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Assessing the Impact of Robotic Welding on the Productivity of Watertight-Door Manufacturing

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Abstract— *The article examines the impact of robotic welding on the productivity of watertight-door manufacturing in shipbuilding. The relevance of the study is driven by the growing shortage of qualified welders and the need to maintain stable construction rates under strict requirements for tightness and geometric accuracy. Automation of welding processes in this segment is positioned not only as a technological improvement but also as a strategic instrument for reducing labor intensity, increasing predictability, and meeting contractual delivery schedules. The work was designed to carry out a complete evaluation of the productivity and technological results obtained from the implementation of robotic welding cells in producing watertight doors. The novelty of this article is scientific since it appears due to its systemic methodological testing of how well major efficiency metrics-arc-on time, normalized takt time, first-pass yield relate to economic cum operational results, and finding out that digital offline planning plus online trajectory correction place weld joint geometry development stability. Key results are that productivity is improved several times over when moving from manual welding (10–30% arc-on-time) to robot-based solutions (60–80%), with simultaneously reduced manufacturing cycle time and defect rate considerably lowered. First pass quality attains 99% with hydrostatic test rework minimized due to intelligent control systems, digital power source availability, and laser sensors. It saw better work conditions and a change in operator tasks to set up and check, which made the production more resilient to a lack of workers. High capex, staff change, and cyber safety were also seen as limits to putting it into action. This article will catch the eye of welding technologists and shipbuilding engineers, along with production managers and industrial automation experts.*

Keywords— *Robotic welding, watertight doors, shipbuilding, productivity, arc-on-time, first-pass yield, manufacturing automation.*

I. INTRODUCTION

The manufacture of watertight doors imposes special requirements on welds for tightness and resistance to cyclic loads, so any deviation in heat input immediately raises the risk of leakage during pressure tests. The ability to maintain the weld root inside the defined area without pausing for fixture relocation is made possible by contemporary six-axis robots with gap-tracking sensors and offline trajectory planners. The review [1], which focused on robotic welding in marine structures, attributes the quick adoption of the technology to the reproducibility of the thermal profile. because it immediately minimizes the amount of rework following hydrostatic tests, this technology is used in shipbuilding.

A shortage of skilled welders constrains efforts to intensify ship construction: industry surveys presented at hearings of the U.S. House Armed Services Committee in spring 2025 report annual turnover in critical trades of up to 30% and identify it as a key limitation on yard schedules [2]. Against this backdrop, automation is seen not as a replacement for people but as the only way to stabilize production rhythms and free up remaining specialists for complex, low-volume operations.

Practical productivity indicators make investments particularly attractive: in serial production, robots raise arc-on-time to about 80% versus 10–30% for manual welding, which is equivalent to a four- to fivefold increase in deposited metal per person-shift [3]. In addition to speed, automation reduces porosity and distortion, which lowers the defect rate and the number of repeat hydrotests. Taken together, these effects move the welding node from a critical bottleneck to a predictable stage of the flow cycle, making robotization not merely a technological upgrade but a strategic prerequisite for meeting contractual delivery deadlines for watertight doors.

II. MATERIALS AND METHODOLOGY

The study is based on an analysis of sixteen up-to-date sources covering robotic welding of marine structures [1], workforce constraints in shipbuilding [2], performance indicators of automated systems [3], regulatory requirements for watertight doors [4, 5], parameters of manual processes [6], and technical solutions from manufacturers of robots, sensors, and power sources [7–10]. Additional information on the labor and economic effects of robotization was drawn from industry reviews and marketing studies describing first-pass yield, arc-on-time, and index indicators of the welding equipment market [11–16].

Methodologically, the work relies on a combination of content analysis and comparative analysis. Content analysis of sources made it possible to identify key technological and organizational trends, from heat-input repeatability and the role of arc-on-time as an efficiency indicator to economic barriers to implementation. Based on a comparison of industry reviews, standards, and technical specifications, a map of factors determining welding productivity and quality was developed.

III. RESULTS AND DISCUSSION

A watertight door consists of a steel or aluminum leaf welded around its perimeter to a rigid frame supported on a sill and equipped with a sealing gasket, a system of dogs, and a remote actuator. SOLAS II-1/13 requires that doors wider than 1.2 m in machinery spaces be operable from a central control station and withstand the hydrostatic pressure of a water column equal to the height from the lower edge of the opening to the

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design damage waterline; testing may be performed ashore under an equivalent water head [4]. These requirements define the baseline dimensions of locking elements, the minimum stiffness of the leaf, and mandatory visual position indication, setting precise constraints for the door's welded joints.

