Solidification Defects :

Although there are a large number of potential defects that can be produced during solidification, two deserve special ~~atten~~ mention.

Shrinkage :

Almost all materials are more dense in the solid state than in the liquid state (fig 13). During solidification, the material contracts, or shrinks, as much as 7%. (Table 1)

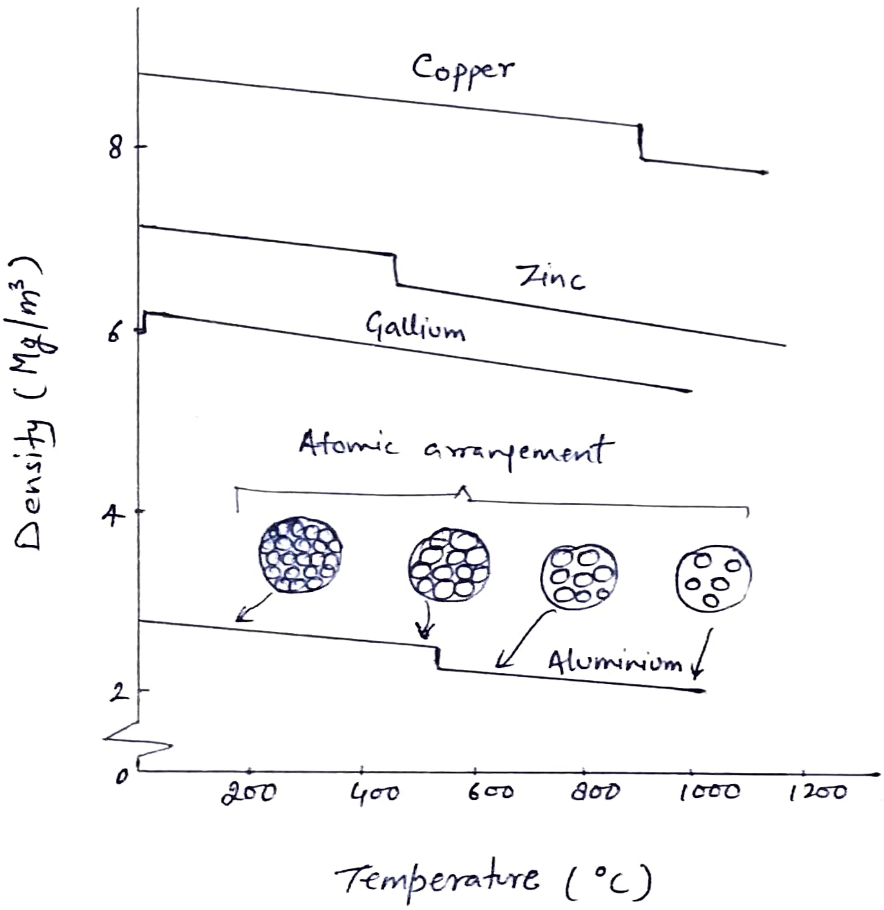

Fig 13 : The density of selected metals versus temperature. Most metals have a higher density as solids than as liquids and thus contract during solidification. Note that gallium has the opposite behavior.

Table 1 :- shrinkage during solidification for selected materials

Material	shrinkage (%)		
Al	7.0	Ga	+ 3.2 (expansion)
CU	5.1	H_2O	+ 8.3 (expansion)
Mg	4.0		
Zn	3.7		
Fe	3.4		
Pb	2.7		

If the shrinkage is unidirectional (fig 14), only one dimension of the solid casting would be smaller than the dimensions of the mold.

The mold could then be made oversized by the ~~approximate~~ appropriate amount in order to compensate for the shrinkage.

However, in most situations, the bulk of the shrinkage occurs as cavities,

if ~~If~~ solidification begins at all surfaces of the casting, or as pipes, if one surface solidifies more slowely than the others. In either case, the casting is defective.

A common technique for controlling cavity & pipe shrinkage is to place a riser, or an extra reservoir of metal, adjacent and connected to the casting (fig 15).

