Robotic Shop

For structural steel welding, automation offers a viable path towards efficiency.

BY GEOFF LIPNEVICIUS

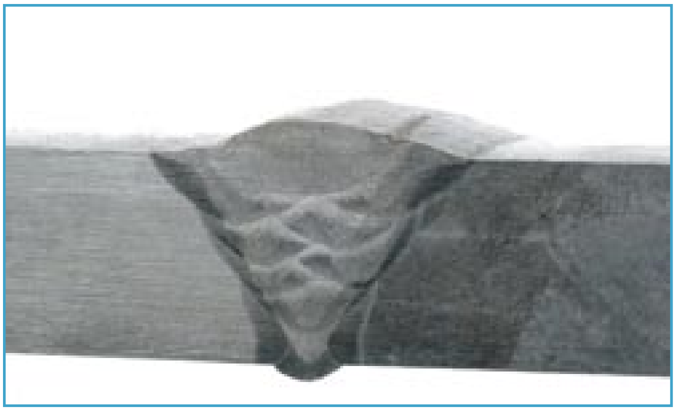
WHILE U.S. DEMAND FOR STRUCTURAL STEEL has increased significantly over the last five years, construction spending prospects have declined rapidly for the beginning of 2009 as the credit freeze recession spreads rapidly through most economies around the world. Now that the economic stimulus plan has passed, questions remain as to how soon we might begin to see the infrastructure projects moving, and whether they will be sufficient in sparking a turnaround for the economy.

The infrastructure section of the package includes funding for building and repairing highway bridges, expanding transit systems, upgrading airports and rail systems, and building and repairing federal buildings. Lawmakers indicate the some of the projects could be up and running within three to six months, spurring steel fabricators to keep a vigilant eye out for technology and processes that give them a competitive advantage in taking advantage of this stimulus. This includes the pursuit of welding productivity improvements and leveraging opportunities that combine equipment, consumables, advanced welding processes, and automation.

Improved Predictability

Construction material prices have varied significantly since late 2003 creating significant challenges for project cost estimators. The downturn in construction demand may result in a stabilization of construction material prices in 2009. Yet only 30% to 35% of the fabricated and erected cost of structural steel is the actual cost of the material. Therefore, it remains very important to be able to accurately predict the cost of shop activities. The use of robotic automation can increase predictability of the variable shop costs. Robots provide the means to secure precision and repeatability via tightly controlled procedures in combination with heavy-duty positioning equipment. They also provide improved weld joint accessibility and numerous other benefits to the structural steel industry, including improved quality, productivity, and manufacturing flexibility. While over-welding is common in manual processes, a robot can be programmed and qualified to produce cost-effective, repeatable procedures that match the correct weld size to the load that is to be applied, reducing waste.

Designers have typically provided for a single-sided bevel rather than a double-bevel to avoid labor-wasting positioning time, which can be a significant hindrance for large fabrication. However, this actually doubles the amount of weld metal for the same effective weld throat. Robotic automation allows for larger fabrications to be automatically positioned for easier accessibility and reduced welding time, resulting in the improved ability to



A synchronized tandem MIG multi-pass weld sample on thick weldment, performed via automation.

A multi-Pass weld sample (some weldments require as many as 70 passes), performed via automation.

reduce and control shrinkage stresses and reduce overall cycle times.

Robot Intelligence Trends

Vision is becoming an increasingly important component of many automation opportunities in the structural steel industry. The integration of vision to robotics has been made easier and more cost-effective in recent years.

Robots can use a vision sensor to "see" the location and orientation of parts, examine and verify part fit-up, find features pre-weld, measure the joint position, detect what is going on ahead of the arc, provide for real-time seam tracking, and signal changes to user-defined process parameters using adaptive parameter control. Laser vision systems are also commonly used for multi-pass welding sequence management and can also be used for error proofing.

Error proofing in automation relates to the ability of a system to either prevent an error in a process or detect it before further operations can be performed. It can be performed on every weld in a process or to monitor critical welds of a process.

