응고 (solidification)

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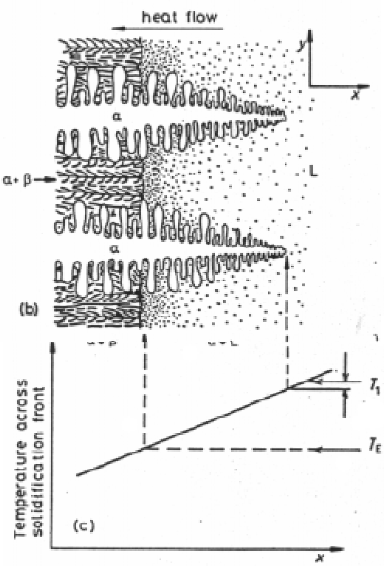
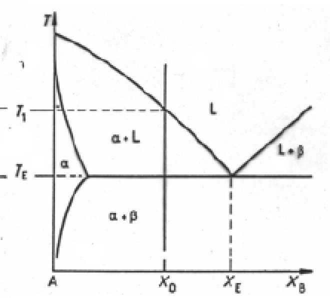
4.3.3 Off-eutectic Solidification

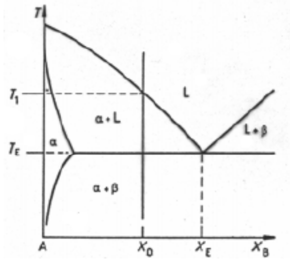


Under steady-state unidirectional solidification conditions at X_0 in the presence of a shallow temperature gradient, draw the possible microstructure of solidification front.



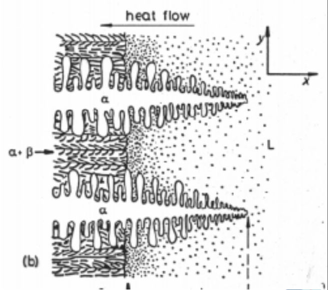
Off-eutectic Solidification

- Off-eutectic solidification
  - Primary α dendrites form at T_1. Rejected solute increases X_L to X_E; eutectic solidification follows.
  - Coring : primary α (low solute) at T_1 and the eutectic (high solute) at T_E.

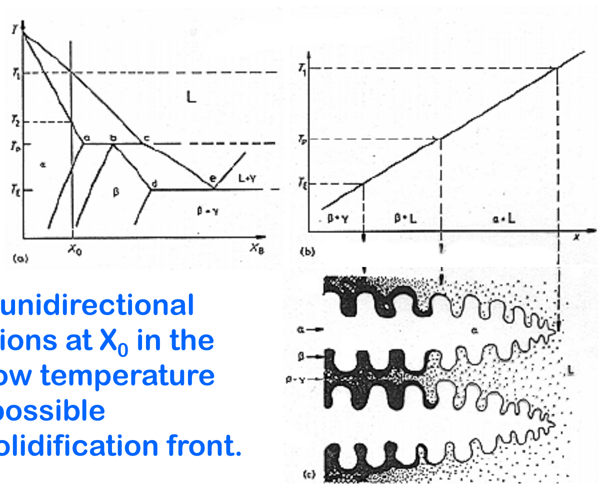


What would happen if the temperature gradient in the liquid is raised above the critical gradient of constitutional supercooling?

→ The alloy solidifies as 100% 'eutectic' with an overall composition X_0 instead of X_E. →in-situ composite materials



4.3.4 Peritectic Solidification

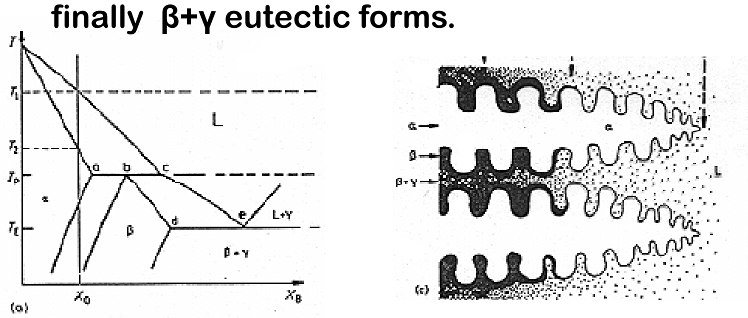


Under steady-state unidirectional solidification conditions at X_0 in the presence of a shallow temperature gradient, draw the possible microstructure of solidification front.

