TTT & CCT Diagrams

Lec-5

ABBAS KHAMMAS HUSSEIN 2014

Isothermal Transformation of Austenite

Experimental Deter. of TTT diagram (1)

1- A steel specimen is first heated to the Austenitic Range -

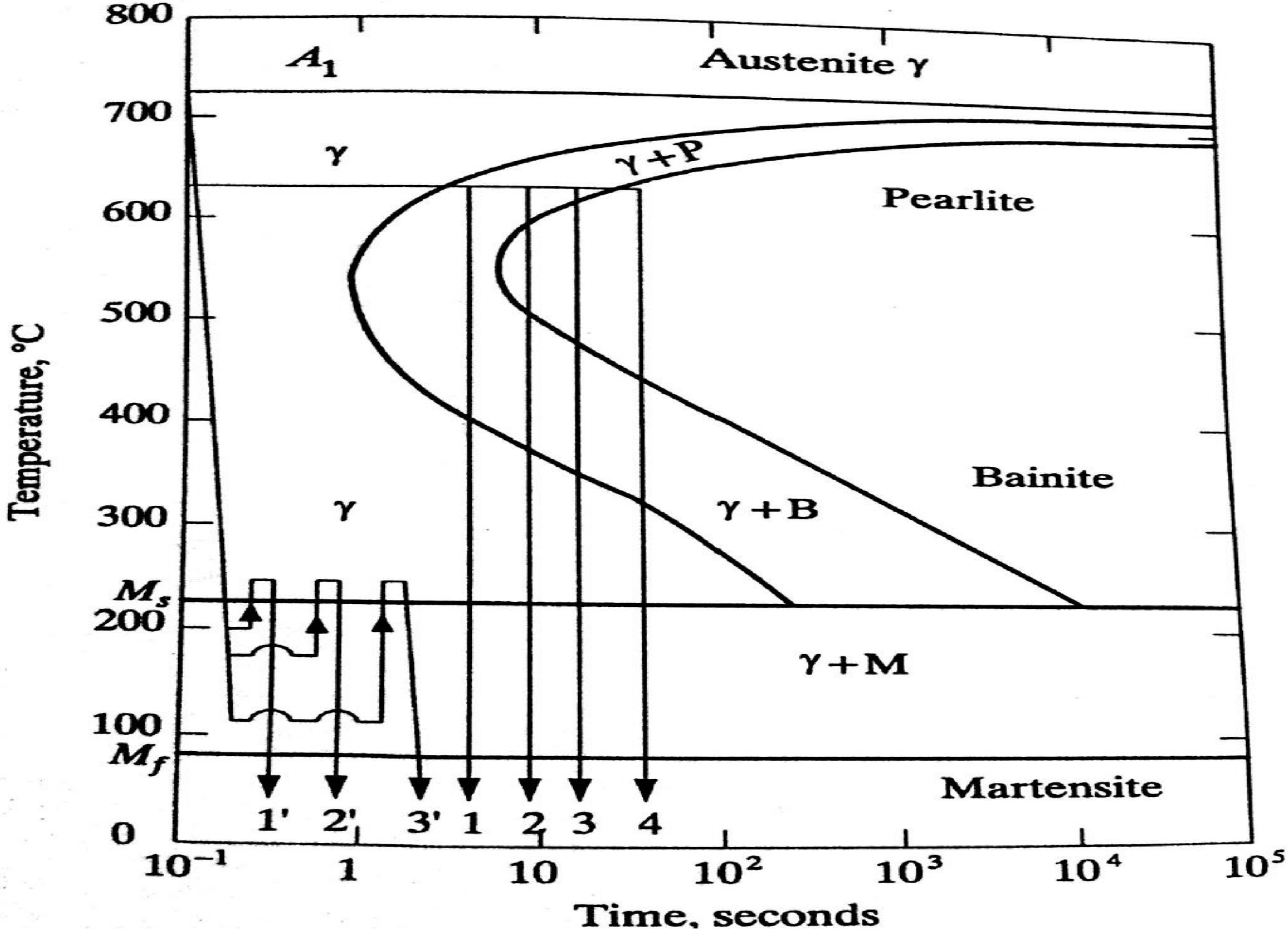
2- Quenching into a molten salt or metal Bath

3- Maintained at a constant temperature ex: 625 °C in the ~~pearlitic~~ Pearlite Region.

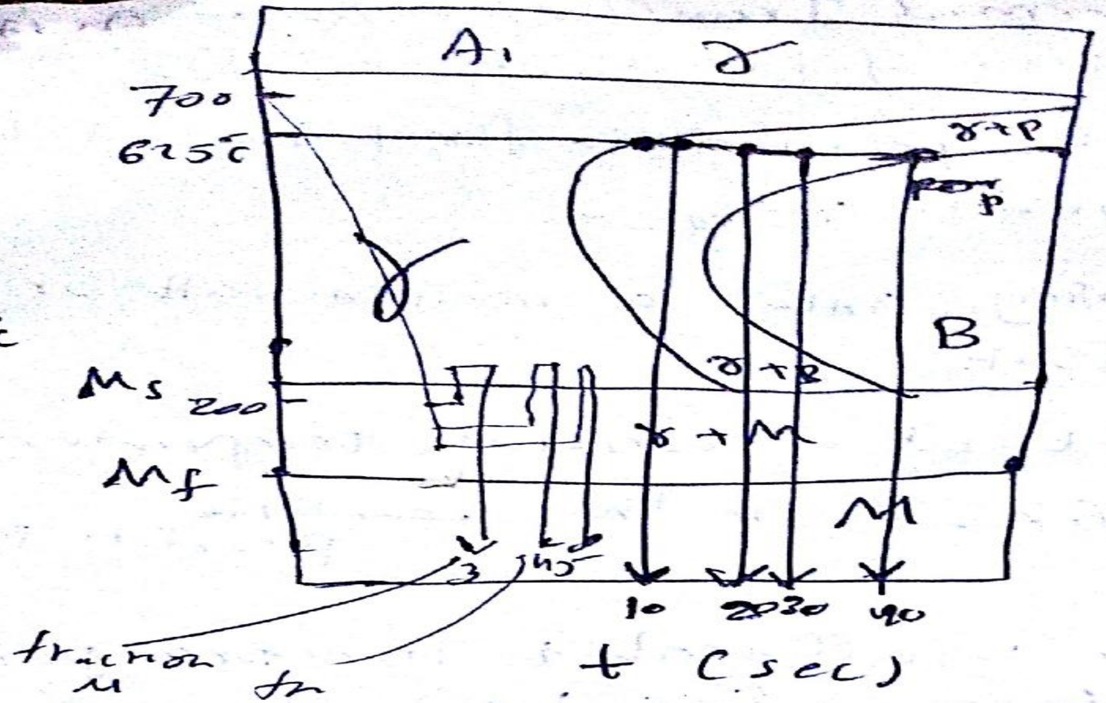
4- specimen is allowed to Transform partially to pearlite by holding for a certain length of time in the bath

5- Quenching to room temp. ⟹ untransformed austenite is converted to Mar. on Quenching.

