Heat Treatment of Steel

- **Heat Treatment** - any process involving controlled heating and cooling to develop certain desirable characteristics

- The temperatures at which this takes place are called **critical temperatures**

Heat Treatment of Steel

- Three components
  - Heat
  - Soak
  - Cool

Heat Treatment of Steel

- **Heat**
  - Above critical temperature (for steel, this is around 760°C to 870°C)
  - This erases stresses previously imparted into the metal

Heat Treatment of Steel

- **Soak**
  - Maintain high temp for a time period appropriate to the mass and thickness of the material
  - This permits the molecules to blend and become homogenous; rearrangement of the internal structure of the steel occurs here

Heat Treatment of Steel

- **Cool**
  - Fast cooling makes steel hard; slow cooling makes steel soft
  - Quenching – fast cooling by immersion in a liquid

Heat Treatment of Steel

- Quenching media
  - Brine
  - Water
  - Oil
- Slow Cooling
  - Air cooling
  - Furnace cooling
  - Sand pack

Heat Treatment of Steel

- **Hardening** – add hardness to steel
  - **Heat –** just above critical temperature
  - **Soak**
  - **Quench -** rapid cooling by immersion in a fluid such as brine, water, or oil; then temper to relieve internal stresses

Heat Treatment of Steel

- **Tempering** (drawing) - chiefly reduces brittleness created by hardening; removes some hardness, and relieves strain to return the part to a usable state

- **Heat** - heat to **less than** critical temperature (at least 1~~00~~°C)

Heat Treatment of Steel

- lower temps - less hardness removed
- higher temps - more hardness removed
- 120°C- 230°C - tempers for *hardness* (strong, but brittle)
- 200°C - 288°C - tempers for *toughness* (strong, but not brittle)

Heat Treatment of Steel

- **Soak** – based upon the mass of the material

- **Cool** - in still air (or oil, water, or a special solution)

Heat Treatment of Steel

- **Stress Relieving** - a process to remove all hardness (extreme tempering)
  - **Heat -** heat to below critical temp, 482°C - 538 °C —
  - **Soak**
  - **Cool** - in still air

Heat Treatment of Steel

- **Normalizing** - removing abnormal characteristics and stresses from heat treating, welding, etc.
  - **Heat** - at least 38°C above critical temp
  - **Soak**
  - **Cool** - in still air, at room temperature

Heat Treatment of Steel

- **Annealing** - a process to relieve internal stresses, **soften** the metal, make it more ductile, and refine the grain structure - the opposite of hardening
  - **Heat** - to above critical temp
  - **Soak** - based on mass (1 hr per 1” thickness)

Heat Treatment of Steel

- **Cool** - extremely slowly (therefore softening)
  - Examples: furnace cooling, or packing the part in dry sand
  - Brings a part back to "**below normal**" condition

Heat Treatment of Steel

- **Case Hardening** - a process to create super hard surface upon a malleable core

- Two Methods
  - Carburizing
  - Nitriding

Heat Treatment of Steel

- **Carburizing**
  - **Heat** - use high temperature oven (~926°C
  - **Soak** - for a short time (1-3 hrs), in a high carbon environment
  - **Cool**

Heat Treatment of Steel

- Advantage - hardness runs deep (~0.070”); good anti-corrosion

- Disadvantage - difficult to retain part’s tolerance after high temperature heating (part often has to be re-machined)

Heat Treatment of Steel

- **Nitriding**
  - **Heat** - low temperature (~538°C)
  - **Soak** - long heat cycle (~ 30 hrs), in an ammonia gas environment
  - **Cool**

Heat Treatment of Steel

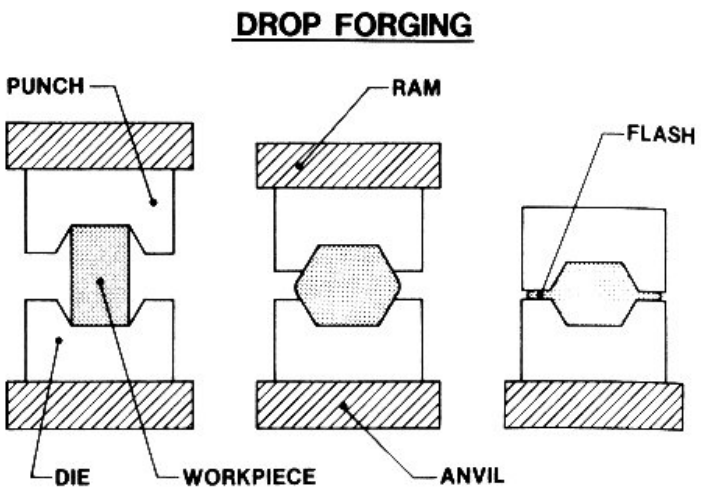
- Disadvantage - susceptible to corrosion, depth of hardening is less (~ 0.035”), dangerous (highly flammable)
- Advantage - close tolerances (~ ± 0.001” or 0.002”)
- typical use: crankshafts, cylinders

Heat Treatment of Steel

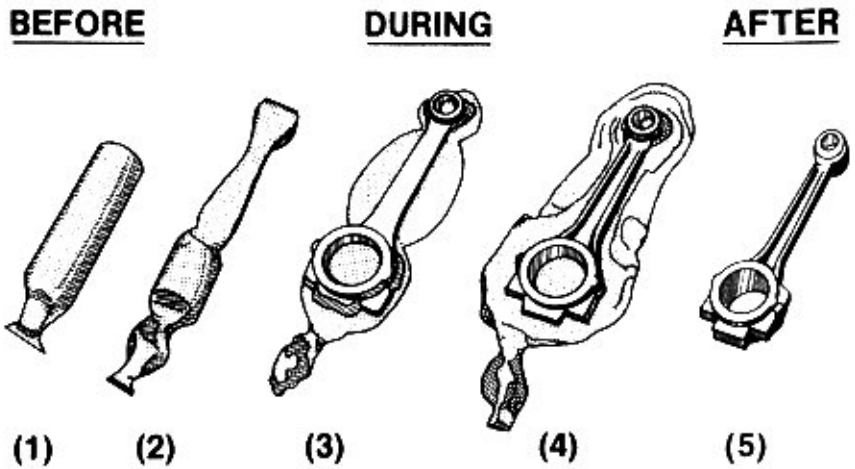
- **Forging** - mechanically working metal at temperatures above the critical range to shape the metal as desired; small parts hammered, large parts pressed.

