

Chap. 8 Carbon Steels

• Key Words

Ferrous Alloys

• Iron & Steels

Iron	$C \leq 0.02\%$
Steel	$0.02\% \leq C \leq 2.11\%$
Cast iron	$C \geq 2.11\%$

• Carbon Steels : 탄소함유량에 의한 분류

Low carbon steels	$C \leq 0.3\%$
Medium carbon steels	$C \approx 0.3 \sim 0.5\%$
High carbon steels	$C \geq 0.5\%$

• Fe-Fe₃C Phase diagram에 의한 분류

Iron	
Hypereutectoid steels	$0.02\% \leq C < 0.77\%$
Eutectoid steels	$C \approx 0.77\%$
Hypoeutectoid steels	$0.77\% < C \leq 2.11\%$

1. Iron

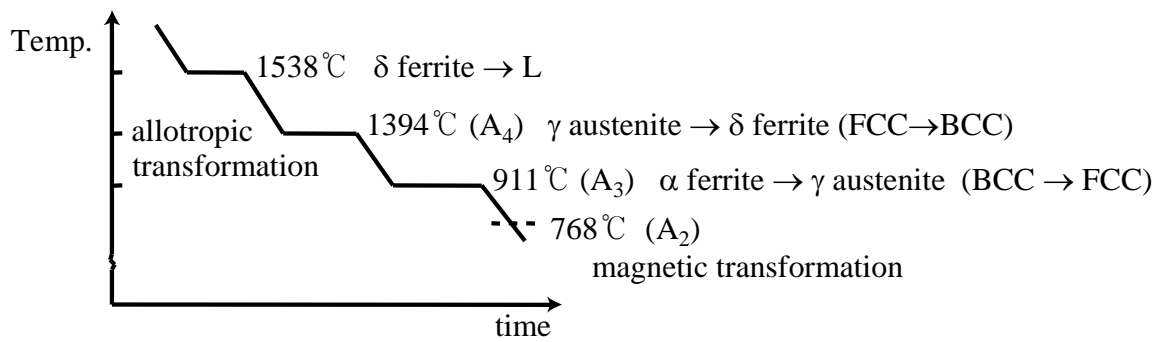
1) Transformation

Magnetic transformation :



Allotropic transformation :