NOTE| The fraction of pearlite formed corresponding to that holding time in the bath is estimated.



800
700
600
500
400
300
200
100
0
M_s
M_f
A_1
Austenite γ
γ
γ+P
Pearlite
Bainite
γ
γ+B
γ+M
Martensite
1'
2'
3'
1
2
3
4
10^{-1}
1
10
10^2
10^3
10^4
10^5
Temperature, °C
Time, seconds



NOTE

1- By ~~Repeating~~ ~~Keep~~ repeating a series of about 10 specimen in a similar fashion it possible to bracket the time for 1% and 99% pearlite formation.

2. similar Tests are conducted at other temps. in the (pearlitic & Bainitic Region) to determine the full C-curves for start + finish of these two transformation.

Determination of Martensite Region in TTT diagram

1- The Austenitized specimens are Quenched to different temp in the Martensitic Range.

2- Heated to temper the Martensite formed.

3. Cooled back to room temp. ⟹ The

4. ~~In the last step,~~ remaining Austenite is converted to Martensite

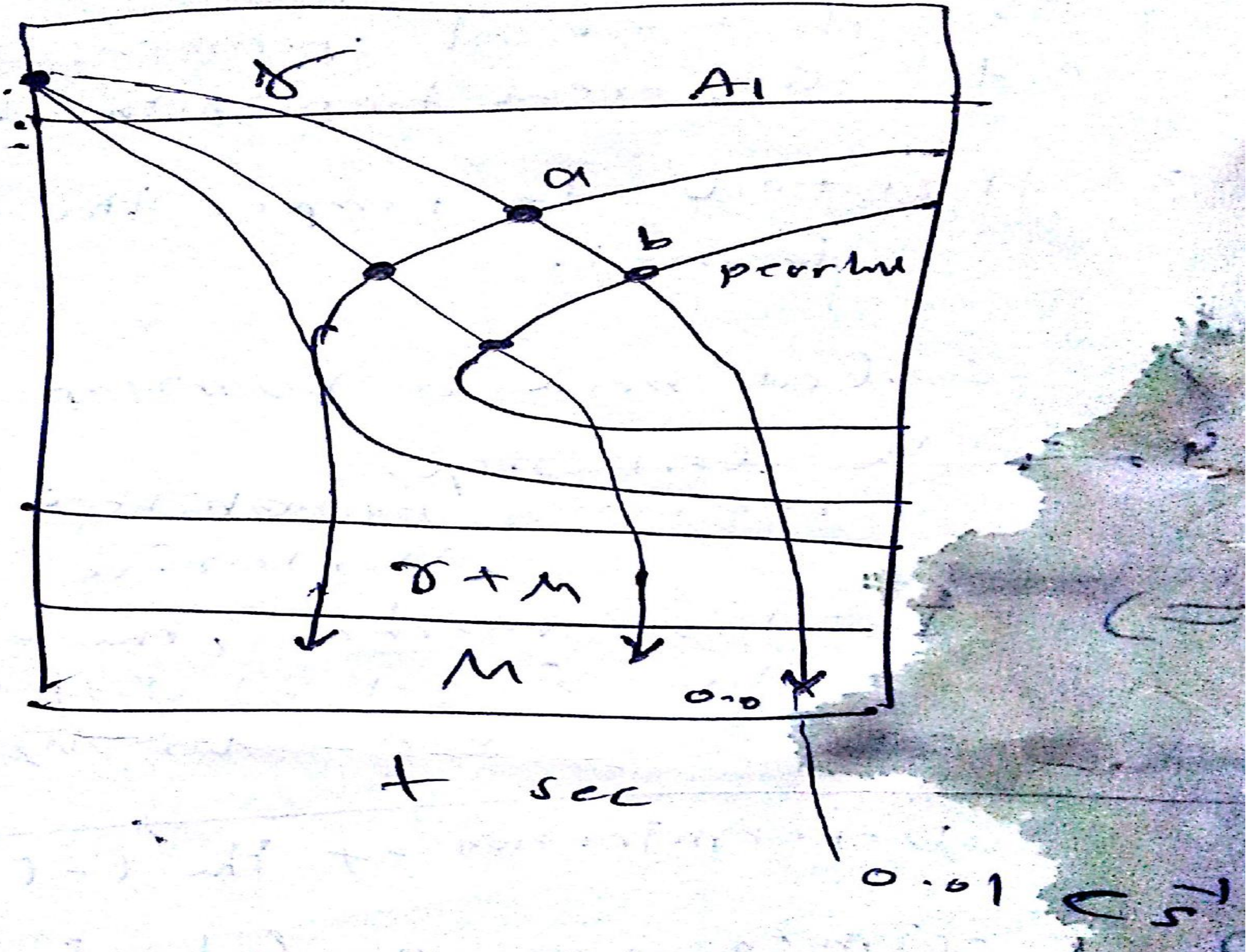
⟹ In this manner, the amount of M formed at diff. Temp as well as M_s, M_f are ~~Dato~~ obtained.

