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AUTOMATION IN TIG WELDING: CONSTRUCTION OF A TRAINING WORKBENCH

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ABSTRACT: This study aimed to develop an automation mechanism for the TIG (Tungsten Inert Gas) welding process using Arduino control. The constructed device automates critical welding parameters, such as torch speed and height, controlled via Arduino. Preliminary tests were conducted to determine the optimal parameters, such as current intensity, welding speed, and gas flow. The project aims to create an educational workbench that, in addition to demonstrating TIG welding automation, provides a practical environment for experimentation and analysis. This automation provides greater precision, quality, and consistency in the process, making it more efficient and reducing dependence on human skills. A literature review on TIG welding and its automation was conducted. Subsequently, a workbench was built using components such as an Arduino Uno and a stepper motor. Practical tests were conducted using 1020 steel plates, demonstrating the feasibility of automation. The project demonstrated that TIG welding automation is feasible and brings significant improvements in the quality and efficiency of the process. The educational bench proved to be a functional model, enabling future innovations in the field of industrial automation.

KEYWORDS: Welding, TIG, automation, parameters.

Introduction

This work consists of systematizing automation in TIG welding through the construction of a teaching bench, with the purpose of discussing automation processes and their practical applications in the current industrial context, as well as exploring improvements in terms of efficiency, quality, and safety in the TIG welding procedure.

It is worth noting that the teaching bench aims not only to demonstrate the theoretical principles underlying automation in TIG welding but also to provide a practical environment for experimentation and critical analysis of the studies conducted. In this way, it promotes a deeper understanding of the variables involved and their influence on the final welding result.

Thus, welding is characterized as a manufacturing process present in the most diverse areas of the metal-mechanical industry, ranging from design to maintenance stages. Consequently, ensuring that the welded joint maintains its mechanical properties is essential.

In this specific context of the metal-mechanical industry, various welding methods are being employed with the aim of achieving the most advantageous mechanical characteristics. Each welding technique needs to be tested to determine the ideal parameters that ensure the most suitable mechanical properties are achieved in the welded joint.

Thus, TIG (GTAW) welding is introduced, which offers advantages over the SMAW process, such as the absence of slag formation. It is a welding method in which filler metal is applied to the workpiece using heat from a torch, which in turn protects the weld with an inert gas.

However, TIG welding faces challenges such as maintaining a constant feed rate for the filler wire, a continuous welding speed, and keeping the torch height relative to the weld joint consistently steady. By controlling and maintaining these parameters consistently, TIG welding achieves higher quality. Thus, we propose the development of a mechanism that can automate TIG welding, ensuring that the parameters presented here can be fully controlled.

According to Oliveira (2018), welding speed is an important parameter that influences the geometry of the weld bead. Additionally, welds can be performed to evaluate this influence using the automated equipment. Furthermore, it is hoped that collaborative work can be developed in which control theory is used to improve the welding process.

In this regard, TIG welding uses a tungsten electrode, with or without filler metal, employing argon or a gas mixture as a shielding gas, and an electric arc established between the electrode and the workpiece, resulting in a high-quality, precision welding process.

The automation of TIG welding, in turn, has gained traction due to the ability to achieve higher-quality welds, ensuring constant torch speed and optimal height. Widely used in the industrial welding of vehicles, machinery, metal structures, and a variety of critical components, the automation of TIG welding has emerged as an efficient solution for increasing productivity and precision, ensuring consistent quality standards and reducing reliance on human skill.

On the other hand, the benefits of TIG welding automation for the manufacture of automotive parts result in a reduction in welding defects and greater uniformity in weld characteristics. Given this, "this is yet another reason for the use of automated welding" (OLIVEIRA, 2018, p. 2).

Therefore, the objective of this study is to identify research that emphasizes TIG welding automation, as well as the construction of a teaching bench that enables TIG welding automation.

