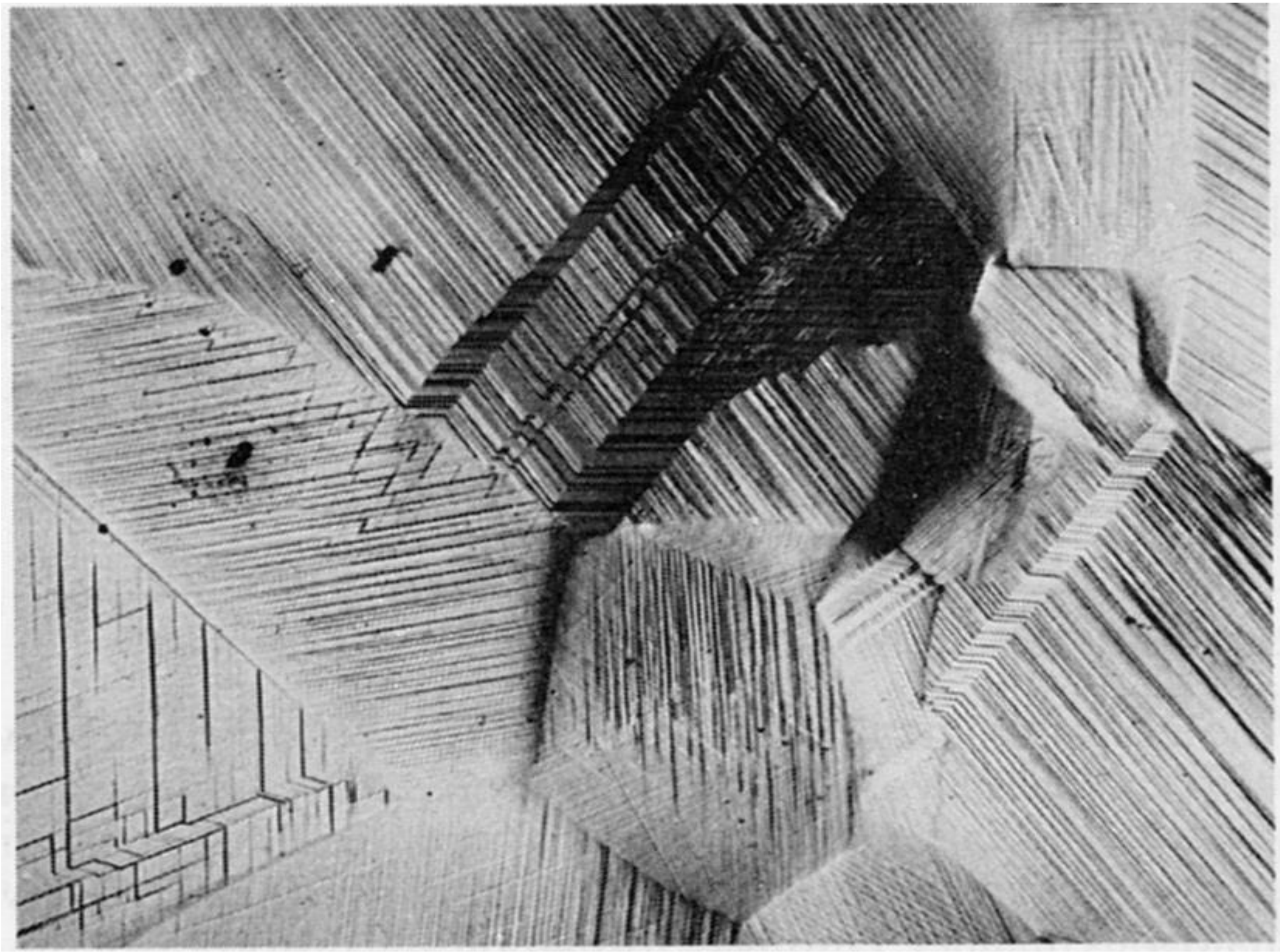


When 2 or more dislocations meet, the movement of one tends to interfere with the movement of the other.



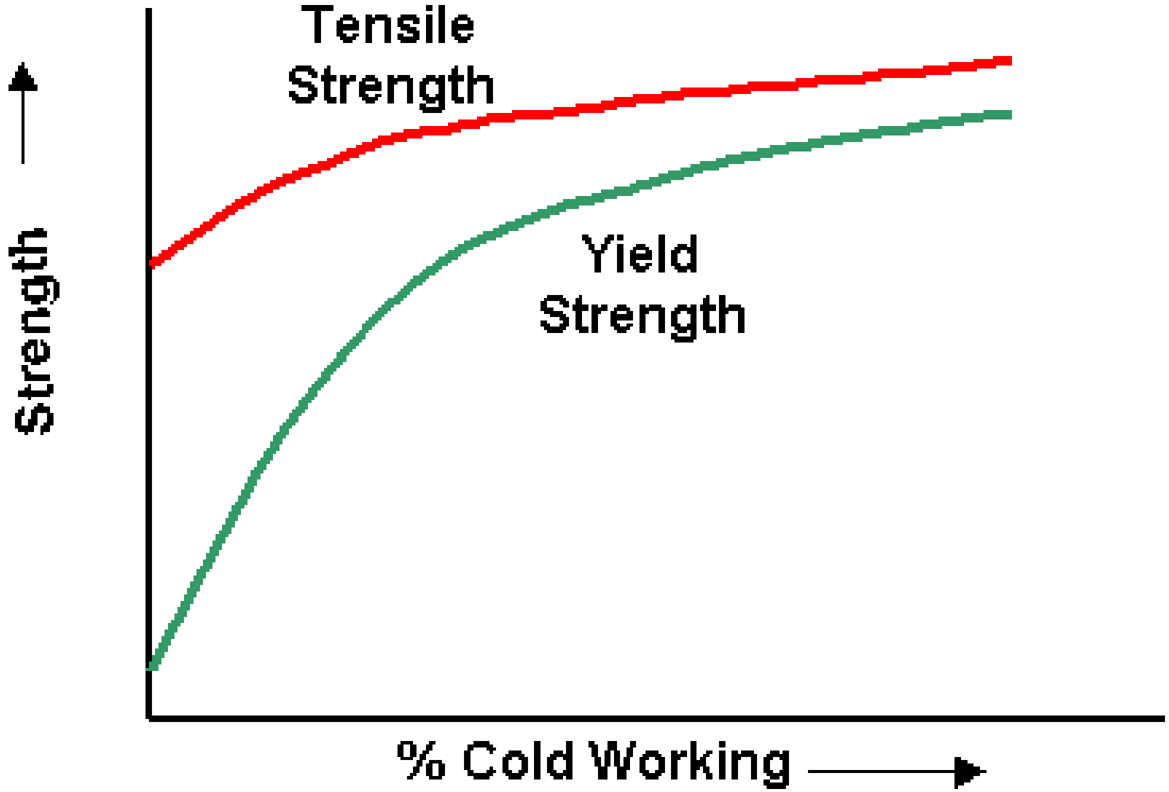


The number of dislocations in a metal crystal structure build up as the metal is cold worked.



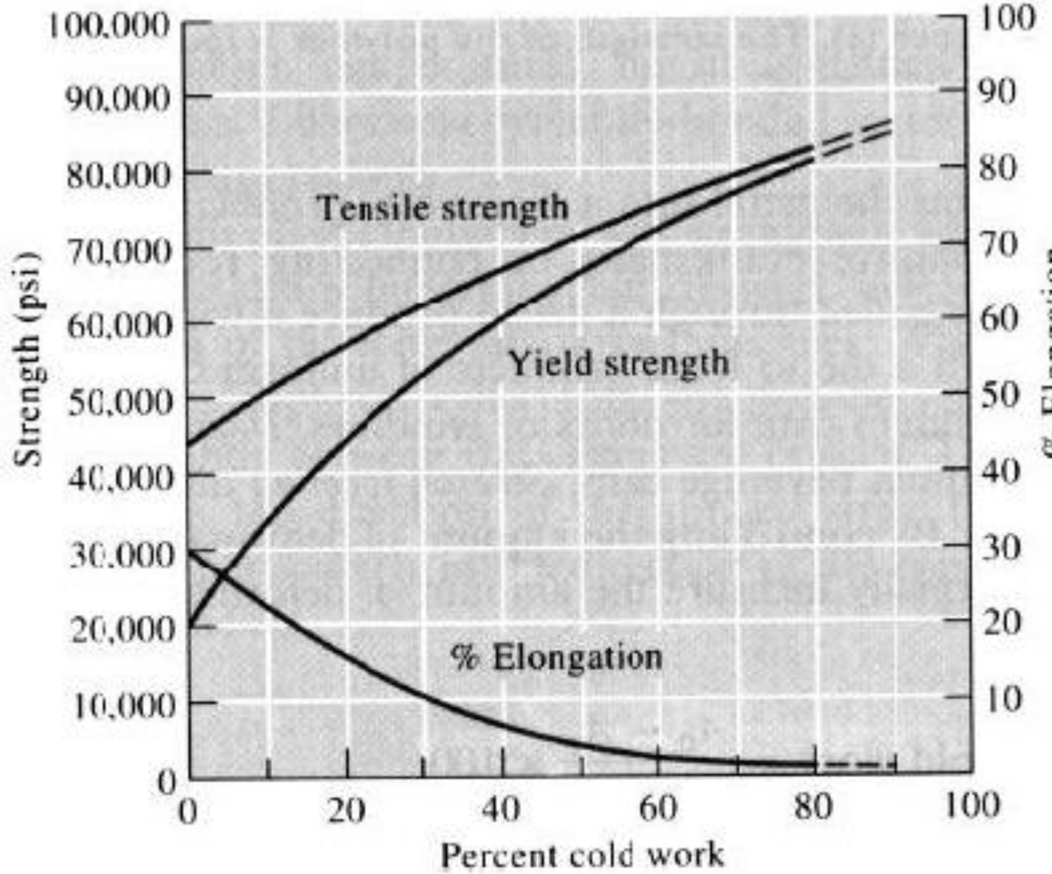
The more dislocations there are, the more they will hinder each other's movement.