As the casting solidifies and shrinks, liquid metal flows from the riser into the casting to fill the shrinkage void.

We need only assure that the riser freezes after the casting and that there is an internal liquid channel that connects the liquid in the riser to the last liquid to solidify in the casting.

Chvorinov's rule can be used to help design the size of the riser.

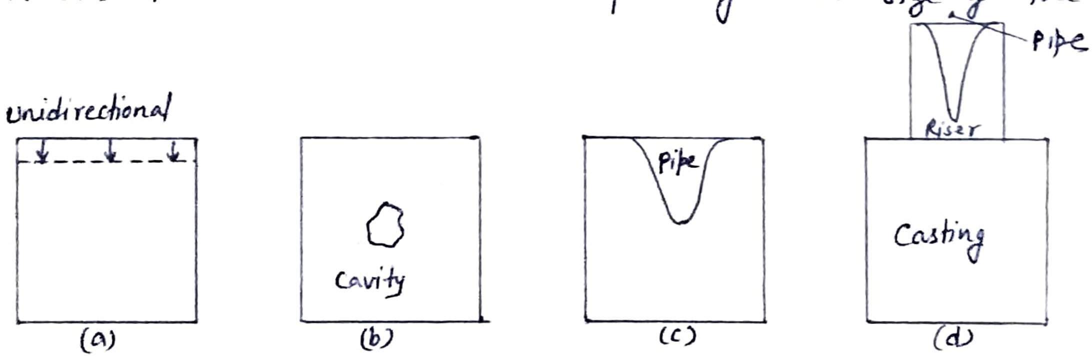

Fig 14 ;- several types of macroshrinkage can occur including
(a) unidirectional (b) cavity (c) pipe
(d) Risers can be used to help compensate for shrinkage.

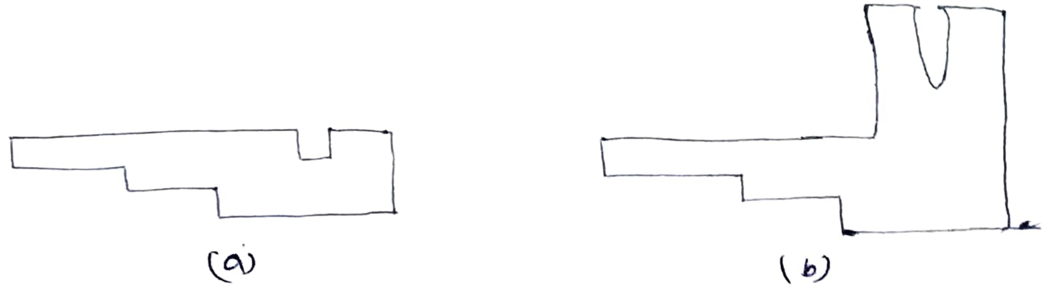

Fig 15: Sections through an aluminium casting.
(a) because no riser is used concentrated shrinkage is present in the thick part of the casting.
(b) shrinkage is contained in the riser, thus producing a sound casting.

EX :- A cylindrical riser with a height equal to twice its diameter is to compensate for shrinkage in a 20 mm x 80 mm x 160 mm casting (fig 16). Estimate the minimum size of the riser.

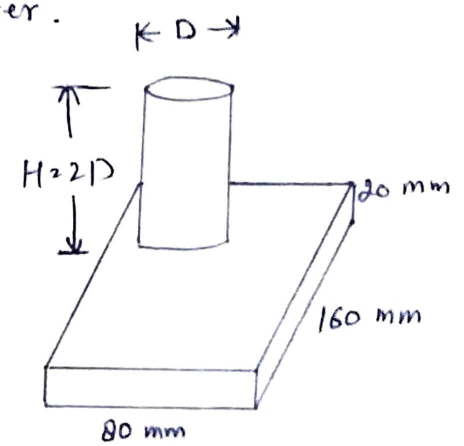

fig 16: Geometry of casting

Ans:

We know that the riser must freeze after the casting

~~$t_{riser} > t_{casting}$~~

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so $B\left(\frac{V}{A}\right)_r^2 > B\left(\frac{V}{A}\right)_c^2$

$\left(\frac{V}{A}\right)_r > \left(\frac{V}{A}\right)_c$

$V_c = (20)(80)(160) = 256 \times 10^3 \ mm^3$

$A_c = (2)(20)(80) + (2)(20)(160) + (2)(80)(160) = 352 \times 10^2 \ mm^2$

$V_r = \frac{\pi}{4} D^2 H = \frac{\pi}{4} D^2 (2D) = \frac{\pi}{2} D^3$

$A_r = 2\left(\frac{\pi}{4} D^2\right) + \pi D H = 2\left(\frac{\pi}{4} D^2\right) + \pi D (2D) = \frac{5}{2} \pi D^2$

$\frac{(\pi/2) D^3}{(5\pi/2) D^2} > \frac{256}{35.2}$ $\quad \frac{D}{5} > 7.27$ $\quad D > 36.4 \ mm$

$H > 72.8 \ mm$

$V_r > 75800 \ mm^3$

Although the volume of the riser is much smaller than that of the casting, the riser freezes more slowly due to its compact shape.

Interdendritic shrinkage is found when extensive dendritic growth occurs (fig 17).

Liquid metal may be unable to flow from a riser through the fine dendritic network to the solidifying metal. consequently, small shrinkage pores are produced throughout the casting. This defect, also called microshrinkage or shrinkage porosity, is diffcult to prevent by the use of risers.

Fast cooling rates may reduce problems with interdendritic shrinkage; the dendrites may be shorter, permitting liquid to flow through the dendritic network to the solidifying solid interface. In addition, any shrinkage that remains may be finer and more uniformly distributed.

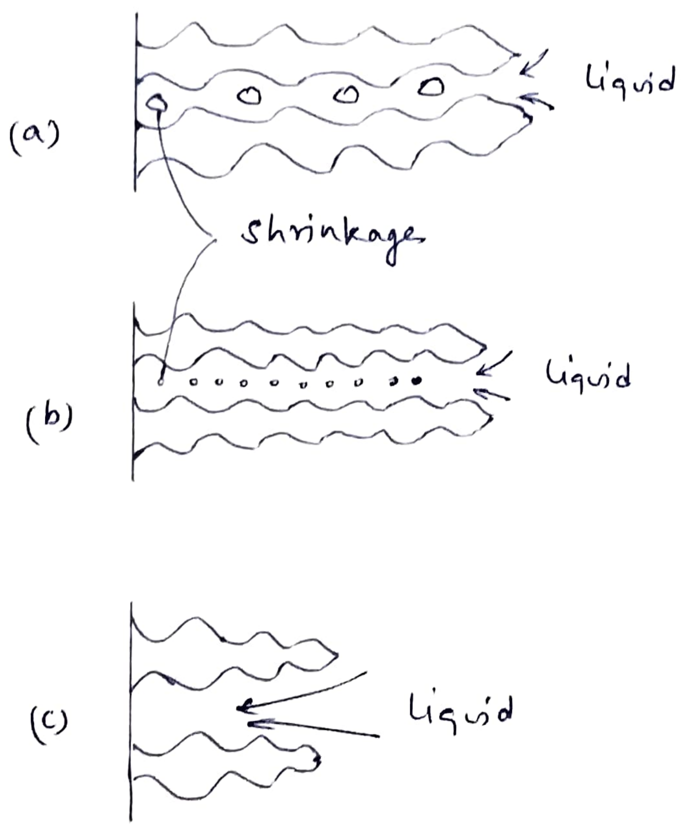

Fig 17: (a) Shrinkage can occur between the dendrite arms. small secondary dendrite arm spacings result in smaller, more evenly distributed shrinkage porosity.

(b) while short primary arms can help avoid shrinkage.

(c) Interdendritic shrinkage in an aluminium alloy.