Learning to Adapt: Combining Technology and Experience to Address Welding Automation Challenges

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Introduction

Since the mechanical revolution, automation has been employed by nearly every industry to streamline production. Many of these industries use welding processes to manufacture their products, and adaptive welding has become a popular automation solution for a wide variety of applications. Successful adaptive welding solutions ensure that the robotic hardware, sensors, and machine logic all work in harmony. Researchers continue to find new ways of measuring welding processes as well as faster methods of producing desired weld features, while the welding industry develops new sensors and adaptive systems. The overall goal of these efforts is to produce better welds with less preparation time and with less operator assistance. Whether the available tools are used correctly will determine the overall success of the adaptive welding solution.

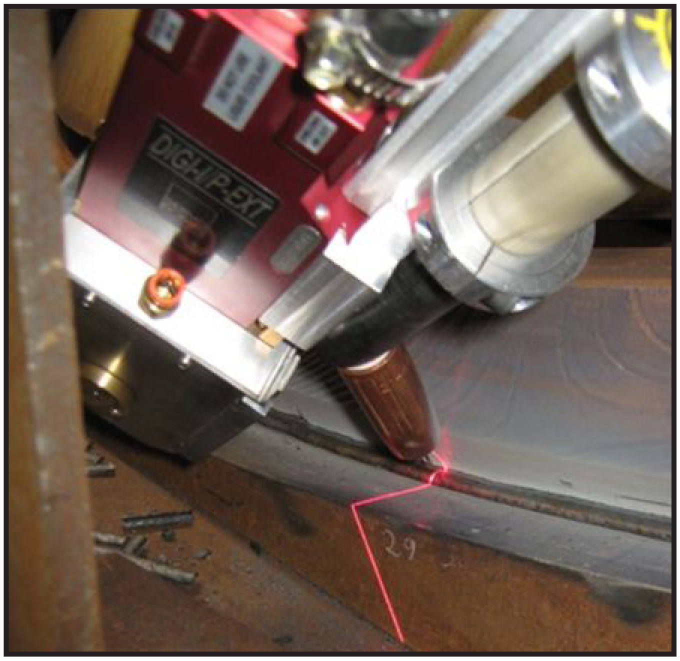

Figure 1: Successive laser scans of a multi-pass weld to measure weld geometry, allowing adaptation of current and future weld pass parameters

Commonly Used Welding Sensors

A variety of sensors are used as measurement tools, including vision sensors, electrical signal sensors, and sensors for monitoring welding process variables such as electrode wire feed speed (WFS) and welding travel speed (TS).

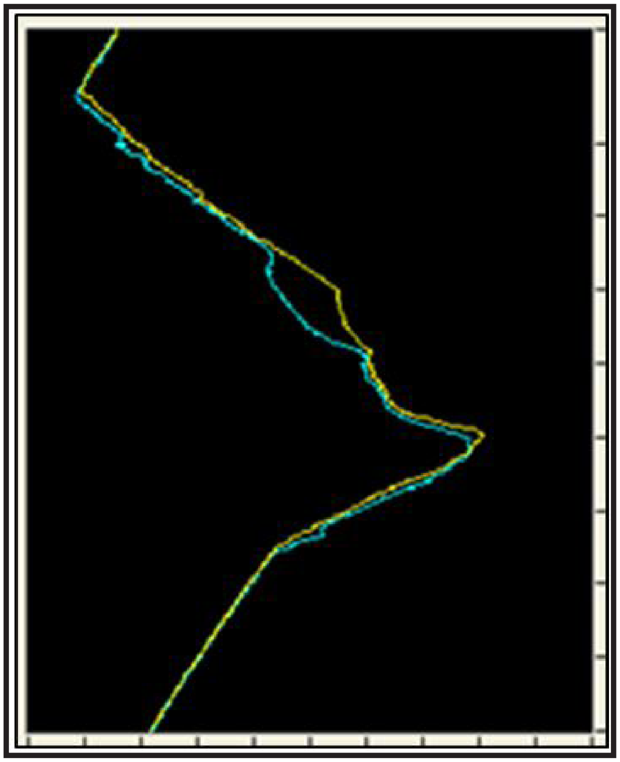

Figure 2: Overlaid successive laser scans of a multi-pass weld

These sensors have become faster and more integrated over time. For example, seam trackers now provide six-dimensional measurements as well as laser and digital camera imaging. Most arc welding robot manufacturers and integrators offer a vision sensing option for seam tracking, joint finding, or post-weld inspection. Some offer more sophisticated capabilities such as dynamic parameter adjustment to adaptively modify the weld bead size as the joint volume changes (Figures 1 and 2).

Common Adaptive Welding Methods

The specifics of a given welding application will dictate the complexity of the adaptive welding solution. A common method of ensuring accurate weld placement is in-process adjustment of the welding robot's trajectory. This can often be accomplished using only the basic seam tracking sensor integrated with the welding robot. In this solution, a vision sensor or electrical contact sensor measures the actual joint location and provides these data to the robot. The robot then modifies its path based on any variation between the actual joint location and the intended joint location. This tool works well for many welding applications and standard joint types. Add-on control hardware and additional motion axes may be required for faster or more precise control in applications such as high-speed laser welding or when wider variations in joint preparation must be accommodated.