Hint : $L + \alpha \rightarrow \beta$

Peritectic Solidification

- Peritectic Solidification
  - L + α → β , Difficult to complete.
  - α dendrites first form at T1;
    Liquid reaches the composition ‘c’;
    β forms as the result of the peritectic reaction;
    α coring is isolated from further reaction
    finally β+γ eutectic forms.



4.4 Solidification of Ingots and Castings

Ingot Structure

- Chill zone
- Columnar zone
- Equiaxed zone

Chill zone

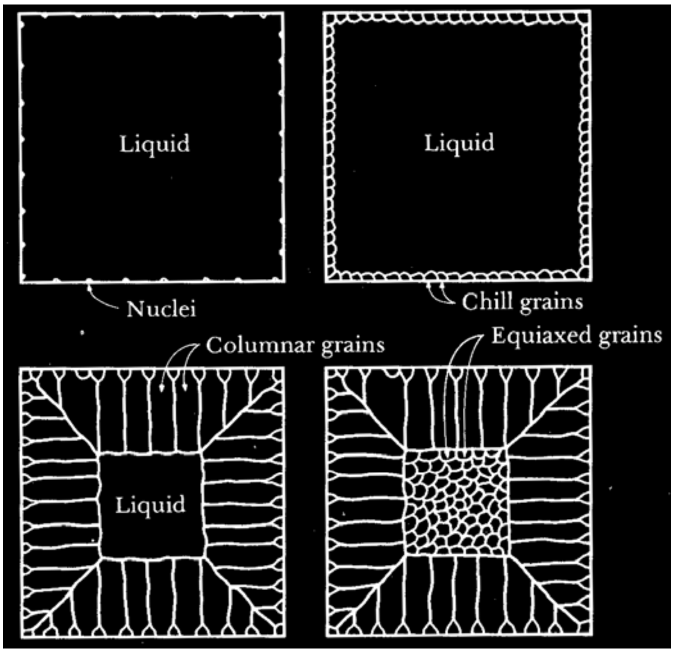
- Solid nuclei form on the mould wall and begin to grow into the liquid.
- As the mould wall warms up it is possible for many of these solidified crystals to break away from the wall under the influence of the turbulent melt.

Columnar zone

After pouring the temperature gradient at the mould walls decreases and the crystals in the chill zone grow dendritically in certain crystallographic directions, e.g. <100> in the case of cubic metals.

Equiaxed zone

The equiaxed zone consists of equiaxed grains randomly oriented in the centre of the ingot. An important origin of these grains is thought to be melted-off dendrite side-arms.



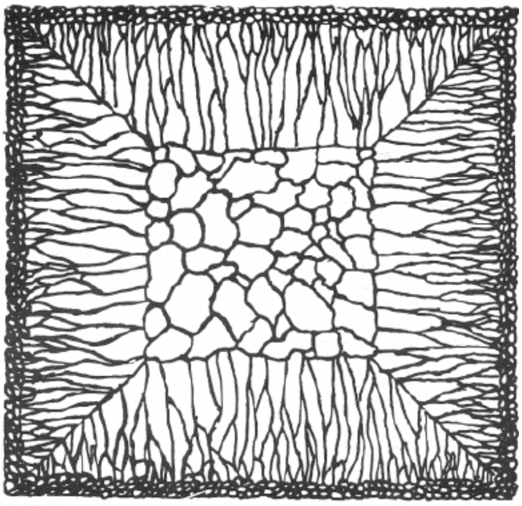


Fig. 4.40 Schematic cast grain structure.
(After M.C. Flemings, *Solidification Processing*, McGraw-Hill, New York, 1974.)

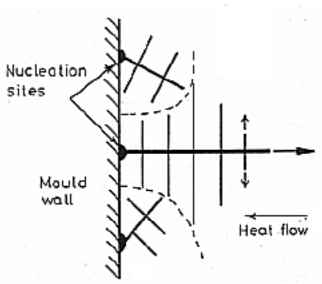


Fig. 4.41 Competitive growth soon after pouring. Dendrites with primary arms normal to the mould wall, i.e. parallel to the maximum temperature gradient, outgrow less favorably oriented neighbors.

