Properties of Materials

Metal Processing

Kinetics

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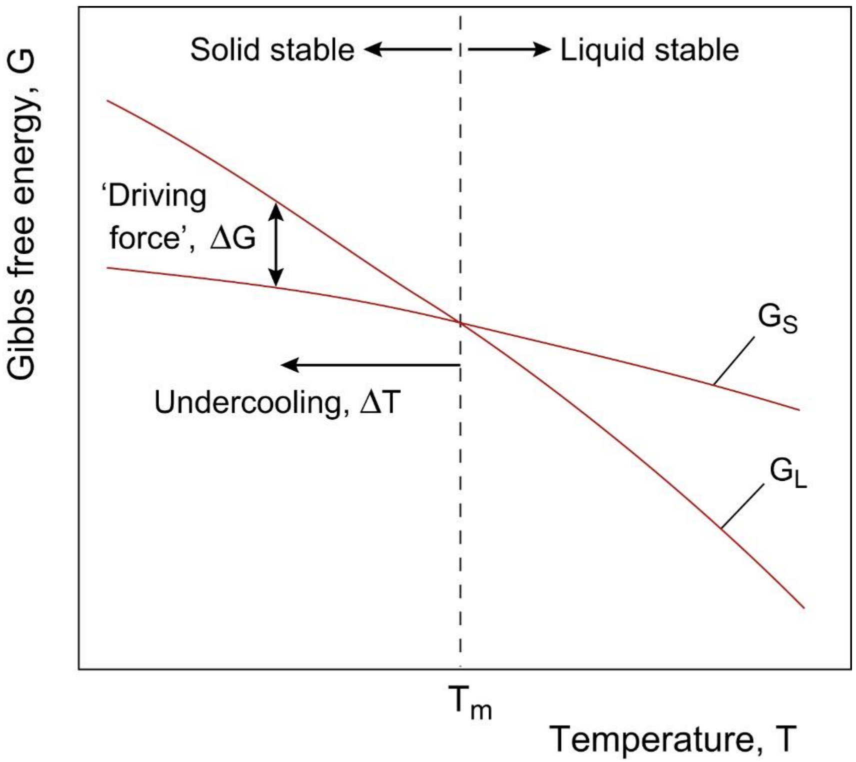
2.7 Queens Building

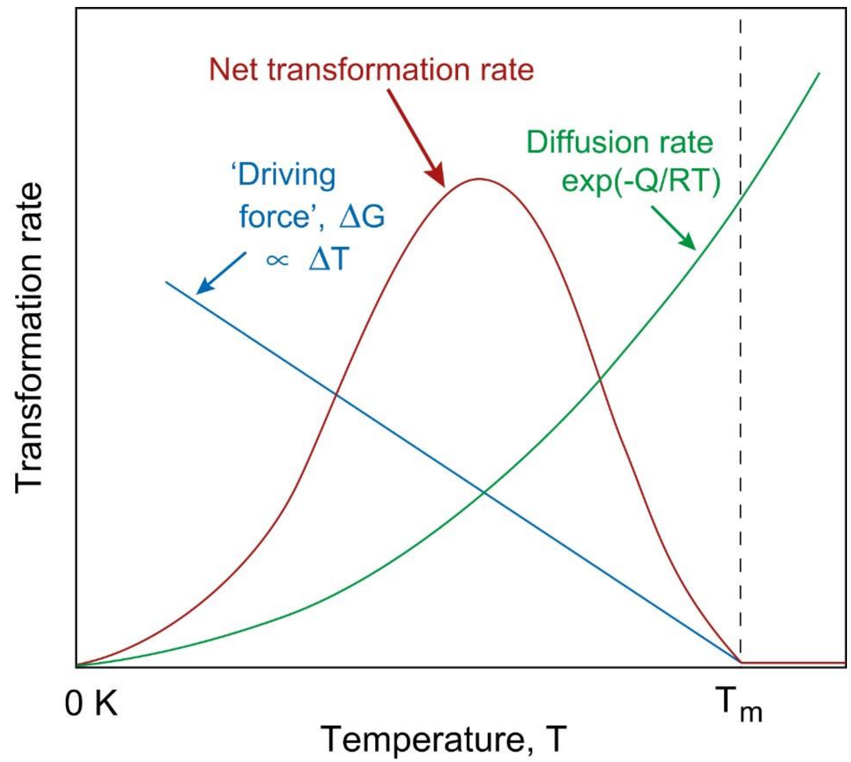
Preview

Intended Learning Outcomes	
Understanding	The idea of a thermodynamic driving force and the kinetic limits on tranformations.
Skills	Able to predict the likely phases/microconstituents after different cooling rates.
Values	Acknowledge the complexity of metal transformations but also the opportunities this presents for property customisation.

- Driving force and kinetics
- Form of TTT and CCT diagrams
- Application to aluminium and steel systems
- Qualitative/Quantitative analysis using TTT and CCT diagrams

