

Improving 400 series weld seams in tube, pipe production

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Fluxes help by removing oxides, improving heat transfer

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Chromium is a miracle element when added to iron, combining with oxygen to form chromium oxide, the compound that prevents rust in stainless steels. The downside is that it also impedes bonding, making stainless difficult to weld. Using a flux can help by improving weld quality and allowing faster welding speeds.

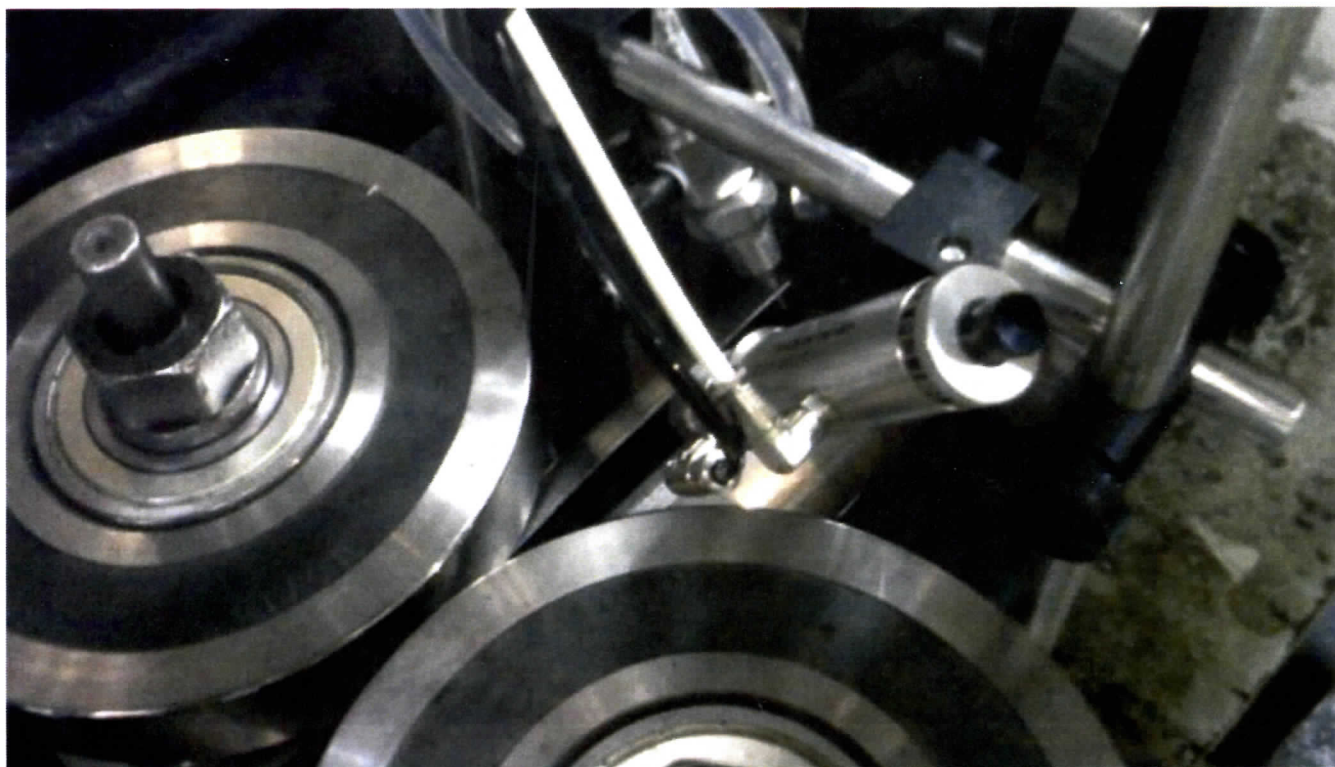


Figure 1

Installed on a mill near the weld box, a low-volume, low-pressure (LVLP) spray system can be set up to maximize flux application efficiency.

Although stainless steels can have quite a few alloying elements, such as nickel, manganese, molybdenum, and silicon, the ability to resist corrosion is based on the presence of just one of them, chromium. Chromium combines with oxygen to form chromium oxide, which is the compound that prevents rust formation. The downside is that chromium oxide impedes bonding, especially when the alloy is subjected to very high temperatures such as those found in a tube or pipe mill's weld box. Many tube and pipe producers that make

400 series products weld the seam as it is, without additives or fillers, and risk the problems associated with oxidation.