Effects of Cold Working



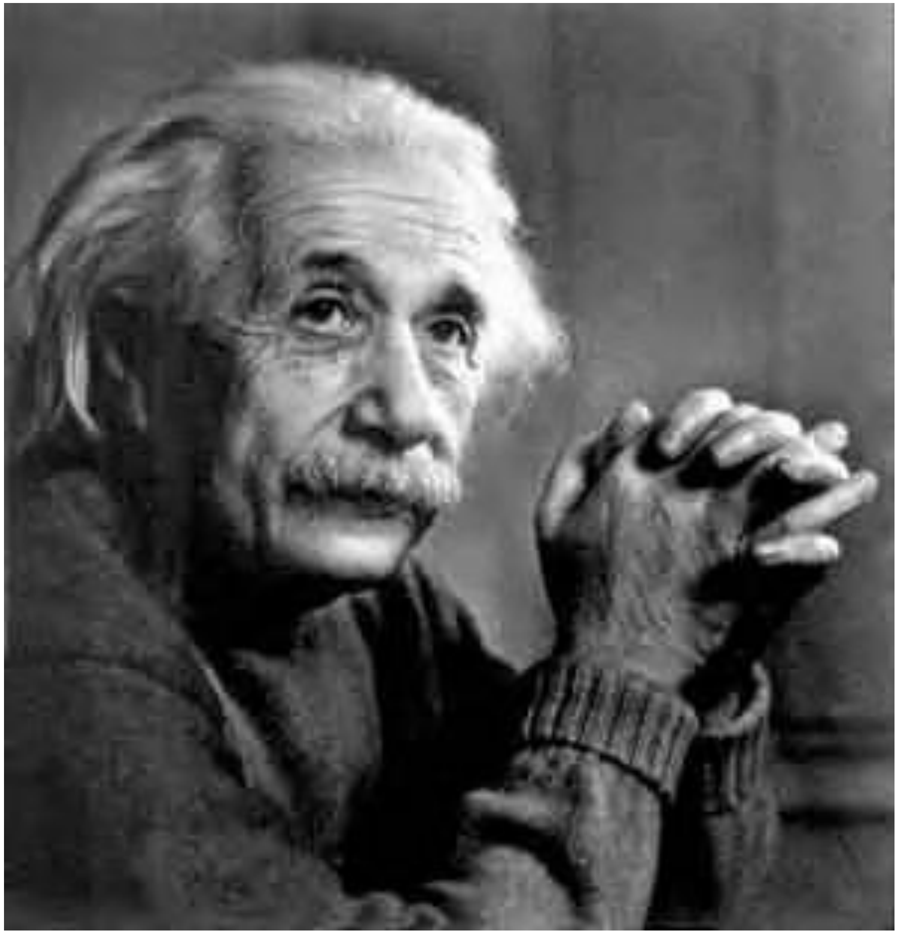
Cold working improves tensile strength, yield strength and hardness.

Effects of Cold Working



Cold working reduces ductility and flexibility.

Lab: Cold Working



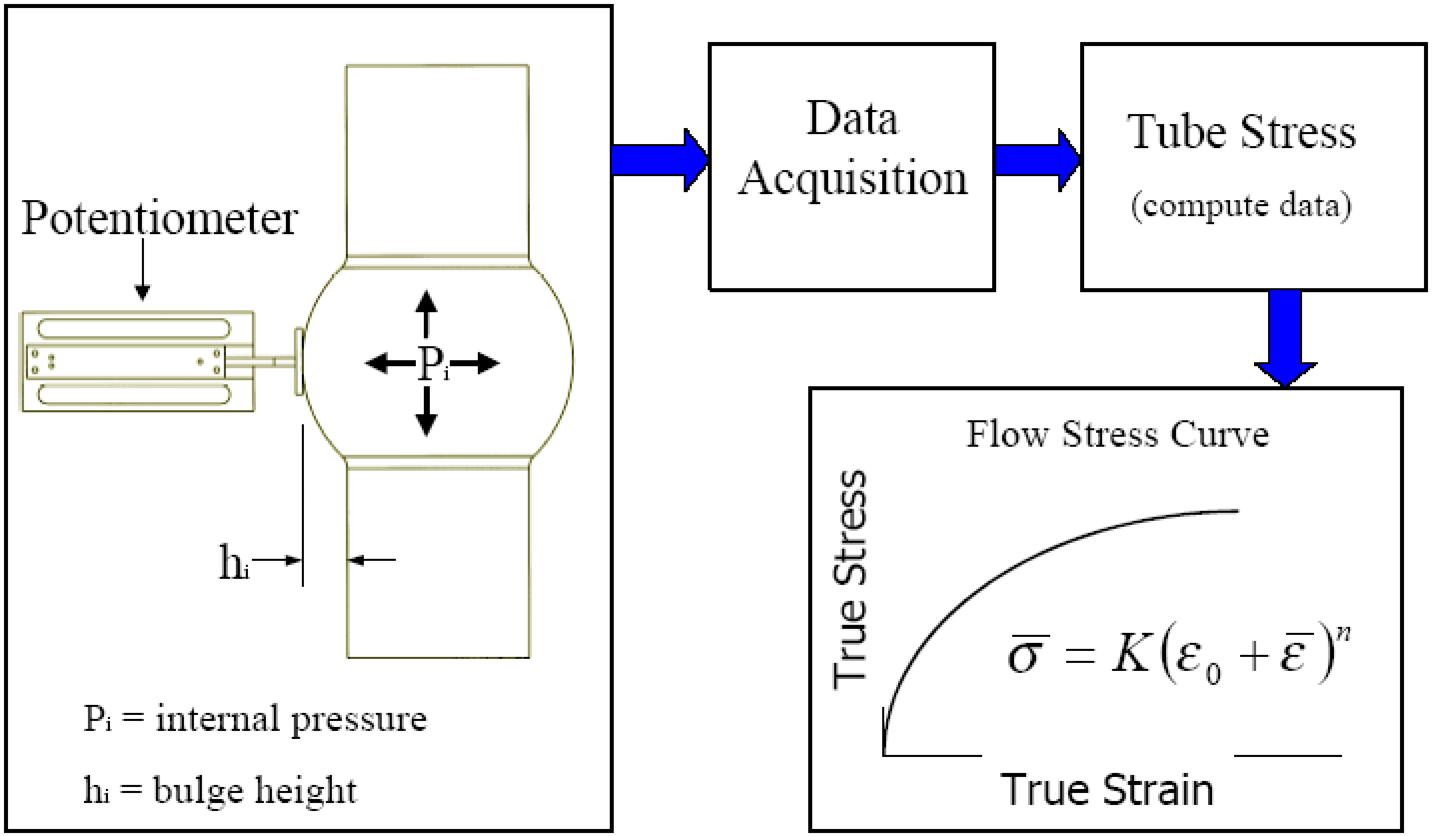
Lab: Cold Working 1

Metal Sample	# of Turns
Non-hammered	
Hammered	

Cold working does not increase the ultimate stress of a metal.

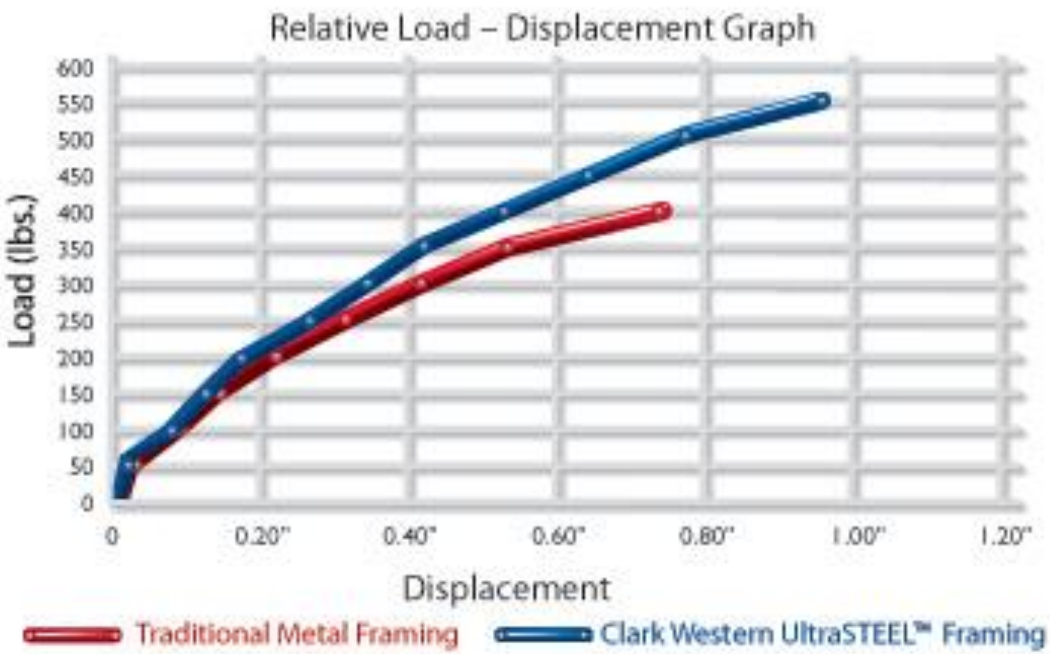
Cold working uses up some of the safety margin of the metal!

Flow Stress



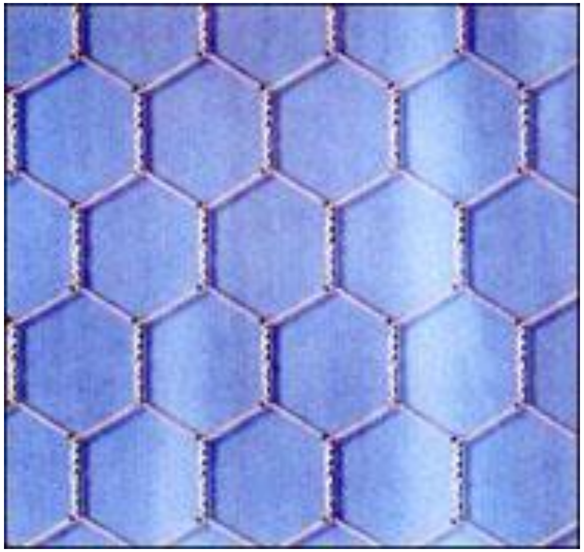
$$\sigma_f = K\varepsilon^n$$

A little cold working could be a good thing.



The added strength is worth the loss of flexibility.