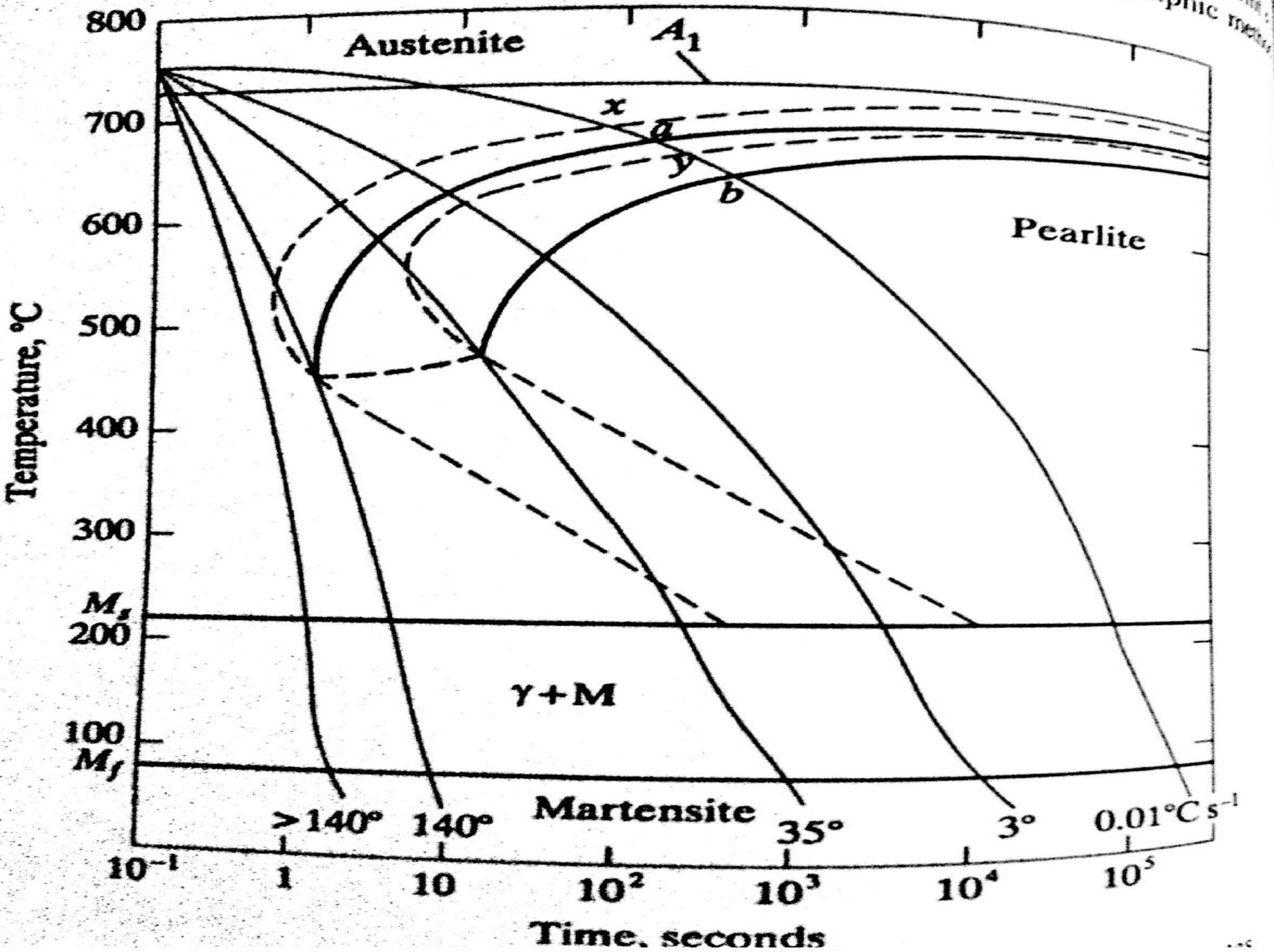
Determination of the C-C-T Diagram

① specimen are cooled from the Austenitic Range at a constant Rate.

② the pearlite start (point a) and the pearlite finish (point b) are determined by the Metallographic method as in TTT diagram.

C-C-T = Continuous-cooling Transformation

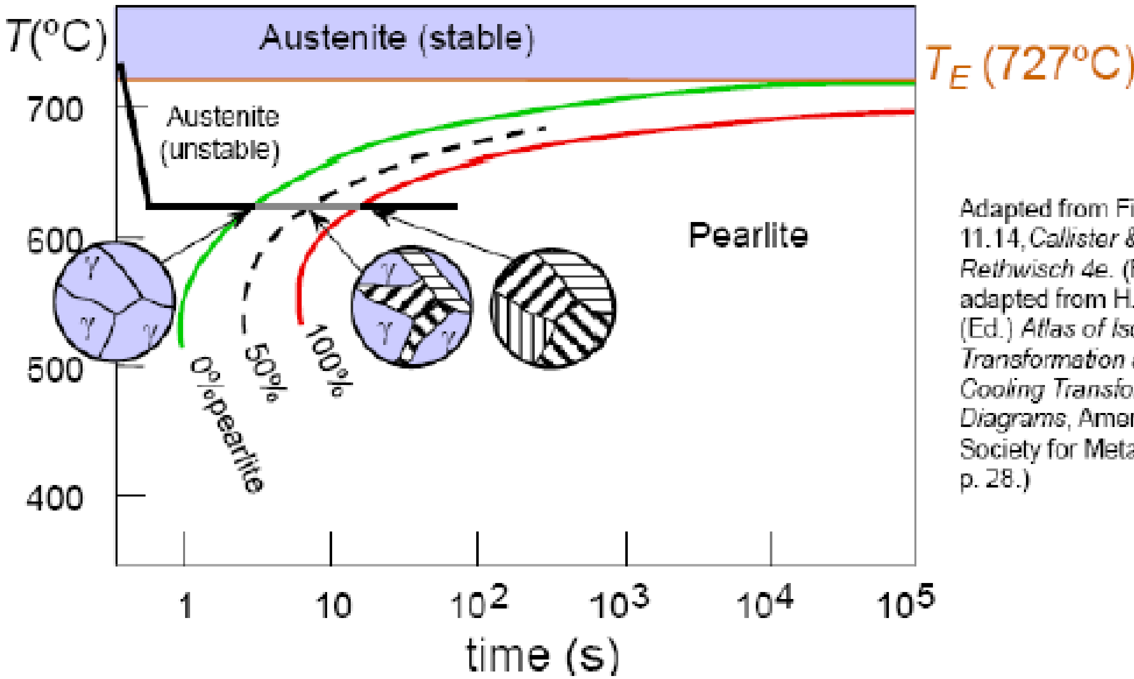

γ
A1
a
b
γ + n
M
0.0
t sec
0.01 (s)


800
700
600
500
400
300
200
100
M_s
M_f
Temperature, °C
Austenite
A_1
x
a
y
b
Pearlite
γ+M
Martensite
>140°
140°
35°
3°
0.01°C s⁻¹
10⁻¹
1
10
10²
10³
10⁴
10⁵
Time, seconds