  – Forging imparts stresses into the steel that may have to be removed via the normalizing process.

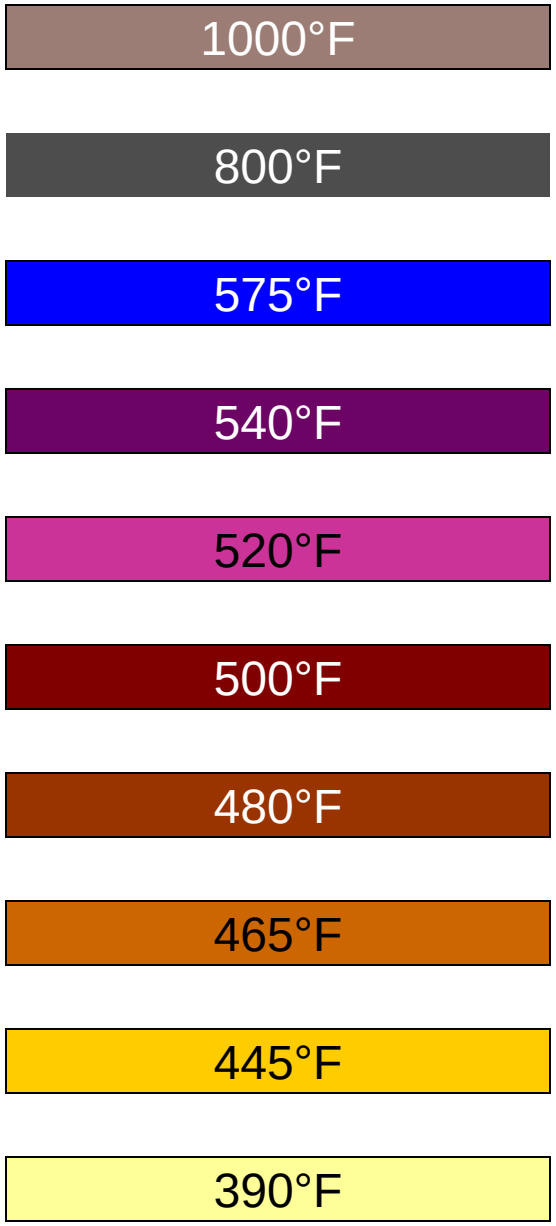
Heat Treatment of Steel



Drop Forging



Heat Treating Temperatures for Steel



Gray, Slight Red 538

Dark Gray 427

Blue 300

Dark Purple 280

Purple 270

Brown / Purple 260

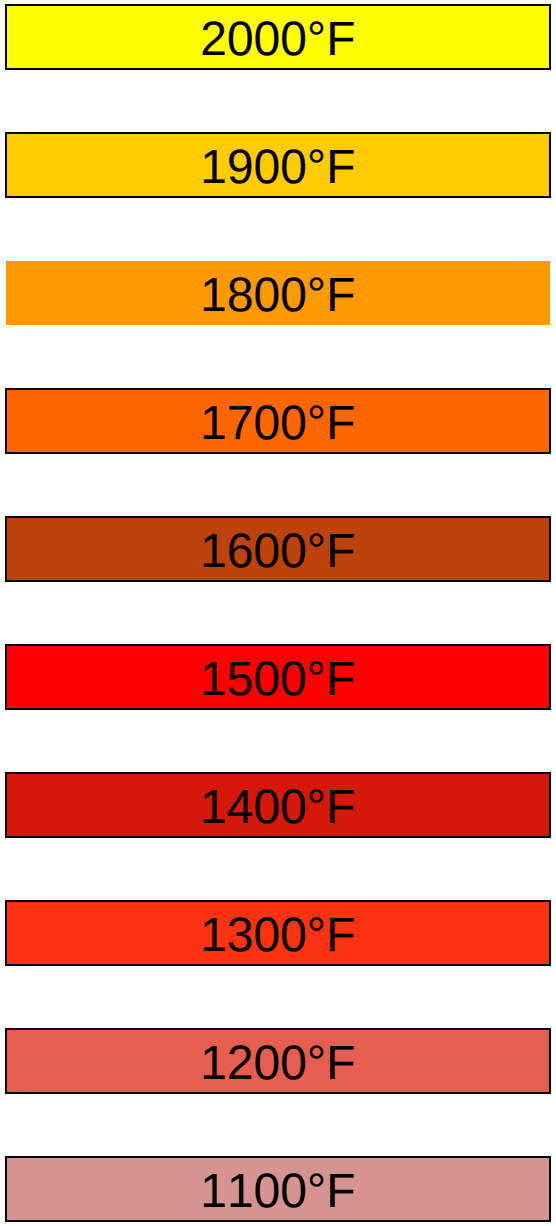
Brown 249

Dark Straw 238

Light Straw 230

Faint Straw 200

Heat Treating Temperatures for Steel



Bright Yellow 1100

Dark Yellow 1038

Orange Yellow 980

Orange 926

Orange Red 870

Bright Red 815

Red 760

Medium Red 705

Dull Red 648

Slight Red 590