Cold Working & Hot Working & Annealing

KMÜ 479 – Materials Science and Tech II
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OUTLINE

Cold Working
- Definition
- Example Methods
- Why/Why not Cold Working

Çağatay Yaylacı

Hot Working
- Definition
- Basic Mechanism
- Application Areas
- Advantages & Disadvantages

Gökhan Uzun

Annealing
- Definition
- Physical Properties
- Stages of Annealing
- Examples

Göktuğ Ural

Goals of the Presentation

Following will be discussed:

- ✓ The properties and process steps of cold & hot working, annealing
- ✓ Examples of Application Areas
- ✓ Advantages and Disadvantages

Cold Working

- Plastic deformation which is carried out in a temperature region and over a time interval such that the strain hardening is not relieved is called cold working.

- Cold working produces additional dislocations within the metal structure.

Cold Working

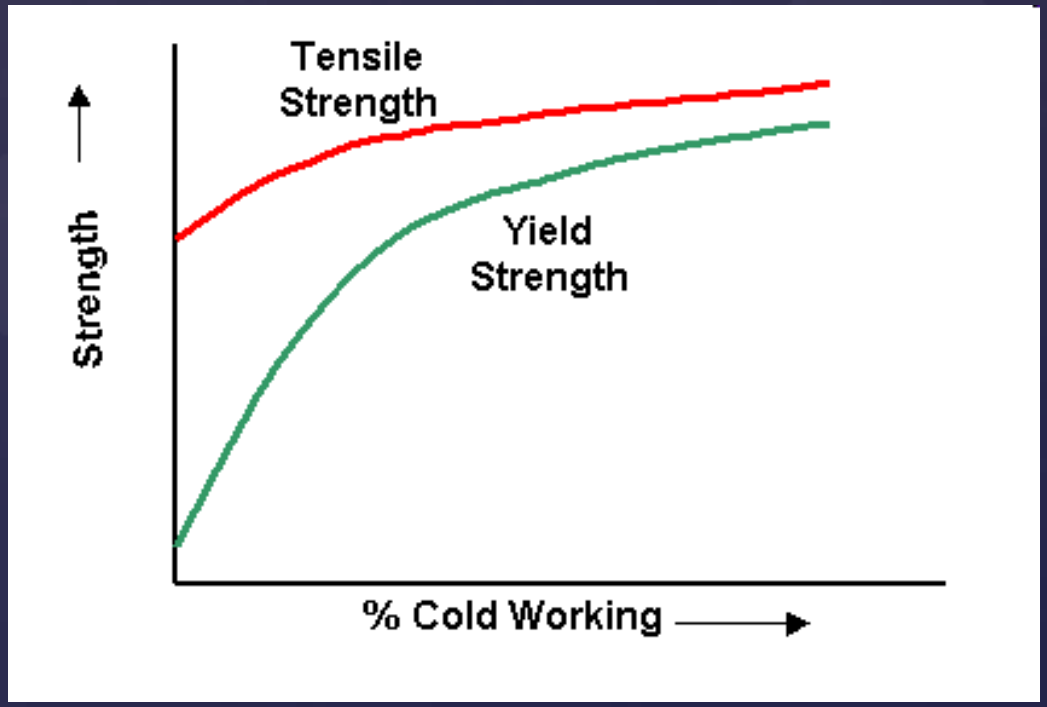
- Initially the dislocations can move through the metal structure.
- As the working continues, however, the movement of the dislocations becomes more difficult.
- The metal becomes less malleable and ductile.

What Does Cold Working Effect?