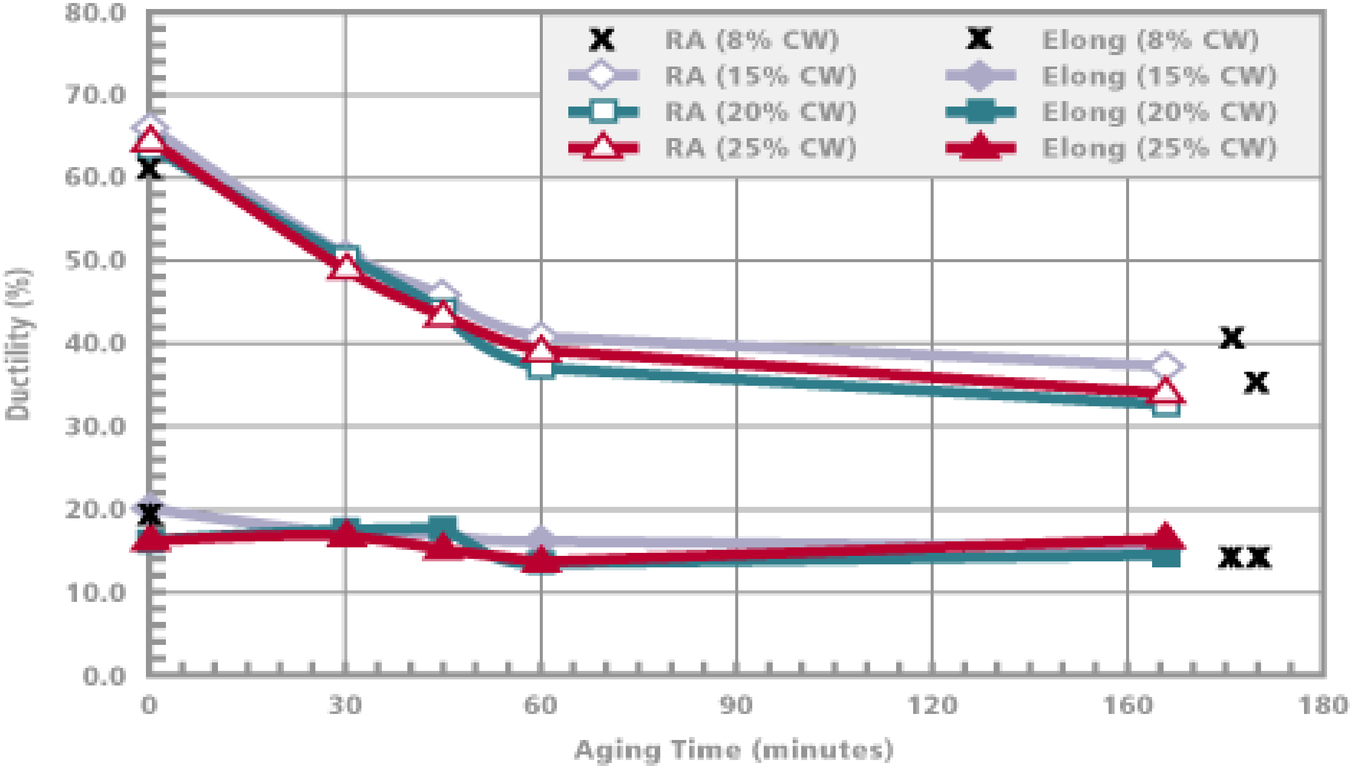
Example-Fencing Wire



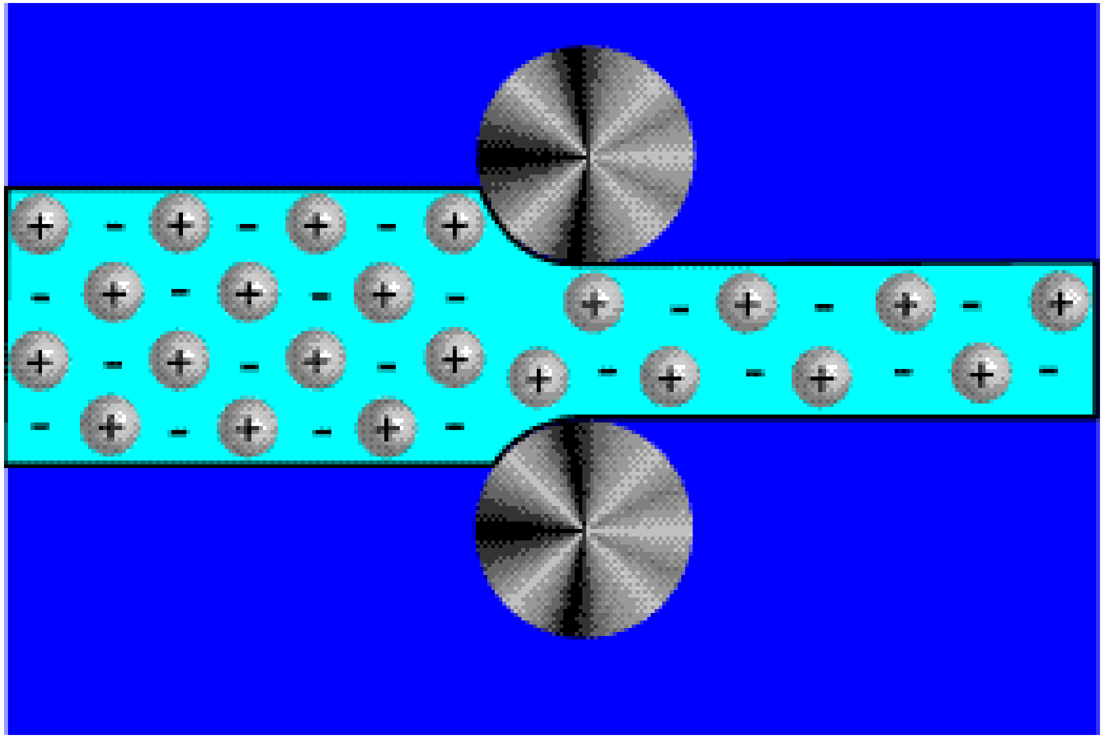
Cold working allows you to pull harder on the wire before it stretches (deforms).

That comes in handy when you are stringing a fence!

Types of Cold Working

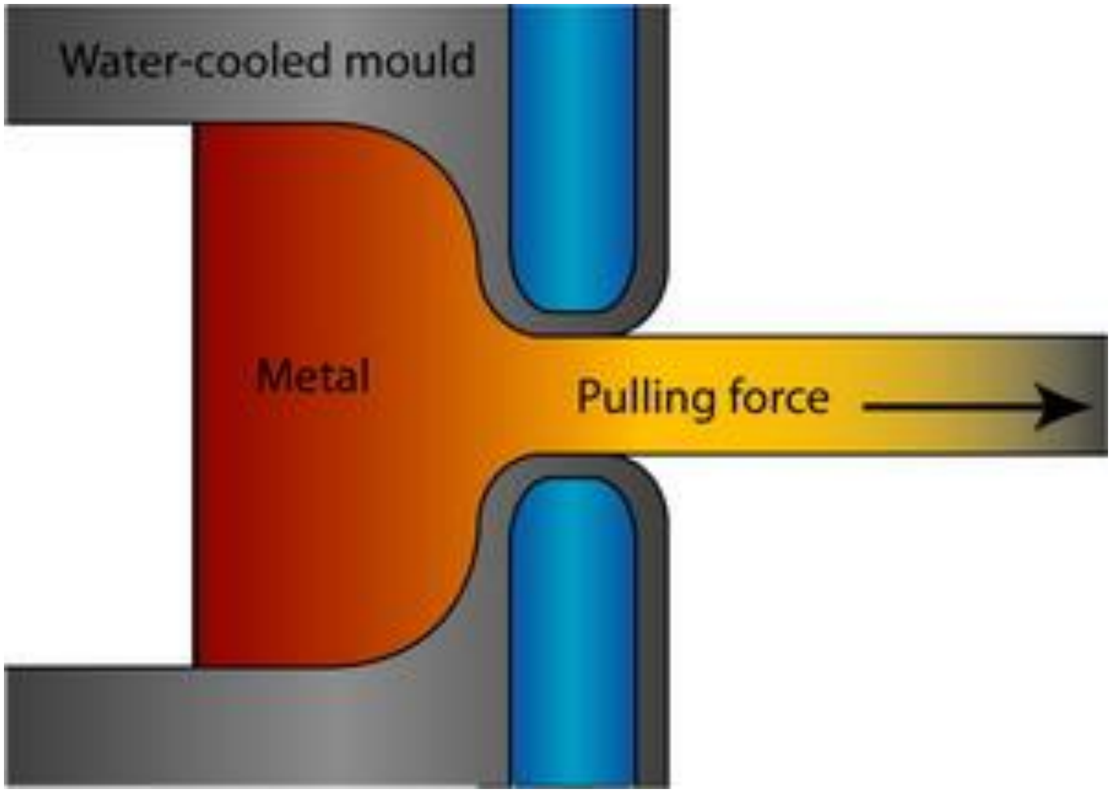


Rolling

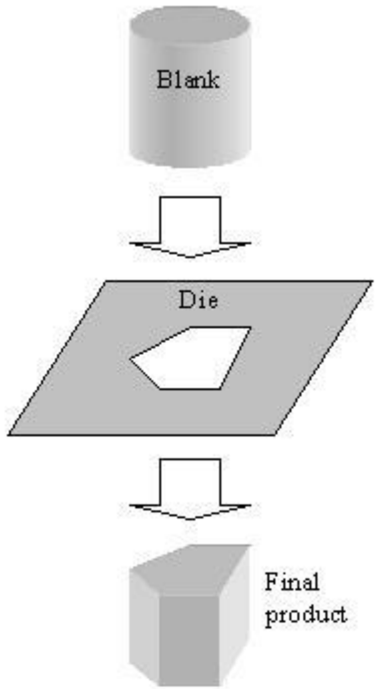


A metal strip is passed between two rolls that have a narrow gap between them.

Drawing



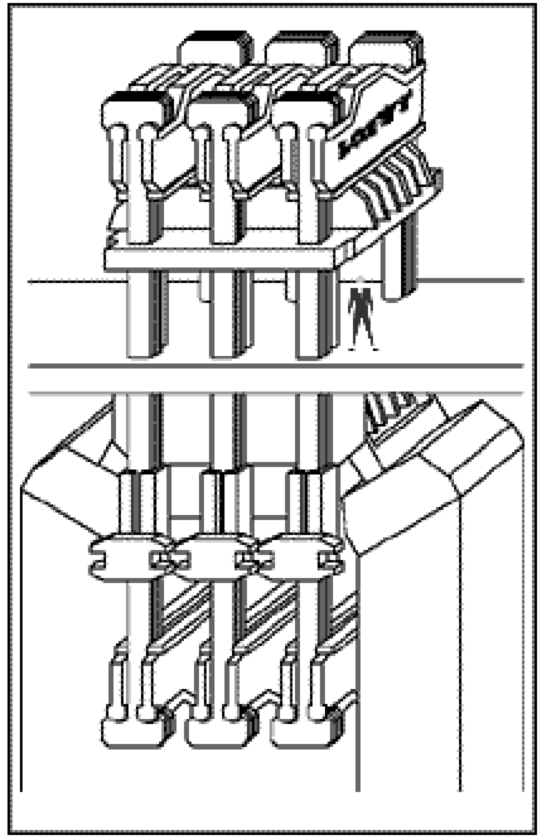
Drawing



The metal is pulled through a small hole in a dye.

