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DEVELOPMENT OF AN AUTOMATED MULTIPROCESS WELDING MECHANISM

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Abstract. *The automation in the welding processes brings great advantages, as the control of the variables and quality of the weld bead. In the study on weldability, such as the behavior of the electric arc, physical and metallurgical aspects of the weld bead it is necessary to present regularity such as welding speed, arc height, depth, and angle of attack. The variables involved in manual welding processes or semi-machined, have a high level of operator dependence, making the reproducibility hard or even making it unproductive to perform a weld with good quality. The study of these variables have a fundamental importance for improving the control of the welding processes, obtaining weld beads without defects, reducing the amount of spatter, predicting the penetration of the pass, evaluating the amount of heat transferred to the base metal and controlling the distortion of the welded structure. The aim of the present work is to realize the mechanical design of a device to automate the welding processes by coated electrodes, gas metal arc, tubular wire and gas tungsten arc, in order to obtain improvements to perform experimental studies, which will allow a better analysis of metallic transfer, weldability, melting rate, influence of parameters and welding variables, with a high degree of repeatability and precision. The construction of the mechanism enabled the mechanical design confirming its ability to act.*

Keywords: *Mechanism, Mechanical Structure, Welding.*

1. INTRODUCTION

Welding is considered the most important method of joining metals and its application extends throughout the industry. According to AWS (2010, page 47), welding can be defined as a "bonding process of materials used to obtain localized coalescence of metals and non-metals, produced by heating to a suitable temperature, with or without the use of pressure and/or addition material. "

In fact, given the importance of welding throughout the industry, there is little point in developing a new material if it does not show good weldability.

According to Fogagnolo (2011) in the weldability study, electric arc behavior and the physical and metallurgical aspects of the weld bead, it is necessary that the process variables, such as: welding speed, arc height, penetration depth and angle of attack show regularity during the execution of the weld. These variables, in manual processes, present a high level of operator dependence, making it practically impossible to reproduce the same conditions in different weld beads and in mechanized processes, although the operator interference is smaller, it still becomes impracticable to accurately repeat the weld beads. These are reasons for using automated welding when studying the weldability of materials. The automatic term, according to Marques et al. (2009), indicates that all functions or steps in the operations are performed by mechanical and/or electronic ways without any adjustment made by the welder except for possible programming of the equipment.

Some of the most common welding processes are those that use an electric arc to heat the base and addition metals providing the junction of the same, namely:

- Shielded Metal Arc Welding (SMAW), a manual process where all variables are executed and controlled by the welder.
- Gas Metal Arc Welding (GMAW), a semiautomatic process in which the welder is responsible for the displacement of the welding torch; arc opening and wire feed are performed by the machine.
- Gas Tungsten Arc Welding (GTAW), an easy-to-automate process in which the welder is responsible for opening the arc and controlling the welding torch.

The activities presented in this work are part of the mechanical design of an automatic multiprocessing welding machine (SMAW, GMAW, tubular wire - FCAW and GTAW) that will allow a better analysis of the metal transfer, weldability, melt rate and influence of the parameters and welding variables, with a high degree of repeatability and precision. With the construction of this proposed project, it will be possible to weld test bodies in the flat, vertical ascending and descending and overhead positions, thus enabling in-depth studies of the process, besides accurately simulating the welding conditions. In the design of the mechanical design was used the software Inventor®, which provided the verification of the interchangeability and degree of freedom of the whole device. The construction of the mechanism enabled the mechanical design confirming the capacity of actuation.

2. THEORETICAL FUNDAMENTATION

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

According to Felizardo (2006), the welding process by coated electrode is manual, since the welder is responsible for the execution of all the activities and control of the welding variables. The GMAW and FCAW processes are semiautomatic, since the wire feed and the opening and maintenance of the electric arc are performed by the machine; the torch displacement is performed by the welder. The GTAW process is classified as manual, but easy to automate.