To preserve tightness and proper seating of the seal, the geometry of the welded structure is controlled more tightly than for ordinary hatches: the U.S. military standard for heavy doors limits leaf out-of-plane deviation to 7 mm over the entire length. It allows frame camber of no more than 1 mm per 2 m in the vertical or horizontal direction [5]. As a result, door welding belongs to high-precision assembly operations in which even minor thermal distortions can drive the product out of tolerance and trigger labor-intensive straightening.

In manual gas metal arc welding, the operator keeps the arc lit only 10–12% of the shift, with the remaining time taken up by fixturing, root cleaning, and changing posture [6]. Low arc-on-time leads to inconsistent heat input, making the long edge prone to waviness and causing porosity in vertical welds. It requires flipping a heavy frame several times and also causes multiple reheat, thereby extending the cycle. The manual process being stochastic makes it difficult to comply with flatness tolerances if they are kept tight. This limitation explains shipyards' quest for robotic cells since only such a setup can ensure continuous welding plus precise positioning that would make it possible to work stably up to the required geometric constraints without reworking afterward.

The key component of a robotic cell for watertight-door welding is a six-axis manipulator with an extended wrist capable of accelerations that keep the arc stable even on long horizontal passes; examples from the AR series show that increased wrist rigidity and the Universal Weldcom function deliver productivity gains without sacrificing accuracy [7]. Working alongside it is a digital pulsed power source that minimizes spatter on high-strength and aluminum alloys, which is particularly important for thin sill skins. The Arc Welding Equipment Market was valued at USD 4.3 billion in 2023 and is estimated to register over 6.5% CAGR between 2024 and 2032, as shown in Figure 1 [15].

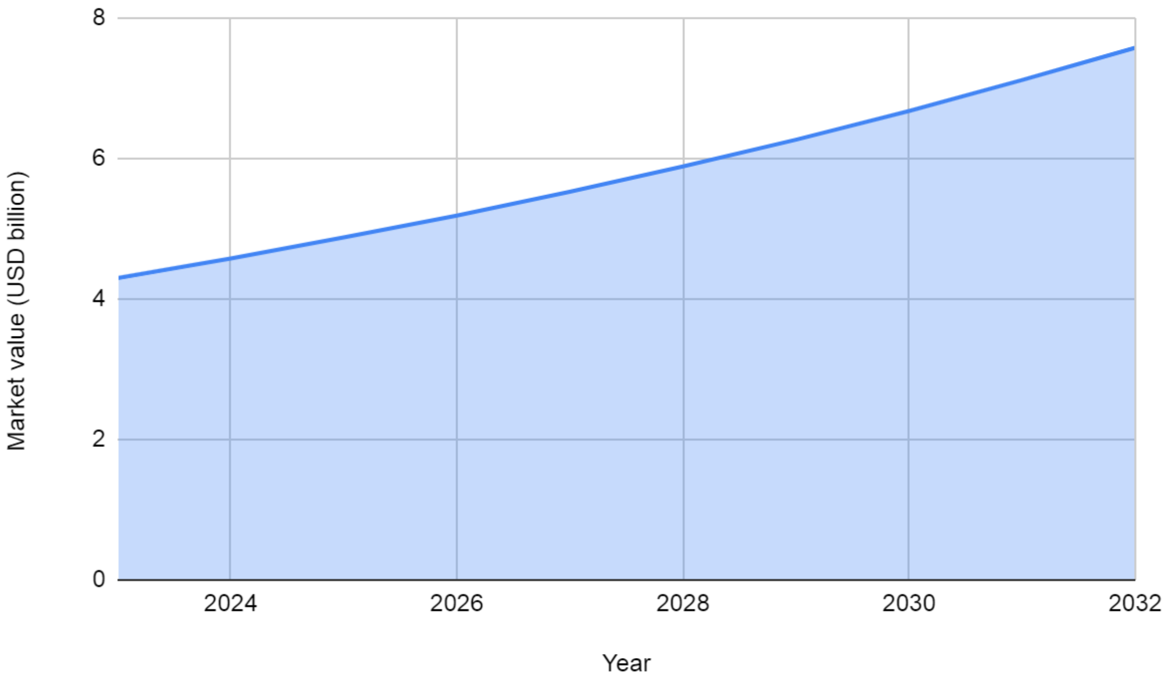

Fig. 1. Compound Growth of Arc Welding Equipment Market [15]

When moving from a single cell to a gantry system, two robots traveling along the X_2 axis above the frame provide an arc-on-time of about 75% and the equivalent of eight manual welders per operator, setting the upper bound of efficiency for mass production of doors of standard sizes [8].

