Automatic welding process : a study case of Soldering Machine

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Abstract

This paper aims to demonstrate the impact of automation – with the use of a robot – in the welding operation in a manufacturing process of electrical and electronic components, located at the Industrial Hub of Manaus. The adopted procedure was the experimental research and case studying, with documentary and bibliographic research with exploratory bias, with variability mapping using bivariate analysis model. The results indicate a high degree in the effectiveness of the robotic manipulator compared to manual operation, based on the variables analyzed, such as soldering time, total amount of applied solder, and dispenser's speed and temperature, as well as total adherence to quality standards.

Keywords

Automation, Robotics, Soldering

1. Introduction

With the expansion in the use of machines in industry, especially after the industrial revolution, production capacity increasingcontinues to expand along,thanks to technological innovation. For Romano (2002), the machines are able to help automate the manufacturing process, and thus represent a large part of this "increase" in industry output.The use of robots in industrial applications have been growing positively in the recent years. They have had a popularization, not only in large industries, but have spread in different branches and industrial applications. However, in many cases, the potential of a robot applied to a process is not fully utilized, because its programming does not allow its performance to be optimized (WU et al, 2000; ÇAKIR et al, 2006).

According to Assis and Coelho (2009), robotics is the technology that is related to the development of robots or robotic devices, a multidisciplinary and highly active concept, allowing the integration of several techniques for the elaboration of equipments.Among their using, the main application of the robots is in sectors that develop the weld. The focus on increasing profitability leads companies to seek in minimizing production costs, avoiding losses, especially in areas such as welding, where material degradation is high (Picanço, 2010).

In the current market situation, and with increasing competition, there is the need for companies to increase the seeking of the competitiveness in their industry. This fact leads companies to seek continuous improvement of their production process and cost reduction becomes a priority for the maintenance of their market (SLACK and LEWIS, 2003).

Therefore, cost reduction should be a priority for companies seeking such a survival in the market. In periods of economic growth with high demands, lower costs can be achieved with higher production, but in resection scenarios with lower demands and low growth, there is a greater difficulty in working with cost reduction (OHNO, 1997).

In this sense, the present article aims to demonstrate the impact of automation in the welding process, in a manufacturing process of electro-electronic components, in which the theoretical reference will be demonstrated, the methodology used contemplating the materials and methods used, and the results of the implementation.

2. Literature Review

2.1 Robotics manipulators

Industry research has been focused on the creation of automation techniques that are applied in small and medium-sized production batches,in order to produce cost-effective and flexible results, culminating in the development of CNC machines, Flexible Manufacturing Systems (FMS), Mobile Robots (AGV's) and manipulator arms.

The development of this latter group is particulary important because of the intrinsic complexity involved in developing the ability to emulate the behavior of the ligament chain of the manipulator arm in order to replicate the movements of the human arm. There are several typologies of industrial robots, and each of them is oriented to a specific activity that allows them to perform specific tasks with precision, rationality and high production. These types of robots are criated through combinations of mechanisms and links to obtain the desired angular and functional configuration.

Cartesian coordinate robots are endowed with three sliding joints known as PPP. These robots are characterized mainly by their small work area, and because they possess a high degree of mechanical stiffness. In addition, this type of manipulator has great accuracy in the location of the actuator (ROSÁRIO, 2005).

There are many advantages of a robotic manipulator when it is used in the industry, so the implementation of this type of robot is essential due to its flexibility of operation, intelligence and processinginformation, what allows cost reduction, accidents mitigation, and everything with a high degree of accuracy. The characteristics presented by the robotic manipulators can be used together to replace the human work at places with environmental difficulties or repetitive works (CAMPBELL et al., 2008).

According to Souza (2001), among the industries that already use robotic manipulators,we can cite the automobilistic one, where they employ a greater degree of use of this technology, employed in any productive arrangement, both the automakers and the manufacturers of auto parts. The main functions of these robots in these industries are to weld, cut, drill, mold, forge, paint, tighten screws, carry parts, among others, with excellent levels of precision and standardization.