2) Properties

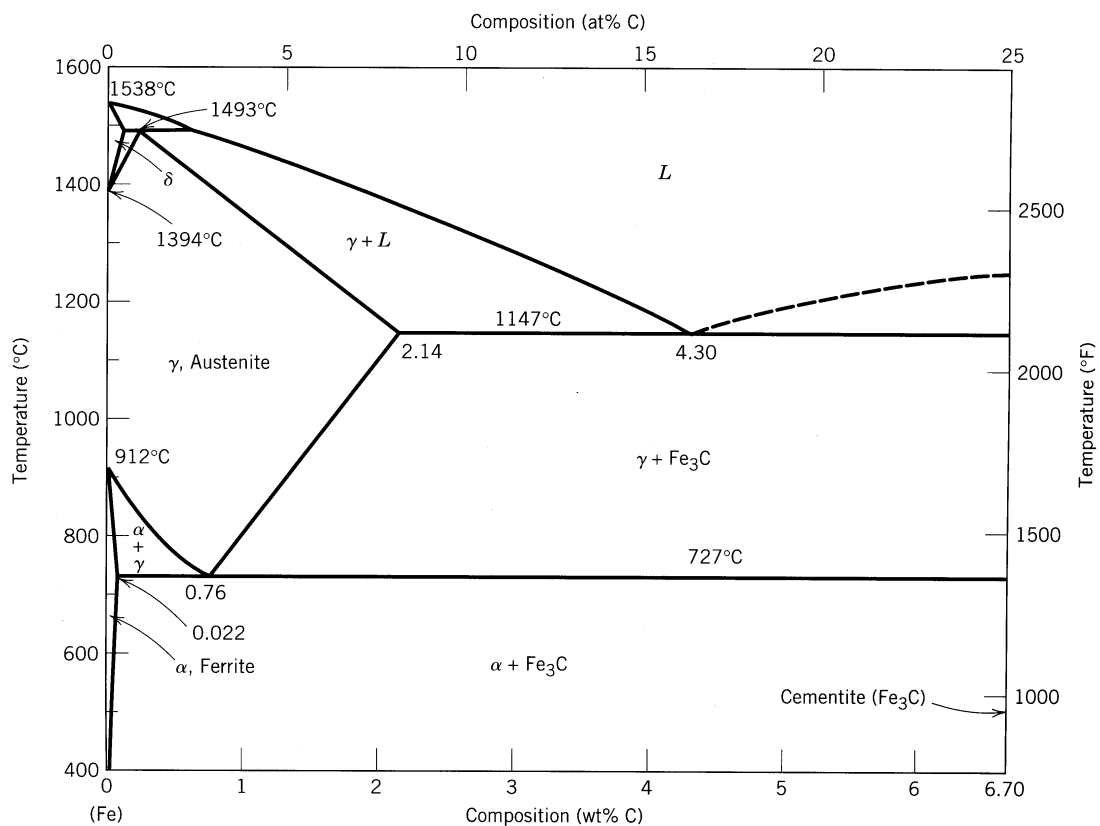
밀도 : 7.87g/cm^3

조직(상온) : Ferritic structure(α 조직)

A_3 점에서 수축(가열 시), 팽창(냉각 시)함

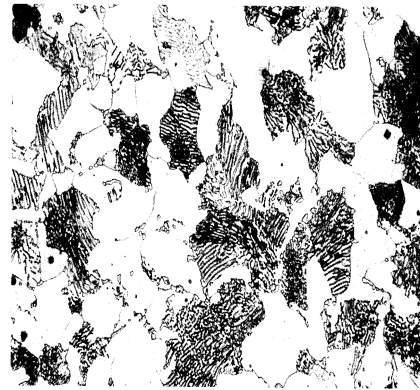
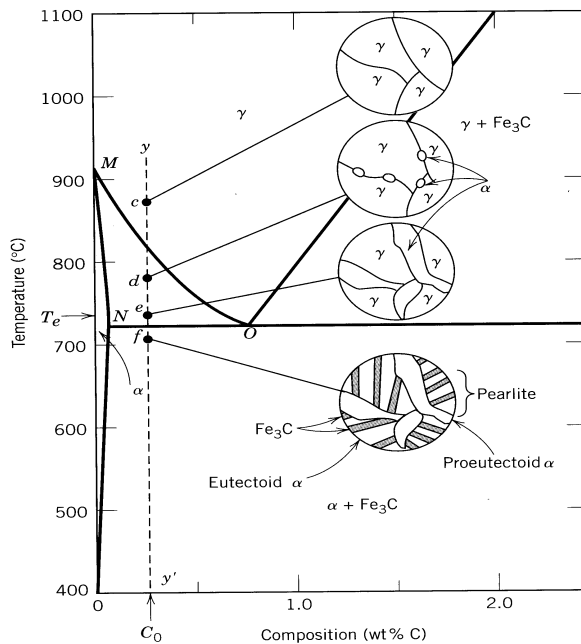
2. Carbon steels