Driving force and kinetics



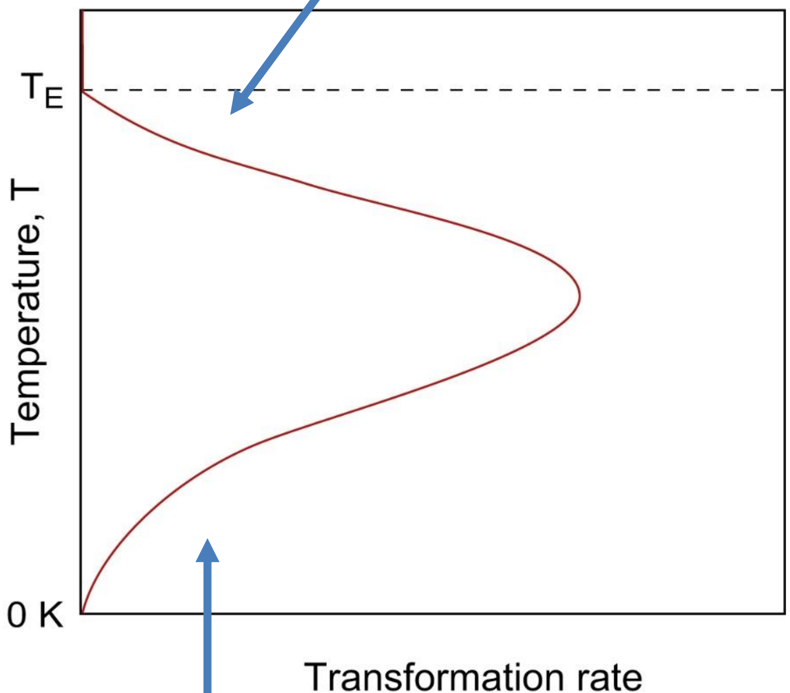


Key idea: We expect faster solidification at lower temperature

Key idea: Limited by diffusion at very low temperature

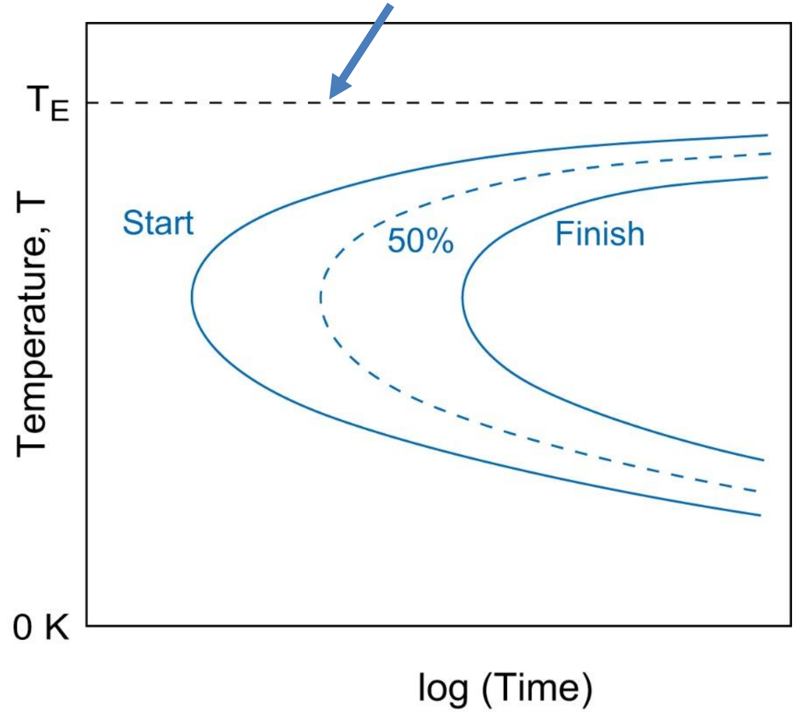
Time-Temperature-Transformation

Rate limited by lack of driving force (undercooling)
(Coarser microstructure)



Rate limited by lack of diffusion
(finer microstructure)

Equilibrium transformation T



Much more useful – how long do we leave the steel once quenched to T?

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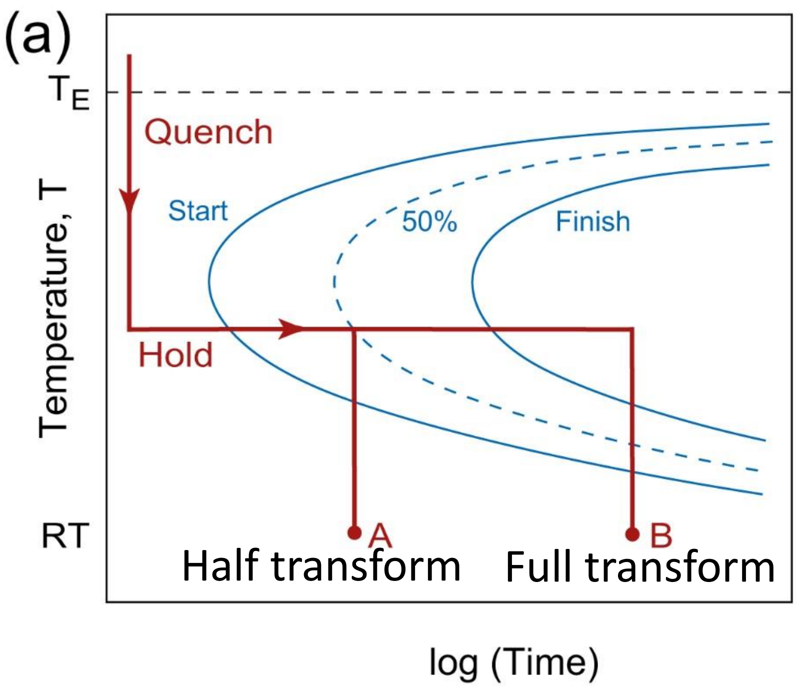
TTT and CCT