Still citing the relation to the physical elements that compose an industrial robotic manipulator, we can destacate the actuators and sensors stand out. Actuators are the elements that convert some type of energy into mechanical movement, what means that they are responsible for the movements of the robotic arms, which can be hydraulic and pneumatic and electromagnetic (CAMPBELL and COUTINHO, 2008; INÁCIO, 2009).

The former are driven by moving fluids. Hydraulics are driven by some liquid, while the tires use compressed air. Electromechanical actuators are mainly motors that are driven by electric power, such as stepper motors, servo motors, direct current motors, among others (INÁCIO, 2009).

An example, the robotic arm (Groover, 1988) is composedby arm and wrist. The arm consists of elements called links joined by relative movement joints where the actuators are coupled to carry out these movements individually, with sensory capability, and controlled by a controlling system. The arm is fixed to the base on one side and to the fist by the other. The handle consists of several proximal joints, joined by compact links, which allow the orientation of the terminal organ in the positions corresponding to the task to be performed.

At the end of the wrist there is a terminal organ (hand or tool) designed to perform the task required by the application. Figure 1 shows schematically a sequence of links and junctions of a robotic arm. In real arms, the identification of the links and joints is not always easy, because of the structure and parts that cover the joints to protect them in the work environment.

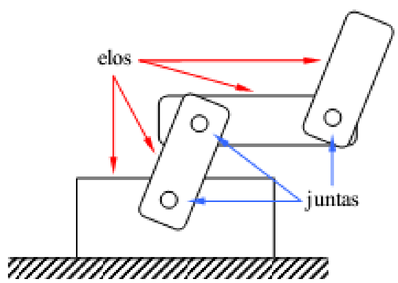

Figure 1. A example of a sequence of links and junctions of a robotic arm

Vale (2011) details that manipulating robots are mainly positioning machines and that they can possess several degrees of freedom, of which the end is fixed the tool or effector, what is mechanism whose purpose is to carry out the work. In this way, the links or joints that compose the robot determine the degree of freedom of the set, and may be of translation (prismatic) or rotational (rotational) movements, so a robot can be classified by the direction of the movements and by its Alimentation.

Craig (1989) further states that Cartesian manipulators are possibly the simplest configuration of robots, composed of 1 to 3 prismatic, mutually orthogonal joints that correspond to the vectors X, Y and Z of the Cartesian plane (Figure 2), which ensures that their inverse kinematics are trivial. Robots of this type can have a very strong structure, which allows them to be very large and still manipulate from small tools for manufacturing to whole cars or aircrafts. It should be noted that another advantage is that their joints are independent, which makes them simplier to project and does not produce any singularities in their kinematics.

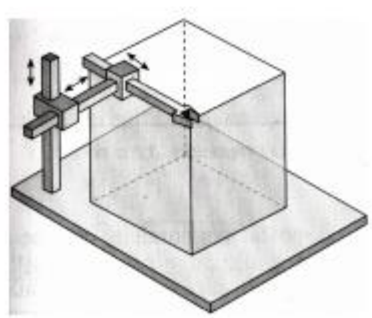

Figure 2**.** Cartesian Robot

On Table 1, below, are the main elements that form an automatic soldering machine (ASM) project, contemplated in the developed automation project.

