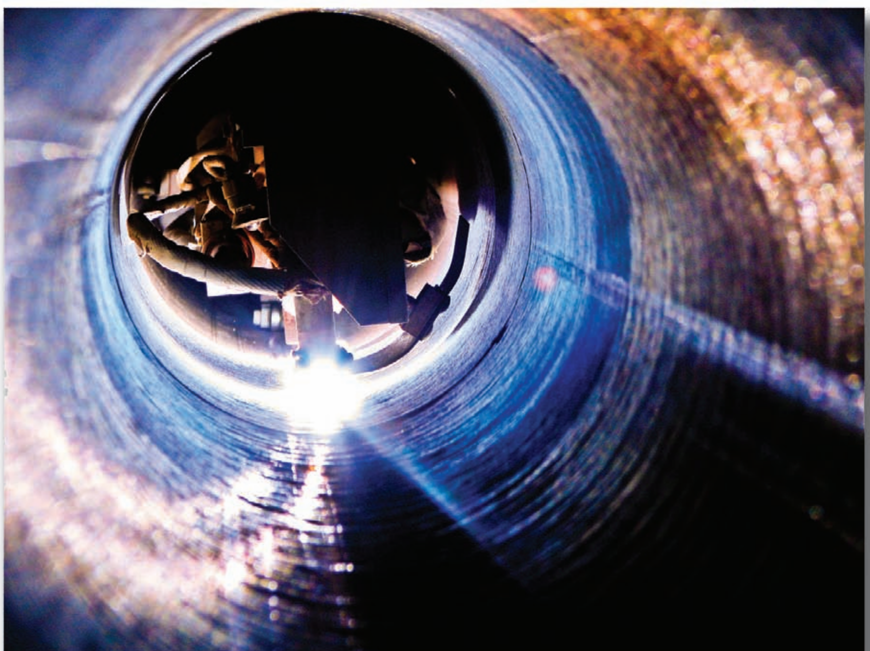
New equipment design and welding technology improve pipe cladding process



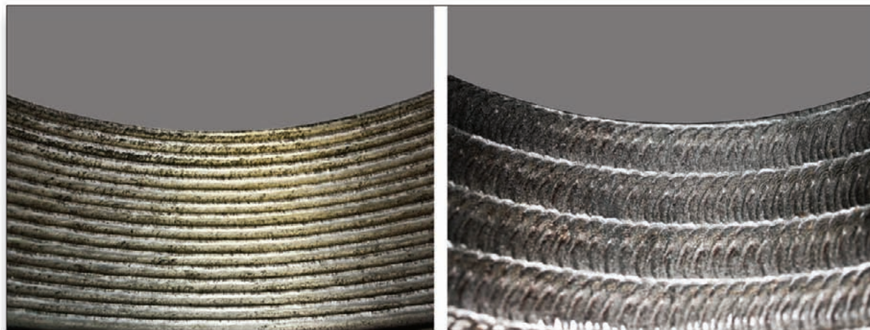
A new patent-pending cladding machine design uses hot-wire GTAW technology to simultaneously weld two layers of a corrosion-resistant alloy to the interior of a steel pipe. Photo by Chris Kahlich, KLADARC.

Sour crude oil is defined by the petroleum industry as crude oil that contains more than 1% total sulfur content as well as hydrogen sulfide (H_2S) and carbon dioxide (CO_2). To mitigate the corrosivity characteristics of sour crude oil—the sulfur in sour crude oil interacts with the iron in carbon steel (CS) pipe surfaces, resulting in a chemical reaction that leaves the steel brittle and susceptible to cracking and failure—CS pipes with surfaces that come into contact with sour crude oil can be metallurgically lined, or clad, with an overlay of corrosion-resistant alloys (CRAs) typically comprised of nickel, chromium, and molybdenum.

"The search for new oil fields had caused drilling to go deeper. These deep wells are hotter, high pressure, and more corrosive," says Dan Allford, president of ARC Specialties (Houston, Texas), a provider of automated and robotic equipment. "To solve this problem, we need to combine the corrosion-resistant properties of nickel alloys with the mechanical properties of high-strength steel."