Pressing

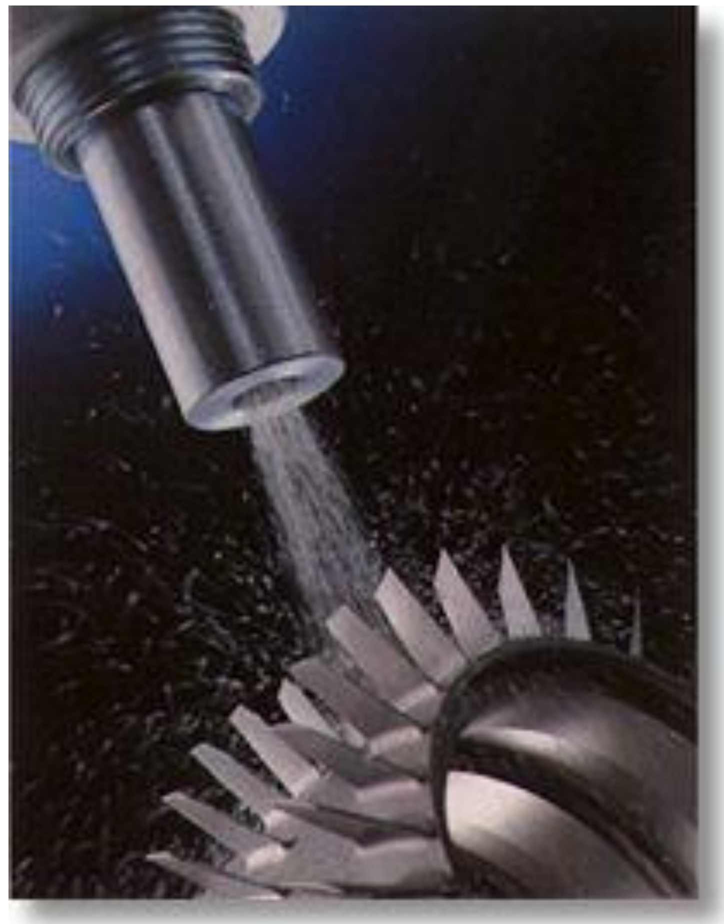
Pressing



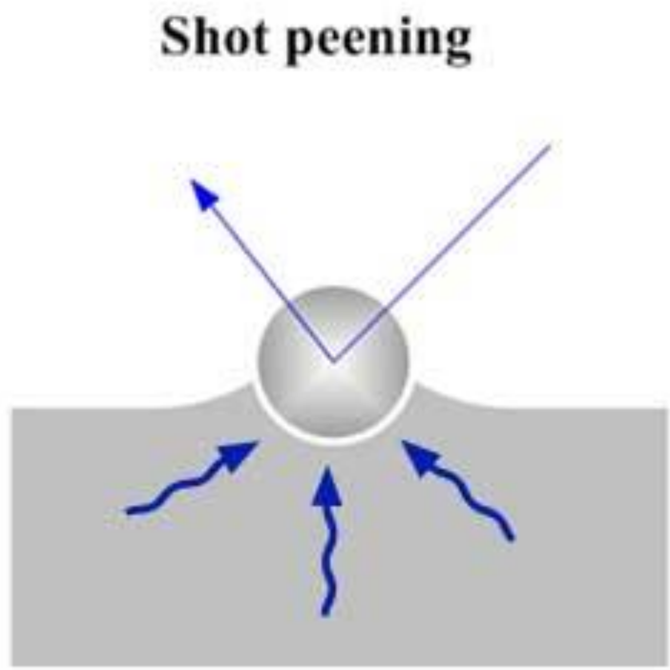
A metal sheet is pressed onto a shape or die to form an intricate shape.

Pressing

Shot Peening

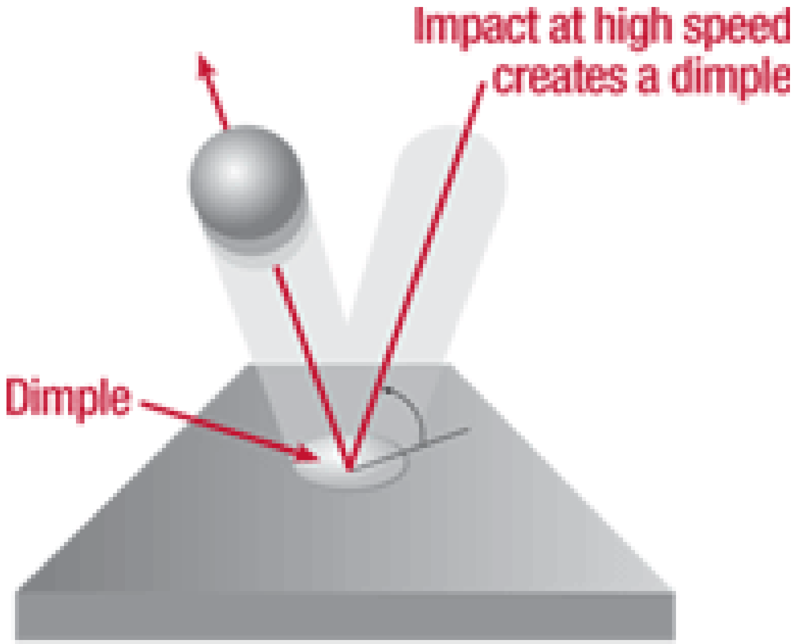


Shot Peening



Small metal or ceramic balls called "shot" are used to bombard the surface of a metal.

Shot Peening



Each shot that strikes the part's surface acts as a tiny peening hammer, imparting to the surface a small indentation or dimple.

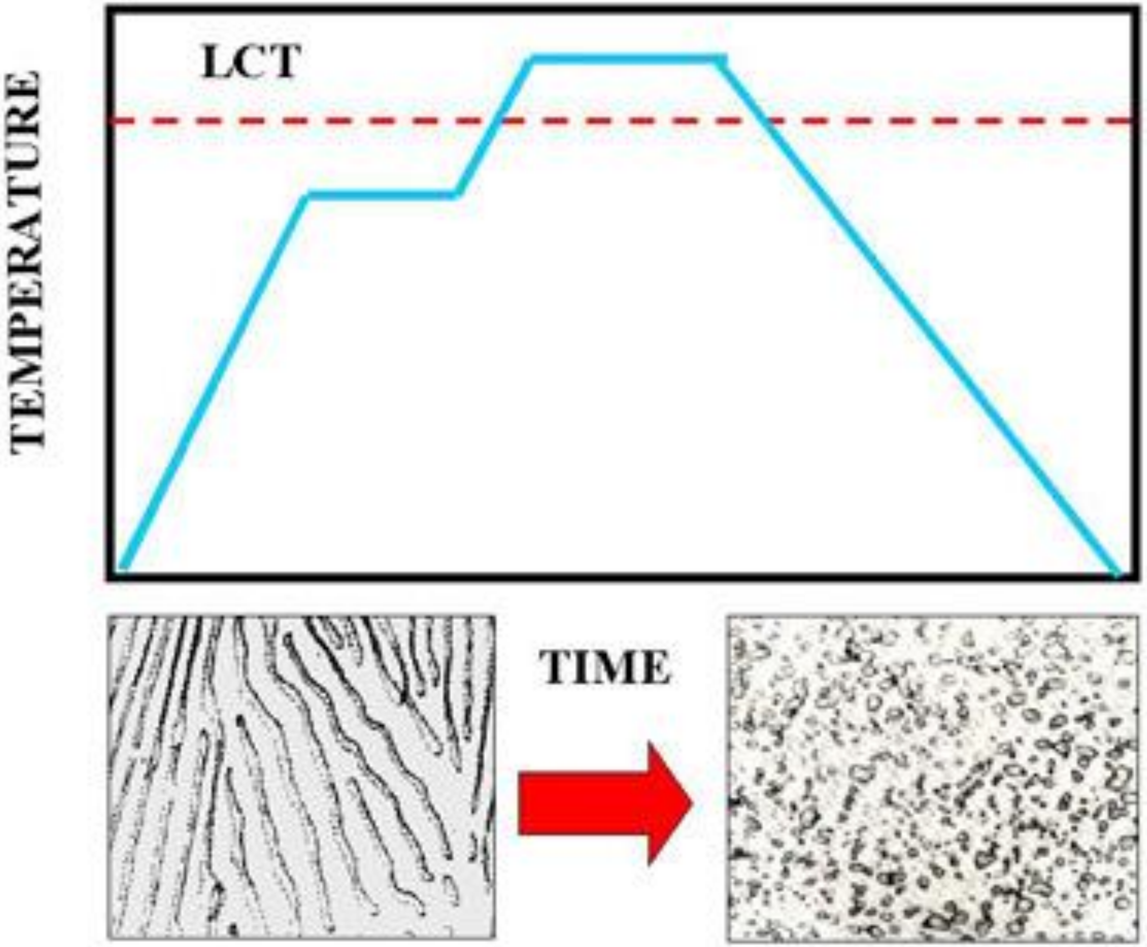
Shot Peening

These dimples create residual compressive stresses at and slightly beneath the surface.

This enable the metal to better resist any fatigue and provides resistance to abrasion.

Hot Working

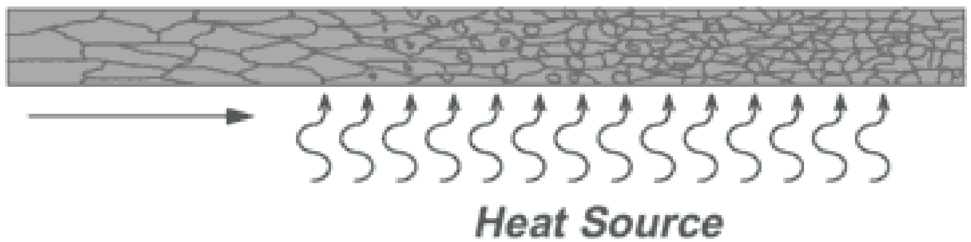
Hot working refers to plastic deformation carried out above the re-crystallization temperature.



