The Need For Protecting The Weld And Rationale

This chapter presents the need of protecting the weld and rationale behind variations in cleanliness of the weld developed by different welding processes. The gas metal reactions and slag metal reactions have also been described besides their effect on elemental transfer efficiency.

Keywords: Cleanliness of weld, gas metal reaction, weld composition, oxides and nitrides, element transfer efficiency

35.1 Welding process and cleanliness of the weld

In fusion welding, the application of heat of the arc or flame results in the melting of the faying surfaces of the plates to be welded. At high temperature metals become very reactive to atmospheric gases such as nitrogen, hydrogen and oxygen present in and around the arc environment. These gases either get dissolved in weld pool or form their compound. In both the cases, gases adversely affect the soundness of the weld joint and mechanical performance. Therefore, various approaches are used to protect the weld pool from the atmospheric gases such as developing envelop of inactive (GMAW, SMAW) or inert gases (TIGW, MIGW) around arc and weld pool, welding in vacuum (EBW), covering the pool with molten flux and slag (SAW, ESW). The effectiveness of each method for weld pool protection is different. That is why adverse effect of atmospheric gases elding processes is different (Fig. 35.1).

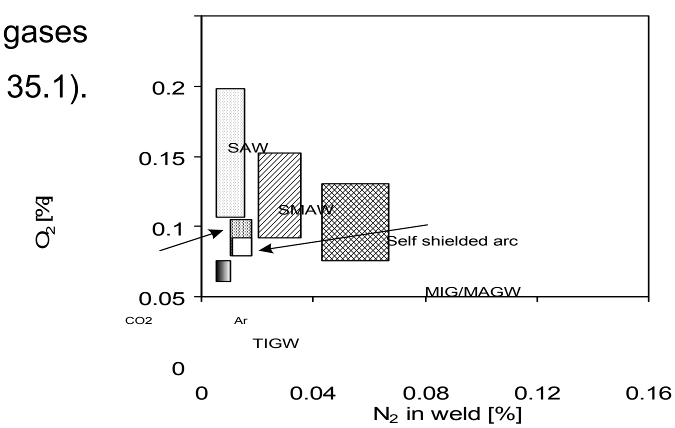

Fig. 35.1 Schematic diagram showing nitrogen and oxygen content in different welding processes

Amongst the most commonly used arc welding processes, the cleanest weld (having minimum nitrogen and oxygen) is produced by gas tungsten arc welding (GTAW) process due to two important factors associated with GTAW: a) short arc length and b) very stable arc produced by using non-consumable tungsten electrode. A combination of short and stable arc with none-consumable tungsten electrode results a firm shielding of arc and protection of the weld pool by inert gases restricts the entry of atmospheric gases in the arc zone. Gas metal arc welding (GMAW) also offers clean weld but not as clean as produced by GTAW because in case of GMAW arc length is somewhat greater and arc stability is poorer than GTAW. Submerged arc weld (SAW) joints are usually high in oxygen and less in nitrogen because SAW uses flux containing mostly metallic oxides. These oxides decompose and release oxygen in arc zone. The self shielded fluxed cored metal arc welding processes use electrodes having fluxes in core act as de-oxidizer and slag formers to protect the weld pool. However, weld produced by the self shielded fluxed arc welding processes are not as clean as those produced with GMAW.

35.2 Effect of atmospheric gases on weld joint

The gases present in weld zone (atmospheric or dissolved in liquid metal) affect the soundness of weld joint. Gases such as oxygen, hydrogen, nitrogen etc. are commonly present in and around the liquid metal. Both oxygen and hydrogen are very important in welding of ferrous and non-ferrous metals; these are mostly produced by decomposition of water vapours (H_2O) in high arc temperature. Oxygen reacts with carbon in case of steel to form CO or CO_2. These gases should escape out during the solidification; due to high solidification rate encountered in welding processes these gases may not come up to the surface of molten metal and may get trapped. This causes gaseous defects in the weldment, like porosity, blowhole etc. Chances for these defects further increases if the difference in solubility of these gases in liquid and solid state is high. Oxygen reacts with aluminium and form refractory alumina which forms inclusions and reduces the weldability. It's formation can be reduced by proper shielding of arc zone either by inert or inactive gases. Only source of nitrogen is atmosphere and it may form nitrides but it creates fewer problems. Hydrogen is a main problem creator in welding of steel and aluminium alloy due to high difference in liquid and solid state solubility. In case of steel, besides the porosity and blow holes hydrogen causes the problem of cold cracking even if it is present in very small amount, whereas in case of aluminium hydrogen causes pin hole porosity.