These producers have options. One is to enclose the weld box and blanket the weld area with argon gas. Because it's inert, argon doesn't remove the oxide coating, but it does help suppress oxidation in the weld box. However, given that it's a dynamic situation, it is almost impossible to keep all of the oxygen out of the weld box.

A second way is to use a flux that dissolves and removes the original oxides, prevents reoxidation, and transfers weld heat to the seam.

Flux Flexibility

Fluxes for the seam welding processes come in two forms, paste and liquid. Both have pros and cons, and the best choice depends on several factors.

A water-based brazing paste has the advantage of being easy to apply by brushing, rolling, or high-pressure spray gun, and it isn't difficult to coat both sides of the coil before it is mounted onto the mill. This has three main disadvantages. First, the flux is applied manually in an offline operation, so it's labor-intensive. Second, much of the flux coating flakes off before it reaches the weld box, reducing its effectiveness. Third, these flakes and particles end up in the accumulator and the rest of the mill, on the plant floor, and in the air. The debris is a nuisance and minimizing it requires relentless cleaning.

The liquid fluxes are water-based and available in two solids contents. They are sprayed on automatically, are clean, and do not pollute. When properly selected, installed, and aimed, the spray system applies the right amount of flux where it is needed, on both edge surfaces, as the strip feeds into the weld box.

Flux Functions

Fluxes are essential when joining metals in ambient air, whether by soldering, brazing, or welding. When heated, fluxes perform four vital tasks:

1. Dissolve or react with surface ox
2. Protect the cleaned surfaces against reoxidation.
3. Transfer heat from the heat source to the joint.
4. Remove surface oxides, allowing the clean metal surfaces to join.

It is important to distinguish brazing fluxes from welding fluxes. The difference is a matter of temperature. Brazing takes place between 850 and 2,200 degrees F; welding of ferrous metals takes place from about 2,600 to 3,000 degrees F. Tube and pipe mill weld boxes operate at approximately 2,600 to 2,800 degrees F, so a welding flux would seem appropriate for this application. However, the heat cycle used in tube and pipe production is too short to activate fluxes formulated for welding. Moreover, the fluoride content of these fluxes is low; high fluoride content is critical to tube and pipe welding applications.

In fact, various silver brazing flux formulations are suitable for this operation. These fluxes are active in the temperature range of 850 to 1,600 degrees F and have numerous industrial uses. The intense heat of the weld box activates the formulations and they remain active during the very short exposure time. The most common inorganic raw materials used in these fluxes are boric acid, potassium, sodium tetraborate, potassium fluoborate, and various fluorides.

Ferrous alloys, especially mild steel, are the most common materials for manufacturing tube and pipe. Among mild steels, typical surface oxides are iron oxides such as FeO and Fe_2O_3 . Generally, iron oxides are either reduced at elevated temperatures or are displaced in the welding process.

A stark contrast is 409 stainless steel, which contains approximately 12 percent chromium. The chromium oxidizes to chromium oxide (Cr_2O_3), a tenacious and refractory oxide that tends to remain on the joining surface and interferes with the welding process. This is an even greater problem with 439 stainless steel, which contains approximately 18 percent chromium. The aluminum in alloys, such as 409 aluminized stainless steel, exacerbates the problem: Heating this material causes both aluminum oxide and chromium oxide to form. Aluminum oxide is also refractory and remains on the joining surface.

Using argon gas or another inert shielding gas affords some protection against high-temperature oxidation, but these gases don't remove the original metal oxide tarnish, and they provide just partial protection in the dynamic environment of the weld box.

This is where fluxes perform their fundamental process function. At approximately 1,000 degrees F, the assemblage of inorganic chemicals is transformed into a glassy complex (at elevated temperatures, the forces that keep the molecules organized in a regular, repeated pattern break down and the molecules become disorganized, as they are in glass). Glass viscosity is important. It must be high enough to serve as a protective blanket, keeping oxygen diffusion to a minimum, while at the same time low enough to dissolve surface oxides effectively.

The primary means for oxide removal by alkali fluoborate fluxes is dissolution. Oxides are absorbed into the glass, leaving a very clean, deoxidized metal surface, which is properly prepared and protected for the welding stage.