1) Fe-Fe₃ Diagram



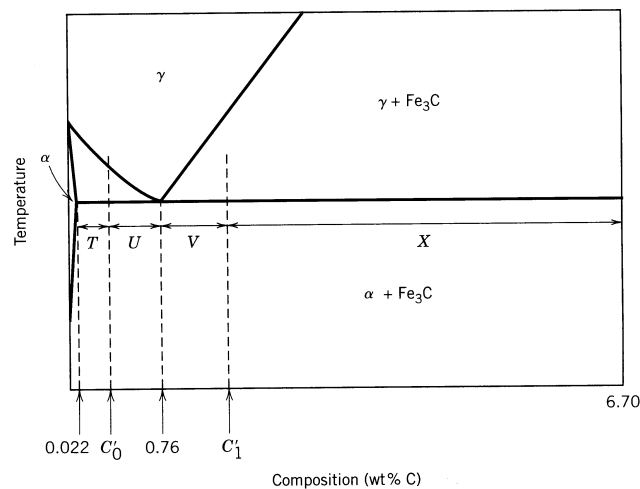
(1) Hypoeutectoid Steels

Hypoeutectoid C_0 point ($<0.76\text{wt\% C}$) → 아공석 조성



Pearlite+Ferrite structure

0.38%wt% C 강 : Pearlite($\alpha + \text{Fe}_3\text{C}$) + Proeutectoid ferrite



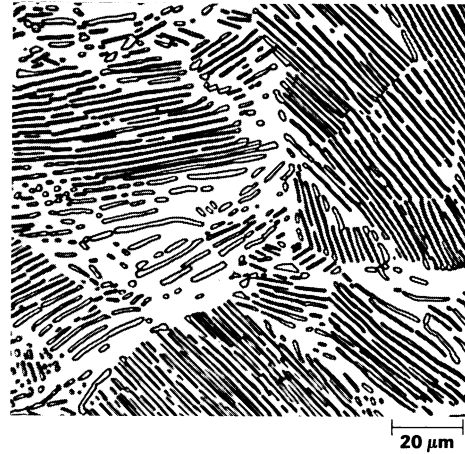
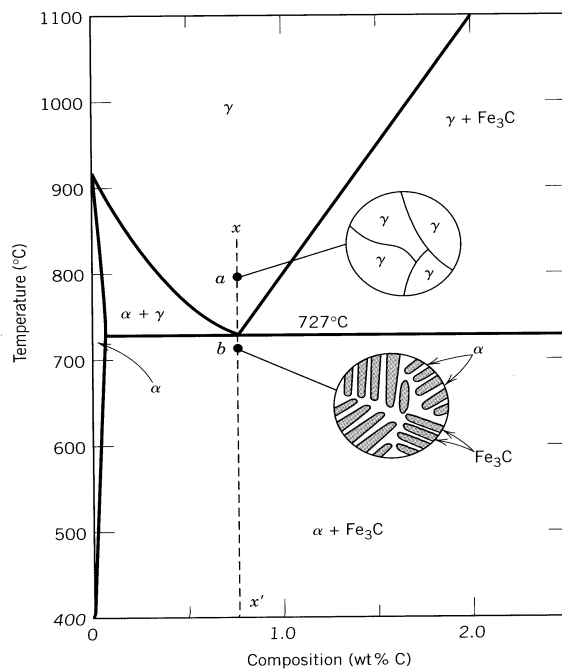
Fraction(Mass or Weight) of Pearlite :

$$W_p = \frac{T}{T+U} = \frac{C_0' - 0.022}{0.76 - 0.022}$$

Fraction of Proeutectoid α :

$$W_\alpha = \frac{U}{T+U} = \frac{0.76 - C_0'}{0.76 - 0.022}$$

(2) Eutectoid Steels

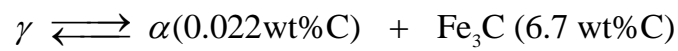


Pearlite 소식

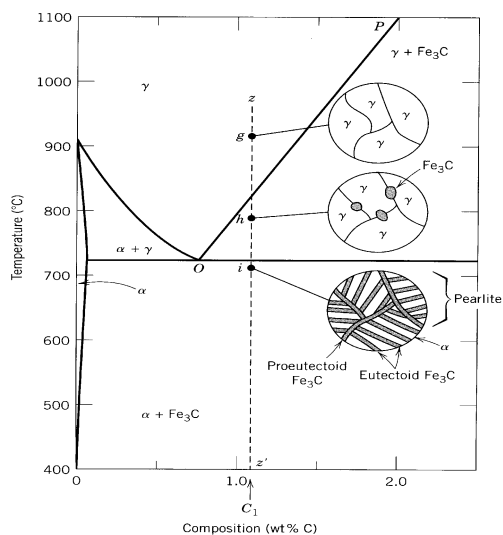
Pearlitic structure (점 b) =

Ferrite (α , Ductile) + Cementite (Fe_3C , Brittle)