Table 1. Auto Soldering Machine – Main Components

Component	**Features**	**Authors**
Robotic Manipulator	In automated welding, a program is used, which when associated with a drive system (step motors and its control drivers) can be able to move in three directions: longitudinal (x), transversal (y), and vertical (z). In this project, we specifically use only two axes displacement toward the welding points, with a 300mm span and the z axis that regulates the distance between the nozzle of the soldering iron and the contacts of the charger, with a maximum range of 100mm. Figure 5 shows the axes of a robotic manipulator.	XIAO et al (2016); ERAYA (2017)
Welding Feeder	Microcontrolled element capable of controlling welding variables such as welding wire feed rate and weld wire length to be deposited at the loader terminals, this displacement is done by 2 step motors, controlled by a microcontroller and actuated by means of your controlling drive.	ERDŐSet al (2016)
Conveyor belt	Conveyor belt equipped with cradles that take the products to be soldered, after previous fixing of these by the operators. The treadmill has a servo motor that is a motor used in processes when it is necessary to process precision, since this must stop constantly for the accomplishment of welding.	MOHSEN (2010)
Sensors	Devices used to determine the positioning of the parts to be welded and to ensure, together with the servo, the correct positioning, for the welding of the products.	POLAJNAR et al (1995); EDMONDSON e REDFORD (2002); HUNT (2007)
Programmable Logic Controller	Elements that, when previously programmed, perform ASM automation. A CLP was used in this project for general process automation, including the safety system according to NR10 and NR12 that works in conjunction with a microcontroller that moves the axes of the Cartesian robot and also controls the solder wire dispensing and later weld the chassis.	SHANAHAN e WITKOWSKI (2000); BARKER e STUCKEY (2003);

2.2 Soldering

The process of welding consists, according to Machado (1996), in the "union of two materials through the fusion of the same in intimate contact; or by melting both and adding another melted material; or simply by contacting these materials in the solid or semi-solid phases.

According to the AWS – American Welding Society, welding is described as the Operation that seeks to obtain localized coalescence produced by heating to a suitable temperature, with or without the application of pressure and addition metal. According to Marques, Modenesi and Bracarense (2009: 26), "Today, more than 50 different welding processes have industrial use and welding is the most important method for the permanent union of metals." The number of methods is justified by the need for good weldability and for the development of new types of steels and other metallic alloys.

3. Methodology

The present work was carried out with the exploratory objective, with bibliographic and do-cumental scanning, aiming to identify the problem of the case study, together with interviews with people qualified to analyze the results of the automation operation (GIL, 2008). In relation to the procedures used, it can be classified as an experimental research, where it was determined a study object and all the variables that could influence it. After the research and planning, the design and fabrication of the device was carried out, and later, the testers. For Fachin (2003, p.123) research is an intellectual procedure in which the researcher aims to acquire knowledge in an empirical way, in order to seek new truths about a fact (object, problem).

And yet, the case study is defined as "an empirical study that investigates a current phenomenon within its contesto of reality, when the boundaries between phenomenon and context are not clearly defined, and in which various sources of evidence are used "(Yin, 2005, p.32).

The case study was used, although the unique cases have obstacles, they present many limits for generalizations in the conclusions, they hinder the development of models and theories from an exclusive case (VOSS, TSIKRIKTSIS and FROHLICH, 2002), for the demonstration of the optimization and impacts of the automation in the welding process.

3.1 Data Collect

Within the research process, the data collection took place through a semi-structured interview, ordered by the script with focus to the formulation questions related to the subject to be investigated (TRIVIÑOS, 1987; MANZINI; BONATO, 2008).

Regarding the data collection, the research instrument – Interview –, which according to Miguel (2010) suggests, when it comes to interview script, verifies the pertinence of visits to the operation in order to detail the phenomenon studied. The visits took place in the company's industrial plant located in the Industrial Pole of Manaus.

3.2 Materials and Methods

The process consisted of developing a solution to minimize and/or eliminate the problems associated with manual welding of chassis, figure 3, these problems being most frequently: accumulation or lack of welding at the chassis terminals and/or solder ball.

The solder ball is directly related to the air or water vapor that escapes in the welding process and becomes liquid during welding. If the vapor in the solder escapes very quickly, a small amount of liquid solder will be withdrawn-from the solder joint, and a solder ball will be formed when it cools.

The problem of accumulation or lack of welding is directly related to the inadequate handling of the soldering iron by the operator and also because the manual process does not have a control in the amount of solder injection in the terminals of the chassis, thus causing an independent accumulation of welding or low soldering.

With this, the need to automate the welding process of the chassis was verified, since the manual welding process, even with intervention and preliminary studies of Engineers and professionals directly linked to this process, has an index of defects and a need to rework larger than 50% in its production.