Automated Monitoring

Robots are increasingly integrating digital technology to network welding equipment and bring data from the factory floor to the business arena. Production monitoring enables any networked power source to be set up so that weld data can be monitored, files can be stored and shared, production tasks can be monitored, weld limits and tolerances can be set, consumable inventory can be tracked, serial number traceability can be performed, and diagnostic troubleshooting can be performed remotely.

Excellent Fusion

Historically, gas metal arc welding (GMAW) has been associated with incomplete fusion defects in the structural steel industry. Pulsed spray metal transfer (GMAW-P), however, takes advantage of the high energy of axial spray metal transfer and alternates this high energy (peak) current with a lower energy (background) current. Many aspects of the GMAW-P waveform can be controlled, and the benefit of the pulsed energy is that it produces excellent weld fusion characteristics and considerably reduces the heat input. The dynamics of the pulse also permit the use of GMAW-P for out-of-position welding. Out-of-position welding, coupled with lower heat input, assists in achieving lower dilution rates, excellent weld metal mechanical properties, and improved Charpy Impact test values.

In semi-automatic pulse applications, an operator can manually adjust the torch height to adjust for variation. In automated applications, to control the length of the arc despite changes in the contact tip-to-work distance (CTWD), welding equipment with adaptive control is required. Adaptive control adds energy to the arc as the CTWD decreases, and it takes energy out of the waveform as the CTWD is increased. The adaptive loop provides stability to the arc length, and increases the overall usability of the pulse waveform in automated structural

The bolted collars in this assembly were shop-welded via robotics—24 in. of full-penetration welds and 64 in. of fillet welds.

Robots in Action

In the fall of 2000, Robert J. Simmons, a 30-year veteran of the structural steel industry, developed a concept for constructing mid-rise residential structures using a steel moment space frame system. From this concept, Simmons founded ConXtech, a company that completes all of its fabricating work in-house and then simply assembles the column and beam components together on the construction site, bolting them in place.

Unlike typical structural steel construction, which usually takes seven to eight months using traditional methods, the steel moment space frame system allows ConXtech to cut structural steel erection time to less than two weeks.

Robotic welding systems used in ConXtech's Hayward, Calif., shop are a critical factor to the company's success. Compared to ConXtech's earlier semi-automatic welding operations, the robotic system offers faster travel speeds, high deposition rates, and superior quality finished welds.

In one ConXtech fabrication example, when welded semi-automatically, it takes 40 minutes to weld one collar piece to a beam. Since there are two ends to each beam, this equates to one hour and twenty minutes of welding per beam. With the robotic system, the cell is able to weld collar pieces to both ends in only five minutes and thirty seconds.

In another example, beams, composed of A992 structural steel, are joined to the A572 Grade 50 collar pieces. The plate requires the use of full-penetration welds on the top and bottom flanges and fillet welds on the beam's web and the back side of flanges. The 24 in. of full-penetration welds on each beam are made in four passes, while the 64 in. of fillet welds can be completed in a single pass.

ConXtech was able to cut production time from 80 minutes to 5½ minutes per beam via automation.

applications, especially when fixturing is prohibitive.

Where hydrogen-induced weld cracking is an issue, the lower hydrogen weld deposit of GMAW-P (<5 mL H(2) / 100 grams) is also an excellent choice. GMAW-P typically provides higher efficiency metal transfer (98%) for solid or metal-cored electrodes. Comparably, the lower heat input of the GMAW-P process can result in lower weld fume generation, helping to meet EPA and OSHA standards.

Synchronized Tandem MIG

The dual-wire synchronized tandem MIG process continues to gain popularity as a means to increase production in automated arc welding applications. The process follows early industry trends of reducing welding costs by developing dual-wire processes for greater productivity in high-speed welding applications or in higher deposition/heavy-fabrication applications. Early developments in multiple-wire welding focused on the submerged arc process. The availability of high-powered inverter power sources has enabled dual-wire welding using the GMAW and GMAW-P processes.

