Robotic Welding Systems:

A guide to implementing automated welding in your facility

Part 1: Planning

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Introduction

According to research, the market for robotic welding is predicted to grow by over eight percent by 2026. Much of that growth will be in the automotive industry, but the electronics and metalworking industries are also integrating automated welding into their processes. In the past, this technology was assumed to be only for large companies with banks of welding cells in massive factories, but that's not the case anymore.

Growing numbers of small- to medium-sized businesses are making the investment in robotic welding, often guided by a knowledgeable integrator. There are many options available to customize a system for what you need and what you aspire to do to stay competitive. Robotic welding is definitely a gamechanger in terms of production volume but also in quality improvement and your ability to respond to a changing workforce. This guide shows what you need to know to plan and implement automated welding in your facility.

1. What are your challenges and goals?

You can accomplish various things with automation: solve production bottlenecks, increase output, address labor or skill shortages, or streamline an aspect of a larger manufacturing process. In your welding processes, the challenges might be easy to spot are the indirect result of problems upstream that are impacting later stages of production. There may be a problem with the welding itself, component preparation, worker skill, or some combination of these things.

Even if your production has few issues, you may have a goal that automation can help you reach. For example, suppose your goal is to expand into a new market or find new customers to supply. If you're struggling to reach quotas or don't have any wiggle room in your production schedule, you'll have trouble meeting your goal of expanding. Automated welding might be the key to higher throughput and greater manufacturing flexibility.

The very first step in considering what automation can do for your company is to identify exactly what is causing your challenges or impeding goals. That way, you know what solutions are feasible in your situation. Objectively assess your current welding situation by:

- Looking for places where actions and behaviors aren't matching the stated procedures
    - Is this due to lack of skill or training, unrealistic expectations, or other factors?
- Not assuming you know what's causing a problem – look for evidence
- Tracing problems back to their source(s)
- Asking "why" until you see a clear cause and effect (5 whys)
- Following problems forward to see if/how they impact downstream operations
- Noting redundant use of equipment or workers and other inefficiencies

Assessing your welding system takes time, and a careful evaluation in the early stages increases the odds that the solution you arrive at will be the best fit possible. While each facility and the parts they weld are unique, these common welding production challenges will he-lp you get started:

Quality (before, during, and after welding)

- Weld defects due to incorrect welding parameters, technique, or both
  - Common defects include porosity, brittleness, cracking, slag inclusions, burn through, distortion, incomplete fusion or penetration, undercutting or overlapping, or poor aesthetics
  - Parameters to monitor include current, voltage, length of arc, angles of torch/gun, manipulation of components, speed (CLAMS), heat/temperature, and gas mixture, flow and pressure. While some critical parameters can be monitored and held consistent by sensors and "condition monitoring" software, it's still necessary to check readings and make needed adjustments manually.

Quality welding is crucial to a quality, long-lasting product.

- Time- and labor-intensive finishing pro-cesses (by design or due to welding technique)
- Joint preparation problems
  - e.g. insufficient cleaning/grinding, filing, deburring, etc. to remove rust, scale, or dirt; inconsistent cuts and bevels leading to poor fit up (especially with manual cutting); insufficient or poor tacking, clamping, or fixturing, surface condition due to cutting process

- Changes in material supplier, base metal materials, or filler wire
- Fluctuations in quality over time or between welders
    - e.g. parts made at the start of a shift meet specifications but defects increase later in the day
- Quality issues stemming from a lack of staff/time for proper preventive maintenance of nozzles, cables, wire feed and supply, checking gas levels, spatter cleaning, etc.

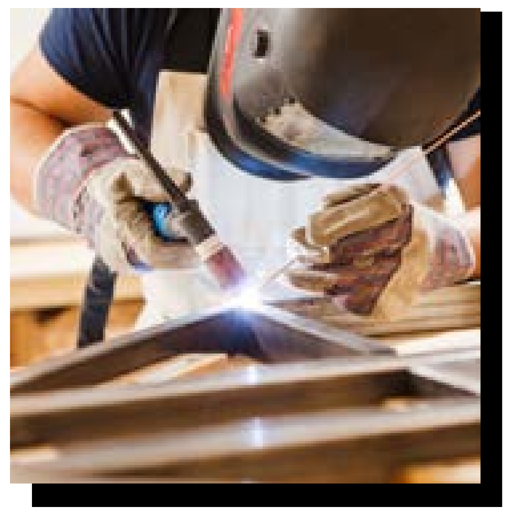
Insufficient skill and/or labor resources