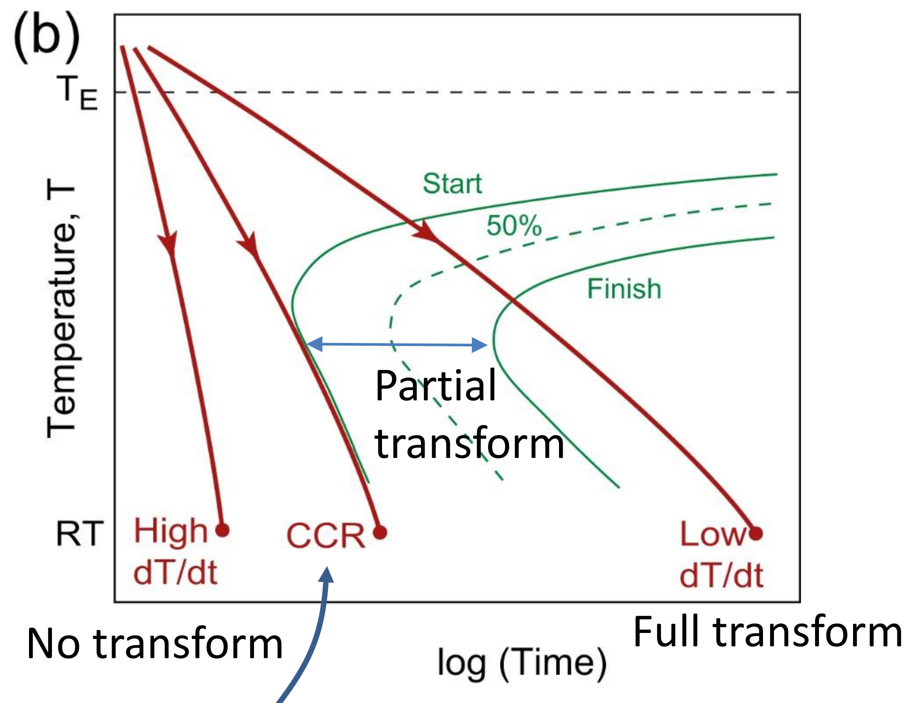
Time-Temperature-Transformation

Isothermal mostly used when uniformity is desired



Continuous-Cooling-Transformation

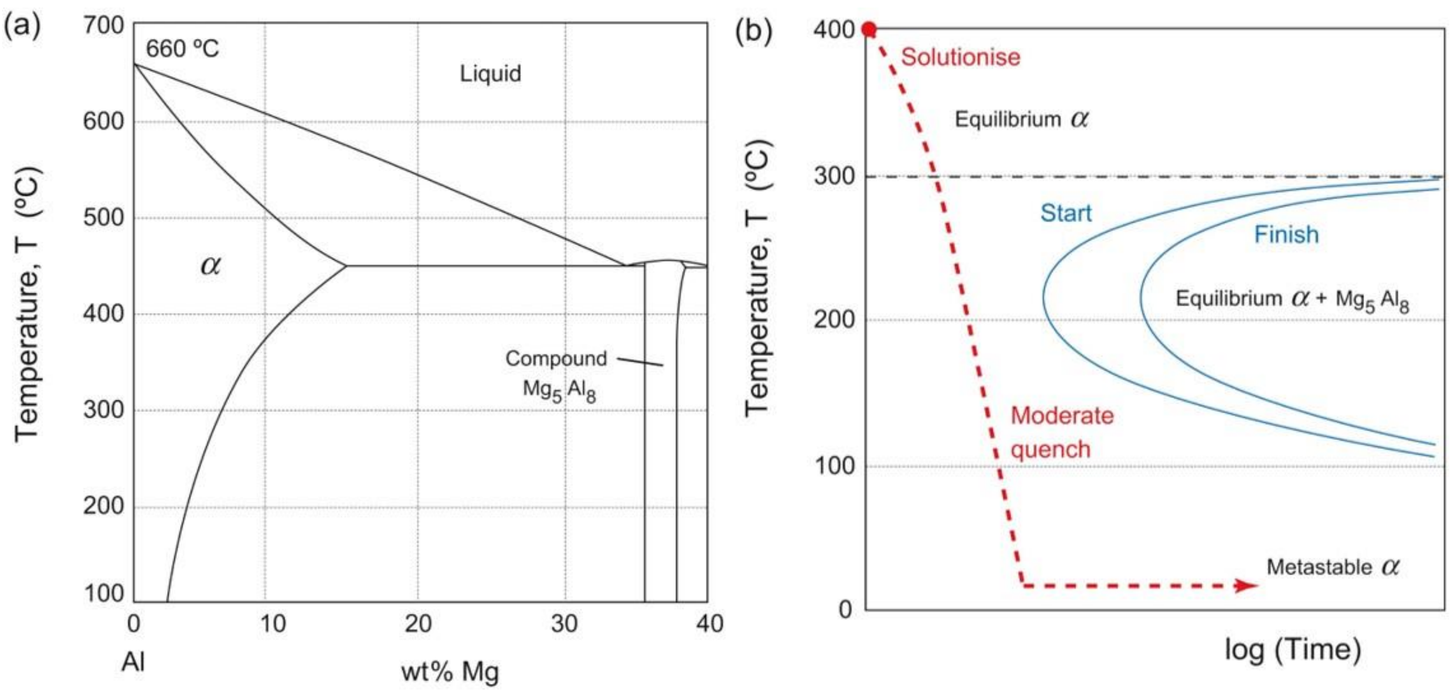
Cooling used when simplicity is desired (or no choice)



Critical Cooling Rate – just fast enough to prevent transformation

Aluminium

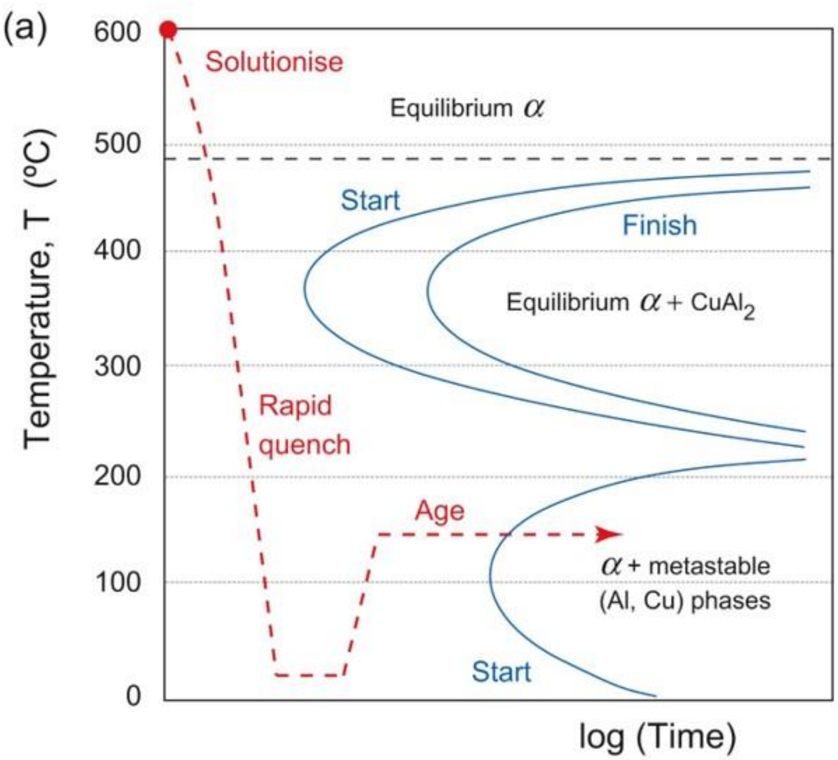
5xxx series aluminium (Al-Mg)