LCT
TEMPERATURE
TIME

Annealing

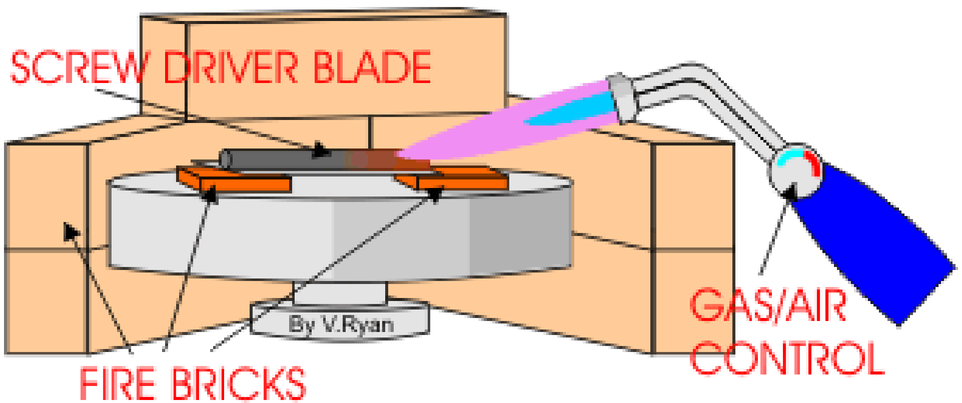
Annealing

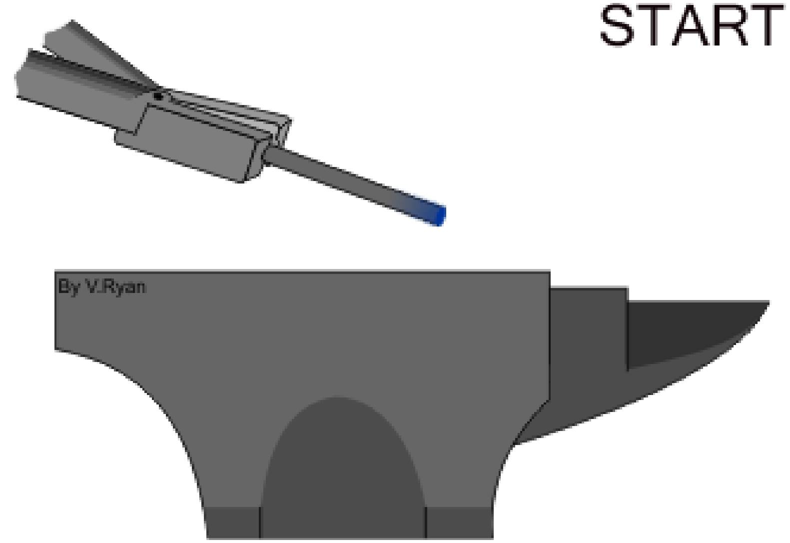


Growth of new grains within old grains during annealing.

Annealing is the process by which the distorted cold worked lattice structure is changed back to one which is strain free through the application of heat.

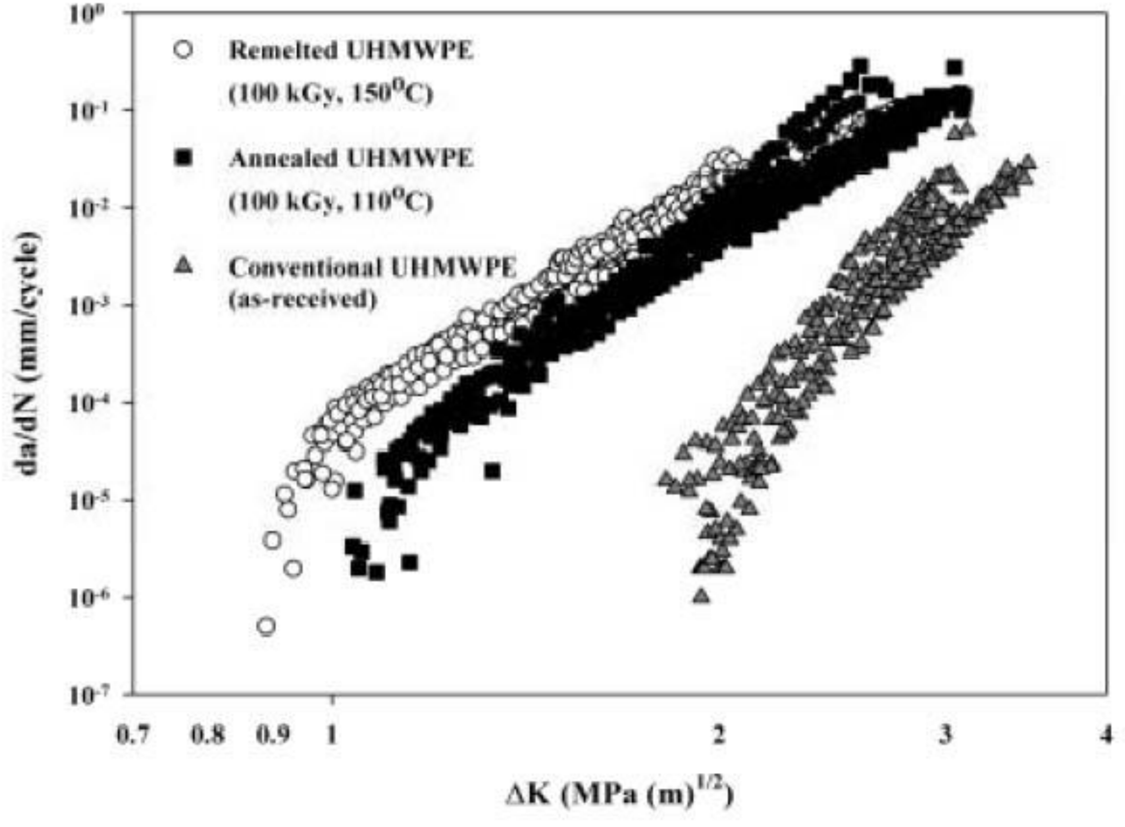
Metal stays in the solid state.



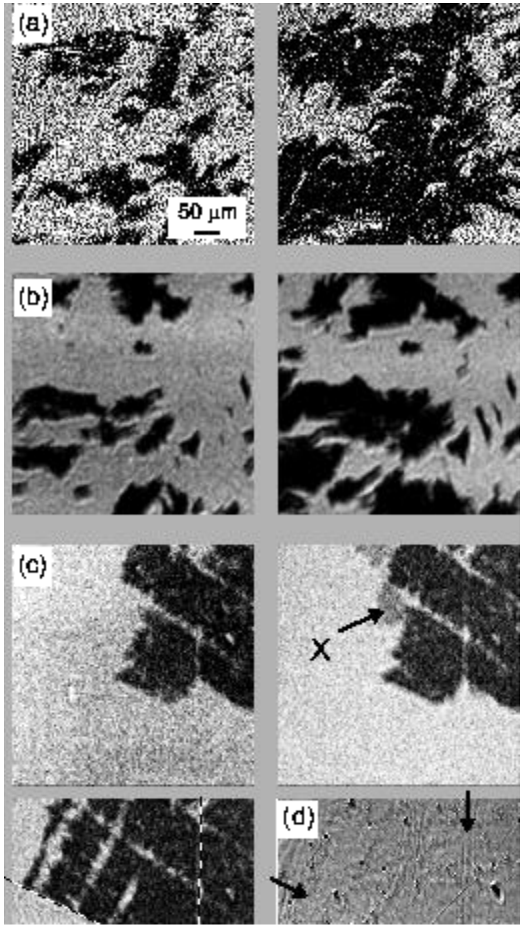


Slow cooling.

Effects of Annealing



Effects of Annealing

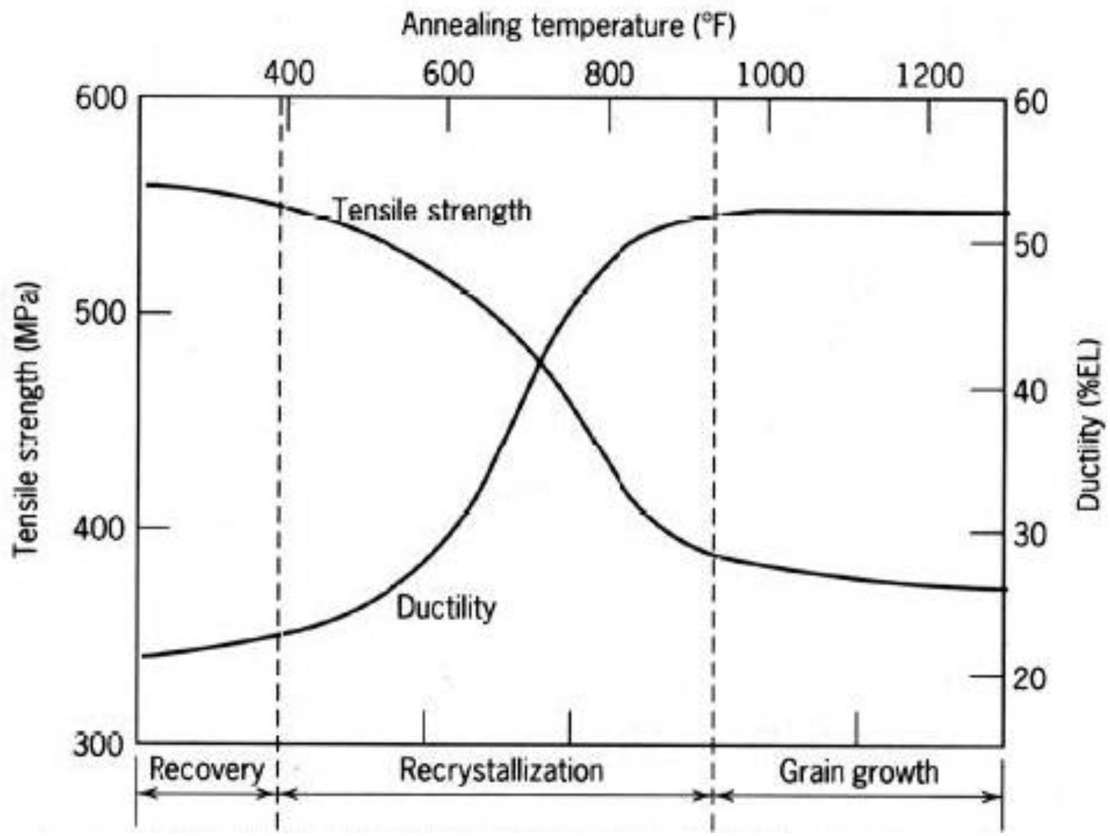


To relieve internal stresses induced by some previous treatment.

Effects of Annealing

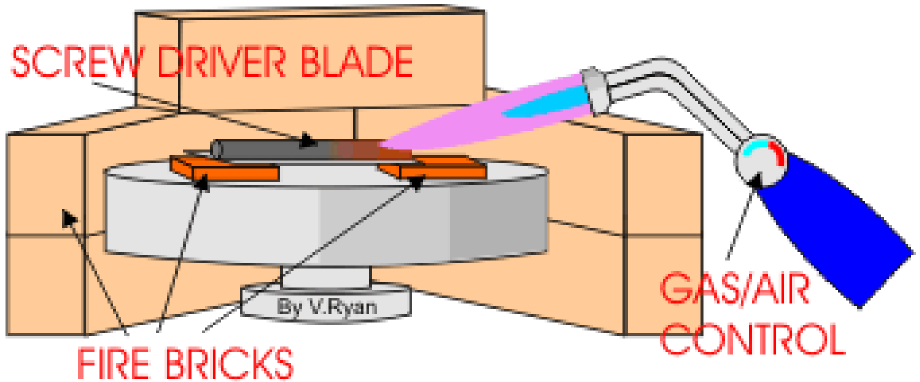
To remove coarseness of grain.