A typical system for process mechanization is gravity welding, which has the purpose of providing repeatability and standardization of weld beads (DANTAS, 2006). There are several types of gravity welding devices, but in all there is the possibility of varying the speed of advance and the quality of the weld bead, through the control of angles and the welding current. Cavalcanti (2011) developed a gravity welding device (Fig. 1), where the electrode is attached to pulleys that slide through a guide.

Figure 1. Gravity welding device. Source: Calvalcanti (2011).

Good results were obtained using the E6013 coated electrode at a 60 ° angle between the electrode and the plate to be welded, 60 ° between the guide and the base and for certain currents, but it offers a limitation for further experiments, such as the working angle used is unusual and the geometry of the device allows only the operation to be performed in the flat position and this prevents this mechanized process from being used in most industrial procedures.

Another mechanism that aims to provide the robotization of the coated electrode welding process is a system proposed by Kang (1996), which consists of an automatic electrode feeding system, where an electric motor is responsible for providing the dipping movement of the electrode; the motor control was carried out through the evaluation of the welding voltage. This feeding system did not present acceptable results since the means of measuring the voltage were not efficient.

Dantas (2006) presented the development of a robotic claw for the welding process by coated electrode, this project had as principle the selection of a system that can be incorporated to a robotic manipulator, this one functions as an electrode holder, providing the passage of current, fixation of the coated electrode and its instrumentation, to extract and provide information to the robot controller. The developed prototype presented and behaved efficiently in the tests performed.

Aures (2013) developed a mechanism for the simulation of welding in tubes by the GMAW process, in which it welds flat plates with the same characteristics of a circumferential welding, called a rectifier duct welding simulator (SSDR), Fig. 2. As for conducting a pipe welding simulation it is necessary for the torch to move and provide the change of position at every moment, passing through the flat, vertical and overhead positions. The developed mechanism performed tests for up and down welding, presenting good results depending on the welding parameters that were recommended for the joint, but in the tests, it was noticed that the SSDR rotation did not remain constant as it rotated, because the speed control mechanism was not efficient.

Figure 2. SSDR. Source: Aures (2013).

Chen, *et al*. (2012) proposed a GTAW welding system integrated to the addition metal fusion mechanism from the GMAW process where a lateral electric arc is established between tungsten and the addition metal as shown in Fig. 3. The elaborated machine obtained a velocity of deposition of material similar to the GMAW process, when using the same welding parameters, but with a better method of electric arc control, similar to the conventional GTAW process. This system performed well in most tests.

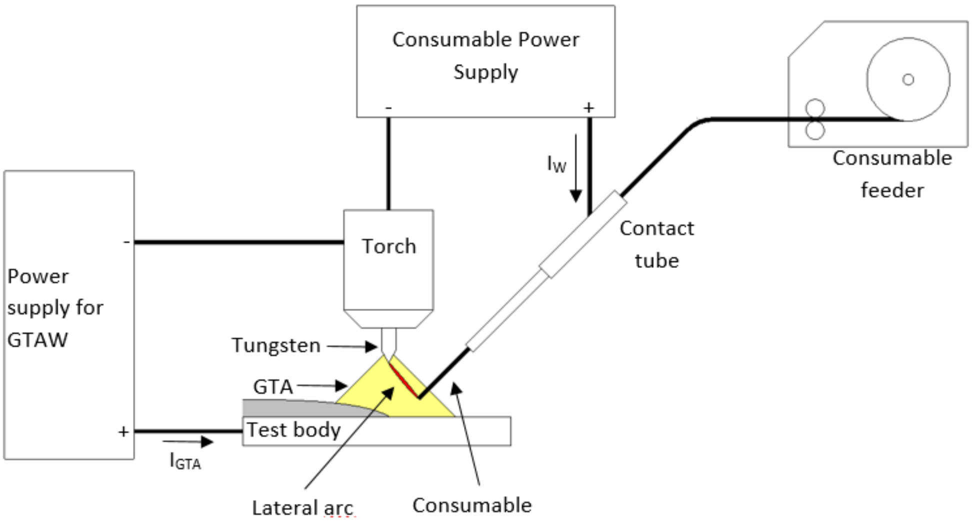

Figure 3. GTAW arc-addition metal system. Adapted from Chen, *et al.* (2012).

