Overview: Section 5

Hydrogen in Ferritic Arc Welding

Hydrogen, regardless of the form it takes, is potentially dangerous if introduced in the vicinity of the welding arc. Once a hydrogen-bearing substance enters the energetic milieu of the welding arc it can be converted into monotomic hydrogen (H) which is sufficiently small to pass through the interstices of the iron lattice and therefore be dissolved in the weld pool. Diatomic hydrogen (H_2) cannot be dissolved in the molten weld pool because the hydrogen molecule is too large to pass freely through the matrix structure of steel.

Upon solidification of the weld pool, the once high solubility of hydrogen in iron is drastically reduced. Hydrogen will be rejected at the solid-liquid interface from the supersaturated liquid, which in turn may result in blowholes, porosity, etc. The remainder of the hydrogen will form a supersaturated solid solution with iron. The hydrogen, which is much more soluble in austenite than ferrite, will diffuse rapidly upon further cooling of the solid weld metal. Some diffuses to the air, some into voids and other into the surrounding base material. At some time after the austenite to ferrite transformation, the hydrogen which remains in the weld metal or surrounding material, combined with residual stresses from welding and a susceptible microstructure,[1] can result in cold cracks.

There are several ways to control the resulting microstructures in the weld zone. Preheating and heat input manipulation are the primary means. In either case the objective is to reduce the cooling rate in order to avoid the formation of martensite. By avoiding a martensitic microstructure the chances of cold cracking are greatly reduced.

In recent years, the welding industry has had much success in reducing the number of cracking incidents related to hydrogen with the development of low hydrogen consumables. But still, hydrogen continues to pose a cracking threat due to the hydrogen which is available in so many aspects of welding.

Water is the major contributor of hydrogen during welding. When water vapor is present with molten steel, it is believed that the reaction to form monotomic hydrogen is as follows:

$$H_2O + Fe \rightarrow FeO + 2H$$

As a result, a potential cracking situation develops. Water may be introduced to the vicinity of the arc as moisture on the weld joint, moisture in the shielding gas, or moisture from the surrounding atmosphere. But by far, the largest contributor of water is the flux or coating related with the flux-assisted processes (SMAW, SAW, FCAW, etc.). The moisture may be combined or held mechanically in a flux or coating. Mechanically held moisture is that which is held in voids either between flux particles or in flux particles. Combined moisture is that which is an inherent part of the crystalline structure. The moisture which is held mechanically is driven off much more easily than the combined moisture. Therefore, the heating of the electrode during welding is sufficient to drive off most of the mechanically held moisture while the combined moisture is much more stable and thus enters the arc, which in turn becomes monotomic hydrogen upon reactions with the weld pool.

[1] A susceptible microstructure is generally one which is martensitic. Whether or not the original baseplate is martensitic, it is possible to produce this susceptible martensitic structure in the heat-affected areas of the baseplate as a result of the thermal cycling during welding.

Most of the hydrogen which originates as moisture is associated with the flux assisted processes, but many other factors also contribute to the formation of monotomic hydrogen which are present in all arc welding processes. The base metal and filler metal are likely to contain hydrogen unless vacuum melting techniques were employed during productions. Ferro-alloys which are used in flux coatings also contain measurable amounts of hydrogen. Oil, grease, paint or any substance containing hydrocarbons also present the potential for monotomic hydrogen to be introduced into the weld pool.

Another major contributor to hydrogen which is often overlooked is rust. Rust, which is iron-hydroxide rather than iron-oxide, contains water which is a potential contributor to the hydrogen content of the weld zone. Ordinary preheat temperatures are not sufficient to cause the breakdown of iron-hydroxide into iron-oxide and water. Therefore, the water present in the iron-hydroxide stands a good chance of entering the weld pool and being further reduced to monotomic hydrogen, which in turn poses a cracking threat.

There are many techniques and an abundance of data which evaluate the effects of hydrogen on the cracking susceptibility of steels. There are also many techniques for determining the sources of, and measuring the amount of, hydrogen in a weld. The results vary from technique to technique, but there is good agreement among investigators on the trends of the results.

The following section on hydrogen in ferritic arc welding deals with various test methods for predicting hydrogen levels and hydrogen-embrittled material behavior during ferritic arc welding.

In some cases, authors present data which correlates the amount of potential hydrogen with actual results obtained in specific weldability tests. In other cases, the authors discuss how changing testing conditions can alter the results of a particular test.

Particular attention should be paid to the procedures and variables involved in predicting hydrogen behavior during welding in order to appreciate and understand the validity of the data obtained by any of the various test methods. For it is this understanding which leads to the development of better testing techniques, further comprehension of hydrogen behavior, and ultimately the prevention of hydrogen cracking during welding.

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