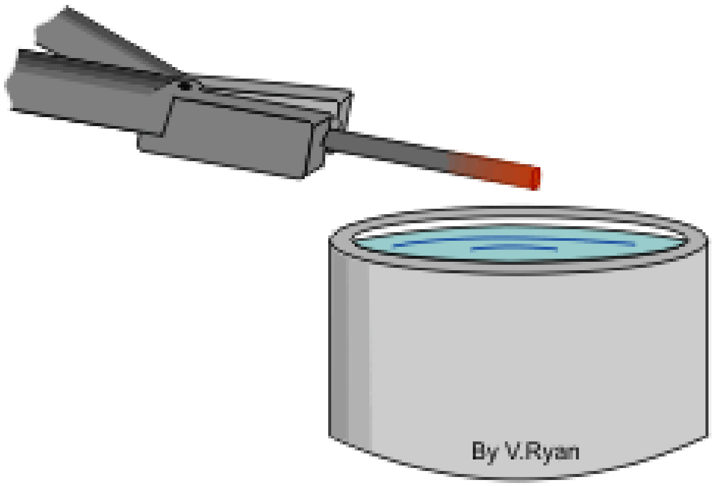
Effects of Annealing



To soften the metal and improve machinability.

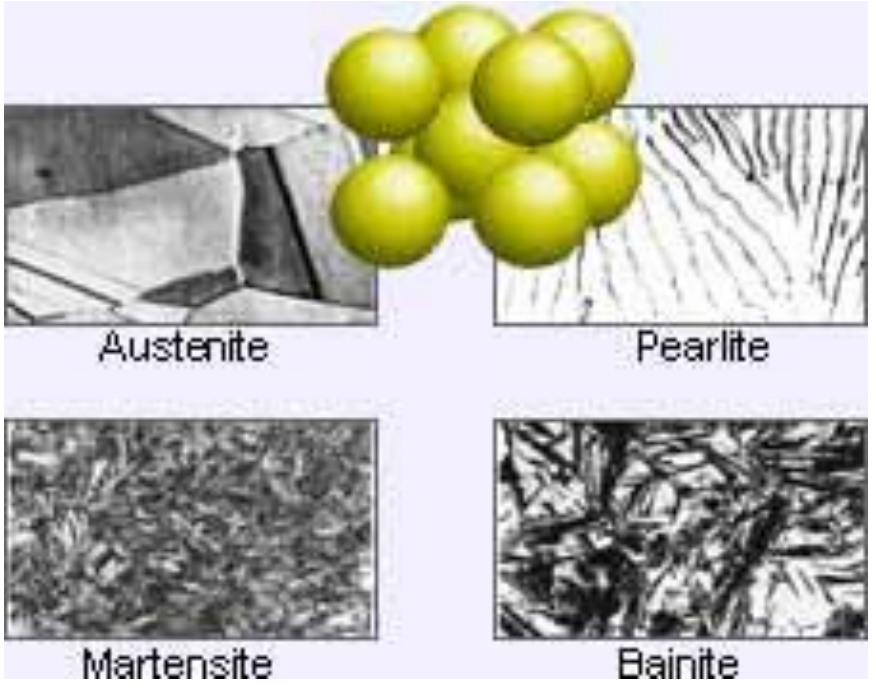
Quenching





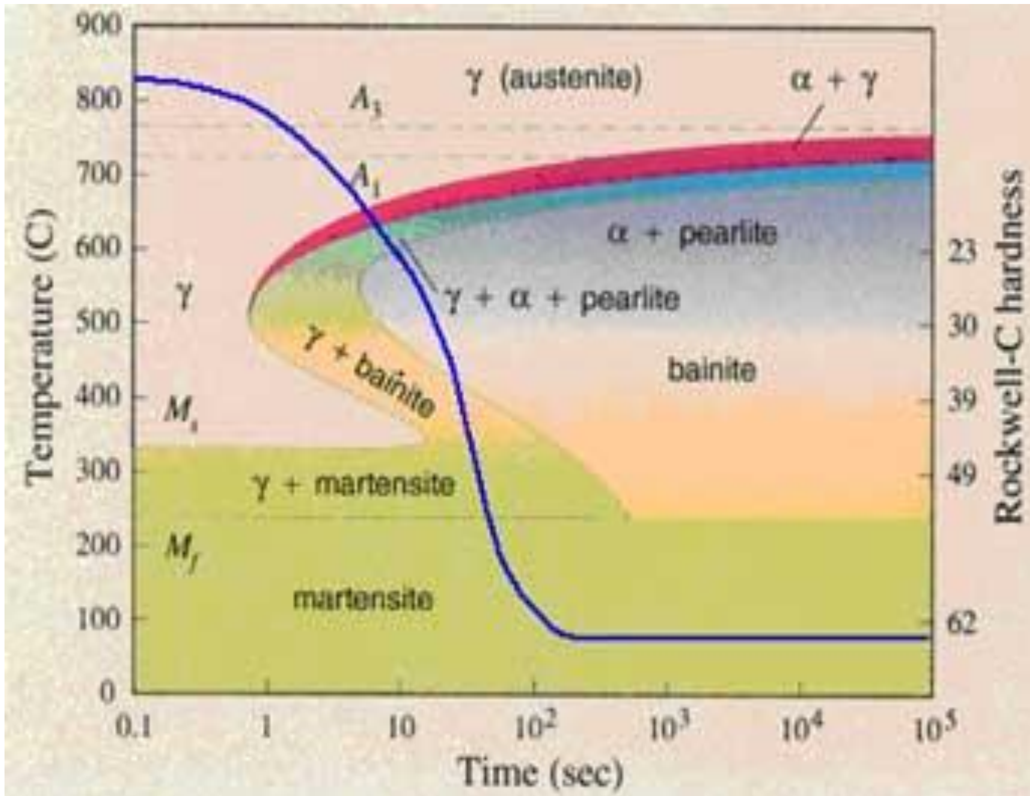
Cooled Quickly.

Effects of Quenching



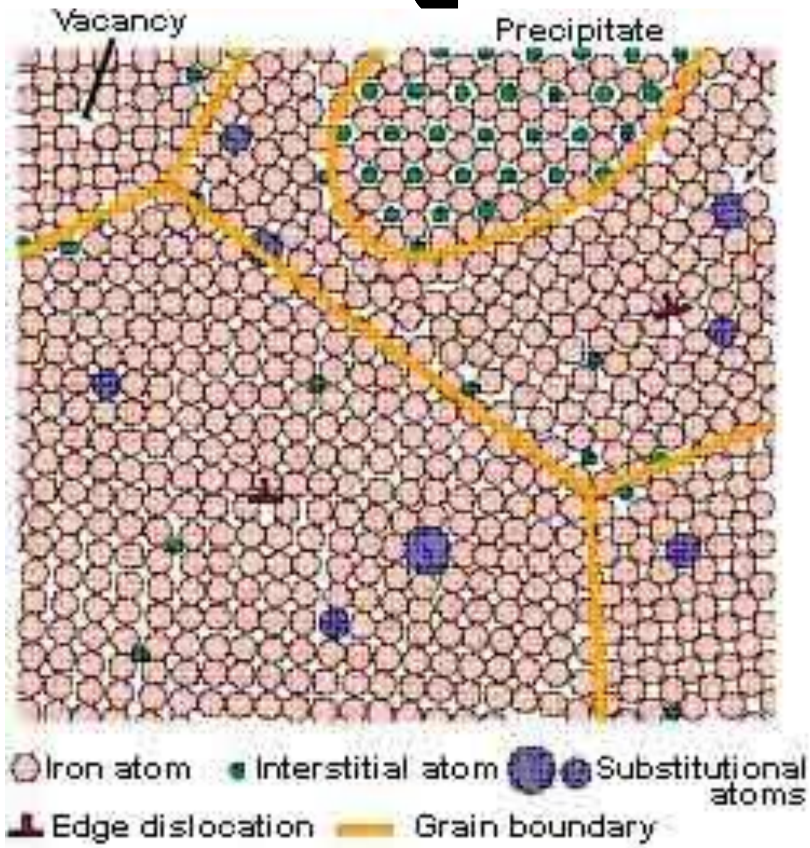
Quenching can be used to increase the hardness of steel.

Effects of Quenching



At high temperatures, alloying metals are completely dissolved in the base metal.

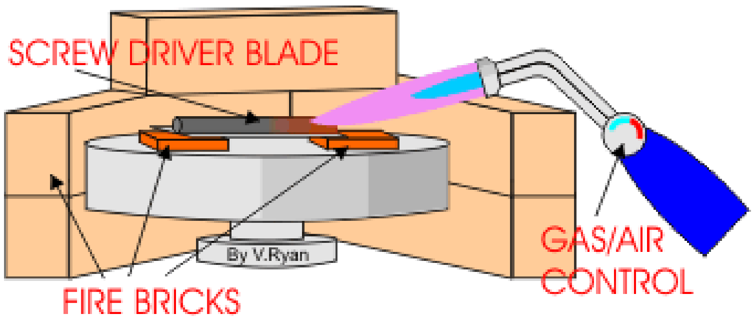
Effects of Quenching

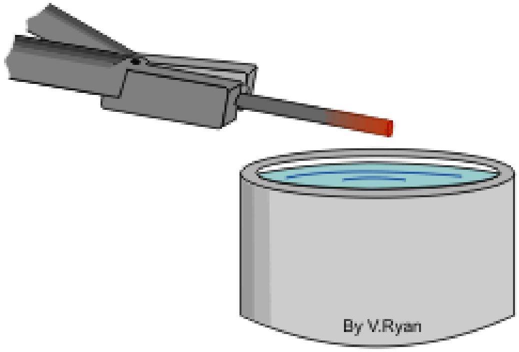


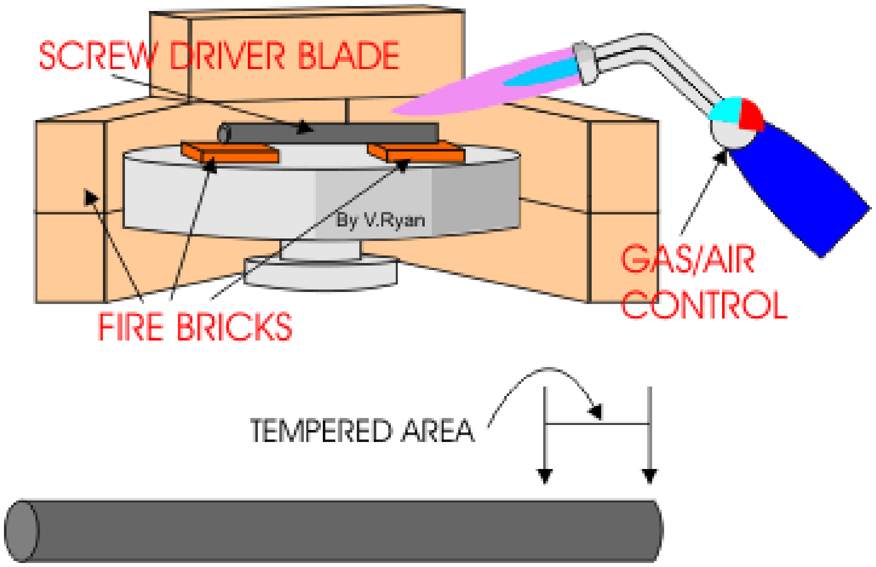
Quenching traps the alloying metals within the crystal structure and does not allow them to precipitate out separately.