Theoretical Framework

Welding is a fundamental process in industrial manufacturing, used to join metallic materials by melting their contact surfaces. This process can involve various methods, such as electric arc welding, gas welding, and resistance welding, among others. Each technique has its specific applications, but all aim to achieve a strong and durable bond between materials. This field encompasses everything from the use of sensors and actuators to advanced control and monitoring systems, enabling not only production optimization but also rapid adaptation to changes in market demands.

In the context of welding, industrial automation plays a crucial role in standardizing processes, reducing waste, and improving product quality. In light of this, ZOU (2024) notes that automation in TIG welding provides a significant improvement in the quality of welded joints, resulting in lower porosity and higher mechanical strength, in addition to reducing the need for rework.

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Similarly, SHARIFF's (2023) research highlights the importance of automation in meeting the stringent quality and productivity requirements of modern industries. Furthermore, JOHN (1993) discusses aspects of TIG welding automation through ergonomic benefits by replacing repetitive and tiring tasks with machine-controlled operations, contributing to a safer and healthier work environment.

Given this, TIG welding automation is not merely a technological trend but a growing necessity in industries seeking to improve the quality of the final product, increase operational efficiency, and ensure worker safety.

All in all, welding automation represents a significant advance for the manufacturing industry, offering substantial benefits in terms of productivity, quality, and safety. However, successful implementation requires a deep understanding of the technologies involved and a strategic investment in equipment and training. With the continuous evolution of automation technologies and integration with Industry 4.0 concepts, the future of welding automation promises even more innovation and efficiency.

Furthermore, one of the advantages of this process is the ability to control the energy transferred to the workpiece, which is achieved solely through the independent control of the heat source and the addition of filler metal. One of the disadvantages of this welding process is the cost of the equipment, which is extremely high compared to other processes; it is also a low-productivity process (WAINER, 1992).

By implementing automation in TIG welding, companies can achieve consistent levels of quality and repeatability that are difficult to attain manually. Specially designed robots can precisely control the arc position and the feed rate of the filler material, resulting in more uniform welds and less rework. In addition, automation reduces cycle time and increases productivity, allowing human operators to focus on higher-value-added tasks, such as programming and process supervision.

Automation in TIG welding has revolutionized the industry by offering unprecedented precision and efficiency. According to a study by Technavio, "automation in TIG welding not only increases productivity but also improves weld quality, significantly reducing defects; using robots in TIG welding not only shortens cycle time but also ensures superior consistency in weld bead placement."

Finally, the adoption of automation in TIG welding is not limited to large industries but is also becoming feasible for medium-sized companies. As noted, technological advances are democratizing access to automation in TIG welding, enabling companies of all sizes to improve their operational efficiency and competitiveness in the global market (Robotic Industries Association). This suggests a trend of continued growth, where automation not only optimizes processes but also strengthens companies' ability to respond to market demands quickly and effectively.

Furthermore, welding is part of an automated welding system, but it is considered separately, since, among all the new technologies available, robots are one of the topics that require special attention, especially when it comes to "production costs" (TREMONTI, 1999).

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In addition to technical and operational advantages, automation in TIG welding also offers significant environmental benefits. Improved precision and control reduce energy and material consumption, minimizing waste and the generation of residues. This aspect is particularly important in a context of growing concern for sustainability and environmental responsibility in industrial operations.

However, automation can contribute to the implementation of more sustainable manufacturing practices, aligning with the goals of reducing carbon emissions and conserving natural resources. Thus, automation in TIG welding not only improves the efficiency and quality of the process but also supports companies in their efforts to achieve environmental and sustainability goals.

With the introduction of advanced technologies, there is a growing demand for operators with skills in programming and maintaining automated systems. This drives the need for specific training programs, promoting professional development and opening up new career opportunities for workers.

In light of this, the integration of automated systems not only raises production quality standards but also enhances the value of the workforce, transforming operators into specialized technicians and expanding their prospects in the job market. Thus, automation in TIG welding not only optimizes industrial processes but also plays a crucial role in the evolution and enhancement of the workforce.

