Solidification time :-

The rate at which growth of the solid occurs during solidification depends on the cooling rate, or rate of heat extraction.

A fast cooling rate produces rapid solidification or short solidification time.

The time required for a simple casting to solidify completely can be calculated using Chvorinov's rule.

$$t_s = B\left(\frac{V}{A}\right)^2$$

where t_s is the time required for the casting to solidify,
V is the volume of the casting,
A is the surface area of the casting in contact with the mold, &
B is a mold constant.

The mold constant depends on the properties and initial temperatures of both the metal and the mold.

Almost always, a shorter solidification time produces a finer grain size and a stronger casting.

EX:- Two castings are produced under identical conditions. One casting has the dimensions 2 cm x 8 cm x 16 cm, and the dimensions of the second casting are 3 cm x 6 cm x 8 cm. which casting will be stronger?

Ans : The casting that freezes in the shortest time should have the higher strength.
from chvorinov's rule

$$t_{s_1} = B\left[\frac{2 \times 8 \times 16}{(2)(2)(8) + (2)(2)(16) + (2)(8)(16)}\right]^2$$

$$= B\left(\frac{256}{352}\right)^2 = 0.53B$$

$$t_{s_2} = B\left[\frac{(3)(6)(8)}{(2)(3)(6)+(2)(3)(8)+(2)(6)(8)}\right]^2$$

$$= B\left[\frac{144}{180}\right]^2 = 0.64\,B$$

Because $t_1 < t_2$

the 2 cm × 8 cm × 16 cm casting freezes faster and is stronger.

The solidification time also affects the size of the dendrites that grow.

Normally, the dendrite size is characterized by measuring the distance between the secondary dendrite arms (fig 7).

The secondary dendrite arm spacing, or SDAS, is reduced when the casting freezes more rapidly. Because there is less time available to transfer heat, additional dendrite arms develop and grow to assist with the evolution of the latent heat.

The finer, more extensive dendritic network serves as a more efficient conductor of the latent heat to the undercooled liquid.

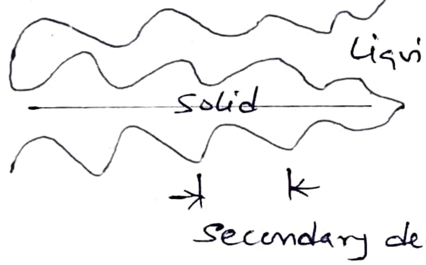

fig 7: The secondary dendrite arm spacing SDAS.

The SDAS is related to the solidification time by

$$SDAS = k\,t_s^n$$

where n & k are constants depending on the composition of the metal. This relationship is shown in fig (8) for several alloys.

Small secondary dendrite arm spacings are associated with higher strength and improved ductility. fig (9).

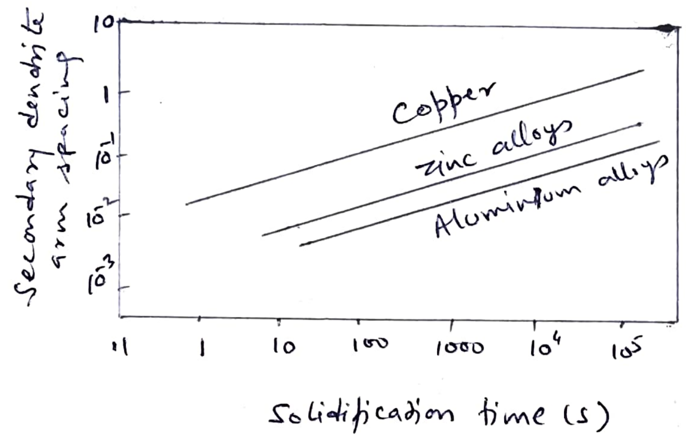

Fig 8: The effect of solidification time on the secondary dendrite arm spacings of copper, zinc & Aluminium.

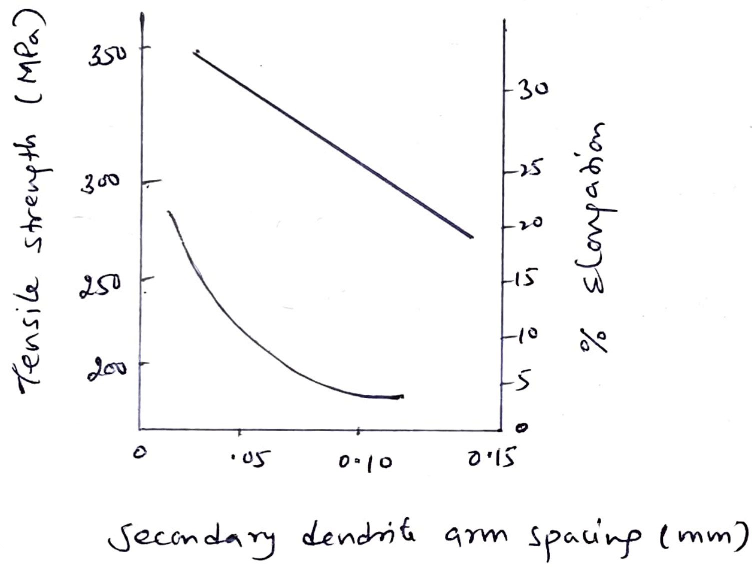

Fig 9: The effect of the secondary dendrite arm spacing on the properties of an aluminum casting alloy.

Rapid solidification processing is used to produce exceptionally fine secondary dendrite arm spacings; a common method is to produce very fine liquid droplets using special atomization processes. The tiny droplets freeze at a rate of about 10^4 °C/s. This cooling rate is not rapid enough to form a metallic glass but does produce the tiny dendritic structure.

By carefully consolidating the solid droplets by powder metallurgy processes, improved properties in the material can be obtained.