The following properties are affected by cold work significantly:

- Tensile Strength
- Hardness
- Yield Strength
- Ductility

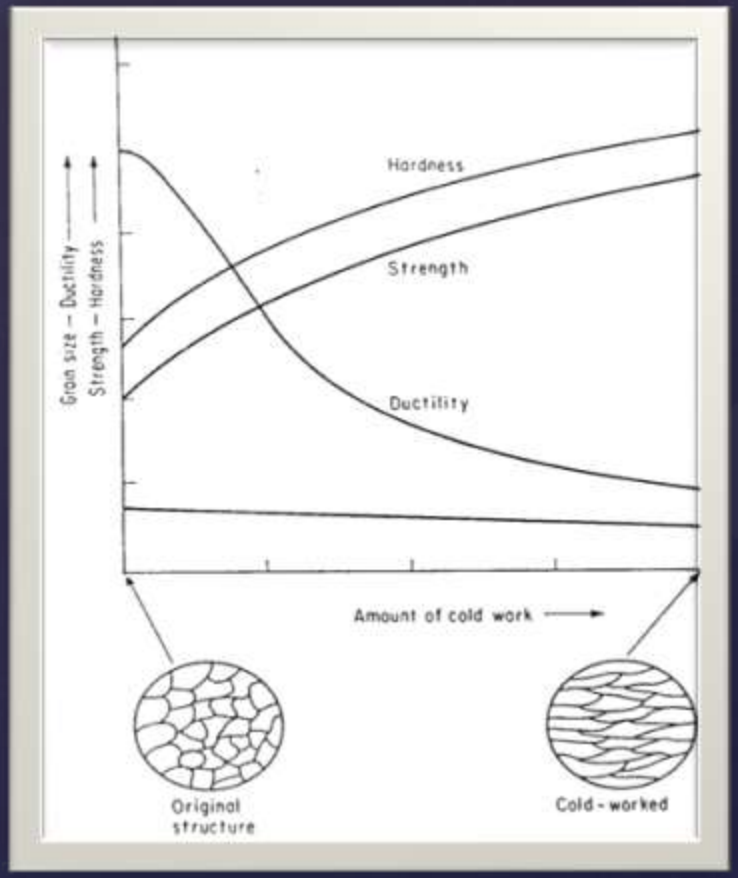
Effect of Cold Working on Yield and Tensile Strength