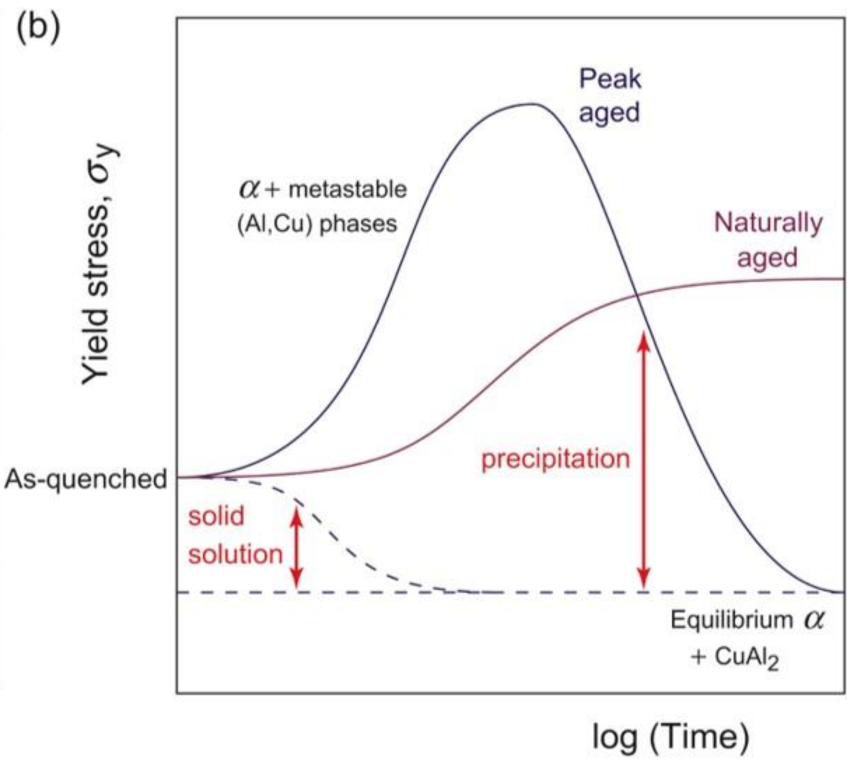


Even slow cooling traps Mg in Al solid solution – no age hardening

Aluminium

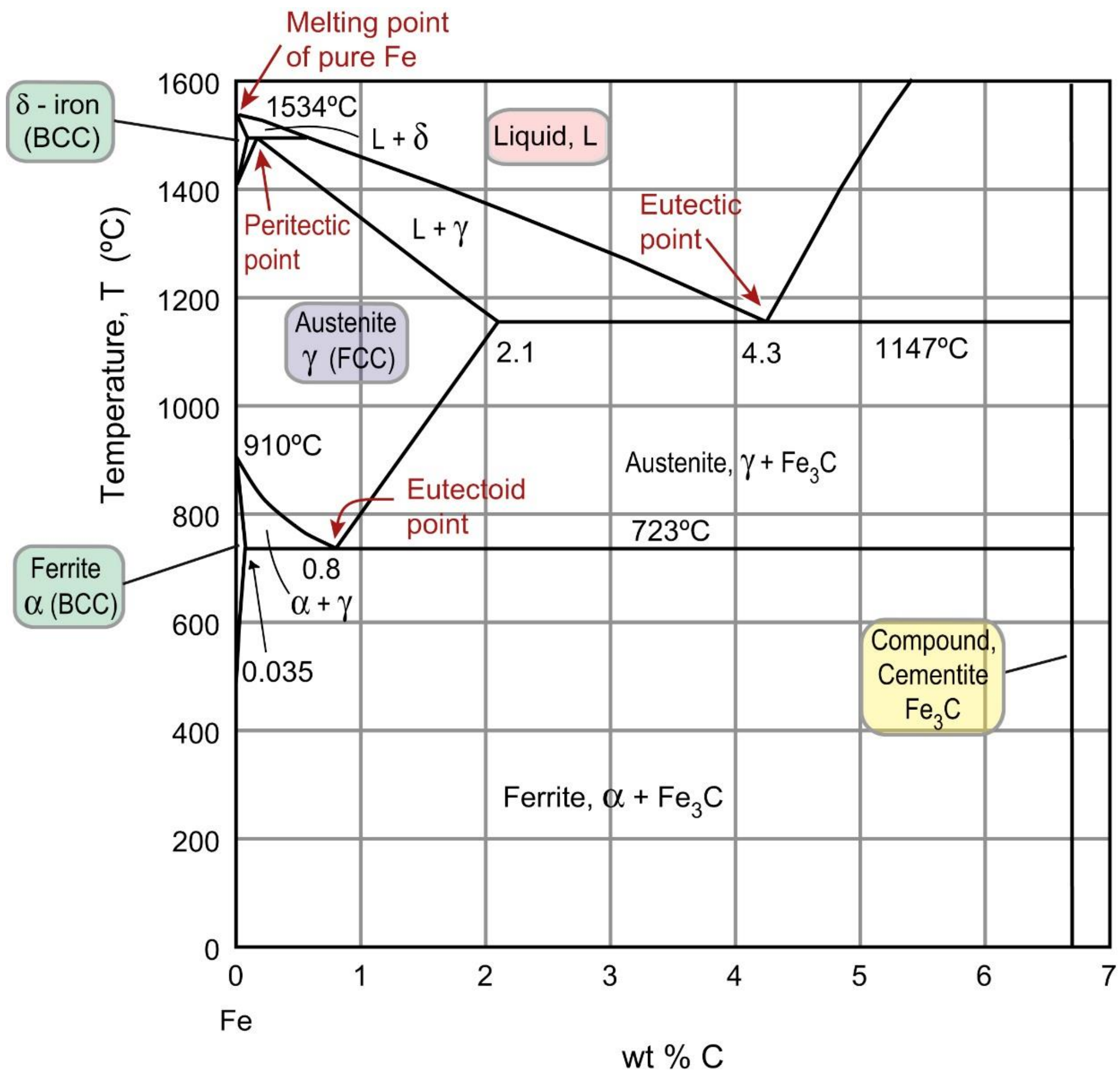

A340
A340-600


(a)
600
500
400
300
200
100
0
Temperature, T (ºC)
Solutionise
Equilibrium α
Start
Finish
Equilibrium $\alpha + CuAl_2$
Rapid
quench
Age
α + metastable
(Al, Cu) phases
Start
log (Time)