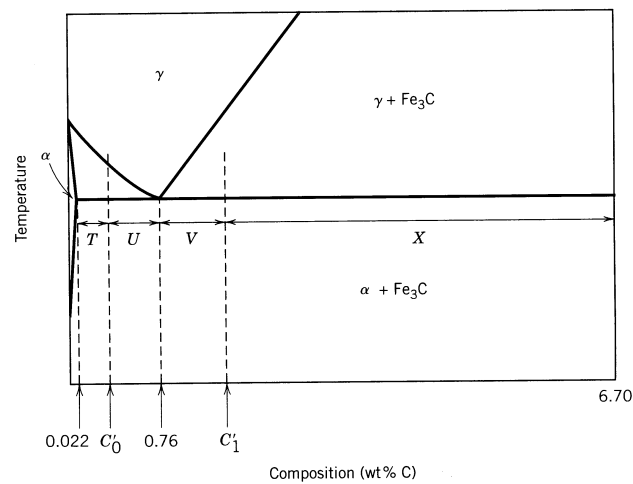
Eutectoid reaction (0.77 wt% C) :



(3) Hypereutectoid Steels



Hypereutectoid C_0 point ($>0.76\text{wt}\% \text{C}$) \rightarrow 과공석 조성

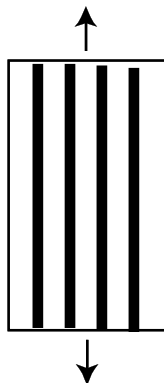


Fraction of pearlite :
$$W_p = \frac{X}{V + X} = \frac{6.70 - C_1'}{6.70 - 0.76}$$

Fraction of proeutectoid Fe_3C :
$$W_{\text{Fe}_3\text{C}'} = \frac{V}{V + X} = \frac{C_1' - 0.76}{6.70 - 0.76}$$

2. Mechanical Properties

1) Rule of mixtures



$$P = P_1 + P_2$$

$$\sigma A = \sigma_1 A_1 + \sigma_2 A_2$$

$$\sigma = \sigma_1 \frac{A_1}{A} + \sigma_2 \frac{A_2}{A}$$

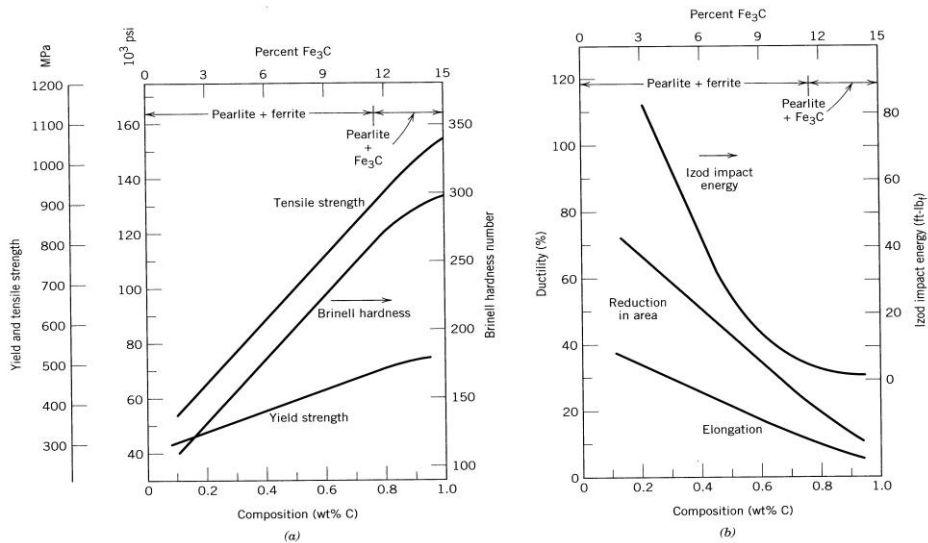
$$\therefore \sigma = \sigma_1 W_1 + \sigma_2 W_2$$

