

Robotics in Shipbuilding

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Background

To be a competitive shipbuilder, the pursuit of operational excellence is a constant, and the foundation of this excellence lies in the skilled workforce that brings Damen designs to life. However, in recent times, the shipbuilding industry has encountered a big challenge: a scarcity of highly skilled workers in production. Talented individuals are increasingly lured by opportunities in other sectors or a similar sector in better-paid countries, leaving a void in our workforce. This shortage has tangible consequences, potentially impacting the quality, cost and lead time of vessels produced by Damen. This challenge forms a desire for exploring innovative solutions, to bridge this gap and elevate the standard of our shipbuilding processes. In response to this desire, Damen Research, Development & Innovation initiated a project to integrate robotics into our shipbuilding processes.

Historical Perspective:

Our exploration of robotic welding in shipbuilding is rooted in the evolution of robotics, taking inspiration from various industrial sectors. While automotive manufacturing has been a notable source of inspiration, the fact is recognized that this industry is vastly different compared to the ship production industry, where products come in relatively low volumes and are generally similar, but not identical.

The implementation of robotics, especially in automotive manufacturing, has demonstrated transformative impacts on efficiency and precision. However, the transition from automotive to shipbuilding robotics shows the distinct challenges posed by the custom and intricate nature of ship components, even within the 'Damen Standard'. Unlike the standardized components in automotive manufacturing, shipbuilding demands a more adaptable and dynamic approach to automatic welding. Also, compared to manual welding, a very clear division needed to be made about grouping parts into part types. Where a manual welder sees a component and recognizes a weld seam, defining this into objective rules appeared to be a challenge. Therefore, a grouping was necessary of components into part types (figure 1). This example indicates challenges that only become apparent when performing physical tests.

In the construction processes for large ships such as cruise vessels or cargo ships, where sections are relatively large and straight, tasks are repetitive and the scale is substantial to justify big automation investments, robotic systems are already integral part. Within this part of the shipbuilding industry, robotics have already proven to boost productivity levels, reduce production time, and maintain high levels of precision in welding of these large sections.

However, the adoption of robotics in the production of smaller vessels is still limited. These ships often contain more complex geometries, with curved sections, intricate details and compact box sections that are less suited to the capabilities of traditional robotic systems. The variability in design and tighter working spaces demand a higher level of flexibility and adaptability than the current technology of robotics typically provides. As a result, production of smaller ships 'the typical Damen vessel' still relies heavily on skilled manual labour. Our goal is to push the boundaries of robotics in shipbuilding by exploring solutions that can bring the benefits of automation to smaller, more complex ship designs, enabling us to overcome both current and future workforce shortages and quality demands.

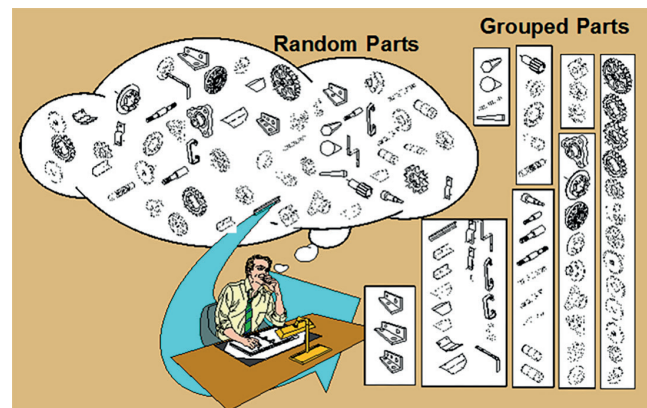


Figure 1: Grouping part types [source: Strategos international]

As we navigated this transition, more specific challenges emerged. Automatic programming, reliant on laser scanning, faced challenges in accurately capturing the complexity of micro panels and small steelwork. This underscored the necessity for advanced modelling tailored to the nuances of shipbuilding, highlighting the need for flexible and adaptable robotic systems.