The WeldControl 200 package reduces trajectory programming time to a few minutes: it imports 3D models, automatically creates welds, checks collisions, and proposes an optimal pass sequence, after which the operator only adjusts the robots' zones of responsibility [8]. During operation, the torch path is adapted in real time by laser sensors: the iST ARC sensor tracks the joint with 0.1 mm resolution and corrects the course under thermal warping [9], while systems such as Inrotech MicroTwin generate a point cloud of the entire weld, allowing the algorithm to vary current automatically and travel speed for each filling strip [10]. This combination of offline planning and online correction ensures repeatable geometry of the door frame with no auxiliary straightening.

To make welding a continuous takt in the flow line, robotic gantries are coupled to roller conveyors on which panels are clamped and fed beneath the welding beam. Large-format door frames are held by positioners from the same product line, eliminating crane regrips and preserving baseline installation accuracy. Integrated weld-inspection cameras stream data to the robot controller, and a unified interface for the power source and the manipulator simplifies the parameter logging protocol, turning quality control from a separate operation into a digital report automatically attached to each door.

Arc-on-time, which reflects the share of pure arc-burning time in a full shift, serves as the basis for calculating the utilization factor of a robotic cell: for manual door welding it fluctuates in the range of 30–40%, whereas in an automated cell it consistently remains at 60–80%, since the manipulator does not pause for torch cleaning, fixture reconfiguration, or operator breaks [11]. Multiplied by the planned equipment availability, this factor enables quantitative comparison of the actual shift capacities of different lines. It translates directly into throughput, which is why arc-on-time is chosen for primary monitoring when transitioning from manual to robotic technology [12].

The second step in performance analysis is cycle normalization: the total routing time of the leaf through the cell is compared with the conveyor's takt time. Increasing arc-on-time to 80% typically shortens the cycle by at least one and a half times, and for repetitive welds on standard door sizes, it delivers nearly a threefold output increase without changing the headcount of attending operators [12].

The final picture is given by first-pass quality: the share of doors that pass hydrostatic testing without rework directly affects effective productivity, because each leak adds re-welding, grinding, and retesting. A smart computer-vision setup like the Path Robotics system shows about 99% first-pass yield compared to 60–70% for manual work [13]. Another study on the costs of using robots notes a matching 15% drop in waste due to less porosity and steady heat input [14]. Thus, these three measures—arc-on-time, normalized takt time, and first-pass yield with the scrap rate—make a linked check method that gives a clear sign of the gains from using robots at every step of watertight-door making, from setting up capacity to figuring out payback.

Robotic cells have transformed the structure of time in which the arc burn exists. Formerly, actual deposition took a tiny portion of the shift; after automation, it comes close to reaching the maximum achievable value, and virtually all of the possible lost time in regripping parts or in operator rest is eliminated. This leap has been the primary source of productivity because continuous heat input now steadily forms welds without repeated starts, transforming welding from a variable into an almost deterministic process.

At the same time, the total time for each door to pass through the area was reduced. Since the robot does not require fixture repositioning and executes the pass sequence without pauses for trajectory adjustment, the entire operation fits the overall line takt. In contrast, previously, a buffer had to be maintained in the schedule for possible departures from the conveyor. The shorter cycle made it possible to increase throughput without expanding floor space and without changing energy consumption per unit, because power sources operate in a smoother, optimal mode.

Human work moved from direct deposition to setup, quality check, and upkeep of machines. Thus, the share of handwork in the welding node drops significantly. Skilled experts can pay more heed to small-batch items and odd blocks where swing proves more than speed. This spread not only cuts the need for rare top-grade welders but also boosts total output strength since all risk linked with human factors is now pinned down to just two spots: algorithm tuning and planned care.

The move to robotic welding brought consistency of heat input into the process, so temperature gradients are distributed evenly and the metal cools without sharp internal stresses. The frame and leaf retain the initial geometry, the sealing gasket seats along the whole length without additional straightening, and the closing force remains within the specified range, which virtually eliminates the need for expensive post-process correction.