Since the introduction of tandem MIG in the early 1990s, the estimated installed base of dual-wire systems has grown to over 1,500 units worldwide. The majority of the systems have replaced single-wire processes that had been pushed to the extreme high end of the useable operating range in an attempt to improve productivity and lower cost by depositing as much metal in the shortest time frame possible. Synchronized tandem MIG extends the welding productivity range beyond what is possible with conventional single-wire processes.

The synchronized tandem MIG process employs two electrically isolated wire electrodes positioned in line, one behind the other, in the direction of welding. The first electrode is referred to as the lead electrode, and the second electrode is referred to as the trail electrode. The spacing between the two wires is usually less than ¾ in. so that both welding arcs are delivering to a common weld puddle. The function of the lead wire is to generate the majority of the base plate penetration, while the trail wire performs the function of controlling the weld puddle for bead contour, edge wetting, and adding to the overall weld metal deposit rate.

The synchronized tandem MIG process can on average represent a 30-80% increase in deposition potential when compared to conventional single-wire processes

Synchronized tandem GMAW enjoys expanded use in girder fabrication for several cost effective reasons, including higher deposition rates, faster travel speeds, lower heat input, and reduced distortion. The lower hydrogen deposit makes it a primary choice for use on high-strength low-alloy or thermo-mechanical controlled processing (TMCP) type steels. And, its use on complete penetration type welds and joining the web to the flange eliminates the need for back-gouging operations.

The system components specified depend upon the level of automation. Automated side beam delivery, tractors, sidecars, and welding bugs are all involved. In some cases, the use of robotic welding automation, which both tracks and welds web to flange connections for girder fabrication, is quite viable.

Combined Advantages

Submerged arc welding (SAW) combines the advantages of AC and DC SAW welding, which was not possible until a few years ago. This technology is increasingly applied to structural steel automation applications due to its superior welding performance and process control.

The latest technology provides for control over the ratio of positive to negative amplitude, as well as the amount of time spent at each polarity. The limiting factor for SAW AC welding is that it takes too long to cross from electrode positive (EP) to electrode negative (EN), and this lag can cause arc instability and penetration or deposition problems in certain structural applications. AC/DC SAW solves this problem by controlling amplitude and frequency, allowing the automated process to take full advantage of the reduction in arc blow experienced with AC, while maintaining the penetration advantages of DC positive and the advantageous deposition rate of DC negative. Using these controls, the shape of the output waveform is changed, and in turn the welding characteristics are controlled. With AC/DC submerged arc welding, you get the best of both worlds: the speed, deposition rate, and penetration that DC SAW offers, and the resistance to arc blow that AC SAW offers.

There are many new opportunities to capitalize on technology to identify cost-saving approaches to project design and construction. If you are welding structural steel manually today, consider looking for opportunities and project types where automation might be able to improve your process. MSC

Geoff Lipnevicius is engineering manager of the Automation Division for The Lincoln Electric Company.

Ready for Robots

Setting up a shop line for automated welding requires careful thought and preparation, and often includes plant layout considerations and a proper balance and optimized flow between robotic and manual operations. On the front end, designing and/or redesigning parts for optimum robotic access makes a dramatic difference that leads to improved weld quality and shorter cycle times.

When tight tolerances are difficult to maintain, robots can be programmed with special software to locate a seam or remain in the weld joint once it starts. When conditions such as significant gaps in plates or gussets are common, or when fixturing is prohibitive to a robot accessing a joint, manual welding can provide a better solution to increase quality and decrease rework.

In addition, the increased flow of material that is expected to work its way through an automated manufacturing cell also needs to be considered and properly planned for to optimize system uptime. Perhaps as important, expectations should be managed for a sensible timeline of success.

It takes time, often multiple weeks, to program the robot, optimize the welding procedure, select operators that have a background in understanding the manual process and then can extend their knowledge to robotics to prove out best practices and maximize the return on investment of the system. But once it's set up, an automated line can provide long-term benefits to a fabrication shop.