Furthermore, automation facilitates the adoption of more sustainable manufacturing practices, aligning with the goals of reducing carbon emissions and conserving natural resources. Thus, automation in TIG welding not only improves the efficiency and quality of the process but also supports companies in their environmental and sustainability goals.

Automation in TIG welding has gained prominence due to its technical and operational advantages, as well as significant environmental benefits. TREMONTI (1999) notes that "among all accessible new technologies, robots are one of the topics that require special consideration, especially when it comes to 'production costs'." This highlights the importance of considering robots and other advanced technologies in the context of production costs and efficiency. Automation not only improves the precision and control of the welding process but also contributes to reducing energy and material consumption, minimizing waste and the generation of residues.

Furthermore, advances in automated technologies are generating a growing demand for operators with programming and maintenance skills for these systems. This scenario increases the need for specific training, promoting professional development and opening up new career opportunities for workers.

In addition to improvements in the production process, automation also has a positive impact on the workforce. As TREMONTI (1999) points out, the introduction of advanced technologies "drives the need for specific training programs, promoting professional development and opening up new career opportunities for workers." Automation transforms operators into specialized technicians, enhancing the value of the workforce and expanding job market prospects. Thus, automation in TIG welding not only raises production quality standards but also plays a crucial role in the evolution and enhancement of the workforce.

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Thus, the integration of automated systems not only raises production quality standards but also enhances the value of the workforce, transforming operators into specialized technicians and broadening their prospects in the job market. Therefore, automation in TIG welding plays a crucial role in optimizing industrial processes and enhancing the value of professionals in the field.

Methodology

This study utilized a TIG welding machine, the LYNUS LYS-250AL POWER, a robust and versatile inverter welder ideal for professionals who need a reliable machine for a variety of welding applications. With its ability to operate with different types of electrodes and its portability, it stands out as a popular choice in the welding equipment market. As shown in Figure 1 below.

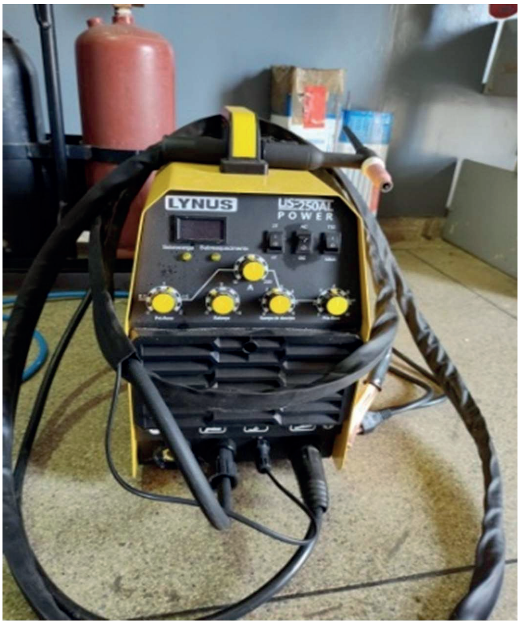

Figure 1 - Source: own

Simultaneously, the parameters to be used in welding were tested; these parameters were obtained through practical experimentation. The parameters obtained were the machine's amperage for the thickness of the sheet to be welded and the appropriate welding speed.

To create the workbench, AutoDesk's Inventor software was used, in which the table serving as the base for the welding torch was designed, as well as the coupling for securing the torch. The design of the support table was based on the dimensions of the TIG torch from the machine available at the Welding Laboratory of the Federal Institute of Education, Science, and Technology of Ceará – Cedro *Campus*. After the design was completed, the support table was fabricated to serve as the base for the torch, the motor, the guide spindle, and the coupling between the spindle and the torch. The table was constructed using steel angle irons that were welded together to form a base table.

