Time-Temperature-Transformation (TTT) Curves

TTT diagram is a plot of temperature versus the logarithm of time for a steel alloy of definite composition.

- ***TTT diagram indicates a specific transformation starts and ends and it also shows what percentage of transformation of austenite at a particular temperature is achieved***.
- ***The aims of TTT diagrams is determined type of structure for and portion in the curve and to obtained on specific properties*** .

It is also called isothermal transformation diagram

Pearlite

- The ***eutectoid reaction is fundamental to the development of microstructures in steel alloys***.

γ (0.76 wt% C) $\rightleftharpoons$ α (0.022 wt% C) + Fe_3C (6.70 wt% C)

-Pearlite is the microstructural product of this transformation.

-Above eutectoid temperature: only austenite exists

-Below eutectoid temperature: nucleation + growth

-The percentage of the transformation product is related to the holding temperature and holding time.

-The thickness of the ferrite/cementite layers in pearlite depends on the temperature. With decreasing temperature, the layers become progressively thinner.

-At temperatures just below eutectoid → relatively thick – layers → coarse pearlite.

-In the vicinity of 540°C → relatively thin layers → fine pearlite

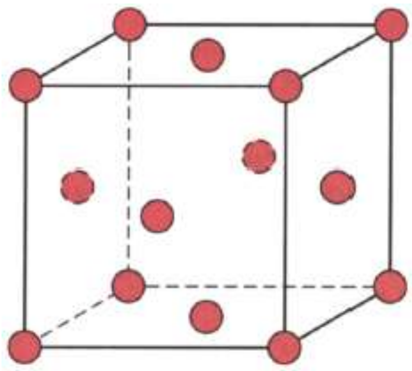
Martensite

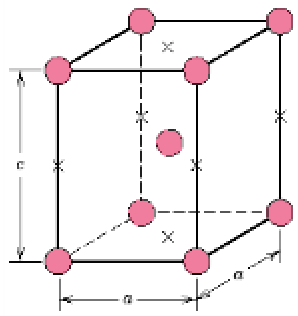
-Martensite is formed when austenitized Fe-C alloys are rapidly cooled (or quenched) to a relatively low temperature .

-Non-equilibrium single phase.

-Transformation of FCC to BCT (body-centered tetragonal).

-The martensite grains nucleate and grow at a very rapid rate .





(BCT)

(FCC) Austenite phase

Martensite

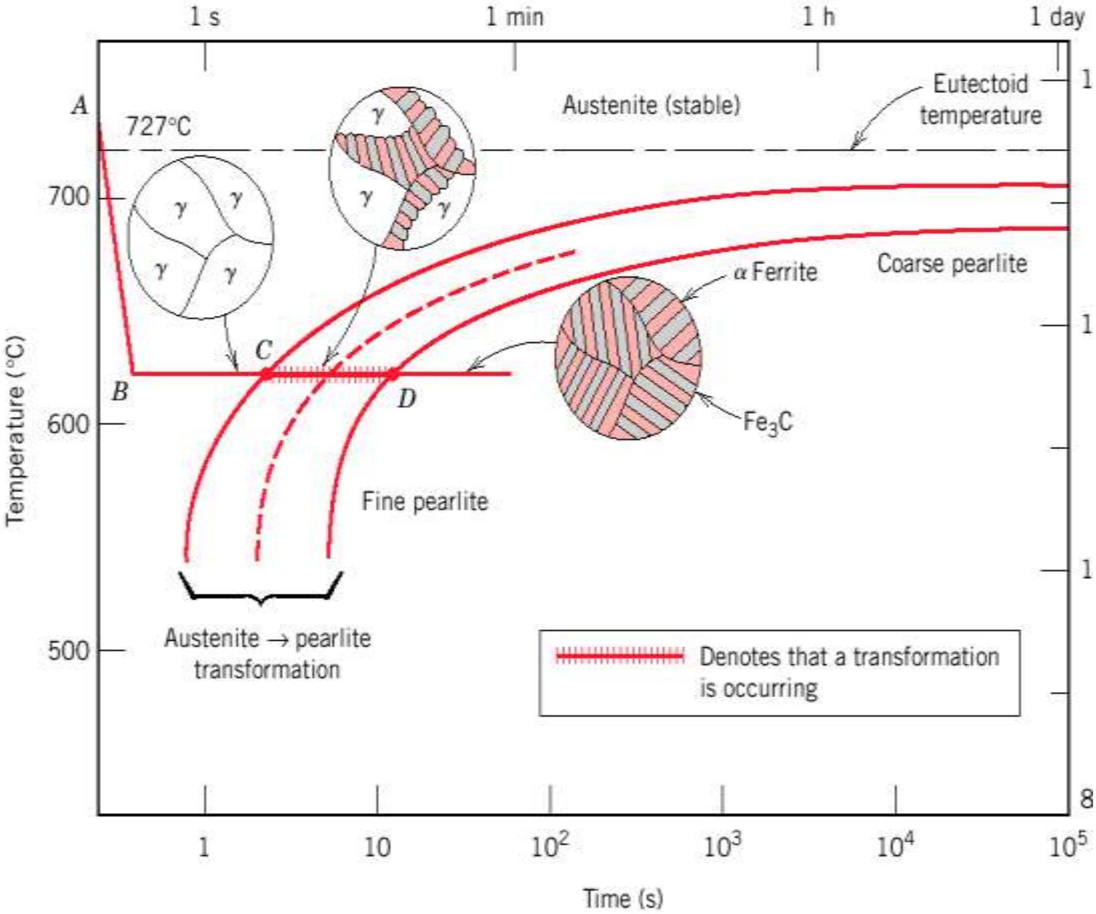
(body-centered tetragonal)

