The Need for Low Hygroscopic Welding Additives

Learn about a test method that helps predict finished weld hydrogen concentration

BY SHAMUS CREAN

It is challenging to manufacture ultra-low hygroscopic welding additive materials. It is equally challenging to test for the moisture stability in a welding material consumable and the resultant residual hydrogen content in the weld.

Certain particle morphologies can have a higher affinity to absorb moisture than others. Additionally, poor processing practices can result in unreacted raw materials residing in the flux additive or arc stabilizer powders. These unreacted raw materials are prone to absorb moisture as well.

Residual hydrogen levels in the finished weld metal come from two primary sources. The first source comes from chemically and physically bonded water molecules, and organic constituents found in the unreacted raw materials. The second comes from a welding consumable's affinity to absorb moisture over time, while waiting to be formed into a cored wire or consumed during welding fabrication.

Regarding particle morphologies, even fully reacted compositions that are not at the target stoichiometry can contain phases that absorb moisture. Highly homogenous raw mixes, along with specific reaction temperatures, and climates are more likely to produce low hygroscopic phases in the finished welding additive. Maintaining high homogeneity while reacting the raw material constituents is also important to achieve those phases not prone to absorb moisture.

TAM Ceramics (*tamceramics.com*), Niagara Falls, N.Y., is a ceramic materials manufacturer that partners with weld rod and welding coil manufacturers to develop on-trend flux materials. It has employed processing techniques that lockin specific stoichiometric chemistries, along with utilizing highly controlled heat reaction profiles, resulting in moisture impervious materials. Given the increased emphasis on higher strength structural steels, the potential for hydrogen-assisted cracking becomes a much larger concern, and ultra-low hydrogen containing additives are required to reduce this risk.

Find out how the company's test method not only helps predict finished weld hydrogen concentration, but also susceptibility to hydrogen embrittlement.

The Importance of Particle Morphology

In the past, granular materials contained fissures on the grain surfaces, which allowed moisture to penetrate and absorb into the particles. The ability for these materials to form free-flow powders with low-moisture content was difficult. Powders that are not free flowing will influence how well a flux-cored wire will be filled. Moisture absorption ranged from 2 to 4.5% on some of these early flux powders.

In the 90s, specialized flux materials were produced by sealing the surfaces of the particles with some type of low-melting additive. Processing consisted of mixing these additives with a sealant material followed by a heat treatment. It was this process that created an impervious layer, preventing moisture from reaching the core of individual grains of material.

Figures 1 and 2 demonstrate the evolution of particle morphology for different titanate arc stabilizers.

Figure 1 is a scanning electron microscopy (SEM) image of the traditional sodium titanate arc stabilizer utilized several decades ago. It displays fuzzy-like surface characteristics that contain grain surface fissures having a high affinity to absorb moisture deep into the grain body.

Figure 2 is an SEM image of the first-generation potassium titanate arc stabilizer. It shows a highly mixed morphology consisting of a combination of amorphous-looking structures, column-type morphologies, and fiber-like particle shapes. Each of the phases highlighted are prone to absorb moisture.

Figure 3 is an SEM image of the second-generation sodium titanate arc stabilizer particulate showing a more uniform morphology and a smoother particle surface. Figure 4 is an SEM image of the second-generation potassium titanate. The particles in Fig. 4 are fully reacted grains with very smooth surfaces, and they have ultra-low hygroscopic properties.

The materials displayed in Figs. 3 and 4 were produced by utilizing im-

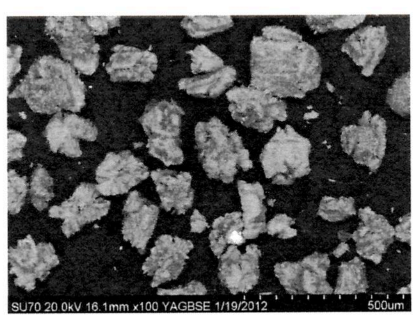

Fig. 1 — SEM image at 100 magnification using first-generation Ruflux® S welding flux with a sodium titanate makeup.

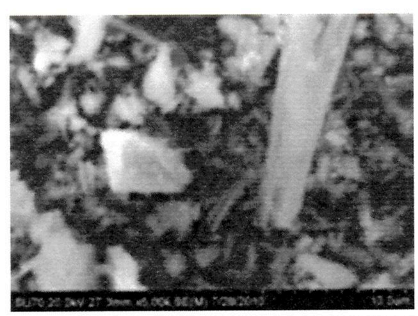

Fig. 2 — SEM image at 5000 magnification featuring first-generation Ruflux® P welding flux with a potassium titanate composition.

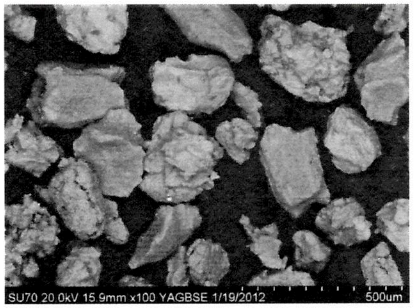

Fig. 3 — SEM image at 100 magnification applying second-generation sodium silico titanate (SST), a welding flux material.