3. DESIGN OF THE WELDING MECHANISM

In the present work, an automated multiprocess welding machine was designed for experimental studies, with the intention of realizing the welding of test bodies in the positions flat, vertical ascending and descending and overhead.

The principle of operation of the mechanism is given by the movement of the test body towards the melting pool, which will be regulated according to the recommended welding speed for each process. For the GMAW, FCAW and GTAW processes there must be a torch positioning system to regulate the nozzle-part position and to realize the opening of the electric arc, in the process by coated electrode there must be the advance movement of the electrode towards the fusion well.

To meet the design requirements, the mechanism comprised the joining of the advance movement systems of the test body to be welded, electrode dipping, angle adjustment and welding position and mechanical structure. The project was elaborated with the purpose of producing a test body with maximum geometry of 350x200 mm, of length and width, respectively.

3.1 Test body feed system

This system has the function of simulating the welding advance movement, providing the welding speed, which must be continuous and constant to allow the accuracy of the test. It was opted for the part to move in place of the electric arc, because in this way, the analysis of the electric arc becomes more efficient, in that it will be fixed in a position facilitating tests.

Knowing that the maximum length of the test body is 350 mm, as already defined above, it is necessary to have a displacement bus for the part with a minimum length of 700 mm, as the test body will perform the welding advance movement.

A linear displacement system was developed, consisting of two linear guides, two linear bearings and a recirculating ball bearing spindle, providing less friction, better control, displacement accuracy and guaranteeing high durability and resistance in different conditions.

For the fixation of the test body a set of two tables was developed, one for the fixation of the linear bearings together with the nut of the spindle, and the other table for the fixation of the test bodies, where a cramp system was used for the locking the parts. The two tables in question were separated by a distance of 10 mm to facilitate the dissipation of the heat generated by the welding process. The material selected for its construction was the austenitic stainless steel, due to the qualities of having mechanical strength with excellent resistance to corrosion in both ambient and high temperatures. In this way, the test body feed system was dimensioned according to Fig. 6.

3.2 Electrode dive system

This system has the function of reproducing the dip movement of the coated electrode, so that it can simulate the movement performed in practice. It was adopted as the maximum length of the coated electrode 400 mm, which is related to most coated electrode lengths in the market. For the GMAW, FCAW and GTAW processes the function of this system is to make the arc opening and control the nozzle-part distance.

Therefore, a linear displacement system similar to that of the test body advance was developed, which also consists of two linear guides, two linear bearings and a recirculating ball bearing spindle. As this system has the function of fixing and positioning the torches for the GMAW and GTAW processes, and the electrode holder of the coated electrode process, it was necessary to differentiate the fastening systems, in this way an assembly was produced to join the linear bearings to the spindle nut, and at the same time, join the different fixation and positioning systems. Based on these requirements, the electrode dipping system was dimensioned according to Fig. 6.

As one of the functions of this system is the fixation of the coated electrode and the GMAW and GTAW torches, the design and construction of two fixation systems, one for the torches and the other for the coated electrode, were carried out. The systems are modular and adapted to the diving system.

The fixation system for the coated electrode is shown in Fig. 4, where it is composed of an electrical insulation system, a conducting cable, and a mandrel for fixing the electrode.

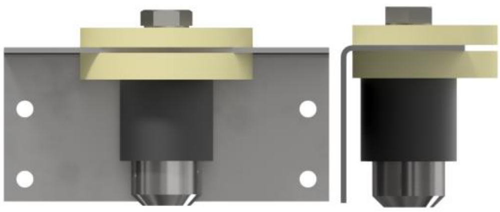

Figure 4. Electrode fixation system. Source: Own authorship.