The time-temperature transformation curves correspond to the ***start*** and ***finish of transformations*** which extend into the range of temperatures where **austenite** transforms to **pearlite**.

- Above 550 C, austenite transforms completely to pearlite.
- Below 550 C, both pearlite and bainite are formed.
- below 450 C, only bainite is formed.

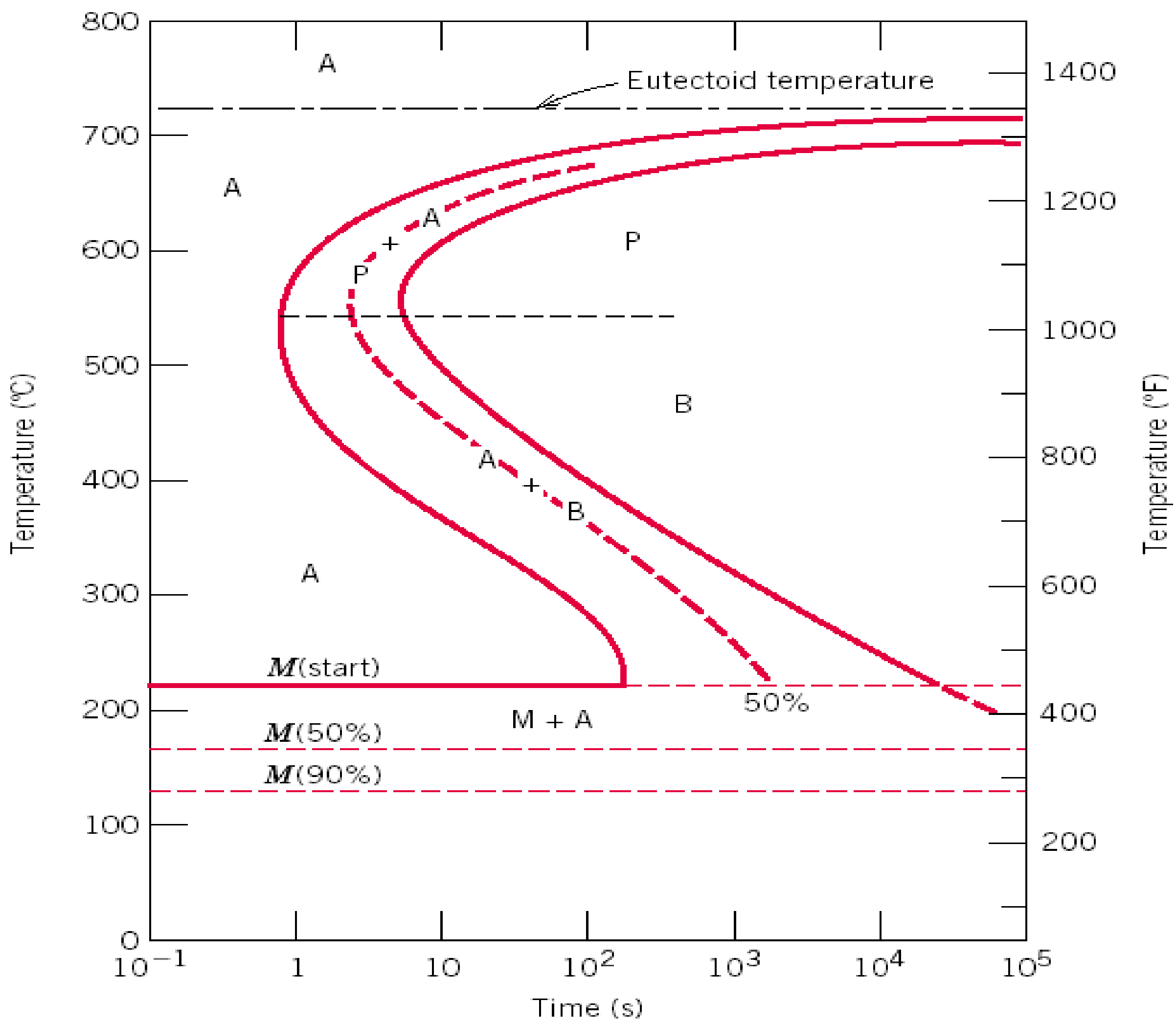
From The below fig. :-

- ***The horizontal line C-D that runs between the two curves marks the beginning and end of isothermal transformations***.
- ***The dashed line curves that represents the time to transform half the austenite to pearlite***.



NOTES

- ***The thickness of the ferrite and cementite layers in pearlite phase is ~ 8:1.***
- ***The absolute layer thickness depends on the temperature of the transformation.***