(b)
Yield stress, σ_y
Peak
aged
α + metastable
(Al,Cu) phases
Naturally
aged
As-quenched
precipitation
solid
solution
Equilibrium α
+ $CuAl_2$
log (Time)

Fe-C Phase Diagram

This is out of order compared to the notes



Eutectic

Liquid (molten iron)

Solid 1 (austenite)

+

Solid 2 (Fe_3C or graphite)

Eutectoid

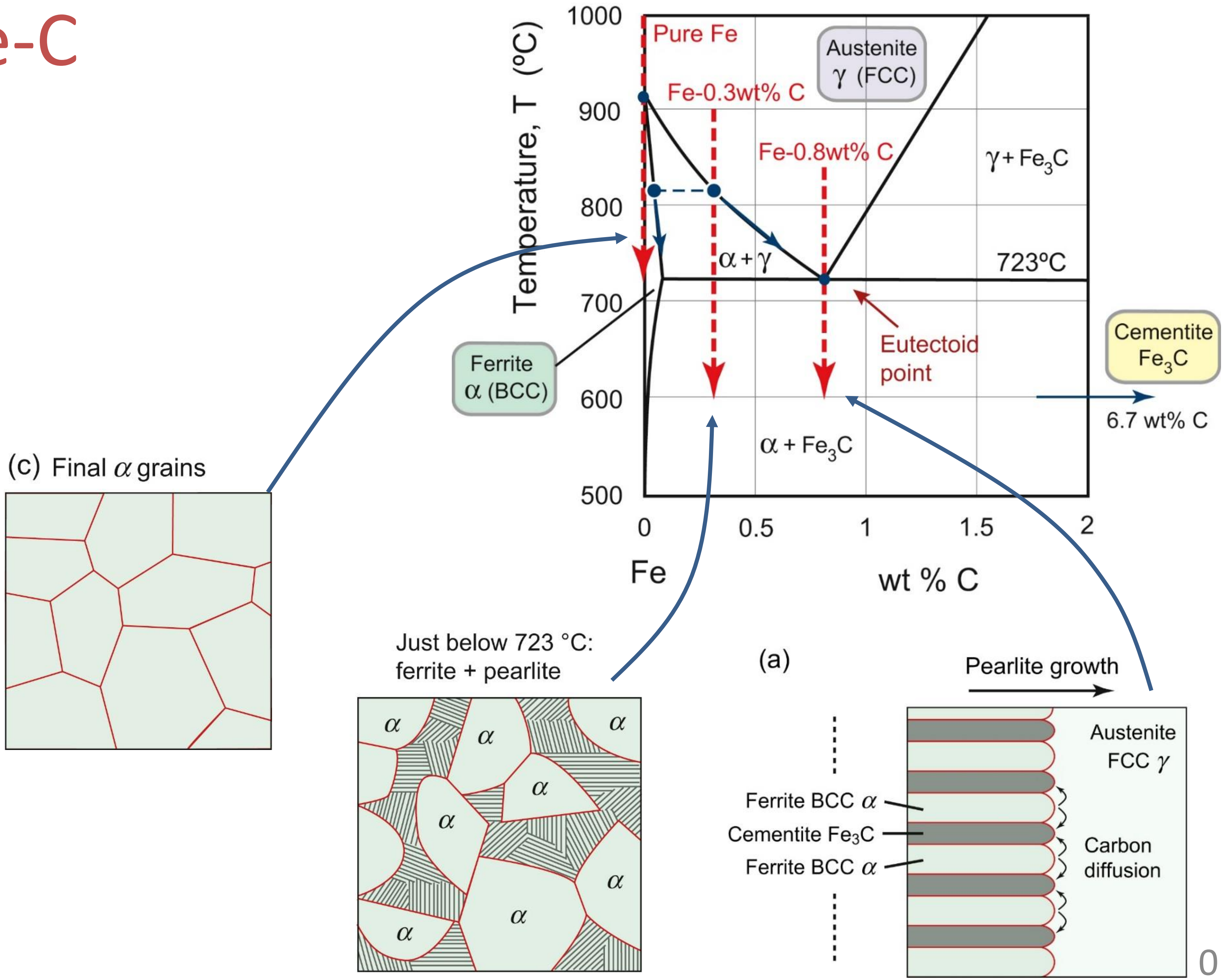
Solid 1 (austenite)

Solid 2 (ferrite)

+

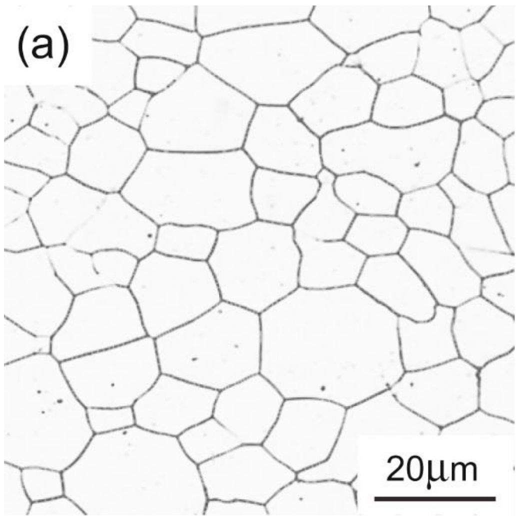
Solid 3 (Fe_3C)