2) Mechanical properties

Ferrite, Pearlite, Cementite

C \uparrow — Yield strength, Tensile strength, Hardness \uparrow

Impact energy, Elongation, Reduction of area \downarrow

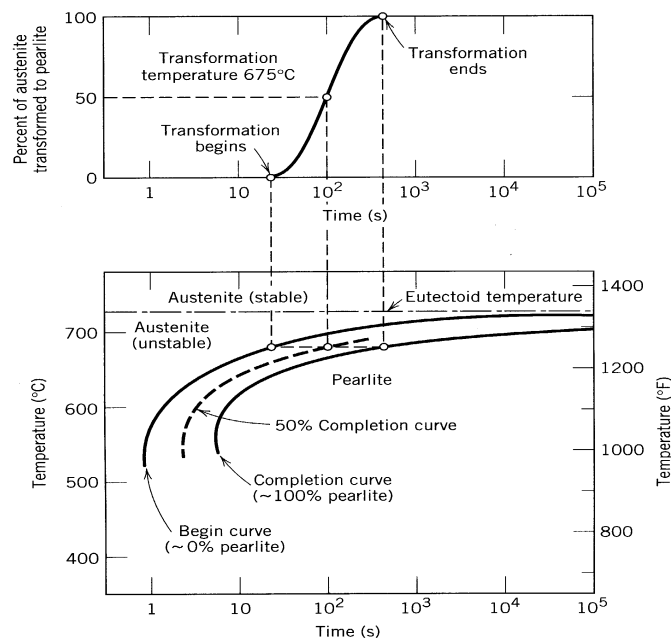


< 탄소함유량-기계적특성 >

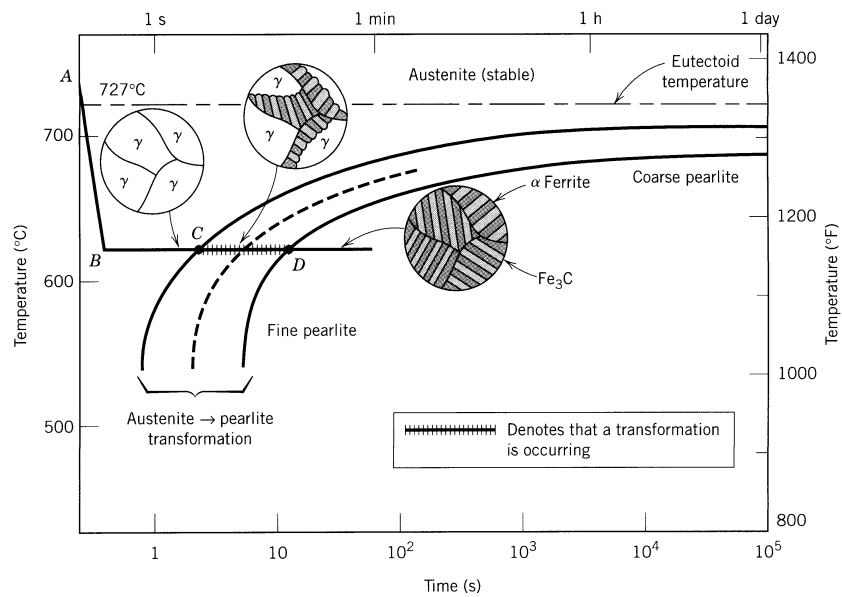
- ▶ **Cold shortness** : P로 인한 **Fe₃P (Steadite)** -충격값 저하
- ▶ **Blue shortness** : 200~300 °C (Fig. 8-12 참조)에서 가장 취약함
- ▶ **Hot shortness or Red shortness** : S + Mn → MnS을 만들어 slag로
서 제거 - 남은 S는 FeS을 만들어 연신율, 인장강도, 충격값 감소

3. Heat Treatments

1) Isothermal transformation diagram



< Pearlite변태 곡선 → T-T-T curve >



< Time-Temp.-Transformation diagram (T-T-T diagram) >



(a) Coarse pearlite



(b) Fine pearlite

► **Pearlite (Ferrite + Cementite)**

- Fe_3C 증가 : 강도증가

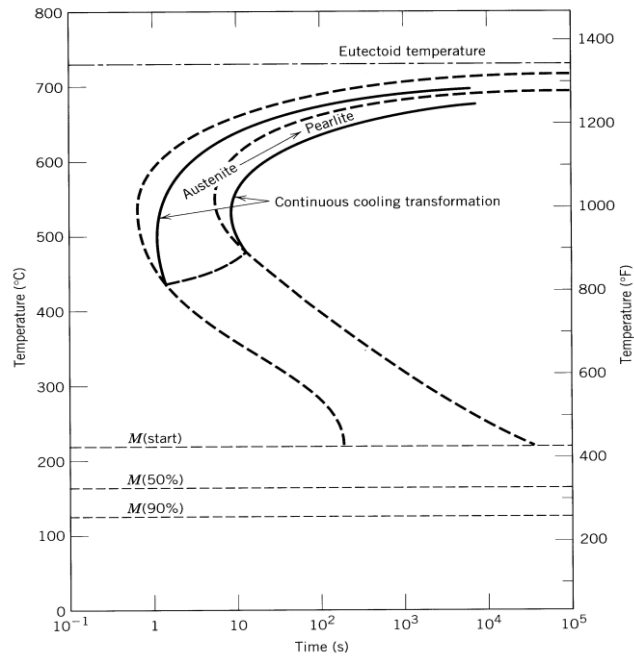
- **Coarse pearlite**의 강도, 경도, 인성 < **Fine pearlite**의 강도, 경도, 인성

