Properties of Materials
BTM 2413

CHAPTER 11:
Heat Treatment of Steels

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Introduction

- Aims
  - To introduce the purpose and types of heat treatments….
- Expected Outcomes
  - Explain the heat treatment processes and the reasons for heat treatment
- Other related Information
- References

- Kenneth G Budinsky & Michael G Biddinsky, Engineering Materials: Properties and Selection, Ed 9, Prentice Hall
  - ……..

Why Heat Treatment ?

- Basically used to modify physical, chemical and properties of material

- Steels are unique in the degree of hardening, strengthening as well as softening.

Types of Heat Treatment

1) Hardening
2) Softening
3) Conditioning

Hardening

- This is a process in which steel is heated up to the austenitizing temperature and quenched to form hard martensite
- Austenitization means to heat the iron, iron-based metal, or steel to a temperature at which it changes crystal structure from ferrite to austenite
- Application

  - tools that made by steel (eg : drill, saw blade)

  - high strength is required (eg : spring on automobile)

  - dimensional invariance

  - improve physical property (thermal expansion or magnetic property)

Softening

- Steels are softened to improve their malleability for steel mill shaping processes by annealing process
- Steel parts are softened by tempering after quenched hardening to improve toughness

Annealing – In this process the temperature of steel is slowly raised to a point where it changes to austenite and then slowly cooling from this temperature after a soak

Tempering – is a variable softening treatment used to customize steel properties (hardness, strength, toughness)

Tempering is a heat treatment process which is used to increase the toughness of iron based alloys. Tempering is usually performed after hardening, to reduce some of the excess hardness. I tempering metal is heated to a temperature below a critical point and then allowed to cool in still air

Conditioning

- Not a standard term
- Refer to heat treating process that have very different and special purposes.

i) Spring aging

Spring made up of high carbon steel, may change shape with time due to inelastic behavior. Steel is treating for 2 h at 600 – 700°F will stop inelastic behavior.

ii) Normalizing

- Is a process of heating a steel to the fully austenite region, soaking at this temperature and air cooling to room temperature
- Usually performed on hot worked shape
- To make both grain size and alloy distribution uniform

Conditioning

Steam Treating

-tempering steel in steam which temperature depends on the alloy and desired appearance

- Blue black appearance
- Widely used on fasteners, drills and metal cutting tools
- Functioning as corrosion resistance and prevent chips from welding to the tool surface

iv) Stress relieving

- Applied when stress relieve is needed
- Eg: i) weldments that require machining of weld deposits

ii) Machining of cold-finished shape

iii) Casting that require significant machining

iv) Part with extremely close dimensional tolerances

v) Long, slender parts machined from heavier shapes

Hardening: Direct Hardening

Austenitizing

- Change in crystal structure from BCC to FCC
- Required for quenching action to trap carbon in crystal structure.
- Ease of a steel to transform to hardened structure during quenching call *hardenability*
- *Isothermal Transformation diagram (IT) or Time-Temperature transformation diagram (TTT*) – used to predict quenching reactions in steels, cooling rate, comparing hardenability of steels.

Quenching

- Rate of quenching depends on fluid media
- Water are most effective, followed by oil, molten salt and gas
- Violent agitation improves quenches further; eg : salt into water → cooling rate will be twice.
- The slower the quench the lower chances to get desired hardness
- Skills in heat treating is correctly choosing the quenching media

Selective Hardening

- Heating to austenitizing temperature and quenching are applied only to selected area.
- Several processes of selective hardening are flame hardening, induction, laser and electron beam

Flame Hardening
- Combustible gas flame as the source of heat for austenitizing
- Material must have sufficient carbon content (0.4%) to allow hardening
- Rapid is almost instantaneous due to low alloy, and low hardenability

Induction Hardening
- Source of heat : electric current flow is induced in the workpiece
- Heated zone is only rounded by wire.
- Advantage is heating time and ability to confine heating on small part

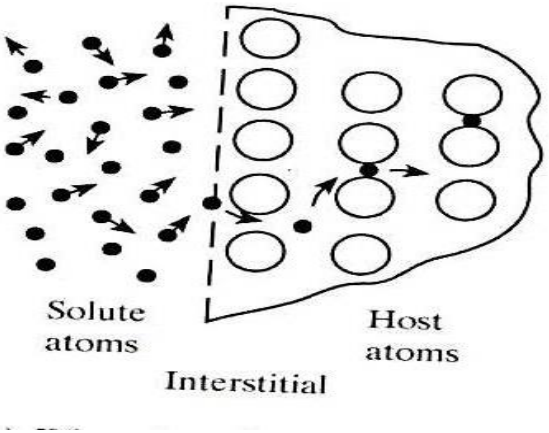
Selective Hardening

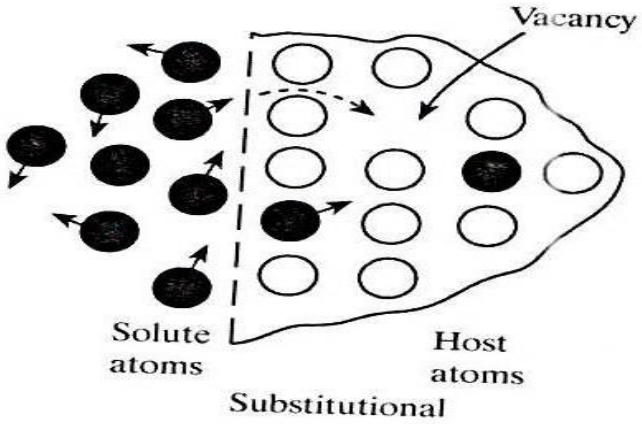
Laser and Electron Beam Hardening

- Applicable only to steels that have sufficient carbon and alloy content to allow quenching hardening
- Laser and electron beam used to raise surface temperature
- Limitation of spot area; electron beam – 5 to 10mm^2, laser - <100mm^2.
- Harden depth : 1-2 mm
- Limitations (i) equipment cost is expensive (ii) high alloy may not respond (iii) certain types of lasers are reflected from shining metal surface.

Hardening: Diffusion Treatment

- In order to allow quench hardening for insufficient carbon alloy, diffusion treatment can be applied to add element to the surface that will make it hard
- Diffusion : is the spontaneous movement of atoms or molecules in a substances that tends to make the composition uniform





Softening

a) Recrystallization

- The transformation of cold-worked grains to an undistorted shape
- Very large, coarse grain can be refined by recrystallization

b) Annealing

- Heating a steel to its austenitizing temperature and then cooling it at a slow enough rate to prevent the formation of hardened structure.
- Cooling rate : 100°F/h
- Slow cool is achieved by furnace off, or take out from furnace and packed in sand or lime.
- Annealing temperature same as hardening temperature

Softening

Tempering

- It is a subcritical heat treating process used to improve the toughness of quench-hardened steels
- The correct temperature depends on the composition of the steel and desired properties
- Normal procedure : quench the part, while it is still warm, put in a furnace at the desired tempering temperature, then soaked at about 2 hours and air cooled