# Influence of hydrogen in weld joints

This chapter presents influence of hydrogen in weld joints on the soundness and performance of weld joints. Further, different types of fluxes, their stability and effect on weld have been described. The concept of basicity index of the fluxes and its effect on weld has also been elaborated.

**Keywords:** Cold cracking, hydrogen induced porosity, sources of hydrogen, hydrogen solubility, basicity of flux, stability of oxides, acidic and basic fluxes

### 36.1 Effect of hydrogen on steel and aluminium weld joints

#### Hydrogen

Hydrogen in weld joints of steel and aluminium is considered to be very harmful as it increases the cold cracking tendency in hardenable steel and porosity in aluminium welds. Hydrogen induced porosity in aluminium welds is formed mainly due to high difference in solubility of hydrogen in liquid and solid state. The hydrogen rejected by weld metal on solidification if doesn't get enough time for escaping then it is entrapped in weld and results in hydrogen induced fine porosity. Welds made using different processes produce varying hydrogen concentration owing to difference in solidification time, moisture associated with consumable and protection of the weld pool from atmospheric gases, use of different consumables (Fig. 36.1). Hydrogen in steel and aluminium weld joint is found mainly due to high difference in solubility of hydrogen in liquid and solid state (Fig. 36.2).

Cold cracking is caused by hydrogen especially when hard and brittle martensitic structure is formed in the weld and HAZ of hardenable steel. Many theories have been advanced to explain the cold cracking due to hydrogen. Accordingly to one of hypothesis, hydrogen diffuses towards the vacancies, grain boundary area and other crystallographic imperfections. At these locations, segregation of the hydrogen results in first transformation of atomic hydrogen into gaseous molecules and then builds up the pressure until it is high enough to cause growth of void by propagation of cracks in one of directions having high stress concentration as shown in Fig. 36.3. Thereafter, process of building up of the pressure and growth of crack is repeated until complete fracture of the weld without any external load occurs. Existence of external or residual tensile stresses further accelerate the crack growth rate and so lower the time required for failure to occur by cold cracking. Presence of both of above discontinuities (cracks and porosity) in the weld decreases mechanical performance of weld joint. Hydrogen in arc zone can come from variety of sources namely:

- moisture ($H_2O$) in coating of electrode or on the surface of base metal,
- hydrocarbons present on the faying surface of base metal in the form of lubricants, paints etc
- inert gas (Ar) mixed with hydrogen to increase the heat input
- hydrogen in dissolved state in metal (beyond limits) being welded such as aluminium and steel

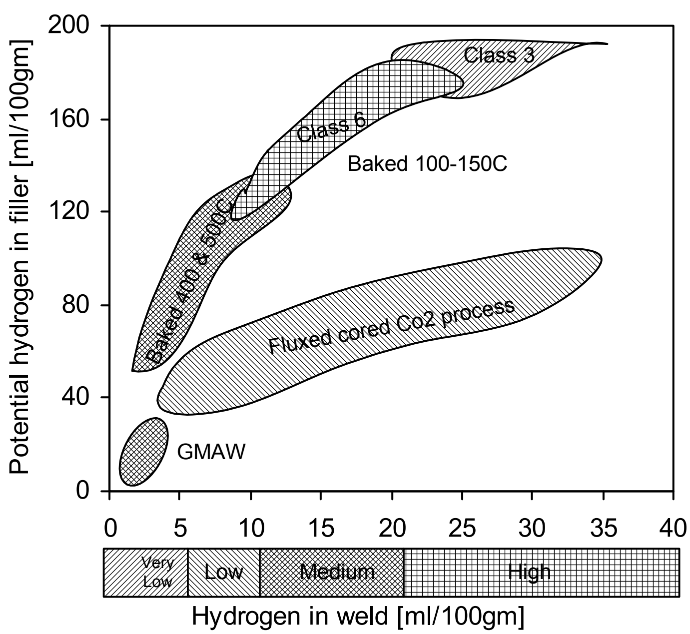



Fig. 36.1 hydrogen content in weld developed using different welding processes

It has been reported that proper baking of electrodes directly reduces the cold cracking tendency and time for failure delayed cracking. Therefore, attempt should be made to avoid the hydrogen from above sources by taking suitable corrective action.