► **Bainite (Ferrite 및 Cementite의 입자보다 작음, 변태온도에 따라 매우 가느다란 형상) → Pearlite보다 큰 강도를 가짐**

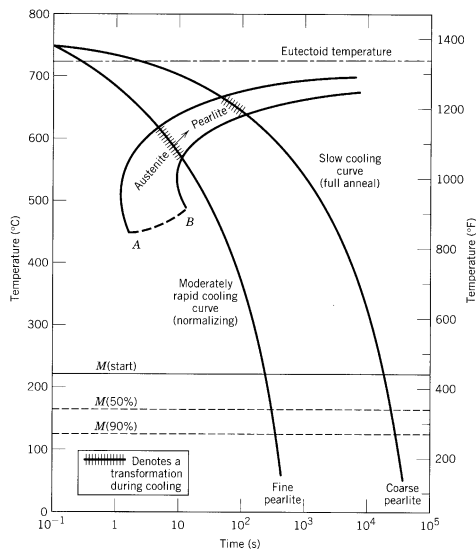
► **Martensite : 고강도(취성, BCT 구조)**

2) Continuous cooling transformation diagram - CCT diagram

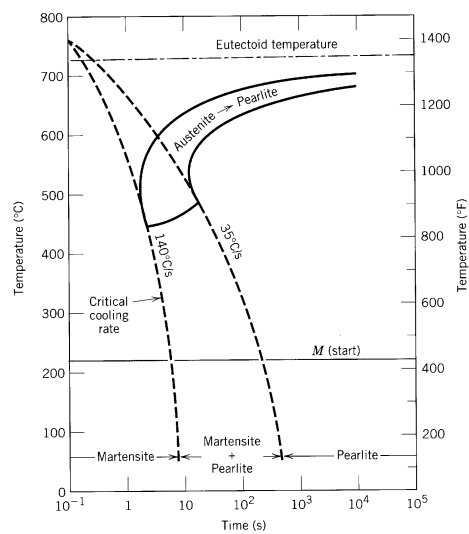
- T-T-T diagram는 항온하에서 유지되는 경우에만 유용하므로 연속적인 변화 (열처리과정)에서 적용하기 어려움
- 연속 냉각의 경우 반응시작 및 완료시간은 지연됨
- T-T-T diagram를 수정함 (점선에서 실선으로 !)



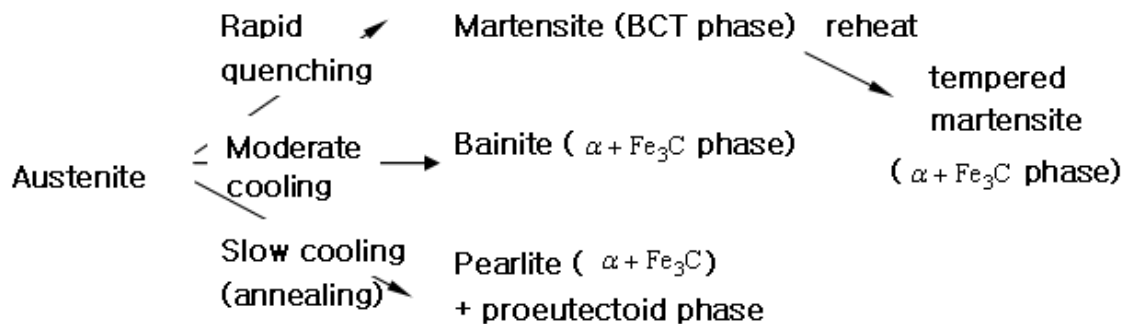
< C-C-T Diagram >



(a) 급랭 및 서냉곡선



(b) 변태에 따른 최종 미세구조 변화



3) Annealing (by furnace cooling)