Cladding is the process of welding layers of one metal over another to combine their properties, and can be accomplished using hot-wire gas tungsten arc welding (GTAW), an arc welding process suitable for tight spaces that uses a nonconsumable tungsten electrode to produce the weld, with the weld area protected from atmospheric contamination by a shielding gas. A constant-current welding power supply produces energy that is conducted across the arc through a column of highly ionized gas and metal vapors known as a plasma.[1]

Basically, CRA wire is fed into a hot-wire GTAW torch that travels along the length of a pipe, melting the wire and inner surface of the pipe as it passes through the pipe to create a molten "puddle" that metallurgically bonds the two metals as the puddle hardens or



A comparison of an overlay with typical arc welding stringer beads (left) and an overlay of wider stringer beads (right) created using arc welding with oscillation. Photo courtesy of KLADARC.

"freezes." To ensure that the overlay of the CRA is seamless, the welding process is performed circumferentially along the inner wall of the pipe as the pipe steadily spins on motorized pipe rollers. Circumferential welds allow the pipes to tolerate long-radius bending after the overlay process, which is crucial for pipes used in a refining process. Since CRAs possess properties that make them impervious to H_2S and the chemical reactions that cause steel to fail, overlaying a CRA to the inner surface of a CS pipe results in a pipe with the structural strength of steel and the corrosion-resistant properties of the CRA.

Although pipe cladding is a long-established corrosion-mitigation practice, engineers with KLADARC (Houston, Texas)—a joint venture between ARC Specialties, Inc. and KLAD Manufacturing Co., Ltd. (Houston, Texas), a producer of weld overlay and clad pipe—have developed a new, patent-pending cladding machine design, based on hot-wire GTAW technology, that reduces oxide inclusions and iron dilution in the cladding process.

Low iron dilution, or limiting iron content, is required for protective CRA cladding that is specified for use in subsea sour crude oil environments, says Jordan Smith, research engineer with KLADARC. To reduce iron dilution during the cladding process, as well as reduce oxide inclusions or voids and enable higher deposition rates, Smith and his engineering team developed a machine design that incorporates dual pulsed-arc hot-wire GTAW torches with oscillation to simultaneously overlay two layers of a CRA onto the pipe's inner surface.

The two welding torches are mounted, 28 in (711 mm) apart, on a rigid torch extension that uses a travel carriage on a glide rail to move the assembly into the pipe. The first torch puts down the initial 1.5-mm layer of CRA, and moments later, the second torch lays down a final 1.5-mm layer of CRA. The equipment is designed to clad lengths up to 20 ft (6 m) in pipes with inside diameters ranging from 5 to 30 in (127 to 762 mm).

With the rigid torch extension design, the engineers discovered that the torch arc can be oscillated without inducing vibrations, says Smith. This allows them to slow the circumferential rotation of the pipe, which keeps the molten metal puddle underneath the protective shielding gas for a longer period of time, subsequently displacing oxygen and reducing the number of voids or oxide inclusions that occur during welding as well as suppressing the penetration of iron from the steel pipe into the nickel overlay. "It's important to reduce the percentage of iron in the cladding so the H_2S from sour crude oil is rendered innocuous," Smith explains. "The iron content in the initial layer is ~15 to 20%, and the top layer has an iron content of <5%, which is in keeping with the NACE International standard for cladding."

Along with the dual-torch design and arc oscillation, the engineers also developed a specially designed triple-pulse waveform in the welding arc's power supply current that alternates between a high pulse, which facilitates a hot welding temperature, and a background pulse that results in a slightly cooler welding temperature. "The benefit of this pulsed-arc welding technology is the combination of good wetting (the spread of the molten material without voids) and fusion attributes from the high pulse with low iron dilution that is characteristic of the background pulse," Smith says.

To continuously monitor the welding process in real time and allow the operator to visually detect welding defects, the machine design incorporates a closed-circuit television system, with recording capabilities for data storage, that features two remote video cameras, one for each welding torch, that are designed to withstand the extreme heat due to the welding process.

Contact Chris Kahlich, ARC Specialties, Inc.—e-mail: ChrisK@arcspecialties.com.

Reference

1 "Gas Tungsten Arc Welding," Wikipedia, the Free Encyclopedia, http://en.wikipedia.org/wiki/GTAW (February 25, 2009). MP