- A mismatch between the level of skill you require and workers available, i.e. the skills gap
    - Can you hire more welders at the right skill level, or do they need to gain experience by training on the job or apprenticing?
    - Do you have enough experienced welders to get their work done as they also mentor new hires?
- Very complex or challenging design and/or materials to be welded
    - Does the work require your best welders and is it consuming most of their time? Is the work beyond the abilities of most of your welders or causing a slowdown due to the time required?
- Limited time to train new employees who have the basics down but need to get "up to speed."
- Poor employee retention
    - Can you provide things like flexible hours, job sharing, remote work, student loan assistance, or generous paid time off to attract and retain the best welders?

> **Consider flexible hours, job sharing, remote work, student loan assistance, or generous paid time off to attract and retain the best welders.**

Ergonomics and human factors

- Fatigue - a tired welder is not a safe or productive welder and may be prone to mistakes
    - Large or complex parts requiring hours of welding
    - Keeping up with rapid repetition or a constant stream of changing components
    - These can also lead to changes in weld placement or quality over the course of a shift or from worker to worker
- Poor ergonomics that contribute to injury, accidents, fatigue, and mistakes
    - Inability to reach spots or joints from the ideal angle, especially blind welds
    - Cumbersome processes for rotating or flipping parts for optimal positioning and access angles
    - Difficult to reach areas that require holding the torch/gun at odd angles
        - e.g. bending, twisting, crouching , kneeling, reaching or stooping
    - Frequent lifting, moving of heavy pieces, manual changeover, and tweaks to settings
    - Static movements, positions, or pressures applied over a period of time
        - e.g. posture when holding one position, gripping trigger, supporting the weight of a part for a long time



- Age-related changes
    - Declining strength, dexterity, speed, coordination, and endurance, especially among workers in their 50's and beyond. This can result in limited or reduced ability to remain standing for a shift, work with hand tools, lift and carry objects, and maintain consistent output volume and quality.

Process inefficiencies

- Frequent, manual repositioning or adjusting of components
- High mix welding environments with frequent manual changeover
- Increasing use of consumables and subsequent expenses
- Lack of standardization
    - e.g. set order of operations, checklists for pre-weld tasks, workflows and routines
- Physical organization, especially if it results in walking back and forth and between stations often
- Time and labor spent on destructive testing to check for weld penetration or correct fit up, especially because it may take several cycles to identify problems
- Rework or repair due to quality or other issues
- Overwelding: making a 3/16” fillet weld where 1/8” is required results 125% extra volume of weld

> **Avoid frequent, manual repositioning or adjusting of components to increase efficiency.**

2. What are the details of your welding process?

To translate a labor-intensive process like manual welding to machine automation, you'll want to pick apart every step and task in the process. Mapping it out in detail helps you and your integrator decide what it will look like and how each step will be performed. Of course, if parts of your process are posing challenges to productivity, as you identified in section one, you'll want to make notes of anything that needs special attention to fix or avoid future problems.

If you're familiar with manufacturing automation, you may have experienced how it can eliminate some steps or create others. It often results in a very different path to the intended outcome compared to the manual process. If you've never undertaken an automation project before, it's important to remember this will not be a one-to-one direct translation where a human welder is replaced by a robot that performs the exact same movements and steps.

In any conversion to automated manufacturing, but especially with welding and its many variables, the integrator you work with needs a detailed picture of what happens before, during, and after the welding process. Here are some things you should be prepared to discuss with them:

Details of the welding

Several things determine the best type of power supply, robot, and other components that go into your automated welding system, such as:

- Materials being welded
- Method of welding and relevant parameters
- Types of joints
- Part shapes and access points
- Design intent of the part
- Tolerances
- Weld length and depth
- Fixturing requirement

- Coupling (integration) of power supply to robot

Mapping out your process in detail helps you and your integrator decide what it will look like and how each step will be performed.