The insulation system consists of two pieces of Nylon 6.6 Technyl, known commercially by Tecnil. According to Figure 4, the parts prevent electrical contact of the screw, which allows the passage of the electric current to the mandrel and to the coated electrode.

The selected conductor cable was the commercial model with a diameter of 10 mm, since it was able to work without heating it during welding.

The selected mandrel was a drill holder, 1.5 - 10 mm 3/8" - 24UNF, for electrode attachment. The same is a low-cost tool and can perform its function of fixing and allowing the passage of electric current, as was proven in the work of Dantas (2006). A 3/8" mandrel was used because it is a model that allows the fixation of electrodes with different gauges and does not provide a significant increase in the torque of the drive motor of the system, in addition to allowing the quick replacement of the electrode.

The fixation system for the GTAW and GMAW torches is shown in Fig. 5.

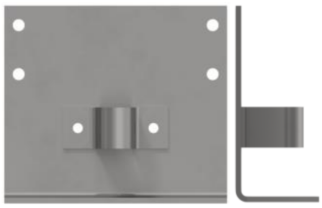

Figure 5. GTAW and GMAW torch clamping systems. Source: Own authorship.

3.3 Welding angle adjustment and position system

This system has the function of pre-establishing the angle between the torch or electrode with the part, support the test body feed and electrode dipping systems, and provide and establish the welding position, flat, vertical and overhead. In addition, this system must behave rigidly, to not to cause any interference at the time of welding.

Consequently, a structure consisting of a shaft, two support discs interconnected to the mechanical structure, two bushings were used to allow the adjustment of the welding position and a system composed of three gears to promote the adjustment of the welding position and the fixation of the whole system. The material selected for the production of the support shaft was the carbon steel ABNT 1045 for its reasonable mechanical resistance in line with its ease of machining. The bushings were made of aluminum because of their high ductility. Therefore, the angle adjusting and welding positioning system was dimensioned according to Fig. 6.

3.4 Mechanical structure

The mechanical structure has the function of supporting and sustaining the other parts of the project. When the system is in operation, it must be able to keep the system level so that it does not impair the preparation of the test body, maintain the balance of the structure and be able to allow the systems to take a 360° turn to select the welding positions.

It was chosen to work with steel tube of square profile by the facility of manufacture in relation to its resistance. To support the angle and position adjustment system a circular carbon steel plate was machined. In the base were fabricated height regulators for level control, the mechanical structure was dimensioned according to Fig. 6.

3.5 Mechanism analysis

The automated multiprocess welding mechanism is shown in Fig. 6 and 7, which show the four systems that make it up.

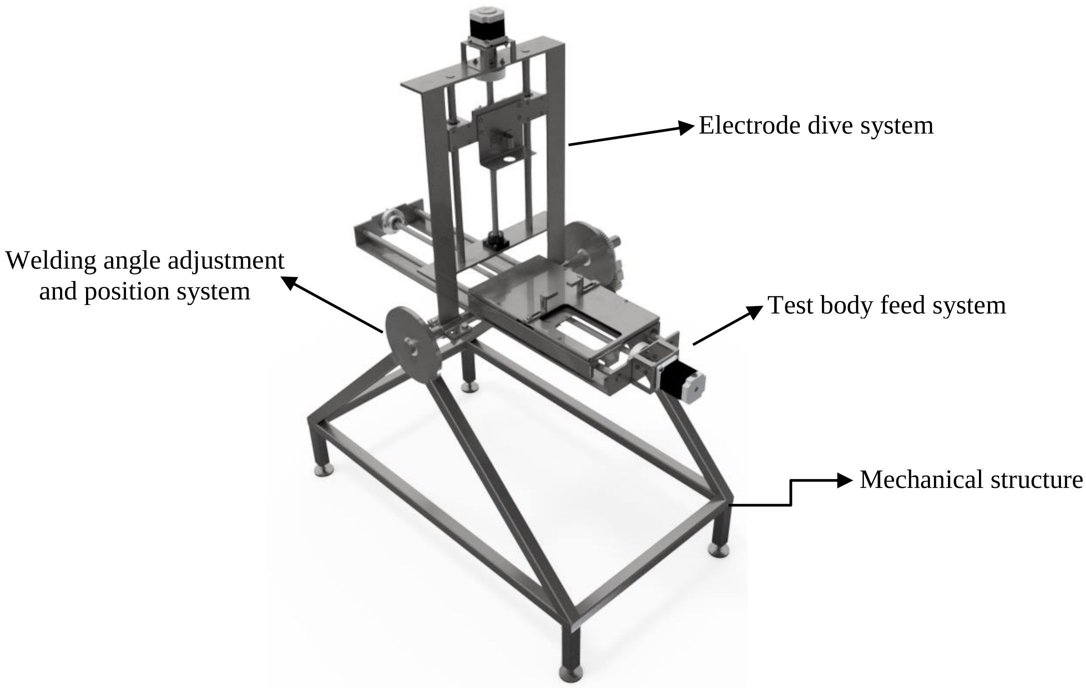

Figure 6. Perspective view of the mechanism. Source: Own authorship.

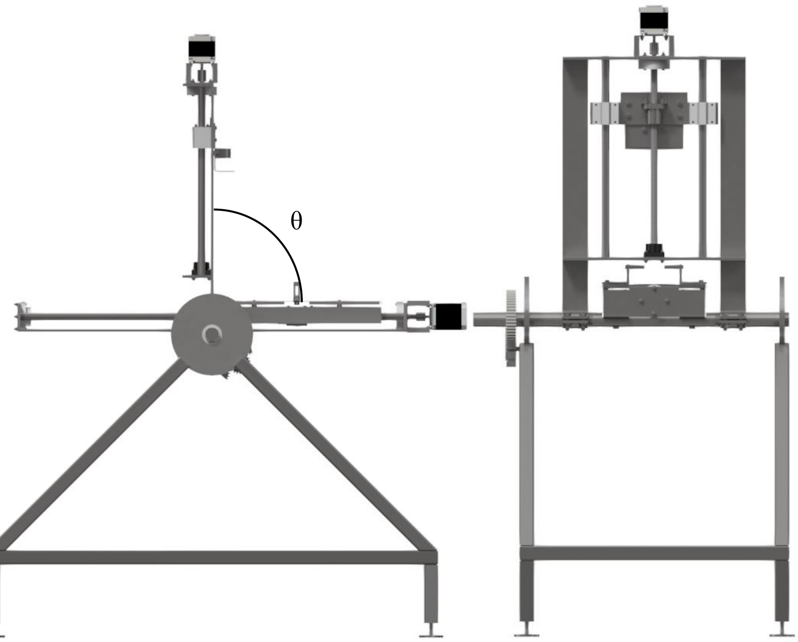

Figure 7. Left and front side views of the mechanism. Source: Own authorship.

Figure 8 shows the relationship between the momentum and slope angle of the dive and control system, where we can see that the maximum moment reached was 64 Nm.

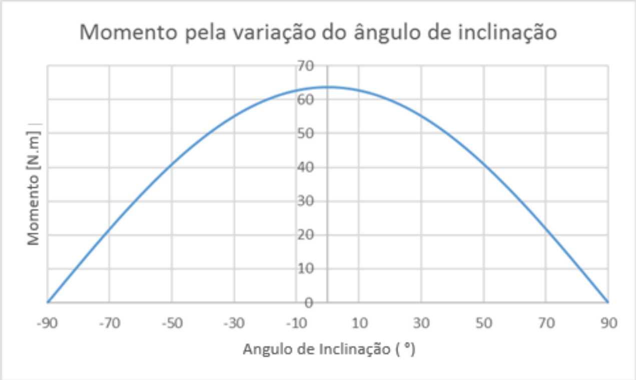

Figure 8. Relation between the moment and angle of inclination of the diving and control system. Source: Own authorship

As shown in Figure 8, the critical loading situation of the structure is when the electrode dip system is at 0°.

Considering the classification adopted by Felizardo and Bracarense (2006) we can affirm that the device in question is a fixed or programmable automated equipment (fixed automation), since the mechanism can act in different welding processes depending on its programming.

4. RESULTS

The welding multiprocess mechanism was manufactured in the mechanical workshop and in the welding laboratory of the IFES, and there was also the support of SENAI / DR-ES unit of São Mateus.

The main manufacturing processes required for manufacturing were turning, milling, drilling, folding and welding, being used together to manufacture the systems that make up the mechanism.

The feed system is shown in Fig. 9. During the movement of the tables the assembly behaved in a stable manner, with no apparent variations in the displacement, but in the processes of welding by coated electrode and GTAW, at the moment of the opening of the electric arc, the table of fixation of the test body showed a small displacement due to the elasticity of the table.

Figure 9. Feed system. Source: Own authorship.

Due to minor inaccuracies in the machine tools, lathe and milling machine, it caused a slight misalignment between the motor shaft and the recirculating ball screw, making it impossible to use a fixed coupling. Thus, due to these imperfections, a coupling of polymeric material was made to compensate for this deviation. Figure 10 shows the coupling made.

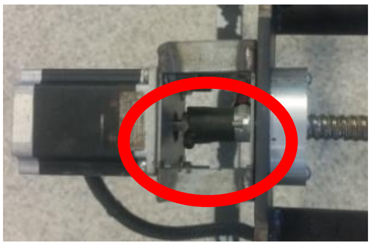

Figure 10. Coupling used. Source: Own authorship

Figure 11 shows the dive and control system. During the displacement of the assembly behaved in a stable manner, both for the opening of the electric arc in the GTAW and coated electrode processes, as well as to maintain the diving movement in the coated electrode process.

Figure 11. Diving and control system. Source: Own authorship.

The clamping systems for GTAW and GMAW torches are shown in Fig. 12. This system was able to position the torches rigidly and accurately.

Figure 12. GTAW and GMAW torch clamping systems. Source: Own authorship.

Figure 13 shows the fastening system for coated electrode. This system presented rigidity in its structure. The electrode exchange behaved efficiently, as the use of the mandrel made the replacement of the electrode fast.

Figure 13. Coated Electrode Fixing System. Source: Own authorship.

The electrical current isolation system performed by Tecnil was able to act as an insulator even when the system temperature was high during welding.

The welding angle adjustment and position system is shown in Fig. 14. The assembly was rigid without any elasticity on the support axis. The system has proved to be efficient, in addition to making future automation in the rotation of the support axis more accessible, and thus simulating circumferential welding.

Figure 14. Welding angle adjustment and position system. Source: Own authorship.

The mechanical structure is shown in Fig. 15, which has been shown to be a rigid structure, with no elasticity. The level control feet behaved efficiently.

Figure 15. Mechanical structure. Source: Own authorship.

The assembled mechanism is shown in Fig. 16.

Figure 16. Automated multiprocess welding mechanism. Source: Own authorship.

5. CONCLUSION

In order to achieve the objectives proposed in this work, an automated mechanism for multiprocess welding was developed and manufactured, which was composed of systems to perform the functions required by the equipment and the elaboration of an interface to control the device.

From the results found in the manufacturing of the mechanism we can conclude that the mechanical design behaved efficiently, showing a rigid structure capable of maintaining stability during future tests.

6. ACKNOWLEDGMENTS

We thank the IFES for the structure assigned to the construction of the project.

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8. AUTHORAL RESPONSIBILITY

The authors are solely responsible for the content of this work.