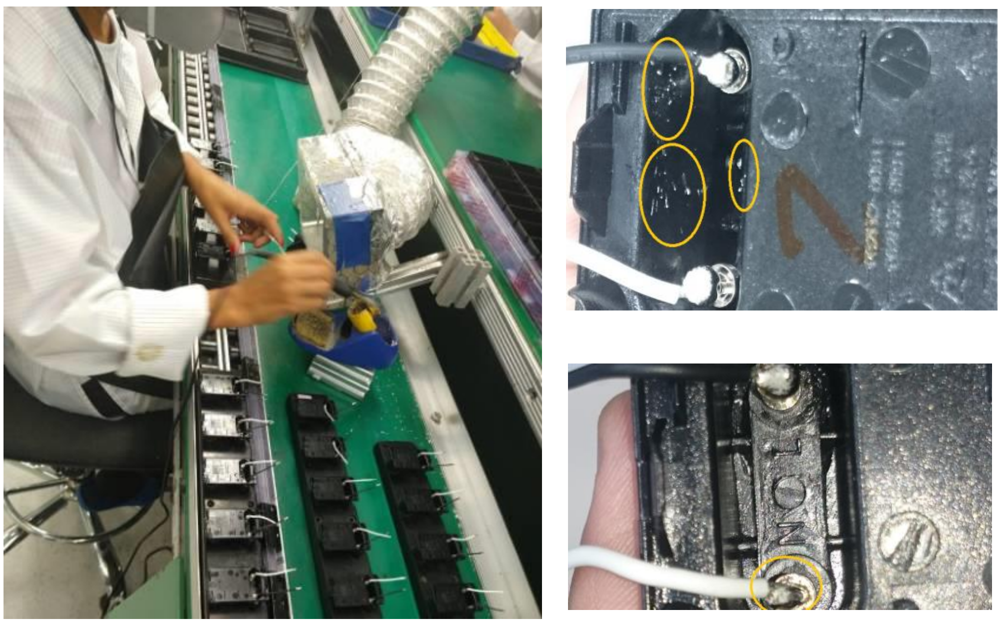

Figure 3.Manual Welding Process and examples of defects

A process of study involving Mechanical and Electrical Engineering was started. In the Electrical Engineering team, after study and verification of the best models of welding automation in processes, it was decided to combine the characteristics of four welding models and these were adapted, to guarantee not only process quality but also greater agility and possibility of having a greater control in the elements involved in the welding process excepted, this way the errors inherent in manual welding.

The main characteristics of the welding models used in this project are: a) Control of welding variables such as welding wire feed rate and temperature control, element from the semi-automatic welding model; and b) Relative movement between the soldering iron and its workpieces is automatic.

Where it was chosen by the types of command: manual (pushbutton), by means of HMI – (application on a screen (touchscreen), which facilitates and makes more efficient the communication between people and machines), in a process and by remote access (Tablets, or Smartphones), where commands trigger the sequence devices of the welding operation and the process consumables, such as solder wire, have the least possible human intervention. Figure 4 shows a typical diagram of an automatic soldering system.

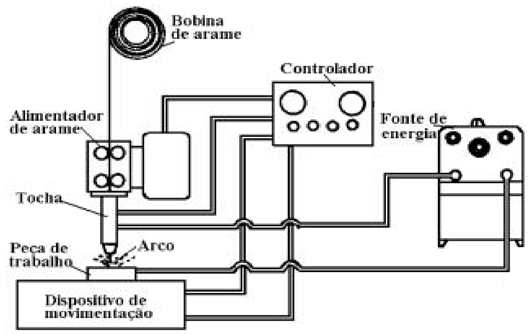

Figure 4. Typical ASM´s diagram

The automatic soldering machine has an operating sequence and what the operator must do is passed through an HMI, which informs him of all the events performed by the machine and transmits the process part to all the actuations performed by the machine in real time, as well as your daily production and cycle time data.

The human performance in the process was minimized only to the insertion of the product to be welded and its subsequent post-solder removal process performed, no longer having human action in the welding process. Figure 5 represents the solution ready according to the legal norms of security and in perspective the control HMI.