Austenite-to-Pearlite Isothermal Transformation

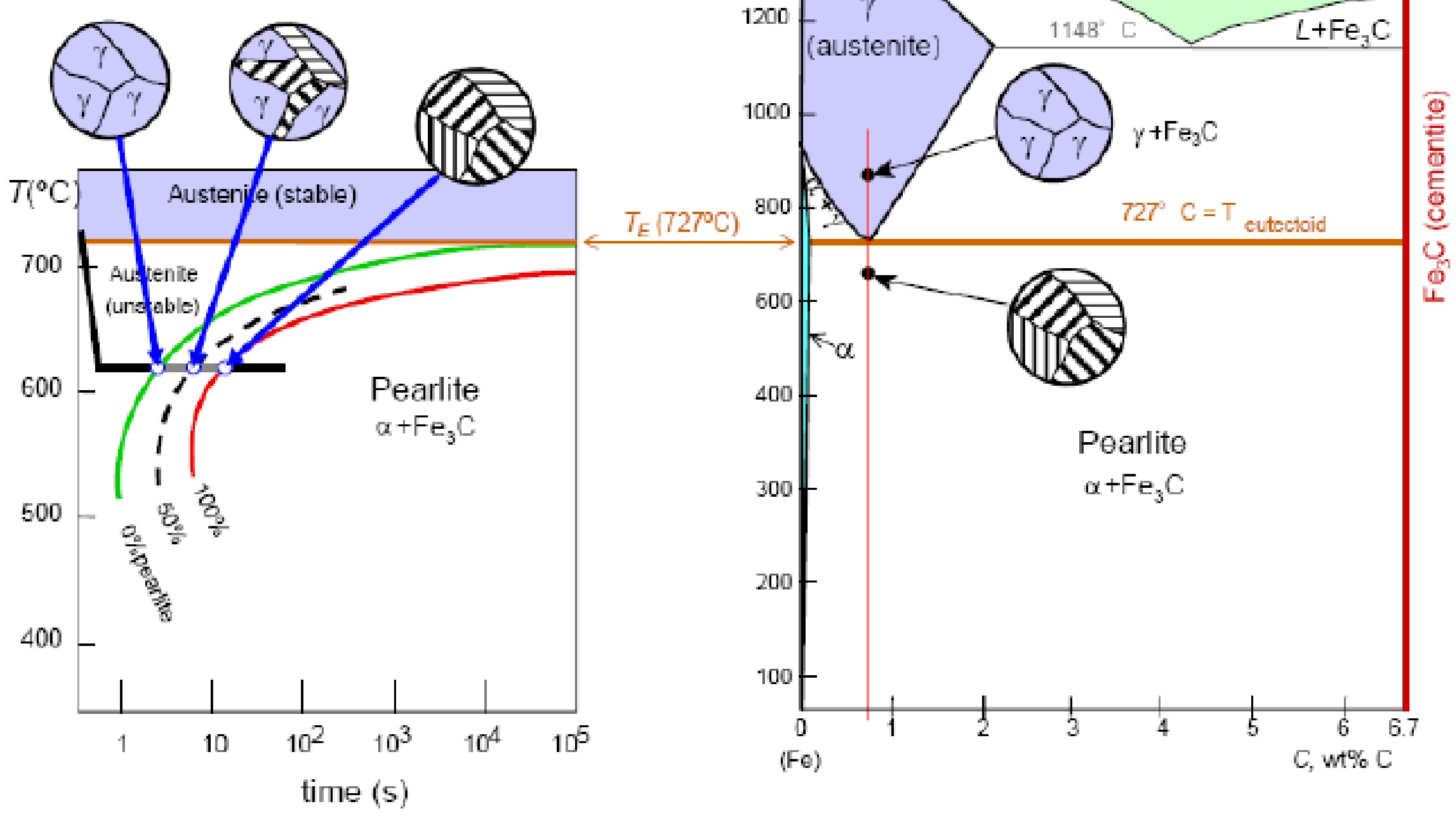
- Eutectoid composition, C_0 = 0.76 wt% C
- Begin at T > 727°C
- Rapidly cool to 625°C
- Hold T (625°C) constant (isothermal treatment)

It takes time!



Adapted from Fig. 11.14, *Callister & Rethwisch 4e*. (Fig. 11.14 adapted from H. Boyer (Ed.) *Atlas of Isothermal Transformation and Cooling Transformation Diagrams*, American Society for Metals, 1997, p. 28.)

Austenite-to-Pearlite Isothermal Transformation



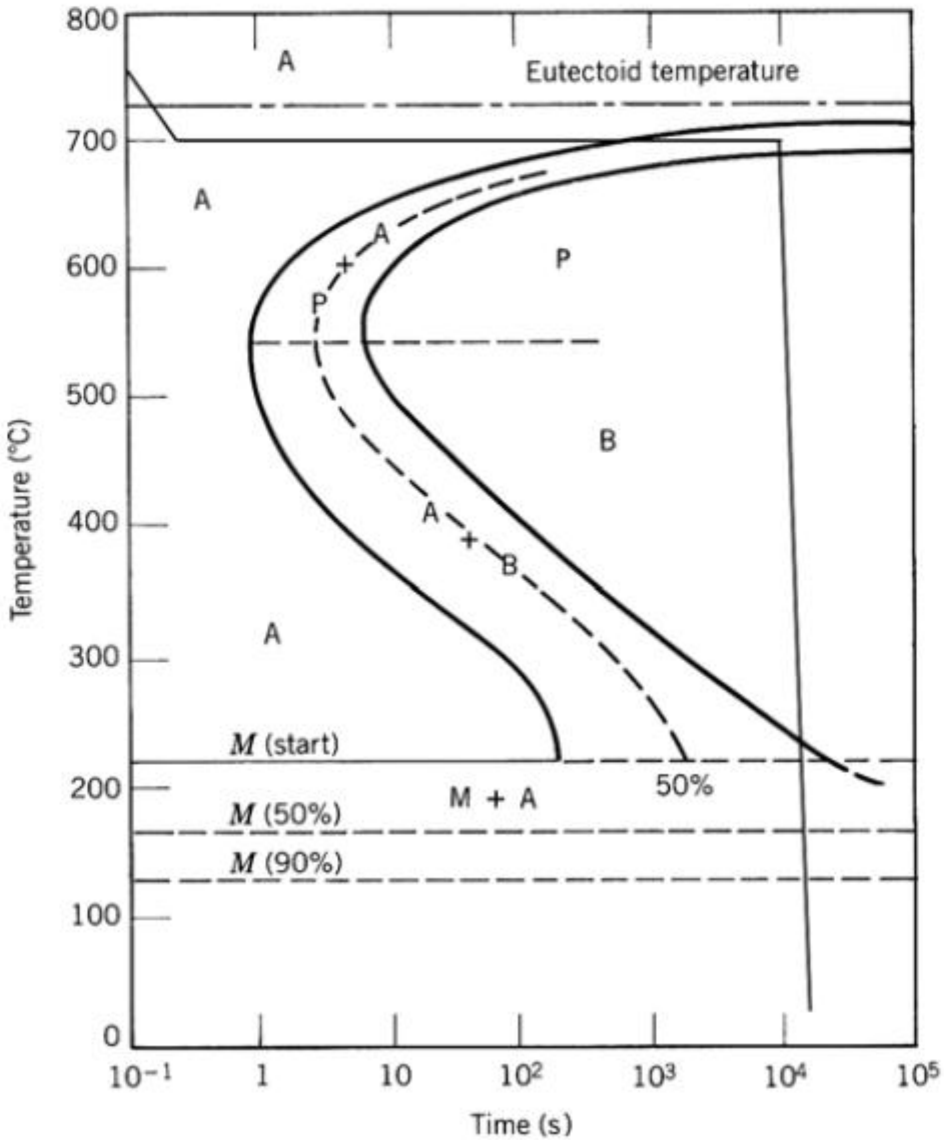
Example

Using the isothermal transformation diagram for an iron–carbon alloy of eutectoid composition (Figure 10.22), specify the nature of the final microstructure (in terms of microconstituents present and approximate percentages of each) of a small specimen that has been subjected to the following time–temperature treatments. In each case assume that the specimen begins at 760°C (1033 K) and that it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure.