Cold Working – Strength Relation*

*http://info.lu.farmingdale.edu/depts/met/met205/coldwork.html

Effect of Cold Working on Strength, Hardness and Ductility

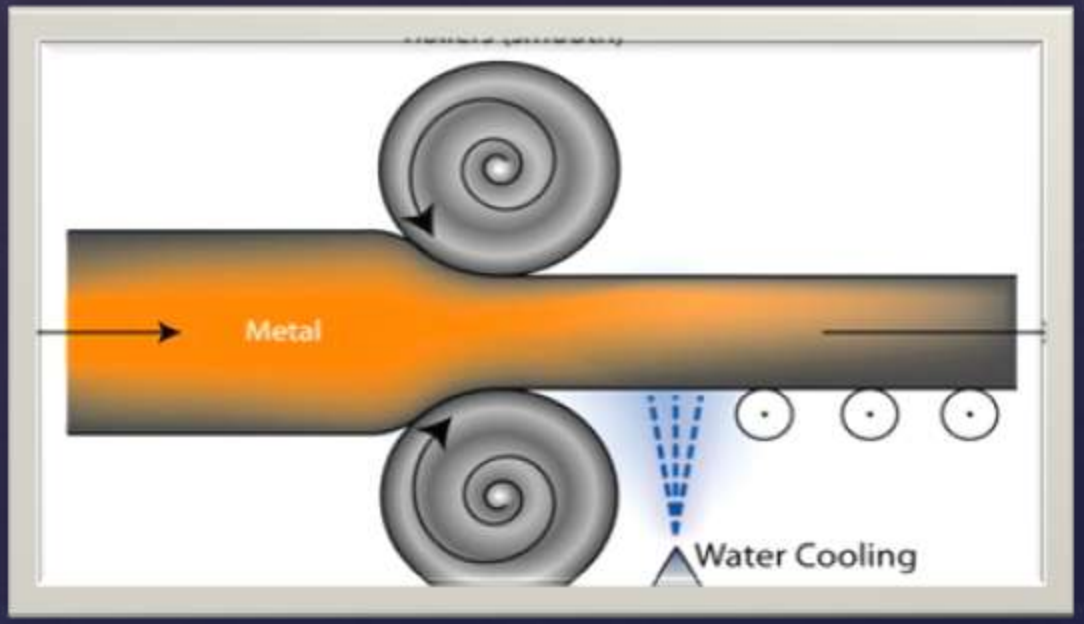


*http://info.lu.farmingdale.edu/depts/met/met205/coldwork.html

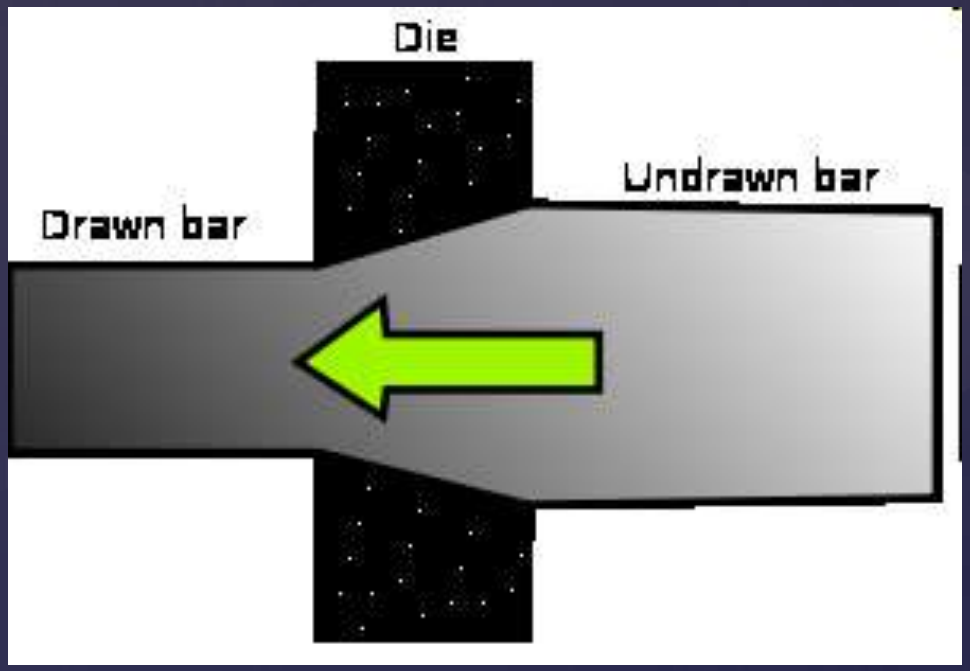
Effect of cold working on tensile strength, hardness, ductility and grain size.*

