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Journal Industrial Engineering

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Knowledge Area

The works must be unpublished and refer to topics of Production systems design, product quality management, operations research, computer simulation, supply chains, quality certification, hydrometeorology and other topics related to Engineering and Technology.

Content Presentation

As the first article, we present, *Defect study of Adidas Chimpunes sneakers using the DMAIC method*, by NAVARRO-ENRÍQUEZ, Laura, RIVERA-MOJICA, Denisse, TOVAR-VÁSQUEZ, Amado and CHAVEZ-MONTELONGO, Ana Lorena, with adscription in the Universidad Tecnológica Paso del Norte, as second article we present, *Identification of the human-machine interaction process through the generation of a grammar based on automata theory, by means of a practical case*, by BENÍTEZ-QUECHA, Claribel, ALTAMIRANO-CABRERA, Marisol, MÉNDEZ-LÓPEZ, Minerva Donají and SANTIAGO-APARICIO, Nallely Elizabeth, with adscription in the Tecnológico Nacional de México, Campus Oaxaca, as third article we present, *Operational innovation in the performance of the anti-corrosive protection process*, by RAMÍREZ-ROMÁN, Adolfo, RODRÍGUEZ-RODRÍGUEZ, Luis Alberto, CHABAT-URANGA, Jacqueline and SUÁREZ-ÁLVAREZ, Ángel, with adscription in the Universidad Veracruzana, as fourth article we present, *Automation of a horizontal electrospinning system to obtain polymeric nanofibers at low cost*, by ROSALES-DAVALOS, Jaime, ENRIQUEZ-PEREZ, Ma. de los Ángeles, LOPÉZ-RAMIREZ, Roberto and MASTACHE-MASTACHE, Jorge Edmundo, with adscription in the Tecnológico de Estudios Superiores de Jocotitlán.

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Defect study of Adidas Chimpunes sneakers using the DMAIC method

Estudio de defecto de los tenis Chimpunes Adidas utilizando el método DMAIC

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Abstract

In recent years, errors have changed in such a way that a strategy must always be in place to avoid them so that if they are detected they can be counteracted, but for this there are very useful tools that were created to solve errors and why they occur. created the DMAIC method so that there is improvement after having solved a separate error is an interactive tool that helps Define, Measure, Analyze, Control and Verify. The study will be structured in two sections. The first defines the process. Then the measure where is used, the tool will be used to determine the current performance of the process and finally it will be analyzed to see how ineffective the current process is, to later propose improvements. Thanks to this tool, it was possible to detect an error associated with a machine that is a fundamental part of assembling tennis shoes, as well as poor efficiency with some workers. In addition, solutions could be proposed to counteract these problems, and prevention measures were created to prevent show up again. And finally, the last section is the conclusions to know what was learned from the method.

DMAIC, Assembling, Define, Performance, Improvements

Resumen

En los últimos años los errores han variado a tal forma que se debe tener siempre una estrategia para evitarlos de tal forma que si se detectan se puedan contrarrestar, pero para ello existen herramientas muy útiles que para eso se crearon para solucionar errores y del porque se creó el método DMAIC para que haya mejora después de haber solucionado un error aparte es una herramienta interactiva que ayuda a Definir, Medir, Analizar, Controlar y Verificar. El estudio se estructurará por dos apartados. En el primero se define el proceso. Luego se utiliza el medir donde, se usará la herramienta para determinar el desempeño actual del proceso y finalmente se analizará para ver qué tan ineficaz es el proceso actual, para posteriormente proponer mejoras. Gracias a esta herramienta se logró detectar un error asociado a una máquina que es parte fundamental para ensamblar los tenis como también la mala eficiencia con algunos trabajadores, además, se pudo proponer soluciones para contrarrestar estos problemas y aparte se crearon medidas de prevención contra que nuevamente se presenten. Y finalmente el último apartado se encuentra las conclusiones para conocer que se aprendió del método.

