Gas Porosity:

Many metals dissolve a large quantity of gas when they are liquid.

Aluminium, for example, dissolves hydrogen. However, when the aluminium solidifies, the solid metal retains in its structure only a small fraction of the hydrogen (fig 18). the excess hydrogen forms bubbles that may be trapped in the solid metal, producing gas porosity.

The porosity may be spread uniformly throughout the casting or may be trapped between dendrite arms.

The amount of gas that can be dissolved in the molten metal is given by Sievert's Law.

$$\text{Percent of gas} = K\sqrt{P_{gas}}$$

where P_{gas} is the partial pressure of the gas in contact with the metal and K is a constant which, for a particular metal gas system, increases with increasing temperature.

We can minimize gas porosity in casting by keeping the liquid temp low, by adding materials to the liquid to combine with the gas and form a solid, or by assuring that the partial pressure of the gas remains low.

The latter may be achieved by placing the molten metal in a vacuum chamber or bubbling an inert gas through the metal. Because P_{gas} is low in the vacuum or inert gas, the gas leaves the metal, enters the vacuum or inert gas, and is carried away.

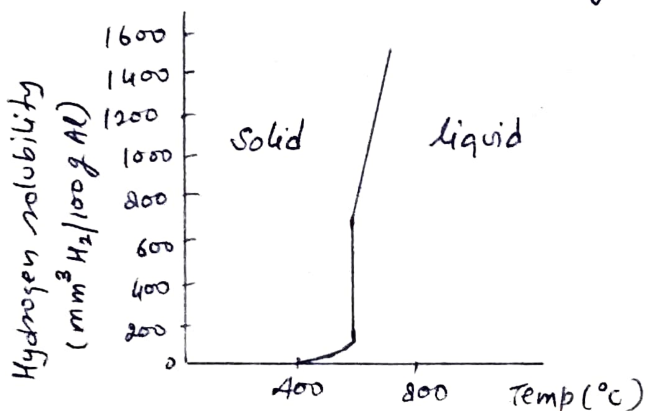


Fig 18: The solubility of hydrogen gas in aluminium. Although solid aluminium contains very little hydrogen, the amount of hydrogen that dissolves in liquid aluminium is large and increases rapidly with temperature.

Ex:

After melting at atmospheric pressure, molten copper contains 0.01% O. How much oxygen would remain if the molten copper were placed in a vacuum at 10^{-6} atm?

Ans: The ratio of the partial pressure of oxygen before & during the vacuum treatment will be the same as the ratio of the total pressures. Thus

$$\frac{p_{initial}}{p_{vacuum}} = \frac{1}{10^{-6}} = 10^{6}$$

by forming a ratio, the constant K in Sievert's Law cancels.

$$\frac{\%\,O_{initial}}{\%\,O_{vacuum}} = \frac{K\sqrt{p_{initial}}}{K\sqrt{p_{vacuum}}} = \sqrt{\frac{p_{initial}}{p_{vacuum}}} = \sqrt{10^{6}}$$

$$\%\,O_{vacuum} = \frac{\%\,O_{initial}}{\sqrt{10^{6}}} = (0.01)(10^{-3})$$

$$= 1\times10^{-5}\,\%$$

Oxygen is often dissolved in liquid steel during the steel-making process. During solidification, the dissolved oxygen combines with carbon, which is present as an alloying element, and carbon monoxide (CO) gas bubbles are trapped in the steel casting.

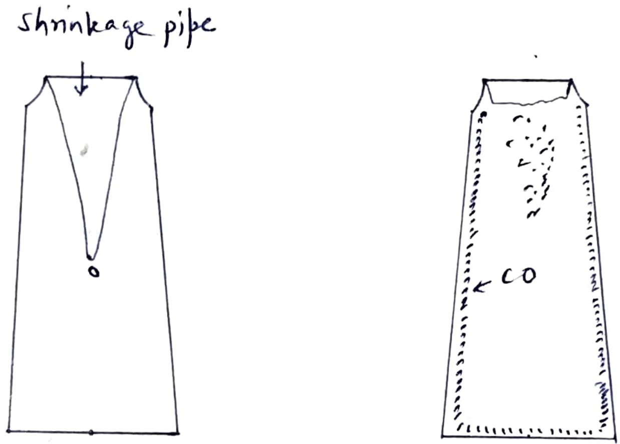
The dissolved oxygen can be completely eliminated, however, if aluminum is added prior to solidification. The aluminum combines with oxygen, producing solid alumina (Al_2O_3).

In addition to eliminating gas porosity, the tiny Al_2O_3 inclusions are instrumental in pinning grain boundaries and thus preventing grain growth during later high-temperature heat treatments.

Unfortunately, the completely deoxidized steel, known as killed or fine grained steel, often displays a deep shrinkage pipe or cavity fig (19a).

Sometimes steels are only partly deoxidized. By adding a small amount of aluminum, a rimmed steel is produced in which enough CO is precipitated to just offset the solidification shrinkage (fig 19b).

In addition to having less concentrated shrinkage, a rimmed steel helps to produce smooth, attractive surfaces on steel sheet after subsequent processing.



Killed
(a)

Rimmed
(b)

Fig 19: The ingot structure of (a) a killed &
(b) a Rimmed steel
after different degrees of deoxidation with aluminum.
The killed steel, which is free of gas porosity, contains a deep pipe, & the rimmed steel, which contains distributed porosity, is relatively free of shrinkage.