Cold Working Methods

- cold rolling
- drawing
- deep drawing
- pressing

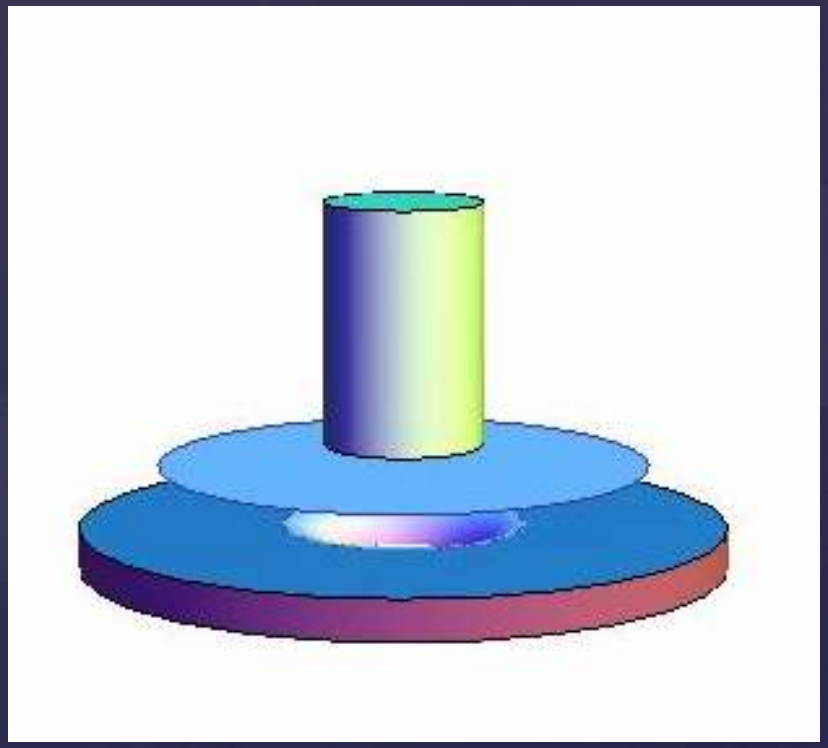


* http://www.hsc.csu.edu.au/engineering_studies/lifting/3282/image3.jpg



Drawing of a metal

http://en.wikipedia.org/wiki/File:Bar_drawing.svg



Deep Drawing of a Metal

http://demonstrations.wolfram.com/DeepDrawingOfMetals/

Why Cold Working?

- Good dimensional control
- Good surface finish of the component.
- Strength and hardness of the metal are increased.
- An ideal method for increasing hardness of those metals which do not respond to the heat treatment.

Why not?

- Only ductile metals can be shaped through cold working.
- Over-working of metal.
- Subsequent heat treatment is mostly needed

How to Calculate Cold Working

$$\%CW = \left(\frac{Ao - Ad}{Ao} \right) x100$$

- Ao -the original area
- Ad -the area after deformation
- %CW is a measure of degree of plastic deformation

Hot Working

Hot working is plastically deforming of the metallic material at a temperature above the recrystallization temperature.

- No Strain Hardening
- Usually performed at elevated temperatures
- Lead and Tin are exceptions (low melting point)
- Lower limit of the hot working temperature: 60% of the melting temperature

Recrystallization Temperature

The temperature at which ***atomic mobility can repair the damage caused by the working process.***

Table: Recrystallization Temperatures of Some Metals *

Metal	**Recrystallization Temperature [°C]**
Lead, tin	10 °C (below room temperature)
Zinc	25
Magnesium, aluminium	150
Gold, copper and silver	200
Iron, low-alloy steels	450
Tungsten	1400

* http://school.mech.uwa.edu.au/unit/MECH2402/lectures/hot_cold_working/

Hot Working Mechanism

- No strengthening occurs during hot working
- Elimination of Imperfections
  - Gas pores can be closed
  - Composition differences can be reduced
- Anisotropic behaviour is gained
  - Surface has a finer grain size than the center.
- Metal remains soft and ductile during process

Historical Applications

Courtesy of *Wikimedia Commons*

Forging is one of the oldest known metalworking processes. Traditionally, hammers are used for production of medieval weapons (swords, armors, etc.)

Statue of Liberty in New York City is builded (1886) from **Strain-Hardened** copper which is supported by a frame of iron bars.*