DMAIC, Ensamblado, Definir, Desempeño, Mejoras

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Introduction

When solving errors in a process, improvement is always sought to avoid an error again and that can put production at risk to satisfy the customer's requirement. When the DMAIC method was created, it has been of great help to all the companies that choose to use it, because, as mentioned, it helps to improve the process (where its acronym tells us that Define, Measure, Analyze, Control and Improve). (Garza, 2016)

With the study of this process, the DMAIC methodology will continue, since I know that there was a direct complaint with the client where his disagreement said that some of the products were not well made and that they were not even well assembled. Therefore, it can generate more complaints with the client, create more losses and apart from that, their expectations and requirements are not met. The study will be structured in two sections. In the first, it will be defined to better understand the process. Then follows Measure where a tool is worn to determine the current performance of the process. Measurement is followed by Analyze to see what is wrong with the process. From there follows the Improvement that will give the best solution or improvements that are most convenient to establish and, finally, Check to see that everything goes according to plan. The second section contains the conclusions to know what was learned in this method. (Ade, 2012)

Theoretical basis

The DMAIC method for improvement

To make improvements consistently within an organization, a standardized improvement model to follow is important. DMAIC is the improvement process that uses the Six Sigma methodology and is a model that follows a structured and disciplined format, DMAIC consists of 5 phases logically connected to each other (Define, measure, analyze, improve, control) illustrated in the figure 1. Each of these phases uses different tools that are used to answer certain specific questions that guide the improvement process (Ocampo, 2012).

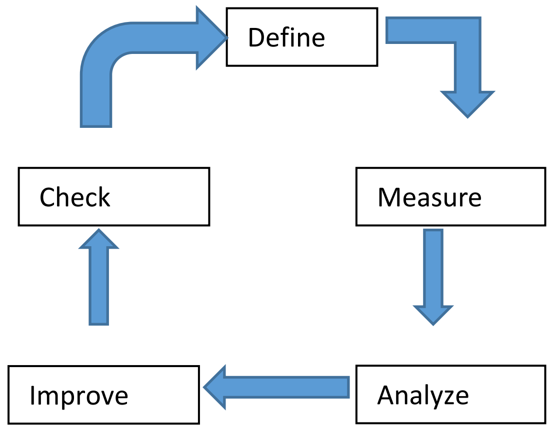

Figure 1 The six-sigma interactive DMAIC process
Source: Ocampo, 2012

Definition: of the problem, client, team.

Measurement: of the performance through a process map in which the reliability of the data is determined.

Analysis: in which the sources of variation and the roots of the problem are identified.

Improvement: development of changes to improve performance.

Control: to keep the improvements made. (Reato, 2019)

I often wonder if Six sigma works for clients' health care, oil exploration, or home construction. My typical answer is that if the process is involved in Six sigma possibly this can help improve this. DMAIC provides a very useful structure to create a closed process for project control. When the goal of the project is to develop a new or radical redesign of the product, process or service, define-measure-analyze-design-verify. Frank Gryna made the following observations about the projects. The DMAIC process was primarily about reducing defects and errors in existing products, services, or processes. Design by six sigma (DFSS) consists of five steps called DMADV (Juran and Gryna, 1988, pp 22.18-22.19)

Legitimacy puts the project on the priority list.(Keller, 2010)

D	Define improvement activity goals and incorporate into project
M	Measure the existing system, establish validation and metrics to monitor progress against goals.
A	Analyze the system to identify ways to close the gap between the current process or system and the desired goals.
I	Improve the system. Being creative finding new ways to do things better, cheaper and faster.
C	Check the new system. Improve the system by modifying incentives, policies, procedures, operating instructions. ISO 9000 can be used to ensure correct documentation and statistical tools.