The digital arc control and automatic seam tracking keep not only current but also voltage and wire feed speed within a narrow band of fluctuation, which is eliminated only in manual methods. Metallographic sections show penetration profile stability, there is no coarse-grained material, and such a smooth bead surface that dressing is not required before painting. Reduced spatter makes the area cleaner; therefore, the probability of inclusions and repeat passes is diminished, which maintains the integrity of protective coatings.

Bright arcs do not continuously visually expose them, and eliminating awkward postures radically improves working conditions at the station. Operators work behind protective screens, controlling the process by interface, welding manually only for unique configurations, thereby eliminating monotonous motion and joint overload. There is no threat from sparks and hot metal above the workspace anymore. Thermal as well as acoustic exposure has been reduced; the injury rate has approached zero, which supports a stable production culture and increases the attractiveness of the profession.

The final level is constituted by intelligent systems that complement the adjusted mechanics with an analysis of the obtained data and a prognosis of changes in modes. Machine-vision algorithms shall present edge land measurements in real time for automatic selection of power-source inductance to keep penetration depth constant irrespective of gap or consumable condition. Neural models trained on sensor archives forecast probability for arc blowout before it happens and preemptively adjust shielding gas flow, thereby making welding a self-tuning process. The cobots are interesting to study because workspace scenarios where space is limited: light manipulators which have safe interaction with humans take long straight welds on flat surfaces while operator handles complex transitions and other small points there tactile judgment is necessary e.g., the main barrier as presented in Figure 2 in implementation percentage terms is very high at 54% followed by technical issues at 35% together with personnel adaptation and cybersecurity concerns both rated at 32%. In comparison, a shortage of qualified personnel is cited less frequently (28%) [16].

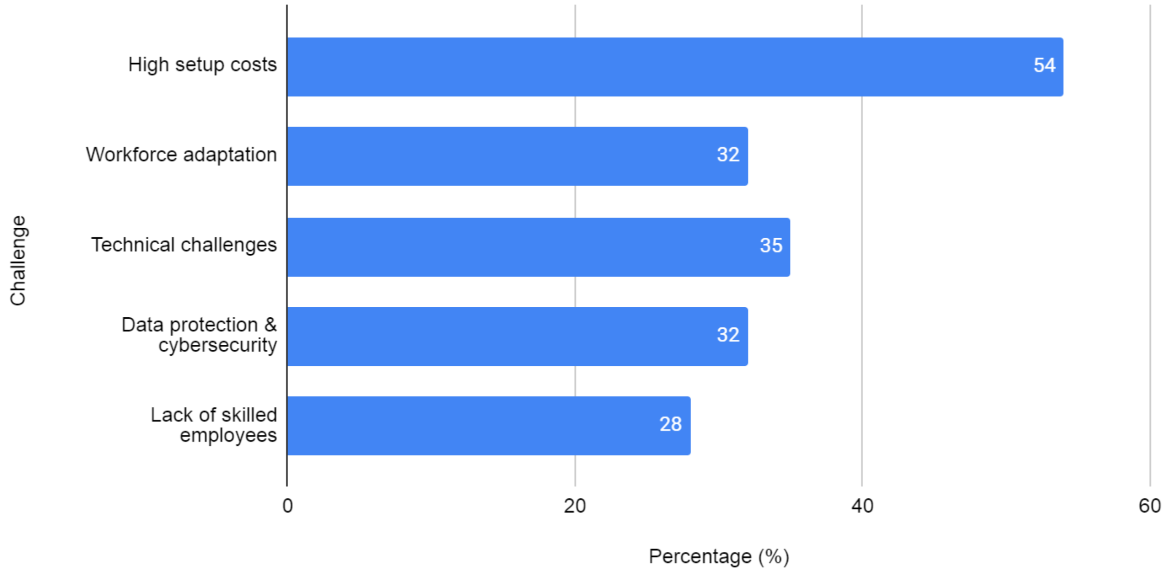

Fig. 2. Prevalence of Perceived Challenges Among Manufacturers [16]