Weld size and feature control is a more specialized technique that uses the same sensors as those used to adjust trajectory, but adds intelligence to the robot, allowing adjustment of the WFS/TS ratio to change or maintain the weld bead size and shape. This technique works well for repetitive or single-layer, multi-bead welds.

Path planning is one of the more sophisticated adaptive welding tools. This approach combines automated weld path and weld parameter creation, weld parameter adjustment, and weld trajectory adjustment. Adaptive path planning uses vision sensors to map the joint or joint layer in 3D and then determines the number of beads required and their ideal locations within the joint (Figure 3). This tool requires knowledge of the welding parameters required to make a bead of the desired size and is best suited for multi-bead, multi-layer welds.

Converting Welding Experience into Machine Logic

More complex applications may require the addition of custom machine logic. This algorithm or set of math equations uses sensor data to determine how to adjust the robot motion and welding parameters to create the desired weld. The nuances of a given welding process and application are often

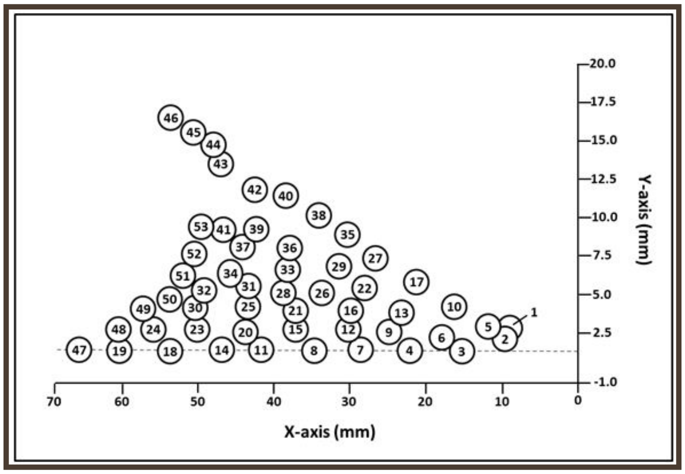

Figure 3: Weld path plan depicting the desired location of each weld bead in the joint

best understood by the welder, welding operator, or robotic programmer. These experts are most experienced in observing the weld in real time and in adjusting the correct external variables. As a result, their involvement in the creation of the machine logic is critical to the creation of an effective adaptive welding solution.

Maximizing ROI

Adaptive welding solutions are application-dependent and as such, there is no single tool that will work for all welds. Clearly identifying the goals of a specific application will help manufacturers select the right tool or tools to maximize their investment. As an example, for heavy equipment manufacturers investing in automation, including a tool that can adaptively adjust weld bead size will decrease programming time and minimize the level of oversight required, allowing the operator to move on to another task. In another example, if fit-up is consistent but weld quality suffers due to changes in incoming material, then electrical signal analysis may be more effective than seam tracking to increase weld quality. The commercially available adaptive welding tools that have been most successful are those that require some initial operator involvement to tailor them to the application. A thorough understanding of the welding process used and of the application itself will allow the manufacturer and system integrator to create a tailored and effective adaptive welding solution.

Increasing Flexibility

Commercial off-line planning software, drag-to-teach systems, point cloud software, and CAD comparison software are other tools to consider. An automated solution that employs these proven commercial tools enhances a welding system's flexibility, allowing it to accommodate part-to-part change-over and high-mix, low-volume production. Off-line planning has the benefit of preemptively digitizing the entire weld joint so the adaptive system can base its logic on an existing path plan. This increases the number of parts an adaptive system can handle. Drag-to-teach (kinetic) robotic systems (Figure 4) allow quick creation of a path from the actual part, reducing up-front programming time. Point cloud software is a tool that can be used to map the weld joint independent of the type of sensor used to gather the data, and CAD comparison software can be used to ensure that the planned solution is still within specification as the weld joint is being filled.

Figure 4: Cobot with drag-to-teach capability

EWI's Research

EWI has been involved in welding sensor testing and development for nearly 20 years, pioneering the conversion of manual welding expertise into machine logic and deploying innovative adaptive welding systems. This work has included the development of adaptive layer planning, synergic weld parameter adjustment for adapting weld bead size, and multi-bead multi-layer path planning systems for mechanized and robotic welding hardware.

EWI is currently working on a project to assess vision and thru-the-arc sensing techniques for adaptive gas tungsten arc welding of curvilinear, formed parts. This work is based on the concept that welding arc voltage and current signals hold valuable information about predicting weld characteristics and that these signals can be used to adjust welding parameters and modify welding equipment functionality to ensure the desired weld condition.

The Future of Adaptive Welding

Continual development of new sensors and robotic welding tools will enable adaptive welding of challenging applications that were once considered impossible to automate. Welding robot manufacturers will continue to incorporate new sensors as part of their product offerings; however, there will always be a need for custom machine logic to solve manufacturing problems that off-the-shelf options are unable to address on their own.

Connie LaMorte *is an expert in the areas of laser-based vision, control systems and adaptive welding. She has been with EWI since 1996, serving in all engineering roles from Researcher to Principal, as well as Team Leader for the Design, Controls, and Automation team from 2007 - 2012. Connie initiates, leads and oversees contract R&D projects for EWI members. She has developed inspection and control solutions in a range of industries with an emphasis on weld-related defect detection. She has published papers on corrosion detection, weld inspection, and adaptive welding.*