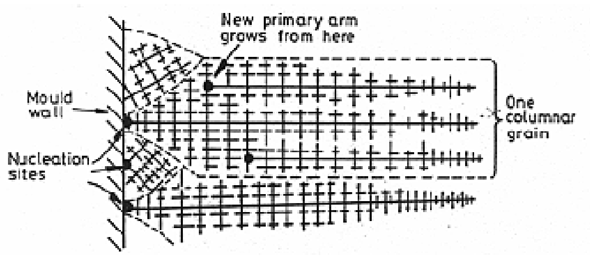


Fig. 4.42 Favorably oriented dendrites develop into columnar grains. Each columnar grain originates from the same heterogeneous nucleation site, but can contain many primary dendrite arms.

4.5 Solidification of Fusion Welds

The effect of dilution & Affect the weld metal

- The composition of the melt is changed.
- The surface oxide layer of the base metal is removed.
- It cools down the melt.

Welding is a dynamic process in which the heat source is continuously moving. The maximum temperature gradients are contstantly changing direction as the heat source moves away.

=> Growing columnar crystals :
Maximum temperature gradient + maintain growth direction <100>

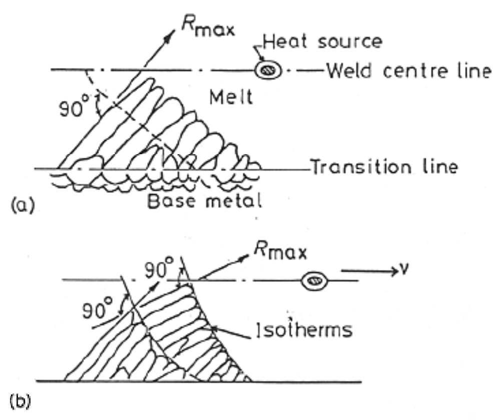


Fig. 4.48 Illustrating the growth of columnar crystal in the weld, and how growth continues to occur approximately normal to the isotherms.

Influence of Welding Speed

An important effect of increasing the welding speed is that the shape of the weld pool changes from an elliptical shape to a narrower, pear shape.

- Geometry of crystal growth :

TIG (Low speed) vs
Submerged Arc Weld (High speed)

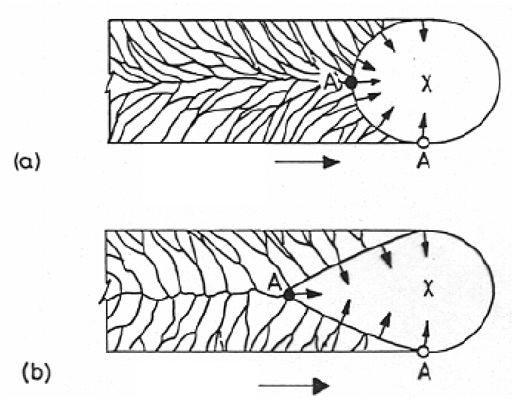
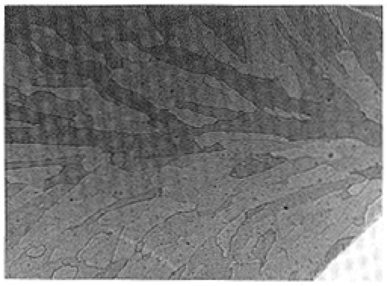


Fig. 4.49 Illustrating the effect of increasing welding speed on the shape of the melt pool and crystal growth in fusion welds.



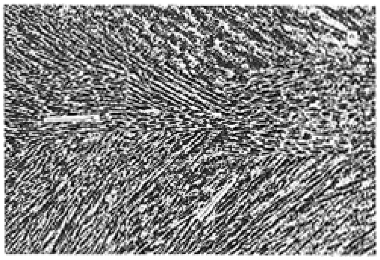


Fig. 4.50 (a) TIG weld of nickel, illustrating low crystal growth speed x 25 (by Gudrun Keikkala, University of Lulea, Sweden).
(b) Submerged arc weld of steel, illustraing high growth speed x 24 (by H. Astrom, University of Lulea, Sweden).