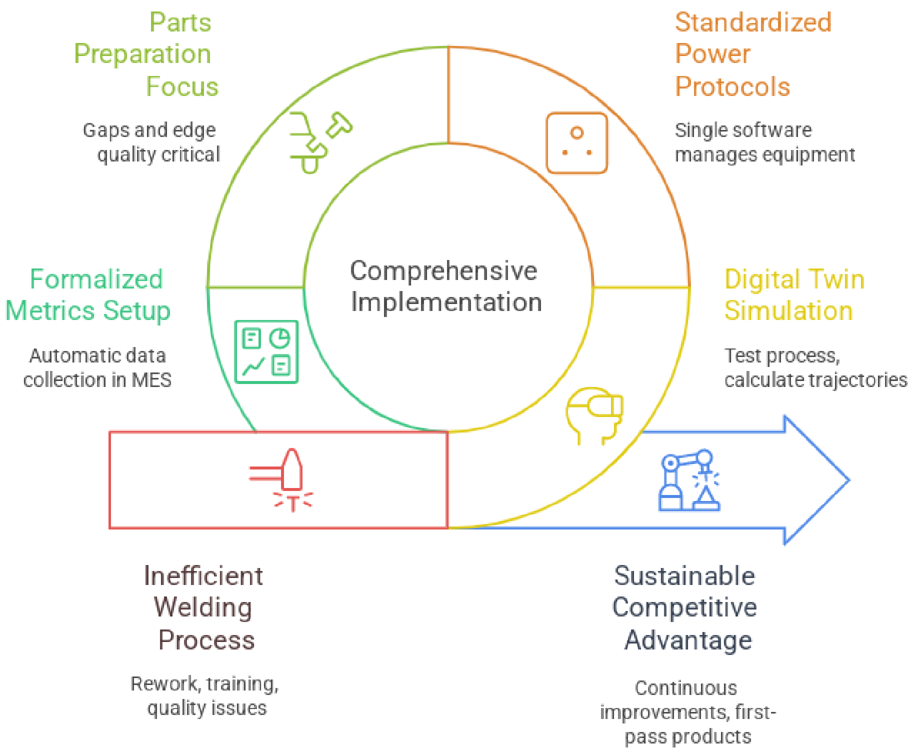

Fig. 3. Optimizing Robotic Welding Implementation (compiled by author)

To extract maximum benefit, enterprises should take a comprehensive approach to implementation, starting with a digital twin of the station. The process is tested in the virtual model, trajectories are calculated, and potential collisions are simulated, which avoids rework on live equipment. Choose a power source based on unified protocols, such that one software environment runs both new and old equipment-this helps minimize personnel training. Pay particular attention to part preparation. Uniform gaps and stable edge quality weigh heavily in weld repeatability; thus, it is more common to realize a greater quality jump from the modernization of cutting and bending stations than raising the class of the robot in terms of accuracy. Finally, at the planning stage, it is helpful to formalize a set of metrics—from arc-on-time to the share of first-pass items—and to configure automatic data collection into the MES. The set of recommendations is illustrated in Figure 3.

Such a closed loop turns implementation from a one-off equipment purchase into a continuous improvement process and makes robotic welding a sustainable competitive advantage.

IV. CONCLUSION

Robotic welding of watertight doors significantly increases process predictability and throughput by repeatable heat input and a substantial rise in arc-on-time. When moving from manual and semi-automatic welding, where arc-on-time is 10–30% for manual mode and 30–40% in typical operations, to robotic cells, this indicator consistently remains at 60–80%, which is reflected in a multiple increase in deposited metal per person-shift, a reduction in product cycle time, and fewer reworks after hydrostatic testing. At the same time, reduced porosity and distortion are observed, resulting in a lower scrap rate and a higher first-pass yield of about 99% for intelligent automated systems compared to a mere 60-70% for manual welding, which translates directly into savings of labor and material.

Six-axis manipulators will be used together with some other factors that shall include offline trajectory planning and online torch path corrections with the aid of laser sensors and point-cloud systems, as well as digital pulsed power sources. Technical success factors also comprise gantry solutions consisting of two robots, including automation packages importing 3D models to automatically create welds and check for collisions, making it possible to bring line takt close to continuous flow at an efficiency level equivalent to several manual welders per operator.

Besides productivity, robotization improves working conditions by reducing adverse exposures and also shifts human resources to setup, quality control, and maintenance, thereby increasing resilience in case of skilled labor turnover. Technological effect is also manifested in the stability of door geometry: even temperature gradients reduce warping in such a way that the tightness of gasket seating is maintained, and there is no need for expensive post-process straightening.

The major implementation constraints continue to be economic and organizational: high capex, 54% of respondents; technical complexities, 35%; personnel adaptation and cybersecurity issues, 32% each; and, less articulated but quite significant in absolute terms, the shortage of qualified personnel, 28%. To maximize the effect, it is advisable to start with a digital twin of the station, standardize control protocols for power sources and manipulators, improve edge preparation and gap consistency in upstream processes, and formalize a set of key metrics (arc-on-time, normalized takt time, first-pass yield, scrap rate) with automatic collection into the MES.