- ***The higher the temperature, the thicker the layers.***



The complete isothermal transformation diagram for an iron-carbon alloy of eutectoid composition.

A: austenite , B: bainite , M: martensite , P: pearlite

<u>TTT diagram gives</u>

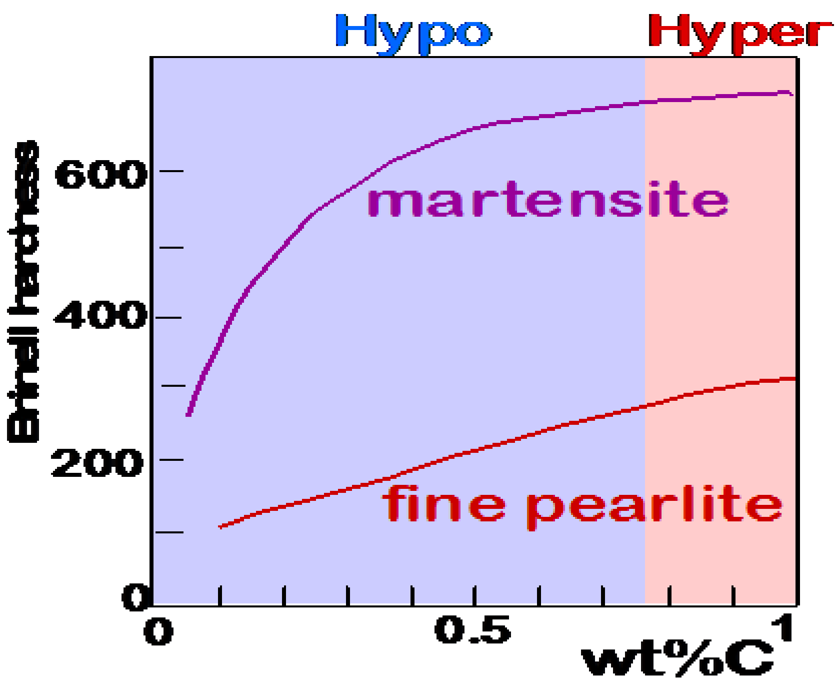
1- ***Nature and type of transformation .***
2- ***Rate of transformation.***
3- ***Stability of phases under isothermal transformation conditions.***
4- ***Temperature or time required to start or finish transformation .***
5- ***Qualitative information about size scale of product .***
6- ***Hardness of transformed products.***

Factors affecting TTT diagram

1- Composition of steel-
(a) carbon wt%,
(b) alloying element wt%
2- Grain size of austenite
3- Heterogeneity of austenite.