The two-part coupling was fabricated using a 3D printer, the XYZ Printing Da Vinci model, which employs fused deposition modeling (FDM) technology, a common method in affordable 3D printers. In this process, a plastic filament (such as PLA or ABS) is heated and extruded in overlapping layers to build the desired object. As shown in Figure 2 below.

Figure 2 - Source: own. Prototyping laboratory.

Thus, a mechanical support was developed (Figure 3) designed to enable the automation of a TIG welding torch, while also allowing for adjustment of the torch's height.

Figure 3 – Two-part plastic coupling. Own source.

The experiments were conducted using 1020 steel plates, measuring 10 cm x 5.7 cm, placed on the workbench. After the parts were positioned on the table, the software was activated and the torch was automatically positioned; pressing the inert gas button turned on the torch, causing fusion in the steel plate.

The following components were also used for automation, as shown in Fig. 4: Arduino Uno: Used as the central controller due to its flexibility and ease of programming, allowing for precise control of welding parameters. Nema 23 Stepper Motor: Chosen for its high precision and motion control, essential for maintaining the welding torch at a constant height and speed during the process. Stepper Motor Driver: Used to control the current sent to the motor, ensuring smooth operation and the precision required for torch movement.

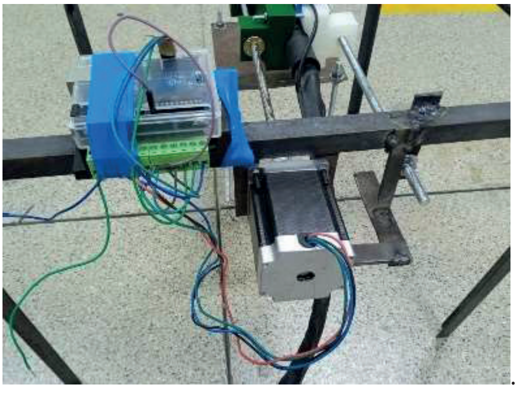

Figure 4 - Source: own

This entire system is powered by a low-voltage power supply that safely and stably powers the Arduino and the stepper motor.

Results and Discussion

The methodology used in the assembly of the TIG welding automation workbench proved to be effective and well-structured. The tests conducted were satisfactory, demonstrating the system's precision and consistency during the welding process. The approach adopted not only enabled the achievement of the proposed objectives but also validated the potential of automation to improve work efficiency and quality.

The teaching bench, Figure 5, proved to be easily adjustable to the size of the joints to be welded, as well as to the desired welding speed. These adjustments can be made by calibrating the stepper motor and modifying the code, ensuring that the system is flexible enough for different welding scenarios. The methodology employed in assembling the TIG welding automation bench proved to be a systematic and efficient procedure. The use of the Arduino Uno as the central controller allowed for flexible programming and the implementation of various functions, while the driver and the Nema 23 motor ensured the precise and controlled movement of the welding torch.

Figure 5 - Source: own

The tests conducted, shown in Figure 6, yielded satisfactory results, with consistent welds of the desired quality, reflecting the effectiveness of automation in reducing human error and increasing process repeatability.

Figure 6 - Source: author

Thus, the welds produced exhibited the weld bead continuity expected for an automated TIG process, that is, constant feed rates and a constant torch height.

Conclusions

The project to build the TIG welding automation bench was successful, with tests confirming the system's effectiveness. Using an Arduino Uno, a driver, and a Nema 23 motor, it was possible to create a robust and efficient setup capable of meeting the precision and quality requirements of welding. The satisfactory results obtained in practical experiments demonstrate not only the feasibility of automation in this process but also the repeatability and control that the workbench provides.

The developed automation workbench not only fulfills its immediate purpose but also serves as a solid foundation for future research and improvements. The project opens the door to further innovations, enhancing the use of automation in welding processes and contributing to the continuous evolution of this field.

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It can therefore be concluded that this project not only represents an immediate advance but also reinforces the importance of automation in transforming welding practices and in the development of smarter and more effective industrial solutions.

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