REFERENCES

[1] S. I. Wahidi, S. Oterkus, and E. Oterkus, "Robotic welding techniques in marine structures and production processes: a systematic literature review," *Marine Structures*, vol. 95, no. 103608, Feb. 2024, doi: https://doi.org/10.1016/j.marstruc.2024.103608.

[2] J. Luckenbaugh, "Navy, Industry Try to Reverse Course on Workforce Woes," *National Defense Magazine*, 2025. https://www.nationaldefensemagazine.org/articles/2025/3/31/navy-industry-try-to-reverse-course-on-workforce-woes (accessed Jul. 16, 2025).

[3] Abagy, "Evaluating the effectiveness of a robotic solution," *Abagy*. https://abagy.com/evaluating-the-effectiveness-of-a-robotic-solution (accessed Jul. 17, 2025).

[4] ClassNK, "SC 156 ," ClassNK, 2024. Accessed: Jul. 18, 2025. [Online]. Available: https://www.classnk.or.jp/hp/pdf/info_service/iacs_ur_and_ui/ui_sc156_rev.3_jul_2024_cln.pdf

[5] "Navy Standard Earth-Covered Magazine Doors," WBDG. Accessed: Jul. 19, 2025. [Online]. Available: https://www.wbdg.org/FFC/DOD/UFGS/UFGS%2008%2039%2055.00%2020.pdf

[6] "What Is Welding Arc-on Time and Are You Overestimating It?," *Millerwelds*, Nov. 20, 2020. https://www.millerwelds.com/resources/article-library/what-is-welding-arc-on-time-and-are-you-overestimating-it (accessed Jul. 20, 2025).

[7] "AR Series Arc Welding Robots," *Motoman Industrial Robots*. https://www.motoman.com/en-us/products/robots/industrial-robots/welding-cutting/ar-series (accessed Jul. 21, 2025).

[8] "Shipbuilding Robotics: In-House Software, In-House Machinery," *Pemamek*, 2019. https://pemamek.com/us/discover/robotics-in-shipbuilding-in-house-software-for-in-house-machinery-2-2/ (accessed Jul. 22, 2025).

[9] "Seam tracking sensor iST ARC," *Binzel-abicor*, 2025. https://www.binzel-abicor.com/US/eng/products/robotic-torches-systems/seam-tracking-weld-inspection/ist-arc/ (accessed Jul. 23, 2025).

[10] Inrotech, "Ada Shipyard invests in Inrotech welding automation for shipbuilding," *Inrotech*. https://www.inrotech.com/ada-shipyard-invest-in-inrotech-welding-automation-for-shipbuilding/ (accessed Jul. 23, 2025).

[11] "How Impactful Are Welding Robots?" *Oxygen Service Company*. https://www.oxygenservicecompany.com/how-impactful-are-welding-robots/ (accessed Jul. 25, 2025).

[12] Techman Robot, "Welding Automation: Maximizing Efficiency and Productivity in Manufacturing," *Techman Robot*. https://www.tm-robot.com/en/welding-automation-maximizing-efficiency-and-productivity-in-manufacturing/ (accessed Aug. 01, 2025).

[13] A. Lien, "The Next Leap in Welding Automation: Tackling High-Mix Complexity with Intelligent Robotics," *Machine Design*, May 13, 2025. https://www.machinedesign.com/markets/robotics/article/55289748/path-robotics-the-next-leap-in-welding-automation-tackling-high-mix-complexity-with-intelligent-robotics (accessed Aug. 02, 2025).

[14] "The economics of robotic welding," *Abagy*, Jul. 2024. https://abagy.com/the_economics_of_robotic_welding (accessed Aug. 03, 2025).

[15] GMI, "Arc Welding Equipment Market Size," *Global Market Insights Inc.* https://www.gminsights.com/industry-analysis/arc-welding-equipment-market?utm_source=chatgpt.com (accessed Aug. 04, 2025).

[16] ABB, "ABB survey identifies fully flexible, connected 'smart factories' as crucial in transition to mixed manufacturing of ICE, hybrid and EV," *ABB*, Feb. 26, 2025. https://new.abb.com/news/detail/123776/prsrl-abb-survey-identifies-fully-flexible-connected-smart-factories-as-crucial-in-transition-to-mixed-manufacturing-of-ice-hybrid-and-ev (accessed Aug. 05, 2025).