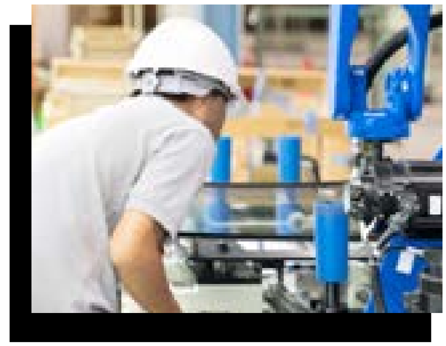
Pre- and post-welding operations

To have the strongest impact, and best ROI, an automated system should fit seamlessly into the big picture with maximum uptime. Thinking systematically about your larger manufacturing process ensures you're covering all the variables while keeping the welding system running efficiently. Your integrator will want to know what happens before and after welding, for example:

- What stations/operations components are coming from before they arrive at the welding station, and where they are headed next
  - This includes the physical workflow, e.g. unloaded from a box or rack, sorted from a bin of mixed parts, arriving or leaving on a conveyer individually or in a container, hand-carried between workstations, being packed for storage or transport, etc.
- How pieces are manufactured or prepared upstream
  - E.g. stamping press, manual bending, CNC machining, plasma, laser, or water jet cutting
- The physical layout or orientation of completed parts in relation to their destination
  - Ex. after welding components into a vehicle seat, a robot can move the seat from the welding station directly into a rivet machine for the installation of a floor track by a worker
  - Location of additional components that make up the completed assembly
- If the appearance of the finished part is critical
  - The location of welds and their visibility may influence things like torch access angles and fixturing in order to achieve an aesthetic weld

- Typical areas that accumulate weld spatter on fixturing and parts
- Finishing processes that can be automated or made less time/labor intensive by the precision and accuracy of robotic welding such as polishing, grinding, etc.

Discrepancies between design, drawings, and physical parts



One of the benefits of a robot is that it can be programmed to make the same precise movements over and over with little variation and create finished parts to spec. The key to this capability is starting with components that are prepared to spec and documented welding processes that work as anticipated in the real world. A robot can't "think about" and then compensate for minor differences on-the-fly the way a human being can, so components that go into the welder must be made to spec, otherwise the resulting part won't be to spec either. If made to spec is not practical, a seam finding/tracking system may be required.

In other words, don't rely on drawings and written procedures to describe your process accurately. Observe the current welding process closely on the shop floor, watching for areas where physical parts and processes vary from documentation or theoretical design, such as:

- Parts that do not match their documentation or meet specs
    - E.g. bevel angles, placement of bends and notches, fit-up between pieces, correct-sized holes.
- Drawings or processes that assume parts are positioned for ideal welds (i.e. flat, right side-up welds) may require particular access points, fixturing, or other factors
- Accounting for the possibility of warping or distortion, lots of welding means lots of heat, warping and distortion
- Situations where welds may burn through components and even the tooling
- "Conflicts of space," such as times where the torch and tooling would be in the same space at the same time
- Physical space and equipment requirements resulting from the new welding station

    - consider where in the facility the welding station will be located, its footprint, and any loading or unloading from the welding cell requiring overhead space for hoists or gantries
    - whenever possible, think ahead to other equipment or workstations that will need to be relocated, as well as any needed upgrades to equipment up- or downstream (e.g. CNC machines, material handling equipment)
- Think about workflow changes required to maximize uptime: increasing infeed to keep the welding robot "busy" as much as possible, avoiding bottlenecks, and positioning components and raw materials around the cell so they can be loaded and withdrawn efficiently.

Questions your integrator should ask

Your integrator needs a complete picture of your welding process, what you need to accomplish, and the surrounding work environment. In addition to the points above, be prepared to discuss these questions:

- Production questions
    - What is typical throughput and cycle time? How do they fluctuate? Do these match the requirements for optimal production?
    - During how many shifts is this part produced? How many welders currently work on it?
    - What is your build-up process like? Is it done in one pass or several steps? Can this change?
- Component and finished assembly questions
    - What documentation can you share (e.g. CAD drawings and part prints, 3D models, dimensional drawings, other documentation)? Do "good" parts match these drawings?
    - How consistent is each finished part in terms of tolerances and specs? If you run several different parts, how similar are they? Are parts in a family or does the mix vary greatly?
    - What is expected from the completed assembly? Are you currently meeting this expectation?

- Welding questions
  - What are your current challenges, and what have you learned from welding this part manually (e.g. odd access angles, cracking, fit-up issues)?
  - What defects are typical (e.g. warpage from heat/distortion)?

The possibility for change

Your integrator may also ask about the flexibility of your manufacturing processes and your ability to make some changes in order to optimize automated welding.