Fe-C



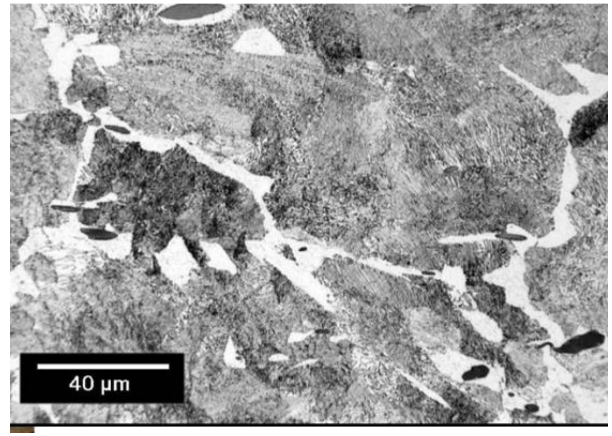
1000
900
800
700
600
500
Temperature, T (ºC)
Pure Fe
Austenite
γ (FCC)
Fe-0.3wt% C
Fe-0.8wt% C
γ + Fe3C
α + γ
723ºC
Ferrite
α (BCC)
Eutectoid
point
Cementite
Fe3C
6.7 wt% C
α + Fe3C
0
0.5
1
1.5
2
Fe
wt % C
(c) Final α grains
Just below 723 °C:
ferrite + pearlite
α
(a)
Pearlite growth
Austenite
FCC γ
Ferrite BCC α
Cementite Fe3C
Ferrite BCC α
Carbon
diffusion

Fe-C Microstructure



Low carbon steel

All ferrite



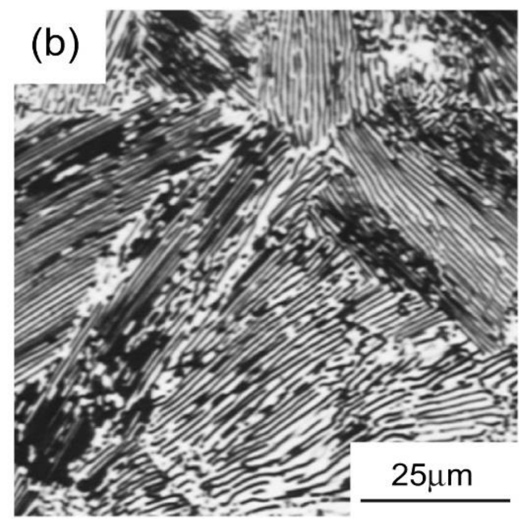
Mid carbon steel

Ferrite + Mostly pearlite

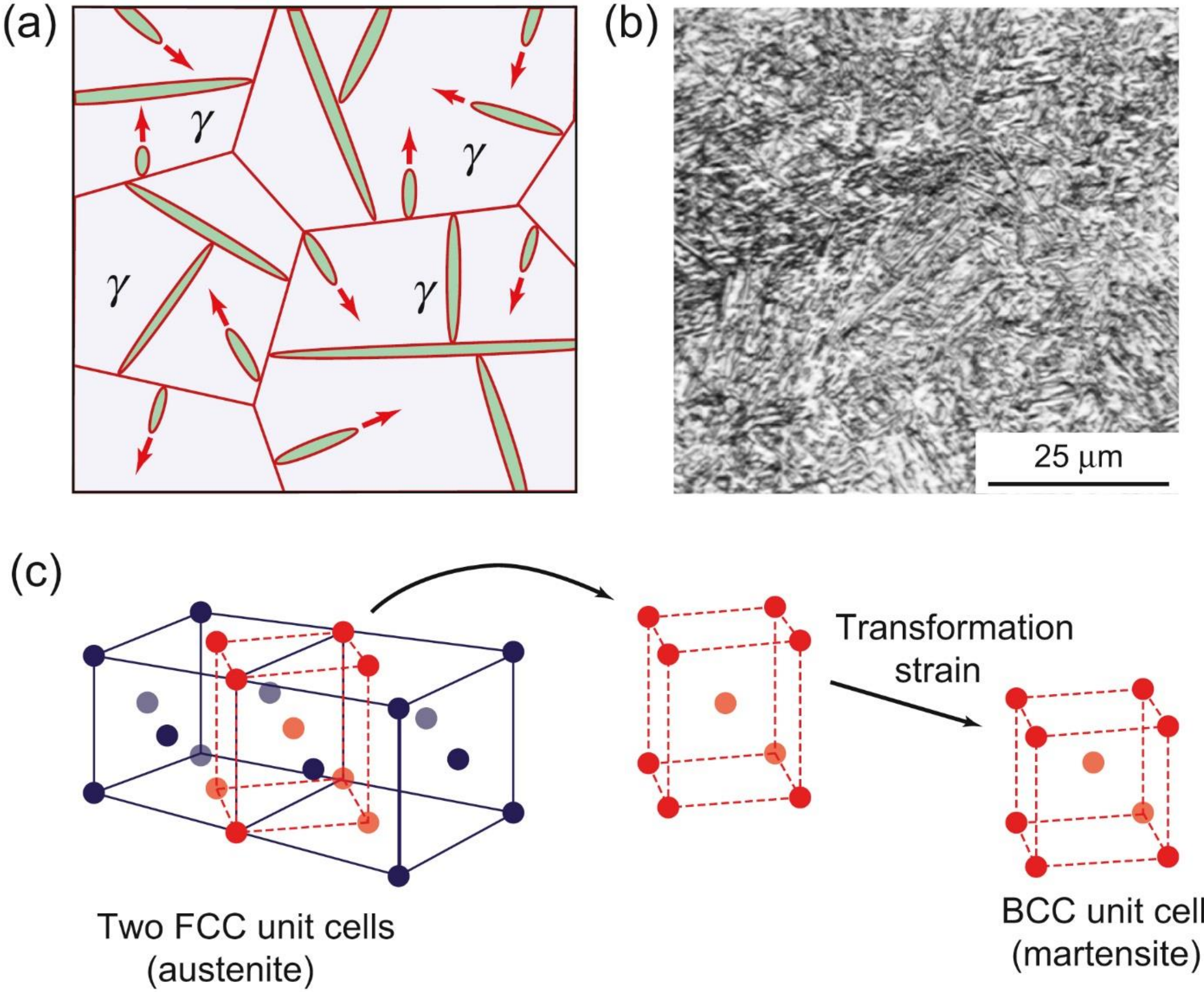
Increasing strength

High carbon steel

All pearlite



Steel – Fast Cooling



Supersaturated solid solution of carbon in ferrite

Properties:

- High strength (yield, tensile)
- High hardness
- Low ductility
- Low fracture toughness