Table 1 DMAIC Overview

There are many reasons why you should plan carefully before starting a project. (Ruskin and Estes 2003, p.44)

Method description

This is a case study carried out in a company that manufactures Adidas tennis shoes in the state of Chihuahua. Its design is based on the DMAIC methodology that consists of five phases. Six sigma is a methodology that aims to improve processes through the reduction of quality variability, which translates into the reduction of defects or failures in the products or services that organizations generate to satisfy the customer needs. (Bahena,2006 y Urrutia, 2015)

Phase 1, Define

It will start with the most used tool, the flowchart to better understand the process where it will help us to solve the problems that arose and therefore improve it. (Socconini, 2020)

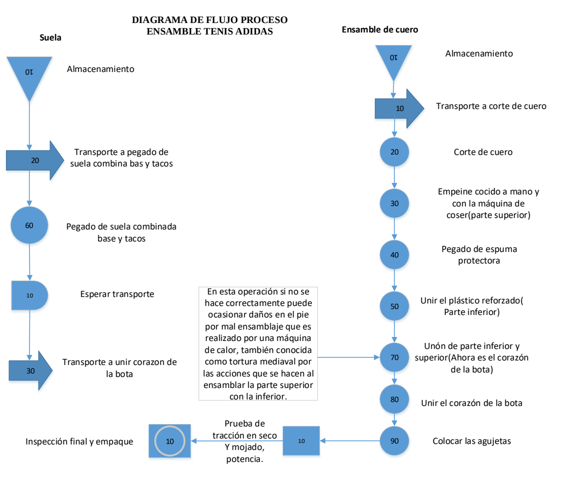

Figure 2 Process flow diagram
Source: Own elaboration

This diagram shows how the sequence of making the product is from the warehouse to its inspection, apart from that it is easy to understand this process in case you want to modify some of the operations, but it is not necessary at the moment.

Phase 2, Measure

In the second stage, the existing defects are described, the process is disclosed in its present state with reliable measurements and that they give a validity to the system, ensuring that the information is pertinent and that it allows decision-making, so that the improvement to be developed. whatever suits you best. See Fig 2. Process diagram. (Desimavilla, 2021)

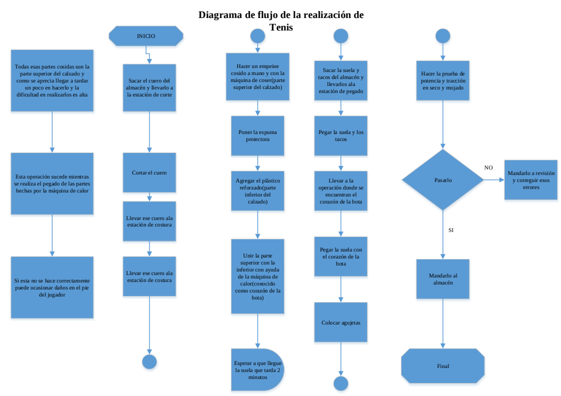

Figure 3 Process diagram. Performing tennis
Source: Own elaboration

As shown in the process diagram, the operation where there is a longer duration in the performance of the process is in the sewing operation where it takes time to sew the leather to form the tennis shoe, so it takes time to reach the next operation and apart from she does the easiest parts by hand, but the most difficult ones help the sewing machine, but it is not a problem since it is normal that it takes a long time. Then the heat machine which is responsible for doing the most work since it unites the important parts of the shoe and is a key part for the shoe to come out well since if it is not done correctly it can cause damage to the player and even dislocate a bone in the part of the foot due to the bad placement of the pieces.

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Phase 3, Analyze

A block diagram will be made to know the opinions and generate that information that the experts will give us. In this way, it will be discovered what causes the poor performance of the product through the summary information that will be obtained. This can be seen in figure 3.