Mechanical Properties of Fe-C Systems

For example :- Fine Pearlite vs Martensite structures



Hardness: fine pearlite << martensite

Example (1) :-

Eutectoid steel cooled from austenite phase at 800 C ,then cooled as (TTT diagram) as below , find the final structure if cooling path as following :

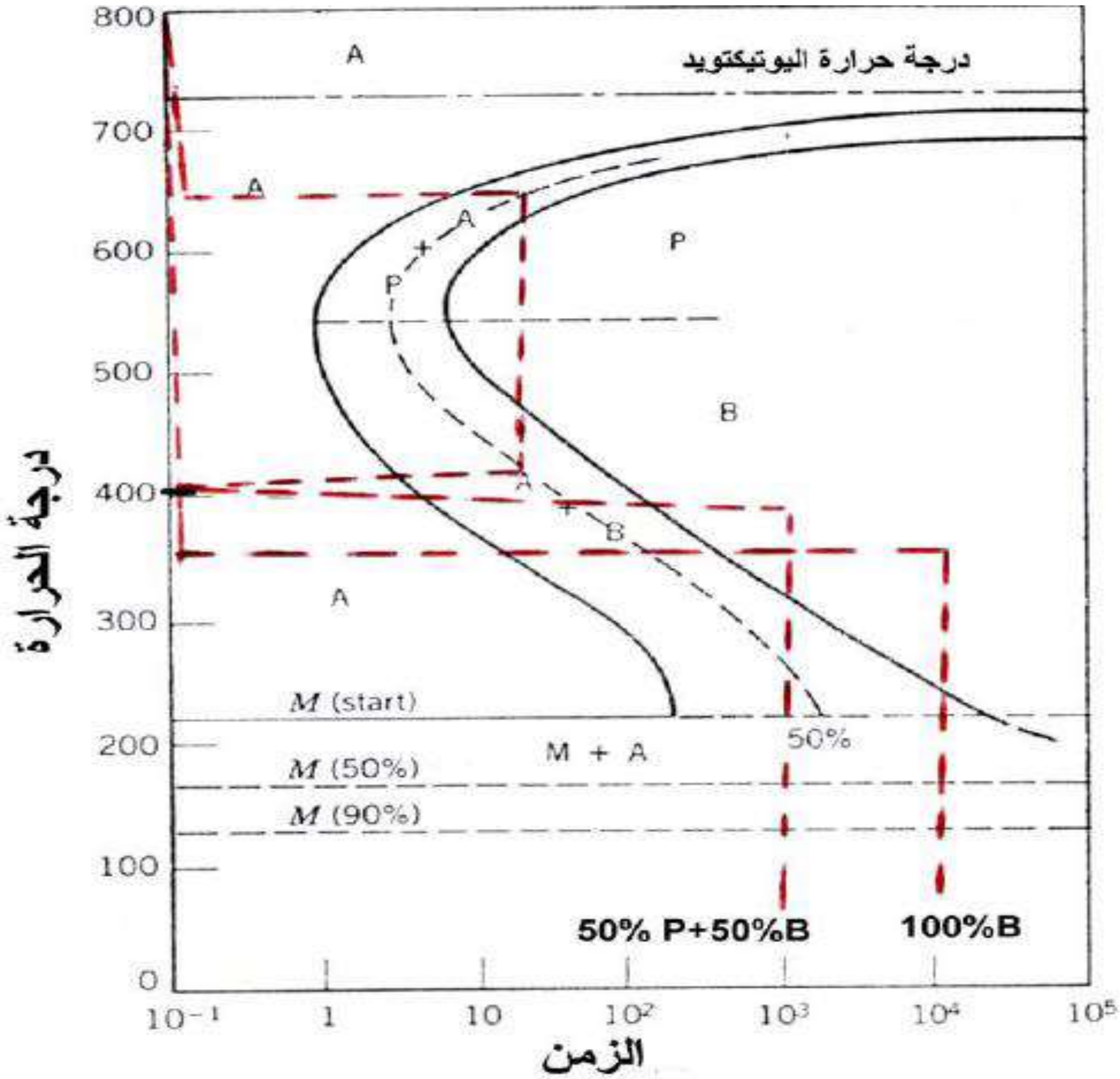
1- rapid cooling to (350 C) and hold to(10^4 sec) , then rapid cooling to room temperature .

2- rapid cooling to (650 C) and hold to(20 sec) , then, rapid cooling to (400 C) and hold at (10^3 sec) , then cooled to(room temperature .

ANS.:- From TTT diagrams below

1- Austenite transform to 100% bainite .

2- Austenite transform to 50% bainite and 50% perlite .



Example (2)

Using the isothermal transformation diagram for an iron-carbon alloy of eutectoid composition, specify the nature of the final microstructure of a small specimen that has been subjected to the following time-temperature treatments.

The specimen begins at 760°C and that it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure.