If you supply parts to an OEM, you may have little or no control over things like part design or weld location. For example, stamped parts require a very large monetary investment in tooling, and it's unlikely an OEM will be willing to change their design at that stage.

It's not impossible, however, for an OEM to consider changes if a strong case can be made that the change positively impacts cycle time, volume, or quality (especially if end-user safety is involved). For example, you may be able to illustrate torch access issues on a CAD drawing and provide alternate examples with a notch added to the part to allow for weld access. If a solid business case can be made, it may be worth the effort.

Your internal processes and set up are likely within your control, and this is where automation can greatly change efficiency, even if a part cannot be redesigned. For example, a bracket that's cut with a saw might instead be cut with a different machine to be more consistent for the welding station.

3. More than just a robot: system and its components

It's easy to focus on the robot and torch, but automated welding is accurately thought of as a system for the entire welding process. This can include inbound and outbound conveyance, pick-and-place robotic arms, barcode scanners, computer stations, and more depending on your needs and process.

Common applications for robotic welding use GMAW, GTAW, or laser welders for aluminum or steel components; however, an experienced integrator can customize a system to meet your goals. Traditionally, automated welding is used in low-mix, high-volume settings with dedicated equipment and limited options for changeover outside of designated part families. But as robot technology continues to evolve, opportunities for high-mix, low-volume welding are expanding.

Typical system components include:

- Welding power supply
  - Generates the power to create heat for welding
  - Many options depending on type of welding and requirements of application
- Cables and supply lines for shielding gases
- Robotic arm
  - Multi-axis arm or a linear (e.g. Cartesian or gantry) movement style
  - Reach and payload affect the size of items it can weld (i.e. the distance it can travel and weight it can support over that distance),
  - Rotation of "joints" adds to flexibility and range of motion; although, limiting factors like part geometry, fixturing, and workpiece position must be taken into account
- Robot controller software and hardware (often a servo motor) that can be programmed to control the precise movements of the robotic arm.
- Interface between power source and robot controller

- Torch
  - Bulk electrode wire supply holder and wire feeder for GMAW and some GTAW arc welding
  - Electrodes for resistance spot welding
  - Laser for laser welding
- Peripheral equipment for efficient operation (e.g. wire cutter to trim excess wire, nozzle cleaning station/reamer, torch changing station, coatings and covers to protect cables, tools, and parts from excess spatter)
- Welding fixtures
  - Position and hold parts in place or rotate them for better access
  - Large parts may require servo-controlled turntables or gantries
  - Design must make it quick and easy to discharge parts, especially if part handling is automated
  - The ability to change out fixturing adds flexibility to accommodate part families or entirely different parts. This can be done manually or with automated movements.
- Sensors, vision, inspection
  - E.g. collision sensing to avoid contact with the torch or other hazardous equipment, seam finding sensors to ensure weld quality and placement, tool center point (TCP) sensors for proper weld placement, sensors and vision cameras to verify clamp and part position

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- Safety equipment (e.g. interlocking switches and keys, guards and physical barriers, sensors, light curtains)
- Electronic controls and human-machine interfaces (HMI)
  - E.g. single button or bank of on/off switches, multi-screen computer software to control all aspects of the work (e.g. positioning the part, monitoring sensors, part discharge and conveyance to the next station), barcode scanner to identify workpiece and adjust settings and fixtures automatically

Case Study Example

Robot greatly reduces manual welding time.

Before: The tooling for oilfield equipment on rigs in the ocean includes massive welded steel tools that took about 30 hours of manual welding.

Now: A human welder assembles and tack welds the piece, loads into robotic welder which then does 6 to 8 hours of welding unattended to finish the piece.

Conclusion

Automated welding can have a huge impact on quality, efficiency, and labor challenges, but only if it fits into your production seamlessly – including up and downstream operations. In part one of this ebook, we've shown you important considerations during the planning stages including objective assessment of the existing process and goals, and becoming familiar with welding system components and options. Working with an experienced integrator, like Force Design, helps make sure you don't overlook important details and understand what's possible.

In part two of this ebook, you'll learn how welding automation impacts your employees and operations, from shop culture and safety to equipment flexibility and ROI. In the meantime, please contact us to talk about your plans for robotic welding.

Ready to Get Started?

Now that you're equpped with a plan, you'll need to work with your integrator to make your vision a reality. We used our years of field experience to put together a follow up guide that will help you navigate the path forward and give you practical tips for putting your plan in action.

Download the Guide

Notes

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