Tempering

Tempering


SCREW DRIVER BLADE
By V.Ryan
GAS/AIR
CONTROL
FIRE BRICKS

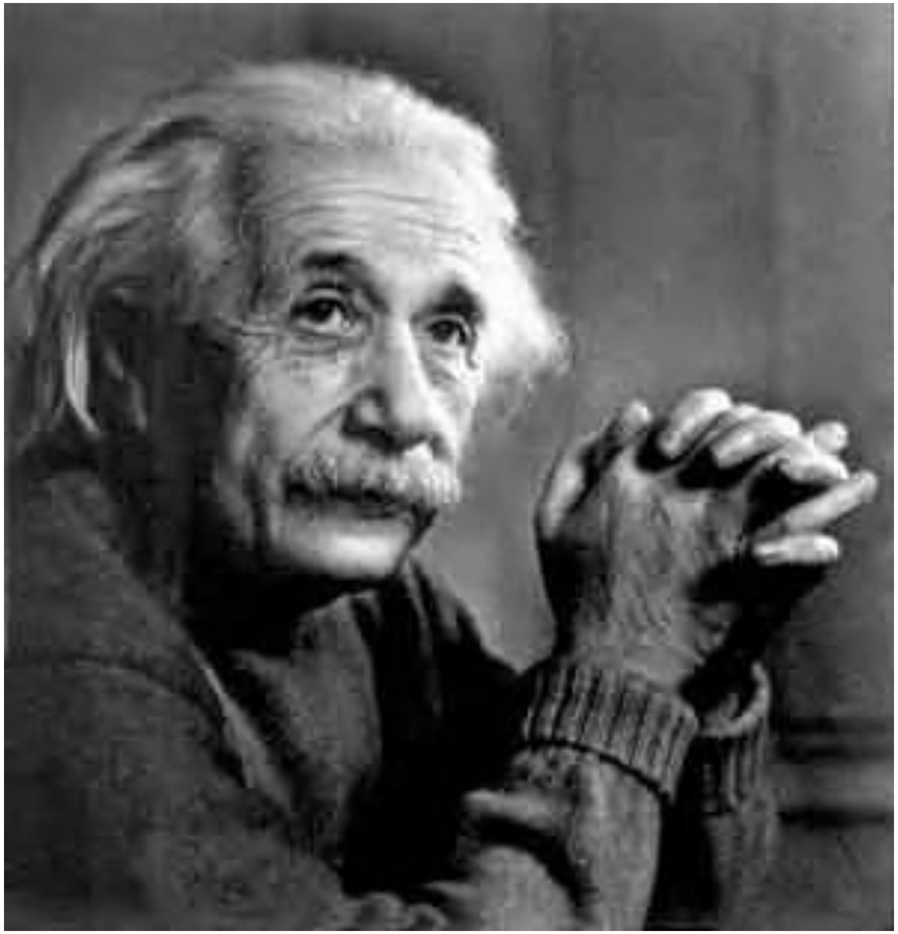

By V.Ryan


SCREW DRIVER BLADE
By V.Ryan
GAS/AIR
CONTROL
FIRE BRICKS
TEMPERED AREA

Tempering

Tempering improves the tensile strength and hardness of the material.

Lab: Heat Treatment

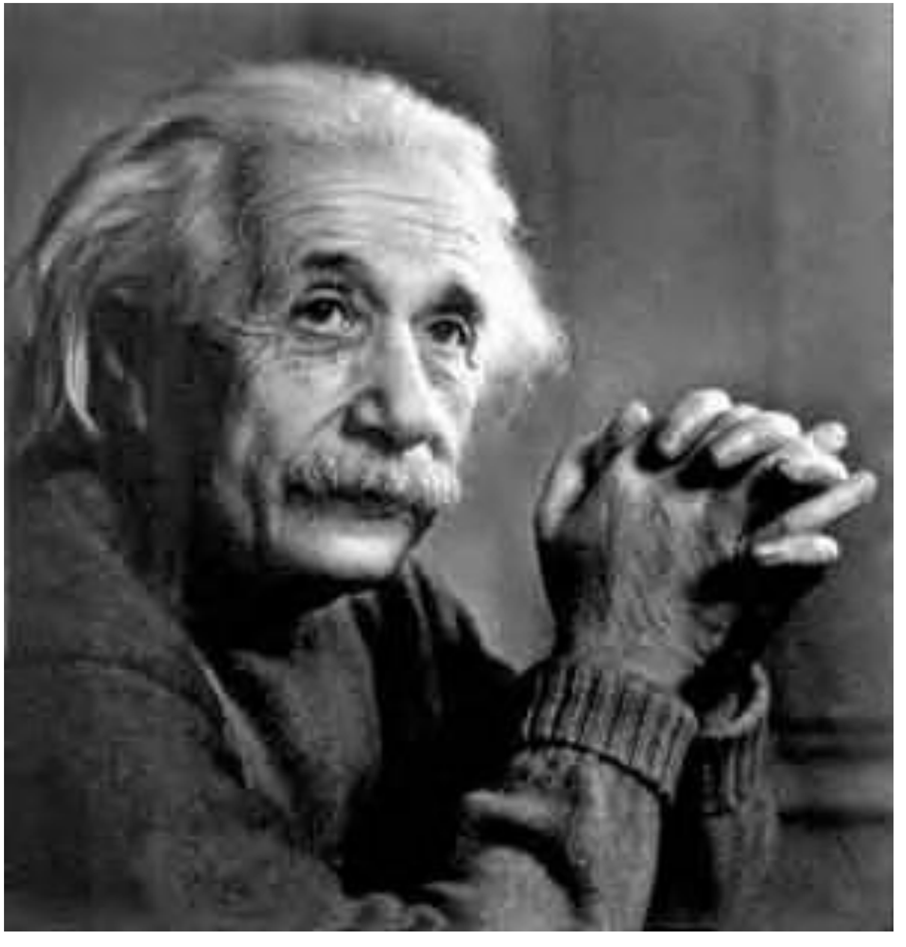


Lab: Heat Treatment

Data Chart

Bobby Pin	# of Turns
Control	
Annealing	
Quenching	
Tempering	

Lab: Heat Treatment (The Inside Story)



Lab: Heat Treatment (The Inside Story)

Data Chart

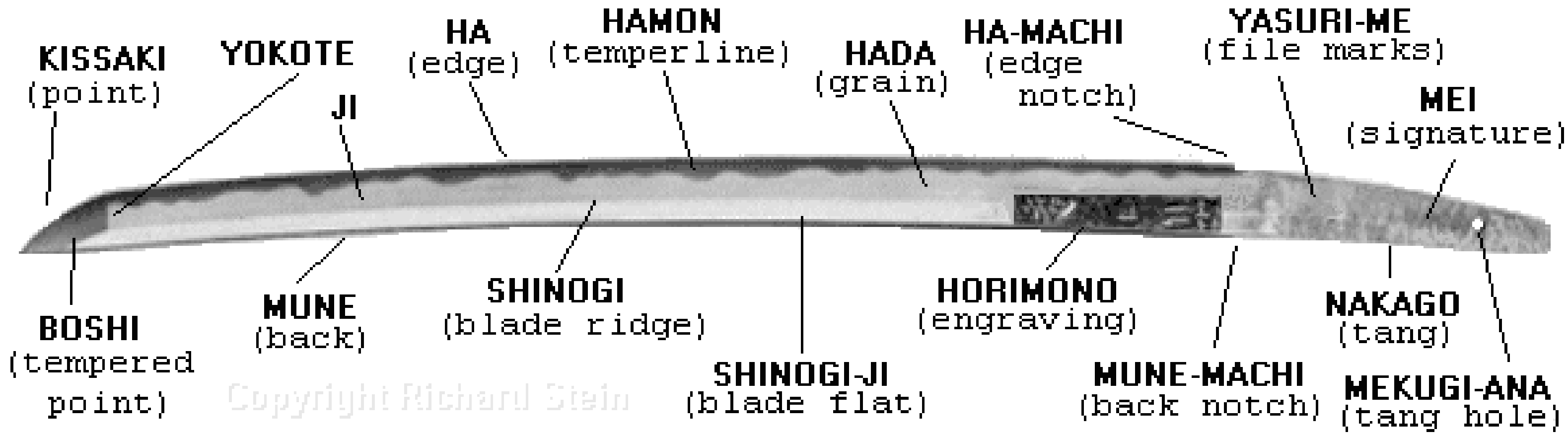
Heat Treatment	Diagram	Description
Annealing		
Quenching		
Tempering		

Temper Color	Temperature ° C	Objects
Pale straw	230	Planting and slotting tools
Dark straw	240	Milling cutters, drills
Brown	250	Taps, shear blades for metals
Brownish-purple	260	Punches, cups, snaps, twist drills
Purple	270	Press tools, axes
Dark purple	280	Cold chisels, sets for steel
Blue	300	Saws for wood, springs
Blue	450-650	Toughening for constructional steels

Hot Working

$$\sigma_f = c\dot{\varepsilon}^m$$

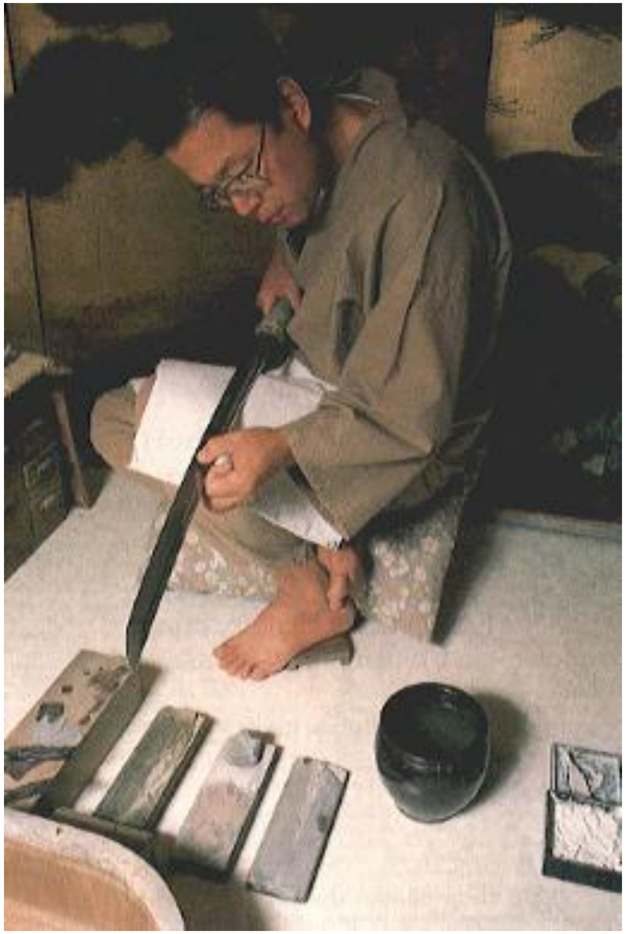
The Mystery of *Katana*



The Challenge

Make a sword that would will not break in battle.