Experimentation and Objectives:

Despite the challenges, the integration of robotic welding in shipbuilding showcased unexpected successes. The efficiency gains and consistent high-quality welds achieved through robotic systems exceeded expectations, already during the first tests performed at Damen Shipyards Galati (DSGa). Our own experimentation with Damen Shipyards Galati marked a first decent and useful experience for Damen in this journey. In a Damen Group-wide collaborative Project, a partnering was established with a robot integrator and an automatic welding system was purchased and placed at DSGa. Placing a welding



robot aimed to familiarize us not only with the robotics market but also with the prerequisites and drawbacks of automated welding, markedly different from manual processes. The experiment exposed practical drawbacks, particularly in the method of programming and recognition and identification of welding joints. Figure 2 shows a panel with various types of stiffeners, that was used to test this. It showed that, while automatic recognition is a method with great potential, practical issues such as reflections of the used laser beams highlight the necessity of doing such real-life tests.

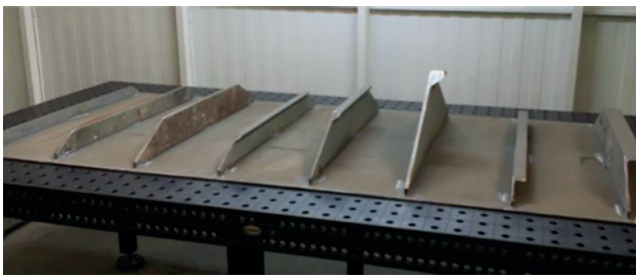


Figure 2: Panel with different types of stiffeners, to test seam recognition (Damen)

It became evident that robotic welding, when fine-tuned, outpaced manual methods, showcasing the potential for significant efficiency gains. The high quality and consistency of welds, combined with the ability to achieve higher arc-on times, underscored the promising future of robotic welding in our niche of shipbuilding. However, the experiment also emphasized that the true value lies not just in welding proficiency but in optimizing the entire process surrounding it. Building upon the lessons learned from this experimentation, successful installations of robotic welding systems have become within hand's reach in our shipbuilding processes. Using the numbers and results obtained in the first project, a potential roll-out and business case was developed for an assembly and welding line of micro panels.

Operational Impact:

The evolution from the first experiment through to practical implementations has reshaped our view of future shipyard operations significantly. In response to the challenges identified during the initial experiment, a new system was chosen. Comprising three gantries capable of welding small panels, this system is strategically positioned between part fabrication and section building locations. This placement optimizes the workflow, creating an efficient panel welding line that minimizes transports and handlings.

This placement has not only overcome the limitations of the relatively small experimental setup but will also enhance the overall efficiency of our shipbuilding processes. The proximity to part fabrication ensures a seamless transition from component production to welding, reducing logistical complexities and streamlining operations.

The implementation of the new robotic welding system marks a transformative step, not only in embracing advanced technology but in strategically integrating it into our workflow for practical and impactful results. Currently, feasibility and business case studies are performed to also apply similar systems with two more yards within the Damen group.

Exploring Collaborative Robotics (Cobots) in Welding:

In a project with Damen Song Cam Shipyard, we chose to take a first step in a slightly different way. Before delving into the collaborative robotics aspect, it's crucial to understand the challenges inherent in traditional robotic welding. One key finding from our former experiment highlighted the proficiency of robots in delivering constant and high-quality results when used correctly. However, mastering the operation of these systems proved to be a significant challenge for welders. While it's possible to teach a programmer to weld, there's a unique advantage in teaching a welder to program. This is essential as welding knowledge is essential in assessing the quality of a weld, as automatic quality inspections are under development, but not yet ready for market. The introduction of cobots addresses this challenge by simplifying the programming process compared to traditional industrial robots.



Figure 3: Welding cobot at Damen (Damen)

The Collaborative Robot Solution:

Collaborative robots, or cobots, emerged as a transformative solution to the challenges posed by traditional robotic welding. Unlike conventional robots, cobots are designed to work



alongside human operators, offering a level of flexibility and adaptability well-suited to the dynamic nature of shipbuilding. Notably, the use of cobots simplifies the programming process into the use of just a few buttons and hardly any programming, making it more accessible for welders.

Implementation Across Shipyards:

This step was strategically chosen to familiarize welders with automated welding processes. Recognizing this as a prerequisite to understanding how automation works and how to handle it, the decision was made to utilize a cobot. The ease of installation, programming, and relatively lower cost make cobots an ideal choice for introducing welders to the world of automated welding. Figure 3 shows the cobot welding during training of one of our colleagues. Together with Damen Song Cam Shipyard, a plan will be made for further rollout based on the future vision of both the shipyard and the technology. Furthermore, the lessons learned with DSCS will be used to define the benefit for other shipyards within the Damen group.