Normalizing (by air cooling)

- 강도저하
- 잔류응력 완화
- 가공성, 성형성 높임
- 조직의 균질화, 미세화

4) Quenching & Tempering (by water, etc))

- 전형적인 경화법
- **Martensitic structure(FCC에서 BCT로)**

Heating Temp. : 너무 높으면 산화, 탈탄이 발생함. 조직이 조대하여

퀵칭성 저하(아 공석강의 경우 - 30⁰ C~ 50⁰ C)

Heating Time : 중심부의 온도가 퀵칭온도에 도달할 때까지 가열

Cooling Rate : Upper CCR (critical cooling rate)

Lower CCR 고려

- **Residual Stress :** 마텐자이트 변태에 의한 팽창의 시간적 차로 인함.

(표면부 - 인장, 중심부 - 압축의 잔류응력형)

- **Quenching crack, Quenching strain**
- **Tempering**(잔류응력제거, 인성부여)
- **Mass effect**

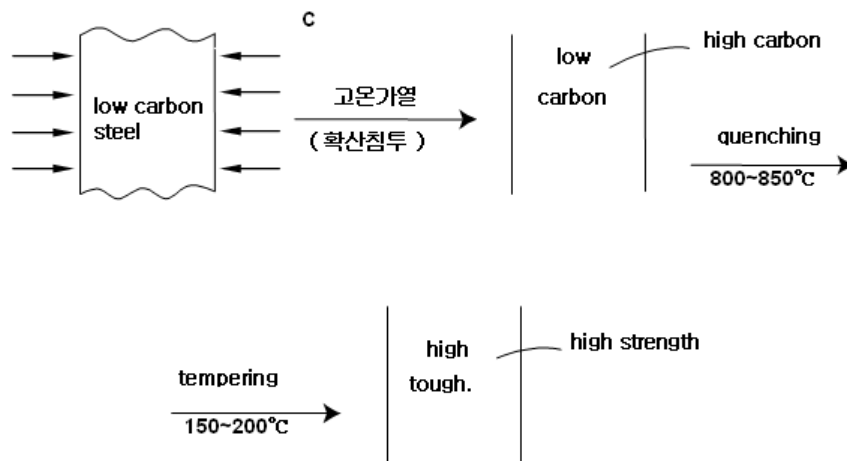
- **Hardenability**

주어진 열처리에서 **Martensite**의 형성으로 인하여 경화되는 능력

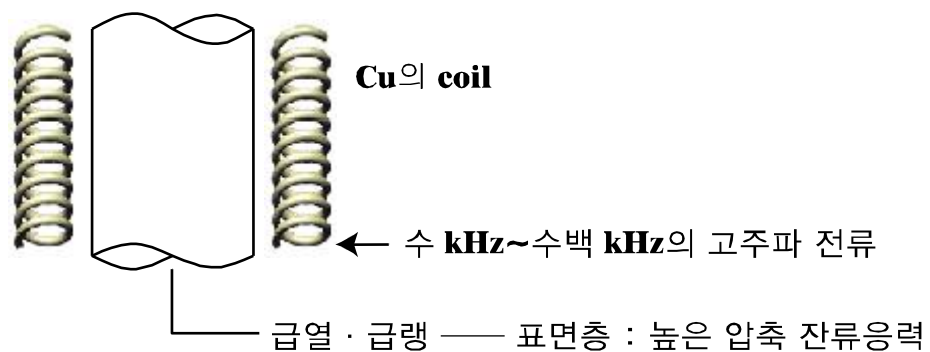
Hardenability test → Jominy end — quench test

5) Surface Treatments

- **Carburizing**



- **Induction Hardening**



: **Hardness, Fatigue limit ↑**

Shaft, Gear, Pin etc.

설비비 ↑, 제품의 형상에 제한있음

- **Flame Hardening**

강력한 화염에 의하여 강재의 표면을 급속히 가열(표면층 오스테나이트 화)하여 퀴칭

5. Applications

냉간압연 강판 (KS D 3512, Table 8-9)

열간압연 강판 (KSD 3501, Table 8-10)

일반 구조용 압연강재 (KS D 3503, Table 8-11)

기계 구조용 탄소강재 (KS D 3752, Table 8-12)