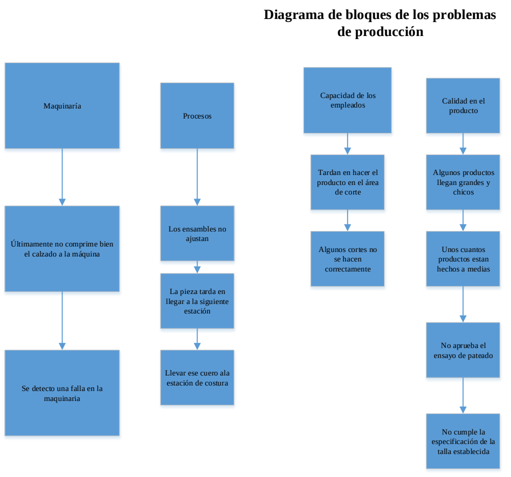

Figure 4 Blocks diagram, production problems

As can be seen in the diagram, where it presents more problems is the machine that performs the footwear badly when compressing or doing the heating act, so that the parts of the footwear are well adjusted, and apart from some employees do not make the cuts correctly and apart from they delay the line since the upper part of the footwear does not arrive on time, even creating downtime in the next operation since they can use it at work, but they cannot because they do not have the piece with which they have to work.

Phase 4, Improve

The improvement is to replace labor with a cutting machine and apart from that, a heat machine will also be replaced, since it is responsible for the defective product. Thus creating two improvements for the process for both the workforce and the heat engine.

Workforce

Expectation 1:

Replace labor by cutting machine.

Goal:

- Reducing errors per cut and increasing strokes per cut.

- When using the cutting machine, about 20 strokes are cut. depending on the type of line being cut.

Expectation 2:

Use the cutting machine to cut all the necessary strokes.

Goal:

- Reduce the time in cutting strokes.

- Reduce the time of elaboration of the product.

- Have precise cuts.

Comparing the new improvement proposal as we can see in the images cutting the strokes by hand and already having the complete strokes with the cutting machine obtaining more production in less time around 80%.

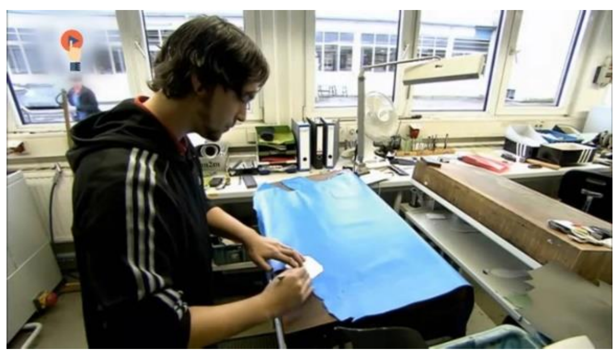

Figure 5 Manual cut
Source: Own elaboration

Figure 6 Complete strokes with the cutting machine
Source: Own elaboration

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Method analysis

Current court and proposal

Cutting time per stroke 1.30 min	Cutting time for every 20 pieces: 2 minutes

You have 30 seconds difference and 80% more stroke breaks.

Advantage:

1. Shorter stroke cutting time.
2. Increased production.
3. Error control in court.
4. Fewer errors in cuts.
5. Precise cuts.
6. Reduce labor costs.

Disadvantages:

1. Cost of machinery.
2. Increases the cost of energy.
3. Having to cut staff.

Check	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Total	%
Check leather cuts of workers	///	//	//	//	//	//		14	21.2
Check condition of sewing machines								0	0
Check hand sewn instep								0	0
Heat machine	///	///	//	////	/	/	//	17	25.8
Power test	///	///	//	//	/	//	//	15	22.7
Wet and dry pull test	//	//	///	//	//	/	//	14	21.2
Check cycle test	/	/		/	/			4	6.06
Check part quality		/		/				2	3.03
Defects								**66**	**100**

Table 2 Operations checklist

Heat machine

Expectation 1:

Replace the current heat machine with one that meets the needs of the operation.

Goals:

- Reduce the errors that afflicted the client.
- Reduce the times in the union of the upper part with the lower part.
- Increases safety when putting on shoes.
- The footwear must come out according to the specifications.

Expectation 2:

Use the machine to make work easier for employees.

Goals:

- The machine must have a basic configuration for the understanding of the workers.
- Easy putting on and taking off the shoe from the machine.
- Give the worker specific measurements for footwear.

Advantage

1. There will be no more mistakes
2. It will increase productivity
3. