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AUTOMATION SYSTEM DEVELOPMENT FOR MULTIPROCESS WELDING MECHANISM

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Abstract. *The metal-mechanic industry has a need to develop new techniques and methods to achieve continuous improvements in the welding area. In the study on weldability it is important that there is the possibility of reproducing several times the same result, which can not be obtained by manual and semi-mechanized operations precisely. The aim of this work is to realize the control project, as well as the automation system for the multiprocess welding mechanism manufactured at the Ifes - São Mateus campus, in order to obtain the control with high precision of the welding variables, as change them as needed. In the control system two stepper motors were used as actuator, which were controlled through Arduino™ as an open-loop system and with a graphical user interface programming in the Processing™ software. The construction of the automation system enabled the built mechanism making it possible to carry out tests, confirming the performance capacity.*

Keywords: *Automation, Embedded Systems, Arc Control.*

1. INTRODUCTION

Today, automation is present in many areas of industry and has become a routine activity where it is necessary to reduce human effort or interference on a process or machine. Welding tests present distortion and inaccuracy in their results when performed by a human operator, and automation brings us great advantages in terms of precision and reliability, such as variable control and weld bead quality (Fogagnolo, 2011).

According to Fogagnolo (2011) in the study on weldability, electric arc behavior, and physical and metallurgical aspects of the weld bead, it is necessary that the weld bead show regularity such as welding speed, arc height, depth, and angle of attack. In the manual welding processes, the variables involved have a high level of operator dependence, making it difficult to reproduce the same result several times. These are the reasons for using automated welding.

The automatic term indicates that all the functions or steps in the operations are performed by mechanical and / or electronic means, without any adjustment made by the welder, except for possible programming of the equipment (Marques, 2009). Thus, with the technological advances associated with the application of electronic automation in industrial processes, several types of automation systems have emerged (Ribeiro, 2001).

The present work has the objective of realizing the control project, as well as the elaboration of the automation system for the multiprocess welding mechanism manufactured at Ifes - São Mateus campus, in order to obtain the control with high precision of the welding variables, as change them as needed. In the control system two stepper motors were used as actuator, which were controlled through Arduino™ boards as an open loop system and programmed a graphical user interface via Processing™ software. The construction of the automation system enabled the built mechanism making it possible to carry out tests, confirming the performance capacity.

2. THEORETICAL FOUNDATION

In the bonding methods, the welding processes are the most widely used in the world. These processes can be used to fabricate and assemble different configurations of structures, as well as in the maintenance industry, where the parts to be welded can be found in several positions (AURES, 2013).

Welding processes can be classified, according to the application methods, which is based on the degree variation of control of the activities related to the process that depend on the human interference (FELIZARDO; BRACARENSE, 2006). According to Marques, *et al.* (2009) these methods of application are defined as manual, semiautomatic, mechanized, automatic, robotic and with adaptive control.

AWS A3.0.2010 (2010, p. 3-49) defines welding processes as:

> Manual welding is the welding with torch or electrode holder held and manipulated by human hands.
>
> Semi-automatic welding is the manual welding with equipment that automatically controls one or more welding conditions.
>
> Mechanized welding is the welding with equipment that requires manual adjustments in the control of the equipment in response to the visual observation of the welding, with the torch or electrode holder held by a mechanical device.
>
> Automatic welding is the welding with equipment requiring only occasional observation or no welding observation and no manual adjustment in controls of equipments.
>
> Robotic welding is the welding that is performed and controlled by a robotic equipment.
>
> Welding with adaptive control is the welding with equipment that has a control system that automatically determines changes in the welding conditions and acts on the equipment so that the appropriate action is performed.

According to the classification above, Felizardo and Bracarense (2006) say that the coated electrode process is manual, since the welder is responsible for the execution of all the activities. The GMAW and FCAW processes are semiautomatic, since wire feeding, opening and maintenance of the electric arc are carried out by the machine, and the torch displacement is carried out by the welder. The GTAW process is classified as manual, but easily automated (ESAB, 2000).

The automatic term indicates that all functions or steps of an operation are performed in sequence, by mechanical and/or electronic means, without any adjustment made by the welder, except for adjustments of the equipment. Automation can also be partial, with certain steps performed by the welder. The aim of automation is to reduce production cost, increasing productivity and improving the quality and reliability of the final product by obtaining repeatability, and being possible by reducing or eliminating human errors (Marques *et al.*, 2011).

2.1 Control Systems: Arduino

Arduino Uno™, as shown in Fig. 1, is an ATmega328P-based microcontroller board where it functions as an open source platform, ensuring that anyone makes Arduino™-compliant boards and adaptations as required for the creation of independent projects or in collaboration with the computer. Arduino™ boards provide low-cost, mass-produced, easy-to-use technology for researchers with little experience in programming and electronics, given the support available from the Arduino™ community and being programmed with simplified C++ language (MONK, 2012).

Figure 1. Arduino Uno board. Source: ARDUINO™ (2016).

According to D'Ausilio (2011) several manufacturers have produced additional items called Shields that are capable of extending the basic capabilities of Arduino™, such as allowing control of DC and stepper motors, allowing multiple Arduino™ boards communicate wirelessly and integrate 3-axis accelerometers. The Arduino Motor Shield™ board, Fig. 2, which is based on the L298 driver, allows you to control the speed and direction of two DC motors or one stepper motor.

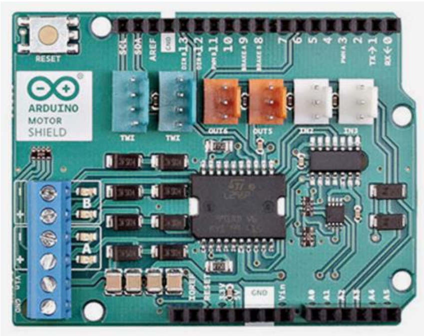

Figure 2. Arduino Motor Shield™ board. Source: ARDUINO™ (2016).

2.2 Control systems: Processing™

Processing™ is a flexible software, with ease of communication with Arduino™, with an intuitive and visually responsive environment in relation to the man/machine interface and a language to learn coding within the context of the visual arts, to make images, animations and iterations (REAS, FRY, 2010).

3. MATERIALS AND METHOD

In the present work the control project was carried out, as well as elaboration, to realize the control the multiprocess welding mechanism manufactured at IFES - Campus São Mateus. The control system has the function of providing the user with an interface to select the welding process to be used, and in sequence the control of the welding variables, so that it is possible to control and simulate the welding variables in the tests.

3.1 Sizing of stepper motors

In the mechanism, it was decided to use recirculating ball bearing spindles, where the balls roll between the screw shaft and the nut to achieve a high efficiency and, according to the manufacturer's catalog OBR Equipamentos Industriais Ltda., the required drive torque is only one third of the normal sliding bolt. Thus, this type of spindle is able to convert the spinning moment into a rectilinear. In order to move the spindle, stepper motors were used.

As in the control system two stepper motors were used as actuators, which are electromechanical devices that convert electrical pulses, following a digital logic, into mechanical movements that generate discrete angular variations (Brites, 2008). The motors have high precision in their positioning due to well determined rotation angles and have a low and non-cumulative positioning error, precision in applied torque and excellent response to acceleration and deceleration due to the rapid alignment of the rotor with the sequential activations of the coils.

For the sizing of stepper motors, the manufacturer's catalog OBR Equipamentos Industriais Ltda. was used as reference. As the device can be used in various welding positions, it has different behaviors in relation to the distribution of loads on the spindles, so it was adopted the most critical situation possible that would be with the motor upright.

The characteristics of the selected motors are shown in Tab. 1 and 2.

Table 1. Feed system motor specification. Source: Adapted from NEOYAMA (2016).

NEMA	CONNECTION	TORQUE (kgf.cm)	CURRENT (A/phase)	VOLTAGE (V/phase)	RESISTANCE (Ω/phase)	INDUCTANCE (mH/phase)
23	Bipolar – sequence	15,0	2,1	4,2	2,0	8,0
	Unipolar	10,5	3,0	3,0	1,0	2,0

Table 2. Technical specifications of the dive system motor. Source: Adapted from NEOYAMA (2016)

NEMA	CONNECTION		TORQUE (kgf.cm)	CURRENT (A/phase)	VOLTAGE (V/phase)	RESISTANCE (Ω/phase)	INDUCTANCE (mH/phase)
23	Bipolar	Sequence	7,0	1,0	5,0	2,4	9,2
		Parallel		2,0	2,5	0,6	2,3
	Unipolar		4,9	1,4	3,5	1,2	2,3

Stepper motors were used in the bipolar-series configuration as it provides better features for the entire system.

The control of the motors was done through Arduino UNO™ boards, where it has a microcontroller based on the ATmega38P and works as an open source platform. Arduino™ boards provide low-cost, mass-produced, easy-to-use technology for researchers with little experience in programming and electronics, given the support available from the Arduino™ community and being programmed with simplified C++ language (Monk, 2012).

Automation was developed as an open-loop control system where the output signal is neither measured nor fed for comparison with the input, being characterized as a time-based sequence (Ogata, 2010). The programming of a graphical user interface was performed in Processing™ software, a flexible software with ease of communication with Arduino™, with an intuitive and visually responsive environment in relation to the man/machine interface and with a language to learn coding within the context of the visual arts, to make images, animations and iterations (Reas, 2010).

3.2 Electrical circuit

In the design of the electric circuit, a diagram was developed initially, Fig. 3, to better visualize the components that integrate this system, in which it is possible to have an overview of the components that are necessary for the structure's operation.

The system features external power, which supplies power to the computer where the graphical user interface is installed, and to the two external sources that power the Arduinos™ and Shields that make up the system.

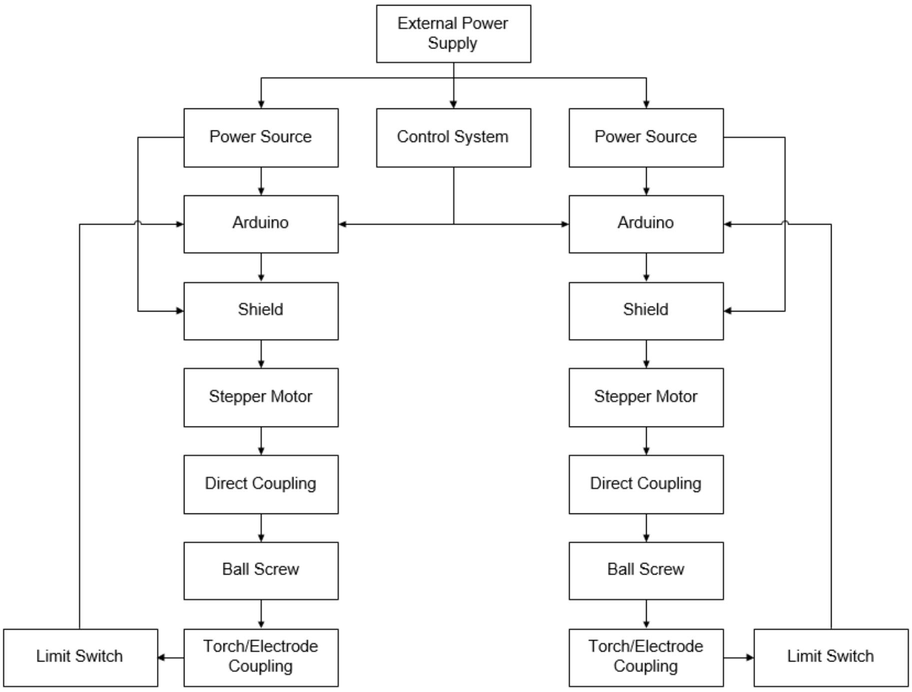

Figure 3. Block diagram for electrical system. Source: Own authorship.

4. RESULTS

The interface between the user and the control system was developed through the Processing™ software and can be seen in Fig. 4. Through it is possible to control the size of the welding arc and the speeds of the stepper motors, as well as inform the Arduino™, via serial communication, parameters necessary for its operation, such as the length and thickness of the part to be welded and the type of welding. The control can be done automatically and it is necessary to calibrate the system before using this mode, or manually for any needs.

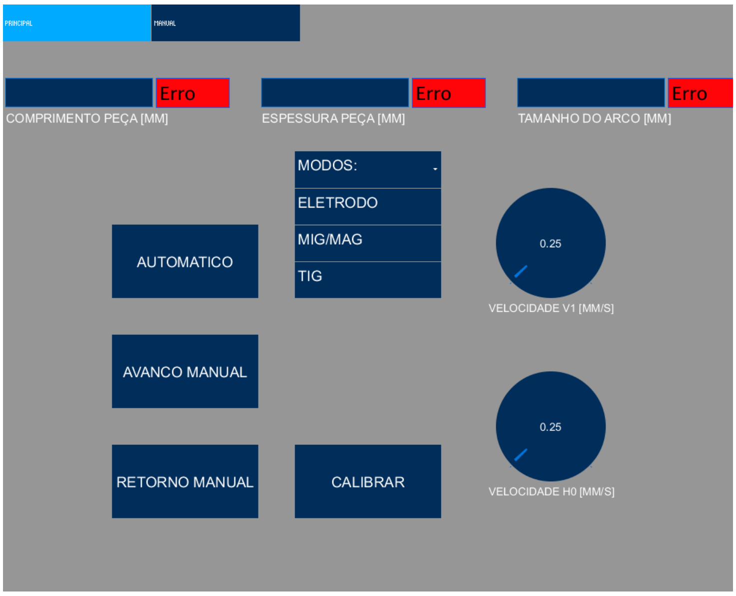

Figure 4. Graphical user interface. Source: Own authorship.

Two Arduino UNO™ boards and two Arduino Motor Shield™ boards were selected, Fig. 5. When the Arduino™ receives the parameters via serial port, it processes the data and executes the control code for the positioning of the torch through the parameters received. The Arduino™ then sends command signals to the shield which, connected to the stepper motor and the external source, is able to control the motor properly.

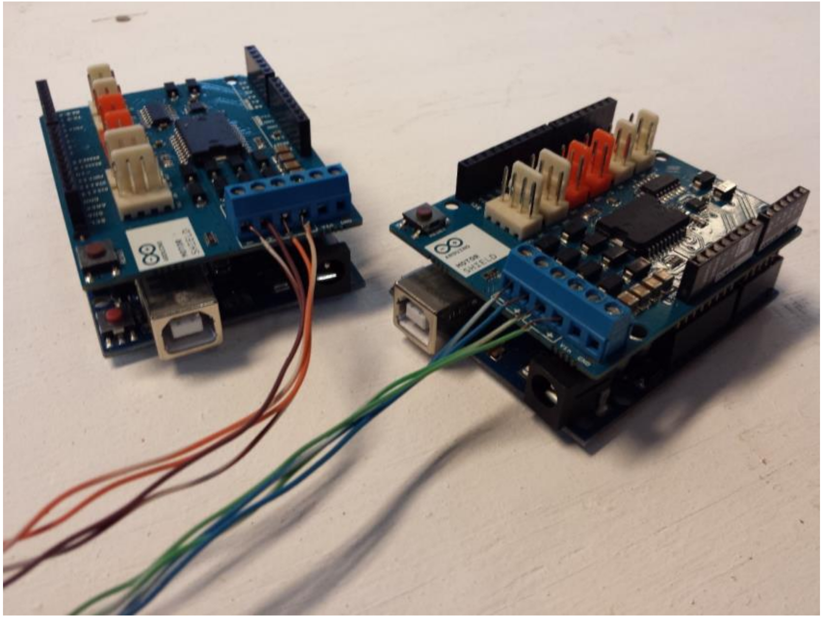

Figure 5. Arduino™ and Shield Attached. Source: Own authorship.

The step motor is coupled to the ball screw, and this is coupled to the torch/electrode holder, which allows the movement of the structure, as detailed in the previous sections. The limit switch is used to indicate the starting position of the machine and for safety measures. As there is no system feedback, the system is characterized as open loop.

In Figure 6 it shows the manufactured mechanism and the equipment being used.

Figure 6. Automated multiprocess welding mechanism.Source: Own authorship.

5. CONCLUSION

To achieve the objectives proposed in this work, an interface was developed to control the device and proved to be versatile in the man/machine control function.

The automated multiprocess welding mechanism presented good results and capacity to be used in future studies involving several aspects in the welding processes. From the results found in the practical tests we can conclude that the mechanical design behaved efficiently, showing a rigid structure able to keep stable during the tests.

With the automation of the mechanism, it can be seen that the movement control was performed in a satisfactory way, presented with uniformity along the course. The stops, speed and direction changes also showed good control and precision.

6. ACKNOWLEDGEMENTS

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8. RESPONSIBILITY NOTICE

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