(a) Rapidly cool to 250°C, hold for 100s, and quench to room temperature

(b) Rapidly cool to 600°C, hold for 10^4 s, and quench to room temperature

Ans :-

1- At 760°C: in the austenite region (g) — 100% austenite

2-Rapidly cool from 760°C to 250°C: 100% austenite

3-Hold for 100 seconds at 250°C: 100% austenite

4-Quench to room temp.: 100% martensite

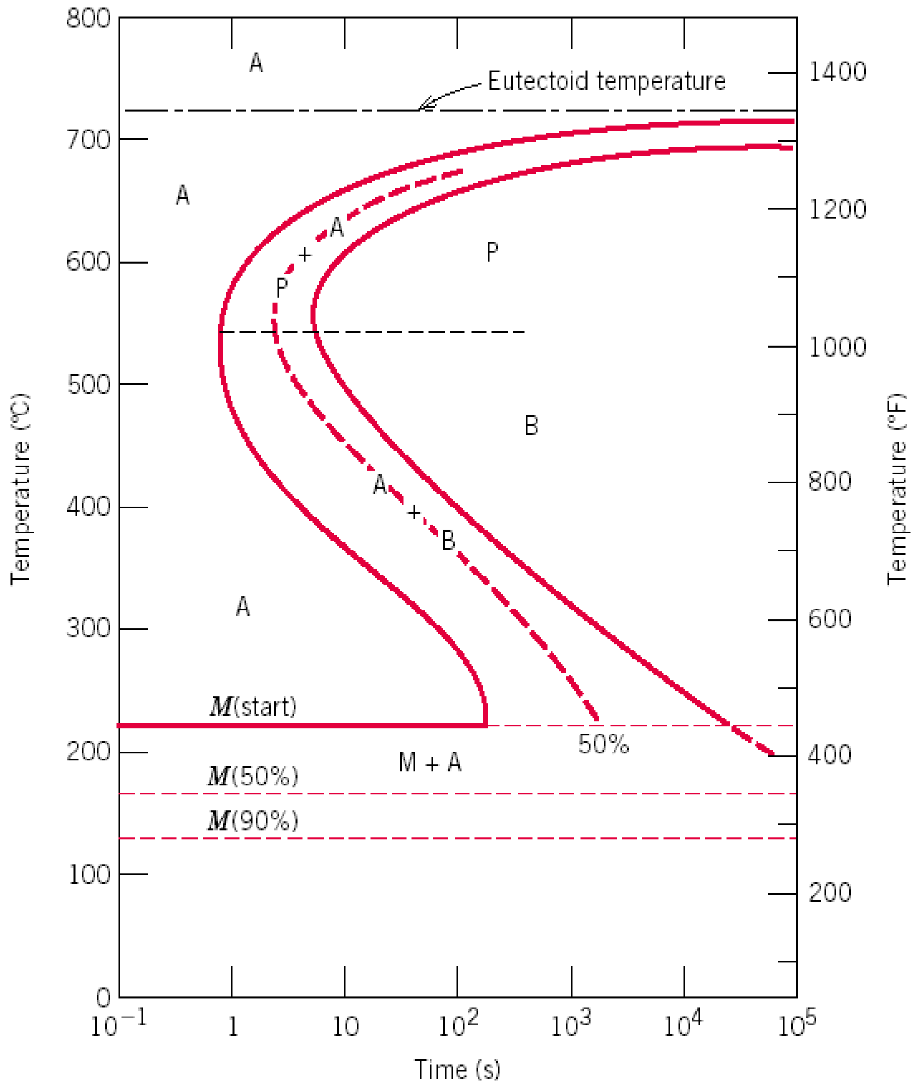
B /

1-At 760°C: in the austenite region — 100% austenite

2-Rapidly cool from 760°C to 600°C: 100% austenite

3-Hold for 10^4 s at 250°C: 100% pearlite

4-Quench to room temp.: 100% pearlite



Example 3 :- (home work)

Samples of Eutectoid steel heated to austenite phase at (850 C) for (1 hr.) ,then cooling as the (TTT diagram) as below .

find the final structure for each sample .

1- rapid cooling to room temperature .

2- rapid cooling to (690 C) and hold to(2 hr.) , then, rapid cooling to room temperature .

3- rapid cooling to (610 C) and hold to(3 min.) , then, rapid cooling to room temperature .

4- rapid cooling to (580 C) and hold to(2 sec) , then, rapid cooling to room temperature .

5- rapid cooling to (450 C) and hold to(1 hr.) , then, rapid cooling to room temperature .

6- rapid cooling to (300 C) and hold to(7 min.) , then, rapid cooling to room temperature .

٧- rapid cooling to (300 C) and hold to(5 hr.) , then, rapid cooling to room temperature .