Use soft steel that would be less brittle.



Make a sword that would hold a sharp edge.

Make the steel very hard so that it would never dull.

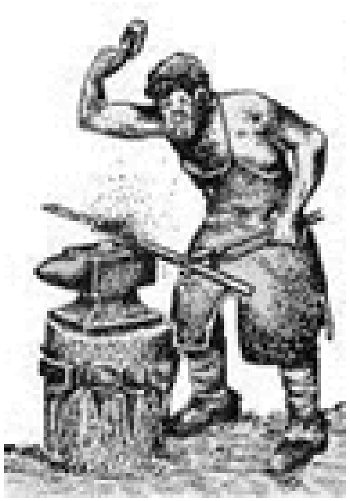
Japanese sword makers solved the problem by hammering together layers of steel of varying hardness and welding them into a metal sandwich.

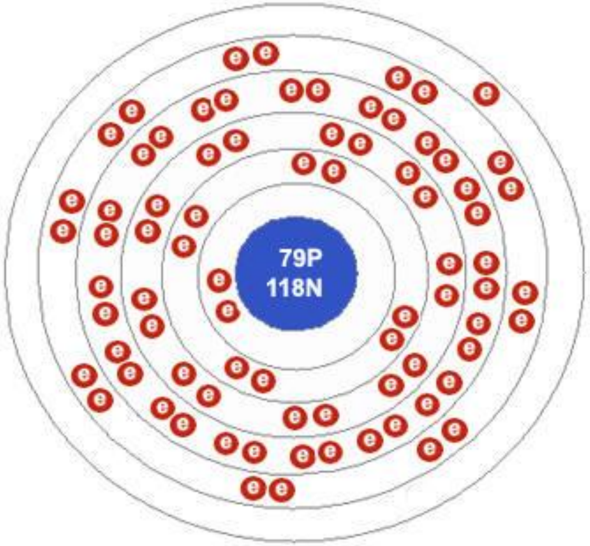
This sandwich of metal layers was then reheated, folded back on itself and hammered out thin again.

After this had been repeated about a dozen times, the steel consisted of thousands of paper-thin laminations of hard and soft metal.

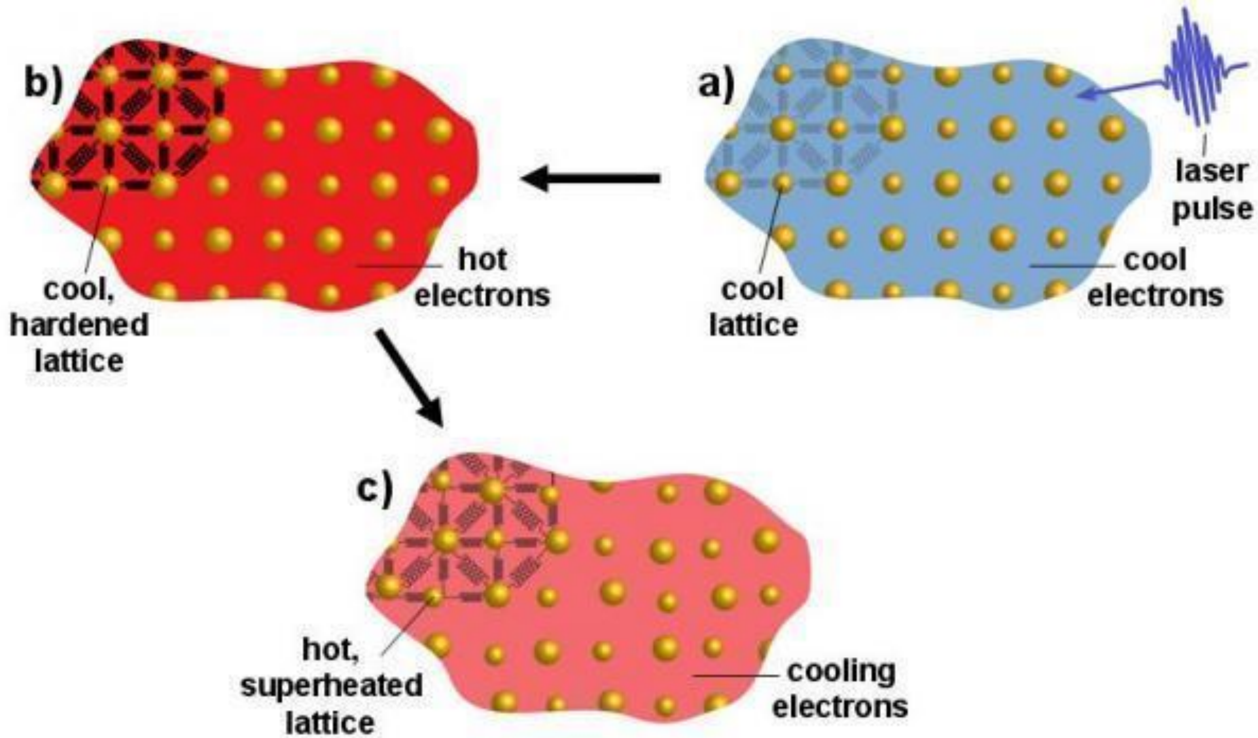
When it was ground to a sharp edge the hard metal stood out and resisted dulling, while the soft steel kept the sword from breaking.

The hard steel forms the sword's outer shell and deadly blade, while the tough steel serves as the sword's core.

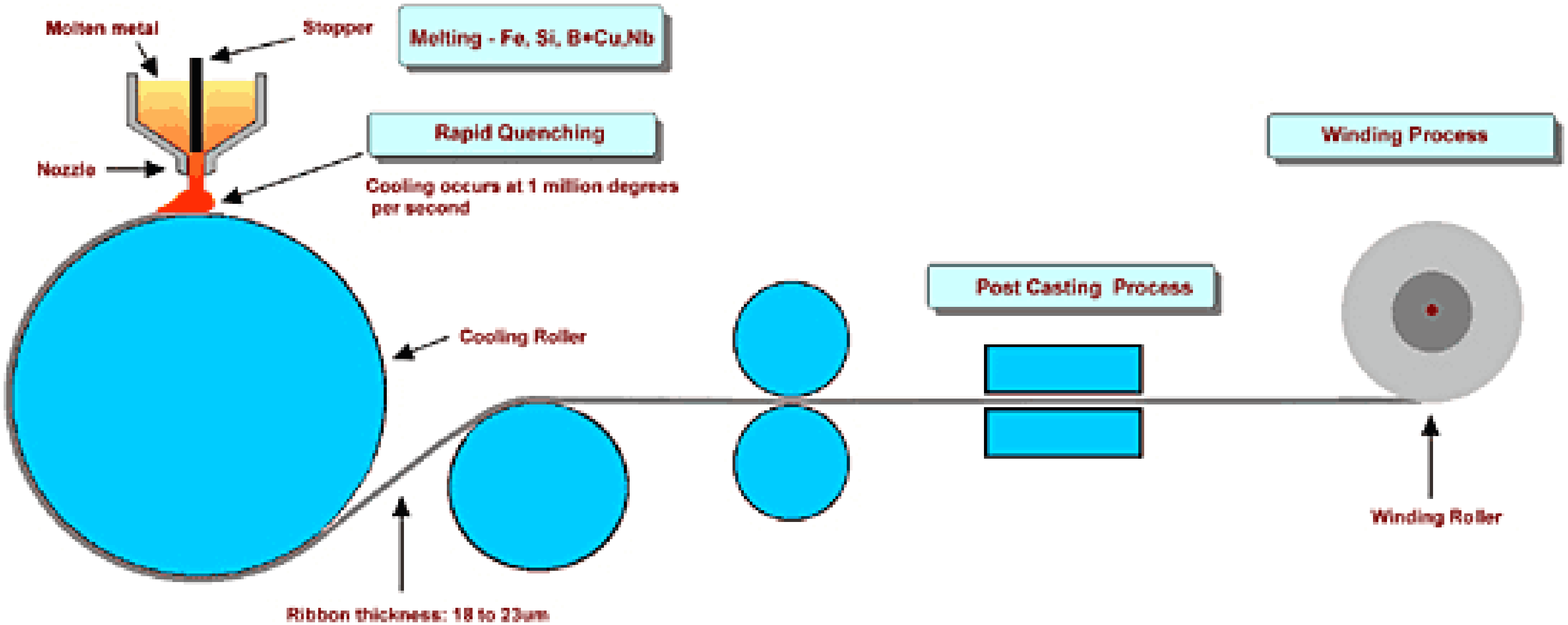


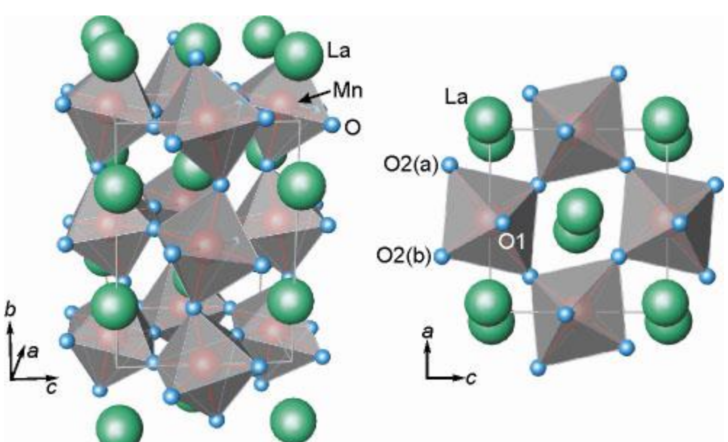


University of Toronto chemistry and physics professor R.J. Dwayne Miller has demonstrated that gold can get harder, not softer, when heated to high temperatures .



The gold was heated at rates too fast for the electrons absorbing the light energy to collide with surrounding atoms and lose energy. The electrons are further away from the atomic nucleus and there is less screening of the positive nuclear charge by these heated electrons. The bonds between atoms actually got stronger.


Molten metal
Stopper
Melting - Fe, Si, B+Cu,Nb
Rapid Quenching
Nozzle
Cooling occurs at 1 million degrees per second
Winding Process
Post Casting Process
Cooling Roller
Winding Roller
Ribbon thickness: 18 to 23um


La
Mn
O
b
a
c
La
O2(a)
O2(b)
O1
a
c