VERY, VERY SCARY TO ENGINEERS

But …

High strength

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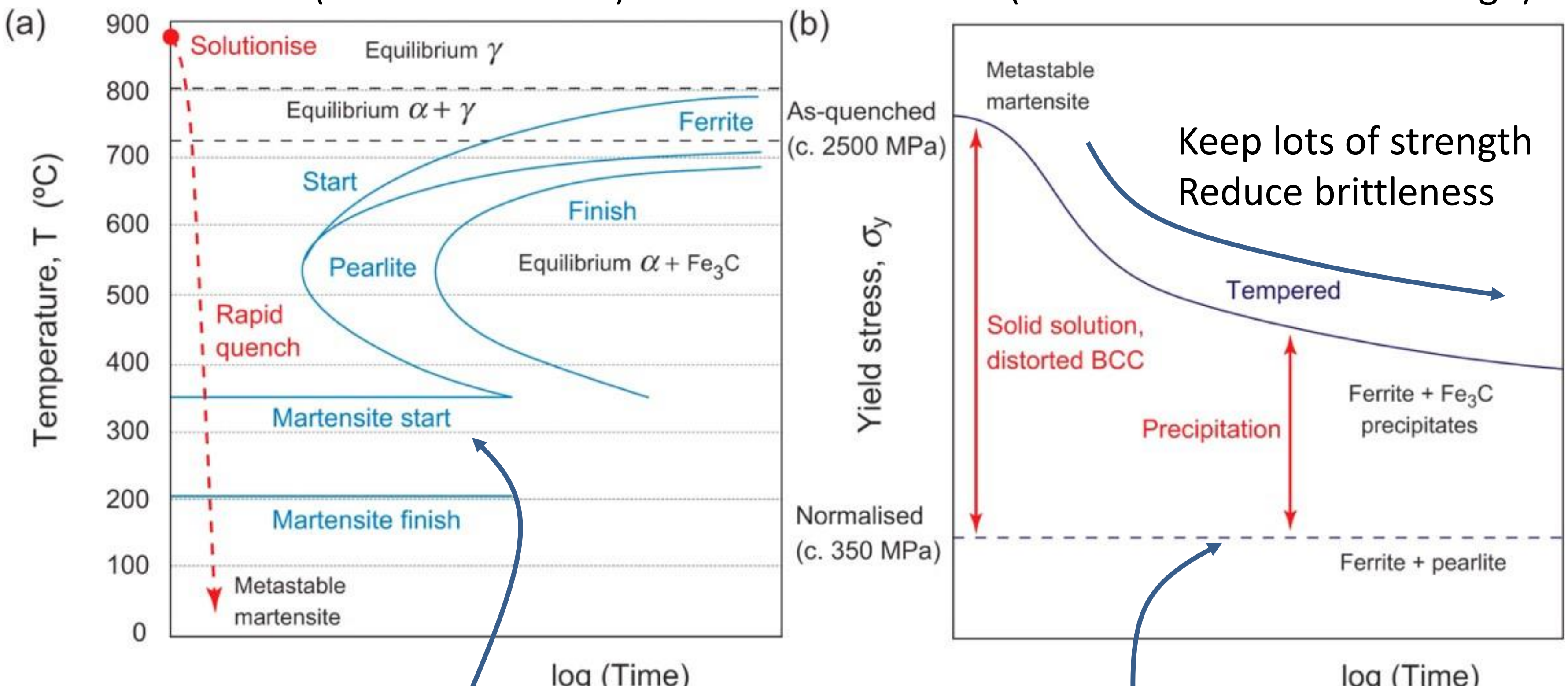
Quenching

Steel - Martensite

Quenching
(make martensite)

Tempering
(make martensite more tough)