Ref: Getty Images

*http://corrosion-doctors.org/Landmarks/statue-construction.htm

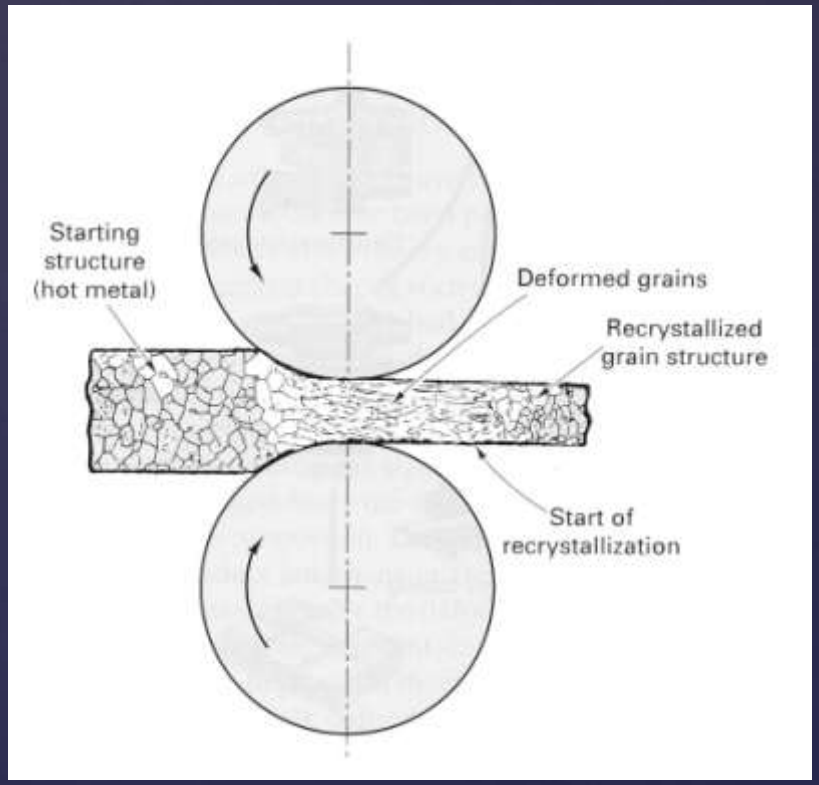
Application Areas of Hot Working

Some processes involving hot working:

- Hot Rolling
- Extrusion
- Forging
- Hot Drawing

http://www.americaslibrary.gov/assets/es/pa/es_pa_steel_1_e.jpg

Hot Rolling



Schematic of Hot Rolling.***

Aluminum is hot rolled into a coil of desired thickness.*

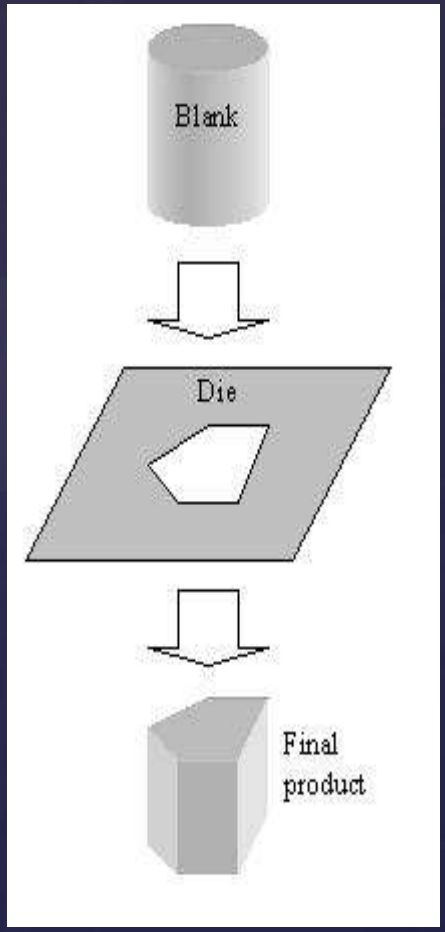
Coil of Hot Rolled Steel**

* http://aluminum-foil.alexanderhiggins.com/aluminum-foil-manufacturing.aspx
** http://en.wikipedia.org/wiki/File:HengereltTekercs10.jpg
*** http://school.mech.uwa.edu.au/unit/MECH2402/lectures/hot_cold_working/degarmo_18-2.jpg

Extrusion

- Extrusion is a process used to create objects of a **fixed cross-sectional profile.**
- Hot extrusion is a hot working process above recrystallization temperature.

Hot extrusion of stainless steel **



Extrusion through a die *

* http://en.wikipedia.org/wiki/File:Extrusion.JPG
** http://www.gspsteelprofiles.com/manufacturing_processes.html

Forging

Forging is defined as a manufacturing process involving the shaping of metal using **localized compressive forces (Very High Pressures)**.