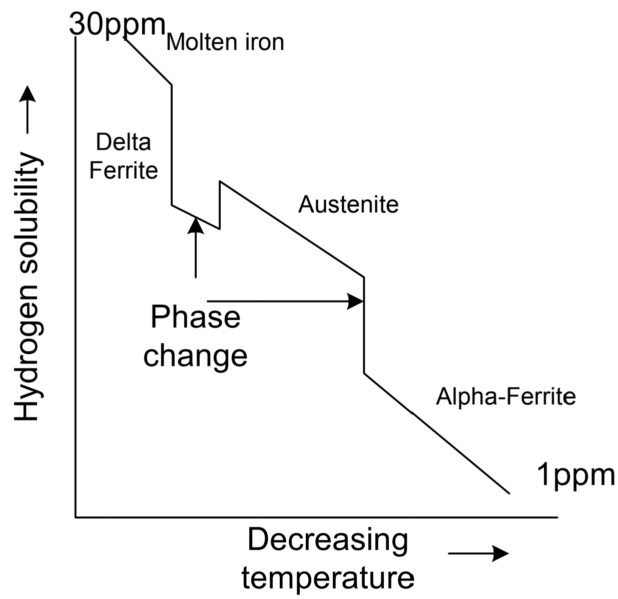



Fig. 36.2 Schematic of hydrogen solubility as a function of temperature of iron

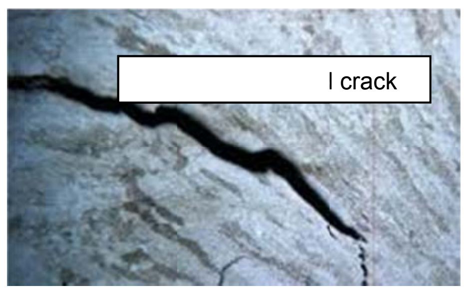



Fig. 36.3 Hydrogen induced crack

## 36.2 Flux in welding

Fluxes are commonly used to take care of problems related with oxygen and nitrogen. Variety of fluxes is used to improve the quality of the weld. These fluxes are grouped in three categories namely halide fluxes (mainly composed of chlorides and fluorides of Na, K, Ba, Mg) and oxide fluxes (oxides of Ca, Mn, Fe, Ti, Si) and mixture of halide and oxide fluxes. Halide fluxes are free from oxides and therefore these are mainly used for welding highly reactive metals having good affinity with oxygen such as Ti, Mg and Al alloys while oxide fluxes are used for welding of low strength and non-critical welds joints of steel. In general, calcium fluoride in flux reduces hydrogen concentration in weld (Fig. 36.4). Halide-oxide type fluxes are used for semi-critical application in welding of high strength steels.

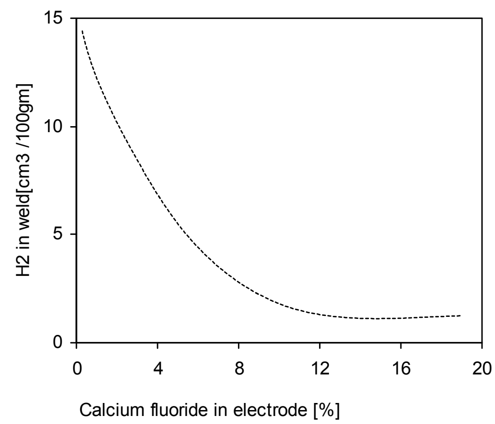


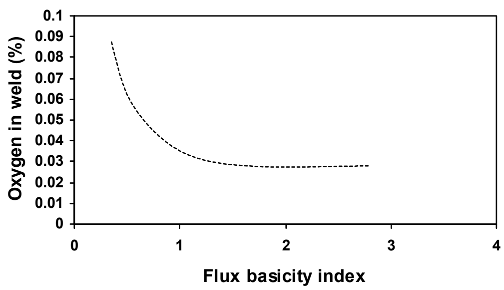

Fig. 36.4 Influence of calcium fluoride on hydrogen concentration in weld joints

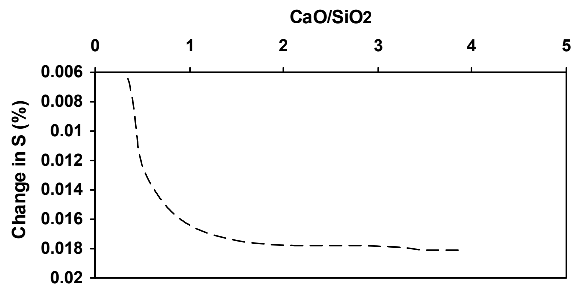
## 36.2 Basicity of the flux

The composition of fluxes is adjusted so as to get proper basicity index as it affects the ability of flux to remove impurities like sulpher and oxygen from melt. The basicity index of the flux refers to ratio of sum of amount of all basic oxides and that of non-basic oxides. Basic oxides (CaO is most common) are donors of the oxygen while acidic oxides (such as $SiO_2$) are acceptor of oxygen. Common acidic and basic oxides are shown in table below. Flux having BI <1 is called acidic flux, neutral fluxes have 1<BI<1.2 while basic fluxes have BI>1.2. Increase in BI of the flux from 1 to 5 results in significant decrease in sulphur content of the weld. The basic oxides act de-sulphurizer as sulphur is removed from the weld in the form of $SO_2$ by reaction between oxygen released by basic oxides and S. Thus, the weld is de-suphurized.

| Type of oxide | Decreasing Strength | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Acidic | $SiO_2$ | $TiO_2$ | $P_2O_5$ | $V_2O_5$ | | | |
| Basic | $K_2O$ | $Na_2O$ | CaO | MgO | BaO | MnO | FeO |
| Neutral | $Al_2O_3$ | $Fe_2O_3$ | $Cr_2O_3$ | $V_2O_3$ | ZnO | | |

In general, an increase in basicity of the flux up to 1.5 decreases the S and oxygen concentration (from about 900 PPM to 250 PPM) in weld joints as shown in Fig. 36.5 (a, b). Thereafter, oxygen content remains constant at about 200-250 PPM level despite of using fluxes of high basicity index. Further, there is no consensus among the researchers on the mechanism by which an increase in basicity index decreases the oxygen content.




a) b)

Fig. 36.5 Influence of basicity of flux on a) oxygen and b) sulphur concentration in weld.

These oxides get decomposed at high temperature in arc environment. Stability of each oxide is different. Oxides with decreasing stability are as follows: (i) $CaO$, (ii) $K_2O$, (iii) $Na_2O$ and $TiO_2$, (iv) $Al_2O_3$, (v) $MgO$, (vi) $SiO_2$, (vii) $MnO$ and $FeO$. On decomposition, these oxides invariably produce oxygen and result-in oxidation of reactive elements in weld metal.

**References and books for further reading**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