(a) Cool rapidly to 700°C (973 K), hold for 10^4 s, then quench to room temperature.

Solution

Below is Figure 10.22 upon which is superimposed the above heat treatment.



800
700
600
500
400
300
200
100
0
Temperature (°C)
A
Eutectoid temperature
A
A
+
P
P
B
A
+
B
A
M (start)
M + A
50%
M (50%)
M (90%)
10−1
1
10
10²
10³
10⁴
10⁵
Time (s)

After cooling and holding at 700°C for 10^4 s, approximately 50% of the specimen has transformed to coarse pearlite. Upon cooling to room temperature, the remaining 50% transforms to martensite. Hence, the final microstructure consists of about 50% coarse pearlite and 50% martensite.

(b) Reheat the specimen in part (a) to 700°C (973 K) for 20 h.

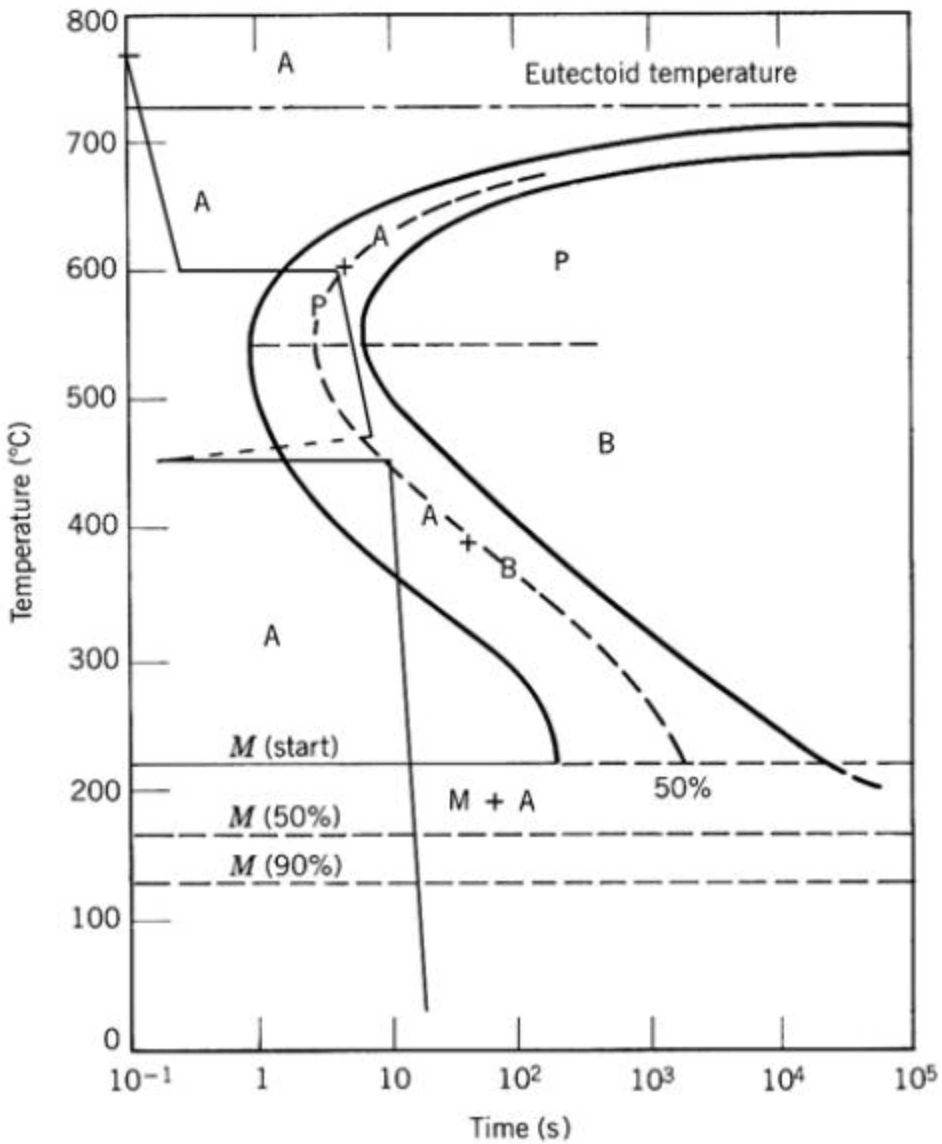
Solution

Heating to 700°C for 20 h the specimen in part (a) will transform the coarse pearlite and martensite to spheroidite.

(c) Rapidly cool to 600°C (873 K), hold for 4 s, rapidly cool to 448°C (721 K), hold for 10 s, then quench to room temperature.

Solution

Below is Figure 10.22 upon which is superimposed the above heat treatment.