Oxides and nitrides formed by these gases if not removed from the weld, act as site of weak zone in form of inclusions which in turn lower the mechanical performance of the weld joint e.g. iron reacts with nitrogen to form hard and brittle needle shape iron nitride (Fe_4N) as shown in Fig. 35.2 (a, b). These needle shape micro-constituents offer high stress concentration at the tip of particle-matrix interface which under external tensile stresses facilitate the easy nucleation and propagation of crack, therefore fracture occurs at limited elongation (ductility). Similar logic can be given for reduction in mechanical performance of weld joints having high oxygen/oxide content. However, the presence of N_2 in weld metal is known to increase the tensile strength due to the formation of hardness and brittle iron nitride needles.

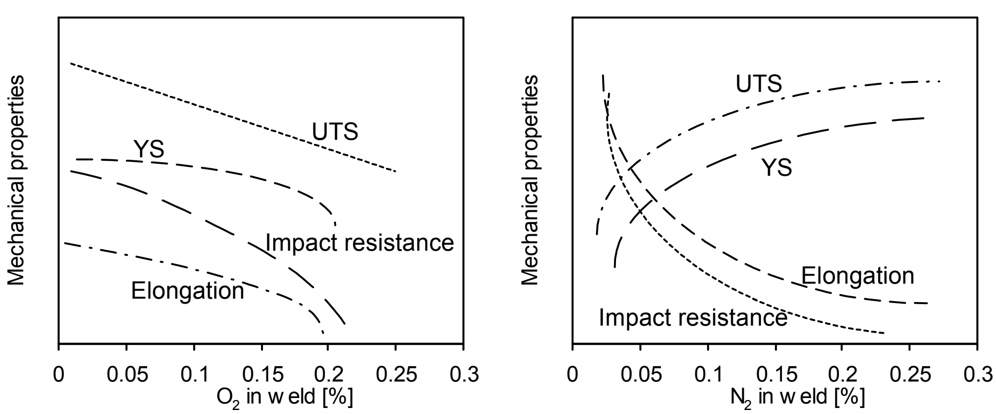

Fig. 35.2 Influence of oxygen and nitrogen as impurities on mechanical properties of steel weld joints

Additionally, these inclusions formed by oxygen, nitrogen and hydrogen break the discontinuity of metal matrix which in turn decreases the effective load resisting cross section area. Reduction in load resisting cross sectional area lowers the load carrying capacity of the welds. Nitrogen is also a austenite stabilizer which in case of austenitic stainless steel (ASS) welding can place crucial role. Chemical composition of ASS is designed to have about 5-8% ferrite in austenite matrix to control solidification cracking of weld. Presence of nitrogen in weld metal either from atmosphere or with shielding gas (Ar) stabilizes the austenite (so increases the austenite content) and reduces ferrite content in weld which in turn increases the solidification cracking tendency because ferrite in these steels acts as sink for impurities like P and S which otherwise increase cracking tendency of weld.

35.3 Effect on weld compositions

Presence of oxygen in arc environment not only increases chances of oxide inclusion formation tendency but also affects the element transfer efficiency from filler/electrode to weld pool due to oxidation of alloying elements (Fig. 35.3). Sometime composition of the weld is adjusted to get desired combination of mechanical, metallurgical and chemical properties by selecting electrode of suitable composition. Melting of electrode and coating and then transfer of the elements from the electrode across the arc zone causes the oxidation of some of the highly reactive elements which may be removed in form of slag. Thus transfer of especially reactive elements to weld pool is reduced which in turn affects the weld metal composition and so mechanical and other performance characteristics of weld.

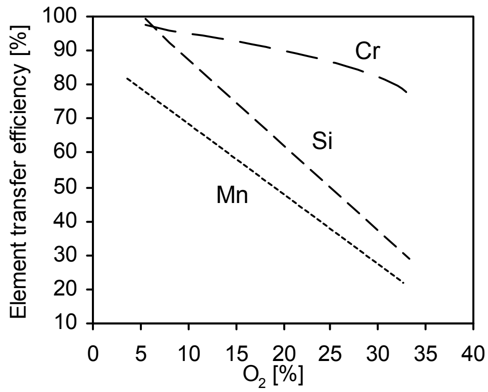

Fig. 35.3 Influence of oxygen concentration on element transfer efficiency of common elements

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