There are many process types:

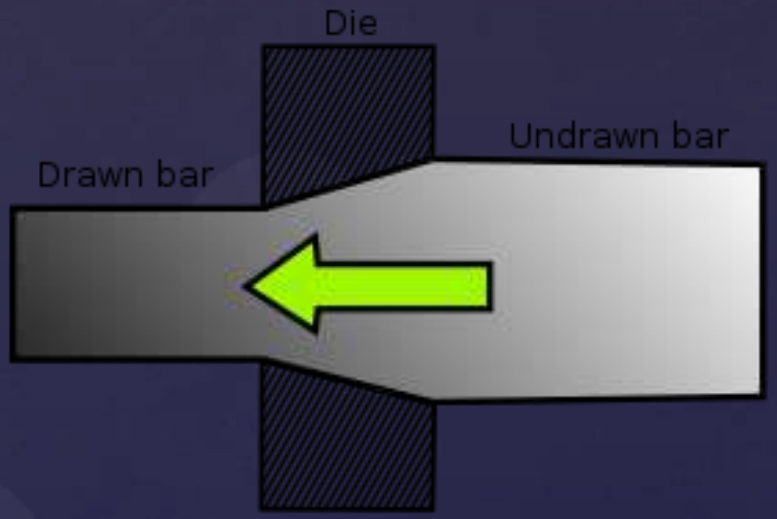
- Drop Forging
- Press Forging
- Roll Forging, etc…

Forging process under a hydraulic press *

* http://www.siegmanandsons.com/wp-content/uploads/2008/03/forge3.jpg

Hot Drawing

- **Drawing** is a metalworking process which uses tensile forces to stretch metal.
- Hot drawing above recrystallization temperature.
- Various types for processed material:
  - Bar Drawing
  - Tube Drawing
  - Wire Drawing



The basic drawing process for a metal bar *

*http://en.wikipedia.org/wiki/File:Bar_drawing.svg

Advantages of Hot Working

- Hardness and ductility of metal is not changed.
- Porosity is eliminated.
- Grain structure of the metal is refined and physical properties improved.
- Large shape changes are possible without ruptures.
- Smaller, faster acting machines.
- Impurities are broken up and distributed throughout material.
- Surfaces need not be clean and scale free.

Disadvantages of Hot Working

- Metal loss due to high temperature a rapid oxidation or scale formation takes place during process.
- Weakening of surface due to metal loss
- This weakening may cause fatigue failures.
- Close tolerances cannot be maintained.
- High cost of tooling for some processes

(High temperature & High Energy Consumption)

ANNEALING

- Heat Process
- Heating to specific temperature(generally until glowing) / colour
- Cool very slowly

Physical Properties of Annealed Materials

- Bend with pressure
- Deformed easily than Hardened Metals
- Low hardness, yield strength, tensile strength of the steel
- Annealing induce ductility
- Homogenised structure

Hardened Materials

*Difficult to cut and shape.
*Impossible to bend
*Heated,then cooled very quickly

reverse of annealing!!

*http://www.technologystudent.com/equip1/heat3.htm

Stages of Annealing

1. **Recovery phase**

***softening metal through removal of crystal defects (dislocation) and the internal stresses

***covers all annealing phenomena that occur before the appearance of new strain-free grains

Stages of Annealing / 2

2. **Recrystallization**
   ***new strain-free grains nucleate and grow to replace those deformed by internal stresses

3. If annealing is allowed to continue, grain growth will occur, in which the microstructure starts to coarsen and may cause the metal to have less than satisfactory mechanical properties.

Setup and Equipment

- Large ovens
- The inside of the oven is large enough to place the workpiece in a position to receive maximum exposure to the circulating heated air
- the workpieces are sometimes left in the oven in order for the parts to have a controlled cooling process

Annealed glass

http://americanglassresearch.com/content.asp?id=12&title=Annealing%20and%20Tempering

Setup and Equipment II

- While some workpieces are left in the oven to cool in a controlled fashion, other materials and alloys are removed from the oven,

- After being removed from the oven, the workpieces are often quickly cooled off in a process known as quench hardening

An annealing oven*

*http://www.garymolitor.com/kilns/kilns.htm

Advantages

- Softens the material.
- Increases the ductility
- Enhances the toughness
- Improves the homogeneity
- The grain size of the material is refined a lot by annealing