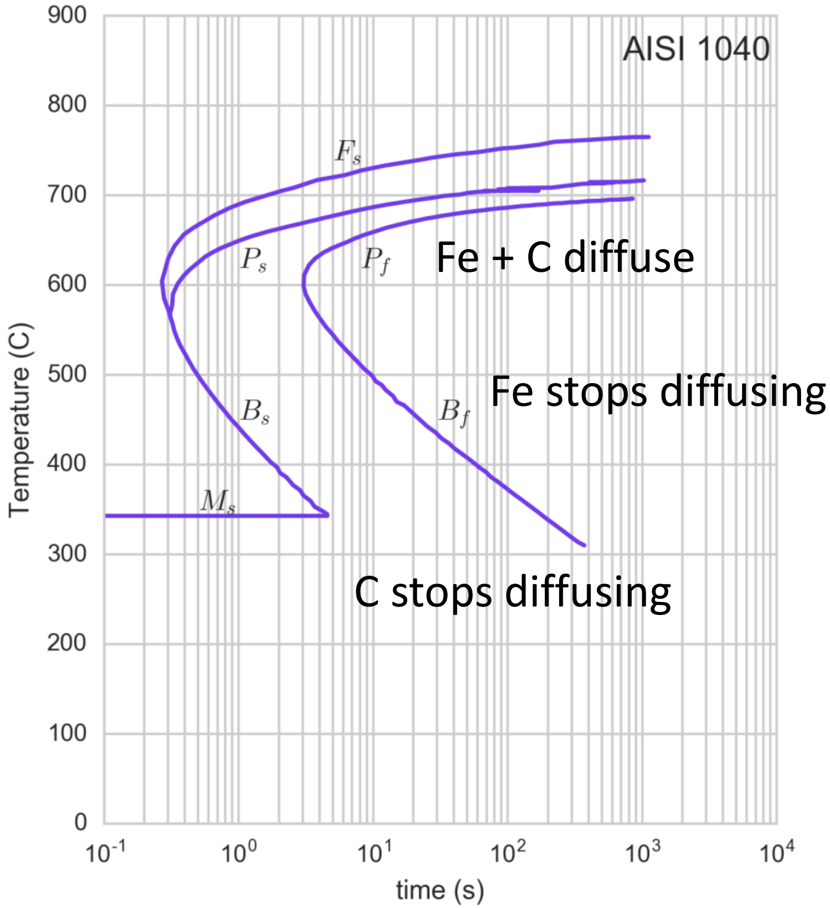


% martensite independent of time just function of T

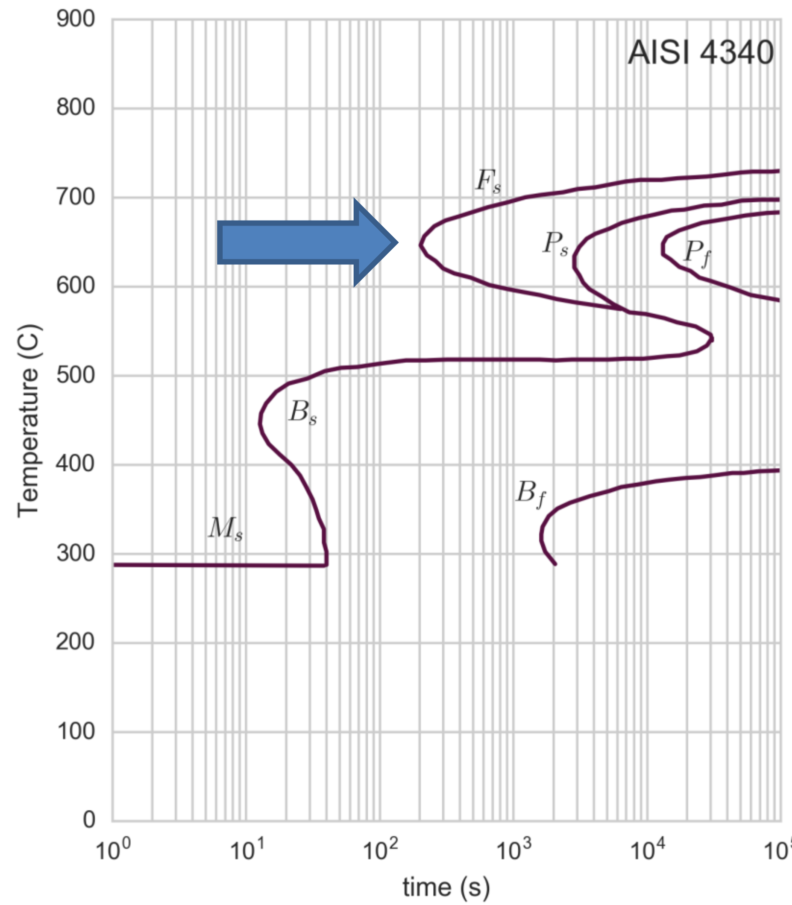
Approach ferrite + pearlite over long tempering times or high temperatures

Real TTT Diagrams

Plain carbon steel (0.4% C)



Low alloy steel (0.4% C+Ni,Cr,Mo)

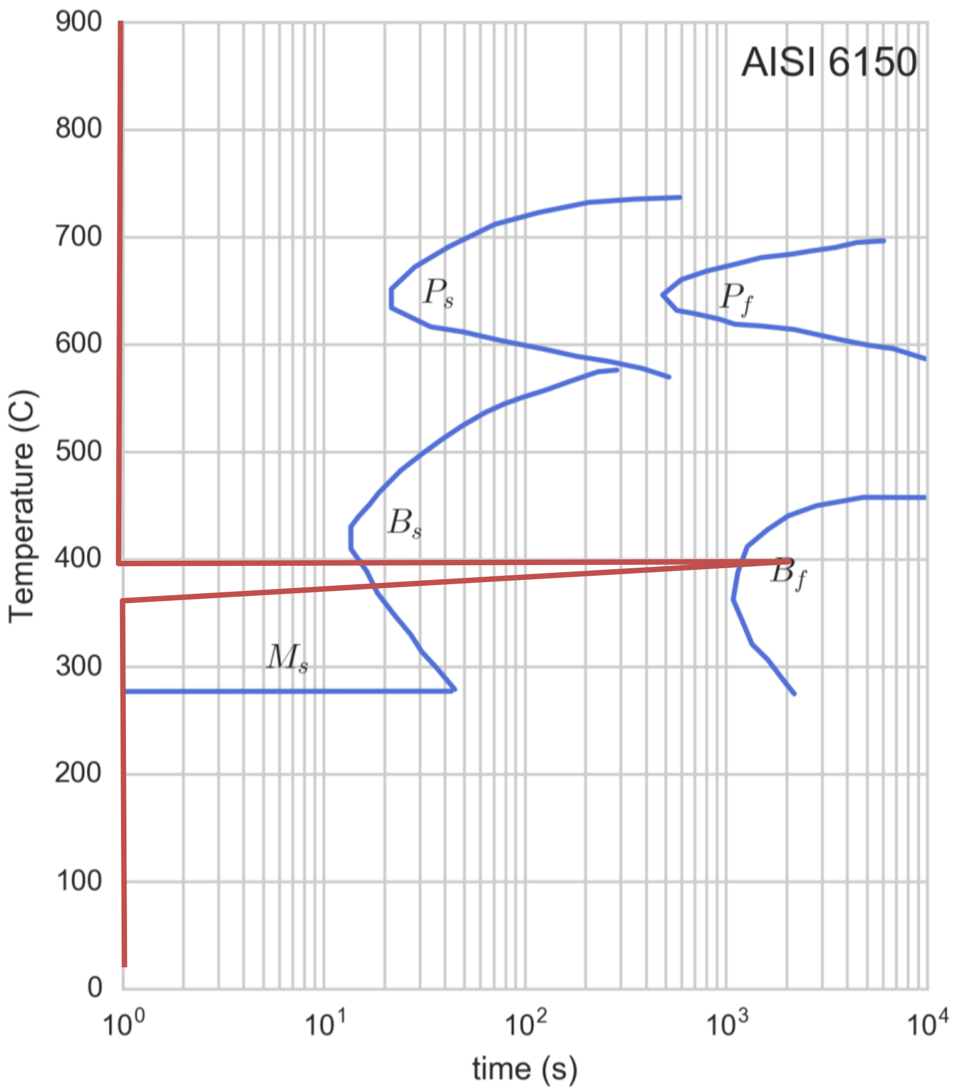


New microconstituent – Bainite

Stronger *and* tougher than pearlite/ferrite

Less strong than martensite, but tougher

Reading Steel TTT



Metal at 900°C
Quench to 400 ° C
Hold for 2000s
Quench to ambient (20 ° C).

What is the microstructure?

Quench 1:
Miss pearlite so 0% pearlite

Hold:
Pass bainite start and finish so 100% bainite

Quench 2:
Restart at t=0 and drop
No austenite to change to martensite

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- **COMPLETE QUESTIONS ->12**