Economic and Workforce Implications

Cost-Benefit Analysis:

The integration of robotics in shipbuilding brings a transformative impact on the economic aspects of the industry. In our experiences, a notable observation has been the potential efficiency gains leading to significant potential of cost reductions. Specifically, we found that one welding robot operated by a skilled operator can replace the work of four manual welders if, and only if, the robot is integrated in the manufacturing process well, ensuring that the robot can achieve high arc-on times. This efficiency not only contributes to cost savings but also enhances overall productivity in the shipbuilding process. However, more important than these cost savings, it is seen that the use of robotics can help mitigate the effects of the potential shortages of skilled personnel mentioned in the start of this article.

Operational Efficiency and Timeliness:

Apart from the direct cost savings, the operational efficiency achieved through robotics can help translate into timely project deliveries. Robotic gas metal arc welding (GMAW), with a speed approximately 1.5 times faster than manual welding, plays a crucial role. However, the main differentiator lies in the arc-on time. While a manual welder operates with an arc-on time of around 18%, the goal with robotic welding is to significantly increase this percentage, aiming for over 60% arc-on time. For this, one of the main challenges is a seamless integration of the system in the production process, avoiding big amounts of transports, handlings and other types of waste.

In addition to the benefits of the application of Robotic GMAW, research is also going out to alternative welding processes, such as Cold Metal Transfer welding, Pulse welding and Laser Hybrid welding. The latter is specifically interesting for relatively large panels as seen in a research project recently with one of the Romanian yards in the Damen Group, as large travel speeds (>2m/min) are observed, while localizing, and therefore reducing, heat input and deformation of the welded structures.

The economic impact extends to workforce optimization and talent attraction. The observation that being a manual welder is becoming less attractive to young people from vocational colleges underscores the evolving nature of skill preferences. Jobs that involve IT-related skills and automation are increasingly appealing. This shift shows a necessity in the approach to attract and retain talent in our sector. Using advanced systems like robotics, we can give the newer generation of shipbuilders an attractive career path. Within the Netherlands, discussions are already ongoing with universities and vocational institutions to make automatic welding part of the education package, in a practical way.

Compliance and Safety Standards:

The integration of robotics in shipbuilding not only brings technological advancements but also necessitates discussions with class societies and other regulatory bodies. As automatic welding is fairly new for class societies, extensive material testing of welded material is requested, and required by end users as suppliers of commercial robotic systems are generally not in contact with class societies. Mechanical tests are performed on welded joints, investigating the weld strength. Furthermore, non-destructive tests are performed on welds with the aim of obtaining a type approval, further discussions with class are needed to smoothen this process in the future.

Future Vision and concept

In addition to the lessons learned from the performed robotic welding tests, there is another future vision that was explored recently within Damen RD&I. A drawback of the commercially available automatic production systems, is that they are in general relatively limited in their flexibility, regarding reach and ability of welding curved seams. For the typical shipbuilding panel this is okay, although it is observed that a large amount (and length) of welds is left untouched to be performed manually. Crucially, these are also the welds that are least convenient for a welder to produce, as they are often in overhead position and/or hard to reach locations. For both these two reasons, no system is available in the market that can assist in this issue.



To explore the possibilities of automating those welds, an initiative was started within Damen RD&I to come up with a concept of a system enabling a robot to reach in tight box sections and hard to reach places. The provisional concept consists of a long, slender and flexible arm, with a relatively small and lightweight robot as end tool, making it possible to reach into a ship section (Figure 4).

The first questions that arose, were related to vibrations as a result of its flexibility. To validate the concept, a joint project was performed together with the Technical University of Twente, to predict the response of such an arm as result of

a vibrating robot. It was found that it is indeed possible to perform welding with the flexible arm concept. On the Damen Maritime Festival of 2023, a demonstrator was presented, showing the concept (Figure 5). In this case it consisted of a standard boom lift with a robot on top, and gave a decent impression of where to go: a futuristic solution where welders are not replaced by automation, but work alongside them in a safe way, taking away the burden of a big part of relatively straightforward jobs, leaving the more interesting and challenging jobs for the highly skilled and qualified colleagues on the shop floor. <<<



Figure 4: Impression of flexible robotic concept (Damen)



Figure 5: Demonstration of concept of flexible robotic system (Damen)