Application Areas

- Bridges
- Skyscrapers
- Example: Coin

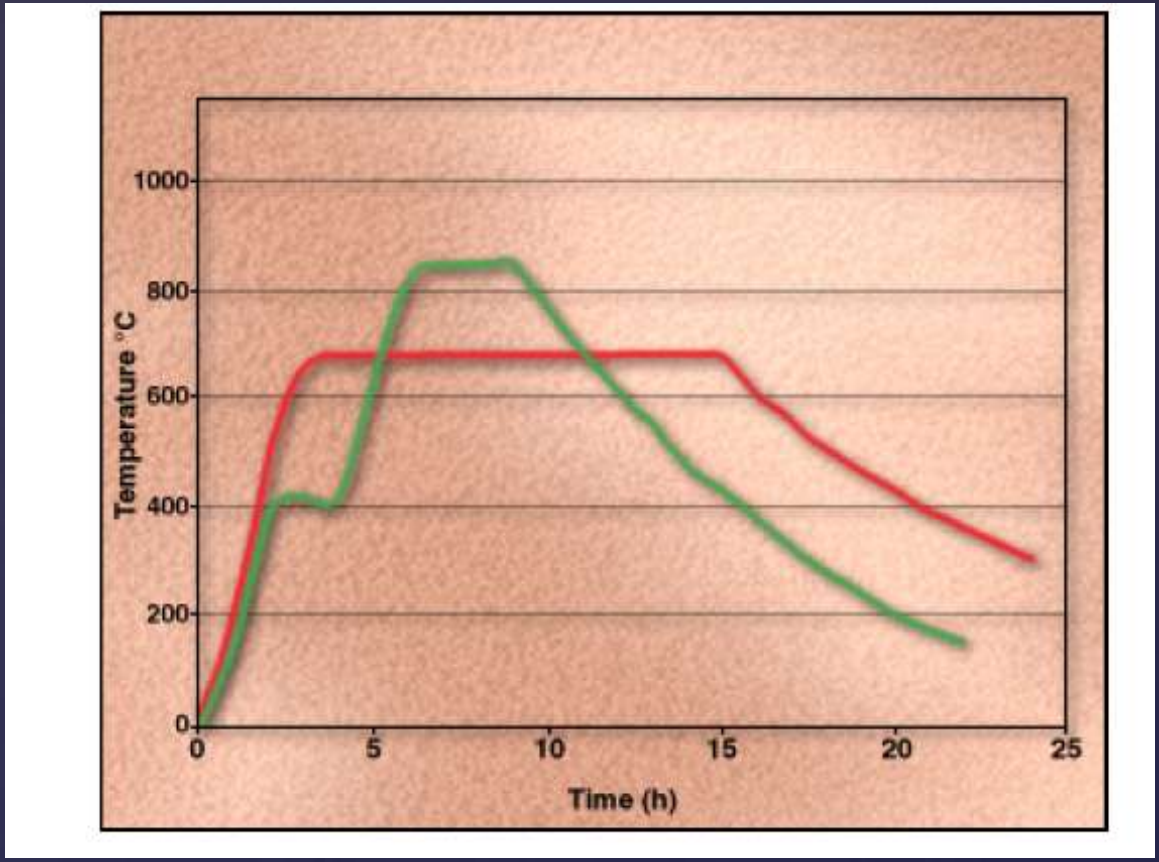
A Traditional Coin*

http://goldprice.org/buy-silver/uploaded_images/us-silver-coin-values-714624.jpg

Types of Annealing

Some types of annealing;

- Full Annealing
- Process Annealing
- Stress Relief Annealing
- Isothermal Annealing
- Sub-critical Annealing



Process annealing and sub-critical annealing cycles*

*http://heattreatment.linde.com/International/Web/LG/HT/like35lght.nsf/repositorybyalias/apps_annealing/$file/Annealing.pdf

Conclusion

- ✓ What is cold working & hot working & annealing?
- ✓ Mechanisms of these processes
- ✓ Some Examples of Application Areas
- ✓ Advantages / Disadvantages

Thank You For Your Attention
:))

Questions?

Hacettepe University | Department of Chemical Engineering | December 29, 2010
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By the way, we wish you a;