Boron oxide (B_2O_3) is the glass former in the flux formulation. It provides the protective blanket for the base metals and the filler alloys, lowering the rate of oxygen diffusion to the metal surface so that it is below the rate of oxide removal from the joining surfaces. Potassium oxide (K_2O) and sodium oxide (Na_2O) are the glass modifiers, lowering the melting point and viscosity of the glass and improving flow.

Fluorides reduce the melting point and viscosity further, because they disrupt the cross-linkages in the borate glass structure. However, the improved fluxing action results mainly from the greater oxide dissolution capability of the glass because of its fluorine content. Fluorine is especially important because it aggressively attacks such oxides as Al_2O_3 and Cr_2O_3 , accelerating their solution in the borate glass.

Silver brazing fluxes usually are used in conjunction with silver-based (BAG) alloys. The flux cleans and protects both the base metal and the filler alloy, allowing the filler alloy to flow and wet the base metal. This is not the case with the tube and pipe welding application because it uses no filler alloys or electrodes. Yet the outcome is the same. The flux removes oxides and protects the surface against reoxidation, yielding a strong, consistent weld seam. The simple addition of flux improves metallurgy, cosmetics, consistency, and stability of the welding process.

Flux Justification

Learning about what flux does and how it does it isn't enough. One important question remains: How does flux benefit a tube and pipe operation?

1. **Better, Stronger Welds.** Removing the centerline oxides results in a better weld. The weld has fewer voids, fewer microcracks, and greater consistency. This is reflected in a sharp reduction of seam splits. Furthermore, when using flux, the mill is more forgiving in terms of line speed, heat, and pressure.

2. **Lower Tube Reject Rates.** Some flux users have reported reject rate reductions of up to 40 percent. This reduces scrap, resulting in a large monthly cost reduction.
3. **Reduced Scarf Scrap.** Without flux, many operators use higher-than-necessary welding temperatures to produce a good weld. This can result in a larger-than-normal amount of squeeze-out, material that must be removed by scarfing. A welding flux allows operators to keep the heat at a normal level, which reduces the amount of material that must be scarfed. It therefore also reduces scarfing tool consumption. This enhances product throughput because it reduces downtime, particularly concerning the ID tooling.
4. **Lower Electricity Consumption.** Some flux users have reported a substantial reduction in electricity consumption. This is because applying flux to the joining surfaces results in cleaner, oxide-free surfaces, which need less current. In some cases, when flux has been added to the process, operators have been able to increase the line speed, thereby boosting throughput, without increasing the welding current.
5. **Cost Savings.** The lower tube reject rates and reduced ID scarf scrap result in cost savings. Spraying flux is a fast, simple operation, whereas brushing or applying paste flux onto the surface is an inexpensive manual operation.

Finally, because flux use reduces tube rejects, it frees engineers and operators to spend more time on manufacturing and process improvements, and less time dealing with problems.

Flux Application

Spray systems have been used to assist in tube and pipe production for decades. Some systems are simple, such as one that sprays an antirust lubricant to the OD. Others are complex, such as a paint system triggered by a nondestructive testing unit to mark a bad weld.

A recently developed liquid flux is well-suited to an industrial spray system. Its viscosity is compatible with LVLP systems. Modern spray systems can hit a target area smaller than 0.13 in. and is adjustable to apply just the right amount of flux, somewhere between too little, which affects the weld quality, and too much, which wastes flux.

Mounting this sort of spray nozzle is a simple affair using an adjustable frame of ½-in. rod stock (see **Figure 1**). The best place to mount the spray valves is after the last set of rollers, but in some cases it is necessary to mount the spray system a few roller sets upstream. Trials have shown that an upstream location doesn't affect the weld, but the spray can build up on the roller sets, necessitating an occasional cleaning.

Connecting the spray system's on/off controller to the mill's start/stop switch is an ideal way to start and stop the spray when needed. A flow monitor alerts the operator to an over- or underflow condition.

Because two valves operate at the same time, a single-valve operation channel can control the flow to each valve. Setup entails just two steps. First, the nozzle's air supply is turned off and the drip rate adjusted for each of the valves to about 1 drop per second. Second, the air supply is turned on and the nozzles' direction adjusted so they apply the spray to the strip's edges.

Experiments using a variety of flux formulations and application methods showed that a liquid flux with a viscosity of 20 centipoise (cP) and LVLP technology produced the best results.

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