Figure 5. Auto Soldering Machine

After switching on the machine, the process technician must wait for the soldering irons to warm up and then validate the temperature. For this purpose, the HMI must be used as a guide and validate the temperature after entering an alphanumeric password and check with the appropriated equipamentthe two solderingirons. The welding setups of the machine resulting from the optimization and testing process (45°).

Table 2. ASM Setup

Parameters	**Setup**
S01 –Welding Setup	2 x 3,5 (two actions), in 7s

S02 - Total welding applied	2 x 22 mm, total de 44 mm ofwelding
S03 –Dispenser speed	100 mm/s
S04 - Temperature	400 °C

With the approval of the operating temperature, by the technician, the machine is ready to go to Home position, which is when the machine aligns the positioning of the treadmill (products in the cradles) with the two soldering irons of the machine. The machine, after its initial position, has been set, and by pressing the start command the machine operates automatically, and welds the chassis, as shown in figure 6.

Figura 6. ASM pre-operational position

4. Results

The determination of the data related to the optimization process of the machine, demonstrates its entry into line mode, in which we can identify the variables balancing (weld time, total solder applied, dispenser speed and temperature) with defect. Table 3 shows the values of the validation tests of the welding, considering a specific period of operation.

Table 3. Operational Validation

Mapping defects variables	**Periods**			
	P1	**P2**	**P3**	**P4**
Solder Ball	21,61%	0,77%	0,00%	1,35%
Wire out of position	0,00%	0,77%	1,01%	0,00%
Burned Wire	1,69%	0,00%	0,00%	0,00%
Low solder	68,22%	61,54%	15,15%	9,46%

Excess weld	7,63%	5,38%	25,25%	0,00%
Crimp wire (-)	0,00%	0,00%	0,00%	0,00%
Wire soldering (residue)	0,00%	0,00%	13,13%	0,00%

For the purposes of operational marking, the four (4) configuration variables were used as a basis for bivariate analysis, in order to infer possible restrictions, and counterpart to the seven (7) mapped defect variables. For the mentioned mapping the Spearman coefficient was used, which describes the correlation between the parameters and the resulting ones (positive or negative). Table 4 below demonstrates such relations where we have -1>ρs> 1 in which the resulting scalar value of 1 means perfect correlation and -1 with inverse behavior.

Table 4.Simulation – Spearman's Coefficients

Defect Variable	**Parameter**			
	S01	**S02**	**S03**	**S04**
Solder Ball	0,02	0,44	-0,01	0,58
Wire out of position	-0,06	-0,01	0,00	0,00
Burned Wire	0,04	0,03	-0,34	0,19
Low solder	0,01	0,00	0,00	0,00
Excess weld	-0,26	0,11	0,06	0,01
Crimp wire (-)	0,00	0,00	0,00	-0,03
Wire soldering (residue)	0,00	-0,01	0,03	0,09

Spearman's correlation coefficient is the most appropriate for variables with ordinal scales (HAIR JR et al., 2005). The correlation coefficient does not measure the cause and effect relation between variables, although this relation may be present (LAPPONI, 2005). The expected result of this analysis is to verify which variables are related to statistical significance, and to indicate the direction (positive or negative) and the strength of the association (correlation coefficient and determination coefficient).

5. Conclusions

Among the main concluding axes are: 1) The feasibility in the implementation of automation in the welding manufacturing process; and 2) The adherence of bivariate analysis to the configuration matrix and defects in the optimization. Record the limitations on detailed test surveys, particularly regarding sample size, as well as quality assessment criteria.

Axis 1: Evidence demonstrates the effectiveness of the automated welding model (robotic manipulator), considering the technologies of sensors, HMI and automatic feeding.

Axis 2: The use of bivariate analysis made it possible to visualize the possible correlations between the variables, inferring important questions about the effects of the parametric combinations of the machine.

Acknowledgements

To the Cal-Comp Institute of Technology (ICCT) for the unconditional support to the elaboration of this research, along with its technical and managerial staff.

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