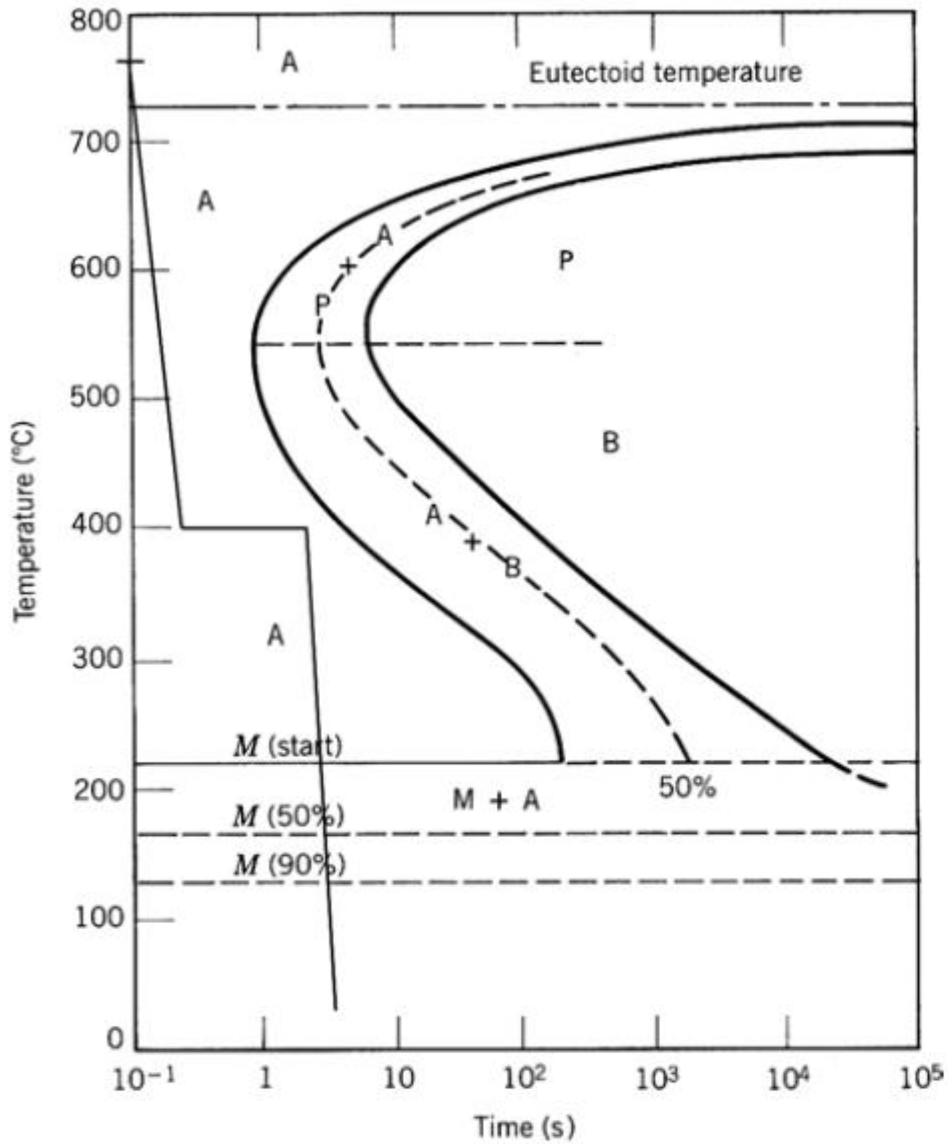

800
700
600
500
400
300
200
100
0
Temperature (°C)
A
Eutectoid temperature
A
A
P
P
B
A
+
B
A
M (start)
M + A
50%
M (50%)
M (90%)
10−1
1
10
10²
10³
10⁴
10⁵
Time (s)

After cooling to and holding at 600°C for 4 s, approximately 50% of the specimen has transformed to pearlite (medium). During the rapid cooling to 448°C no transformations occur. At 448°C we start timing again at zero time; while holding at 448°C for 10 s, approximately 50 percent of the remaining unreacted 50% (or 25% of the original specimen) will transform to bainite. And upon cooling to room temperature, the remaining 25% of the original specimen transforms to martensite. Hence, the final microstructure consists of about 50% pearlite (medium), 25% bainite, and 25% martensite.

(d) Cool rapidly to 398°C (671 K), hold for 2 s, then quench to room temperature.

Solution

Below is Figure 10.22 upon which is superimposed the above heat treatment.



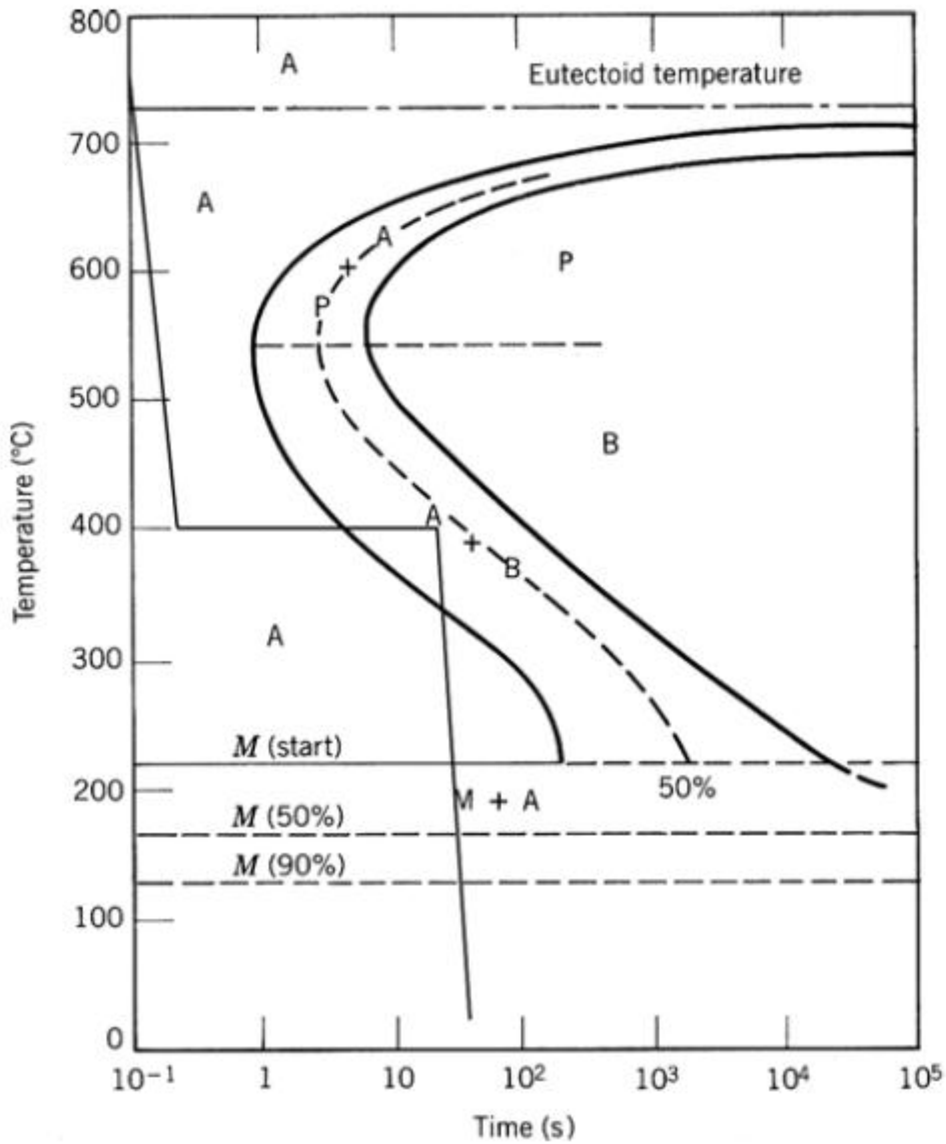
800
700
600
500
400
300
200
100
0
Temperature (°C)
A
Eutectoid temperature
A
A-+-P
P
B
A-+-B
A
M (start)
M + A
50%
M (50%)
M (90%)
10−1
1
10
10²
10³
10⁴
10⁵
Time (s)

After cooling to and holding at 400°C for 2 s, no of the transformation begin lines have been crossed, and therefore, the specimen is 100% austenite. Upon cooling rapidly to room temperature, all of the specimen transforms to martensite, such that the final microstructure is 100% martensite.

(e) Cool rapidly to 398°C (671 K), hold for 20 s, then quench to room temperature.

Solution

Below is Figure 10.22 upon which is superimposed the above heat treatment.



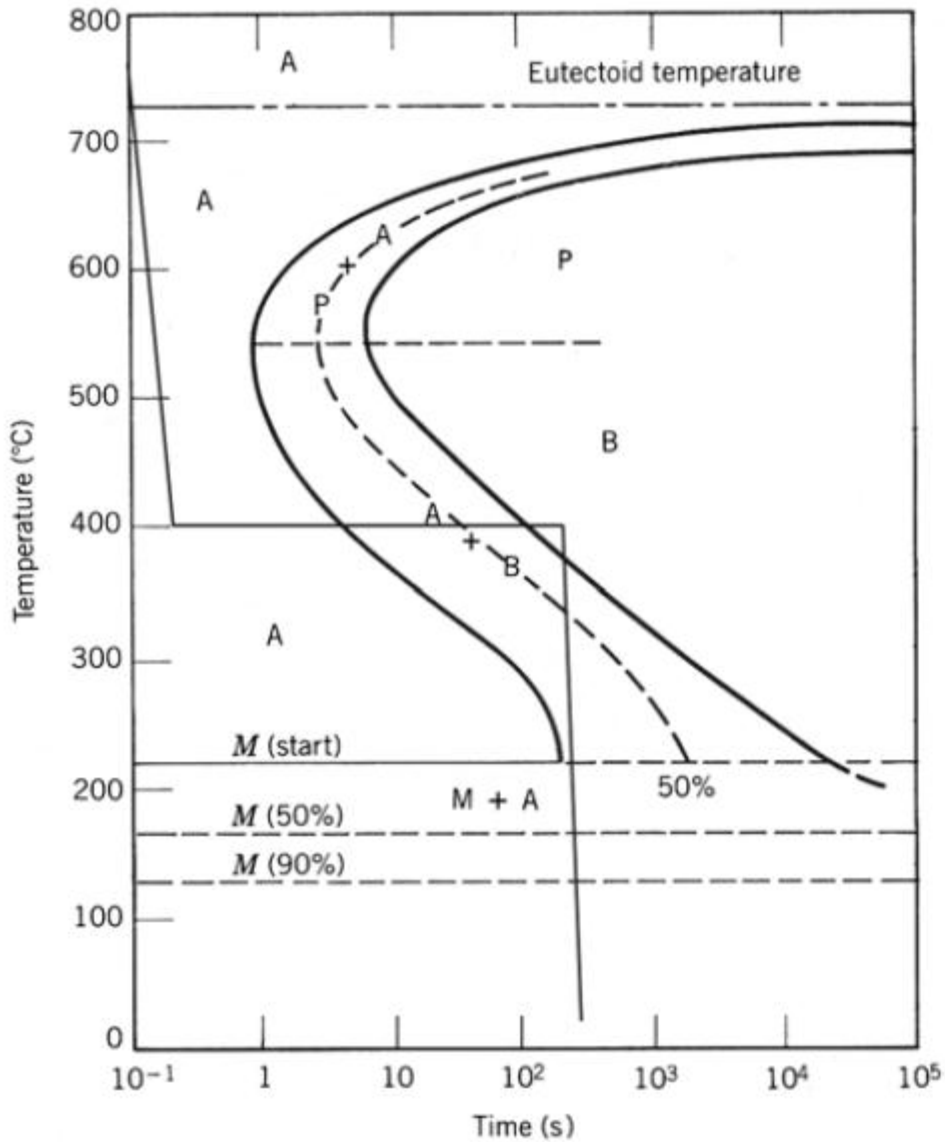
800
700
600
500
400
300
200
100
0
Temperature (°C)
A
Eutectoid temperature
A
A
+
P
P
B
A
+
B
A
M (start)
M + A
50%
M (50%)
M (90%)
10−1
1
10
10²
10³
10⁴
10⁵
Time (s)

After cooling and holding at 400°C for 20 s, approximately 40% of the specimen has transformed to bainite. Upon cooling to room temperature, the remaining 60% transforms to martensite. Hence, the final microstructure consists of about 40% bainite and 60% martensite.

(f) Cool rapidly to 398°C (671 K), hold for 200 s, then quench to room temperature.

Solution

Below is Figure 10.22 upon which is superimposed the above heat treatment.

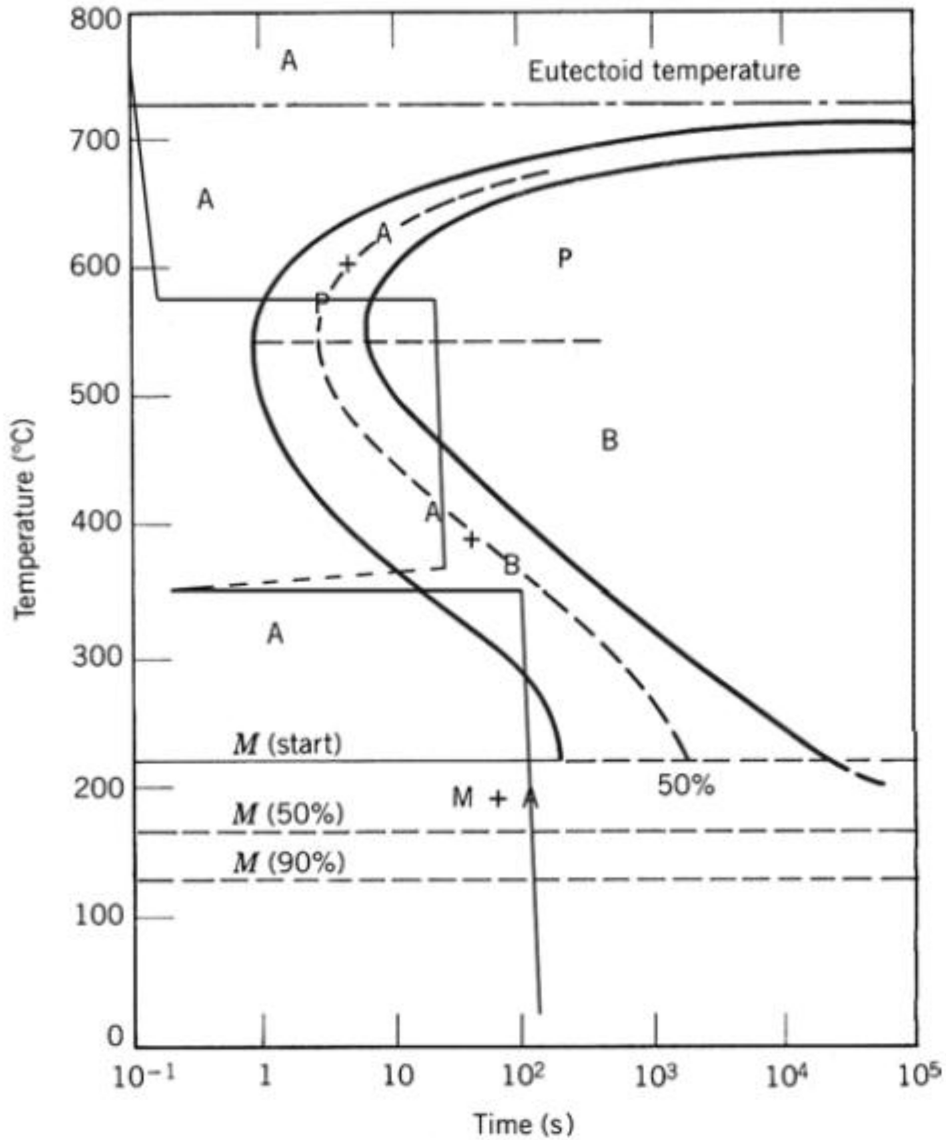

800
700
600
500
400
300
200
100
0
Temperature (°C)
A
Eutectoid temperature
A
A
+
P
P
B
A
+
B
A
M (start)
M + A
50%
M (50%)
M (90%)
10−1
1
10
10²
10³
10⁴
10⁵
Time (s)

After cooling and holding at 400°C for 200 s, the entire specimen has transformed to bainite. Therefore, during the cooling to room temperature no additional transformations will occur. Hence, the final microstructure consists of 100% bainite.

(g) Rapidly cool to 575°C (848 K), hold for 20 s, rapidly cool to 350°C (623 K), hold for 100 s, then quench to room temperature.

Solution

Below is Figure 10.22 upon which is superimposed the above heat treatment.



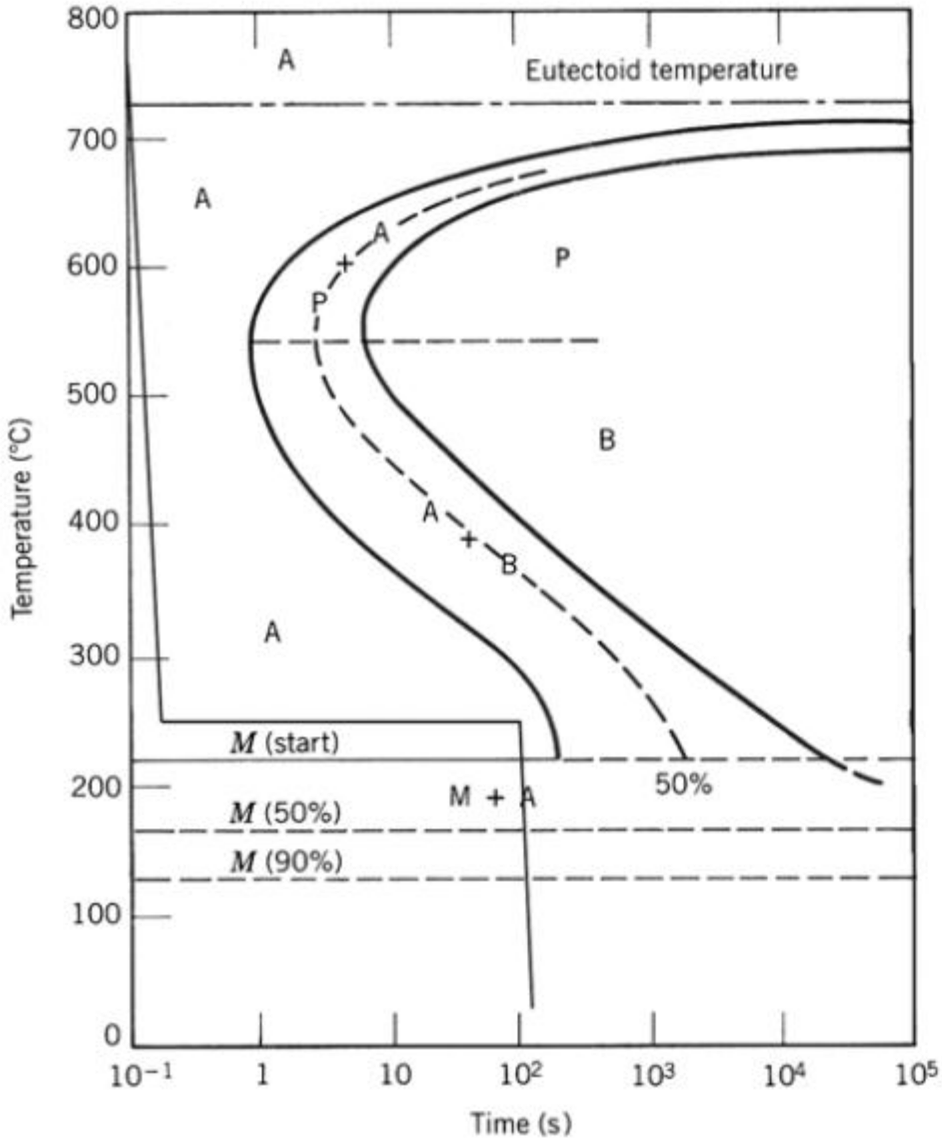
A
Eutectoid temperature
A
A
+
P
P
B
A
+
B
A
M (start)
M + A
50%
M (50%)
M (90%)
800
700
600
500
400
300
200
100
0
Temperature (°C)
10⁻¹
1
10
10²
10³
10⁴
10⁵
Time (s)

After cooling and holding at 575°C for 20 s, the entire specimen has transformed to fine pearlite. Therefore, during the second heat treatment at 350°C no additional transformations will occur. Hence, the final microstructure consists of 100% fine pearlite.

(h) Rapidly cool to 250°C (523 K), hold for 100 s, then quench to room temperature in water. Reheat to 315°C (588 K) for 1 h and slowly cool to room temperature.

Solution

Below is Figure 10.22 upon which is superimposed the above heat treatment.


Eutectoid temperature
A
A
P + A
P
B
A + B
A
M (start)
M + A
50%
M (50%)
M (90%)
Temperature (°C)
Time (s)
800
700
600
500
400
300
200
100
0
10−1
1
10
10²
10³
10⁴
10⁵