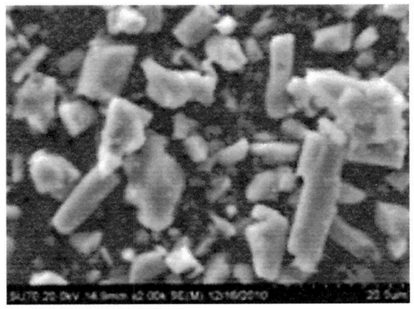

Fig. 4 — SEM image at 2000 magnification utilizing second-generation potassium titanate-free flow-low hydro (PT-FF-LH), a welding flux material.

proved processing techniques and low-melt additives. This combination results in fully reacted grains, with closed fissures and sealed surface porosity, leading to very low moisture absorption properties.

Test Methods to Predict Residual Hydrogen Content in Finished Welds

Over several decades of developing and manufacturing welding additive materials, TAM Ceramics has adopted and modified its own specialized method for measuring the maximum moisture absorption in a material.

The test method developed and employed at the company accounts for the worst-case humidity conditions a welding additive powder can experience before use. Gas chromatography is an accurate way to measure hydrogen content in materials; however, these elemental analyzers do not predict how much moisture a material will absorb after the gas chromatography test, and gas chromatographs cannot be used on the finished cored wire product, only on the finished weld.

Exploring a Different Way

TAM's test method starts by measuring the weight on a sample that has been heated to a temperature removing any loosely bonded water. Note: It is assumed that any organics or chemically bonded water molecules were driven off during the reaction step in the additive forming process.

Next, the sample is placed into a sealed vessel, which acts as a vacuum. An ammonia-based liquid is introduced into the vessel, creating a high-humidity condition greater than 80% relative humidity. The vacuum action forces moisture onto, and potentially into, the material for a 72-h duration. After 72 h, the sample is removed and weighed. The percentage of moisture absorption is recorded and reported to the customer.

This test procedure has been a critical part of developing low-hydrogen-containing welding consumables.

Percentage of Moisture Data Details

The chart in Fig. 5 displays the percentage of moisture results, utilizing the test method developed at TAM, as a function of time on materials manufactured at the company over the last two decades. It shows the materials produced in the 1990s had moisture levels ranging from 3 to 5%.

In addition, Fig. 5 shows materials developed and manufactured in 2010 had percentage moisture levels of 0.25%, resulting in hydrogen contents of 5–6 mL/100 g. It also shows the materials developed and produced in recent years have very low moisture levels of 0.12 to 0.15%. The 0.15% moisture levels strongly correlate to H4 weld hydrogen content, which is 4 mL/100 g of hydrogen.

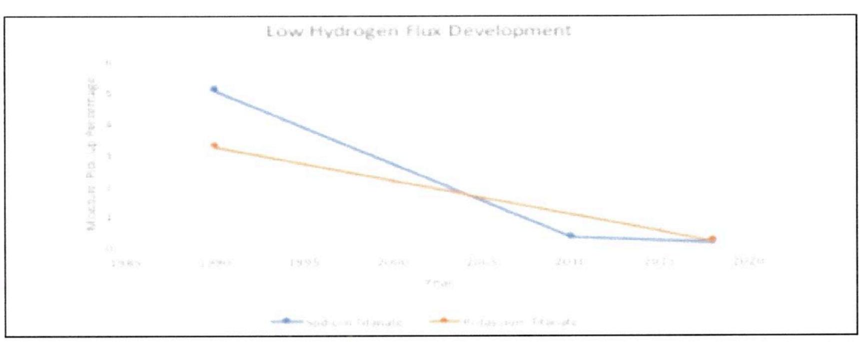

Fig. 5 — This chart displays 72-h moisture results as product improvement has progressed over the decades.

In Summary

Synthesizing low-moisture-containing materials is challenging. Equally challenging is verifying the ultimate moisture absorption in a welding consumable material. It is important to know the maximum amount of moisture absorption as it strongly drives the resultant hydrogen content in the weld.

It is desirable to design a product that will not absorb moisture while sitting in a warehouse waiting to be consumed and has a long shelf life. TAM Ceramic's test method simulates a worst-case humidity scenario for the powder, and therefore, helps predict finished weld hydrogen concentration and susceptibility to hydrogen embrittlement. Low hydrogen levels in the flux materials help decrease weld spatter and also create a smooth ionizable path for the arc to travel.

Low-hydrogen flux materials provide two benefits. First, they decrease fabrication times by eliminating the need to pre and postheat the welding surface, or fabricated components, to remove residual hydrogen in the weld that originated in the flux additives. Second, TAM's additives allow for a much cleaner weld deposit for the operator.

Next-generation, low-hydrogen flux and slag former additives are currently in development at TAM to keep pace with the increasingly stringent requirements advised by the American Welding Society (AWS) on critical military welding specifications. WJ

SHAMUS CREAN (screan@tamceramics.com) is manager, sales engineering at TAM Ceramics, Niagara Falls, N.Y.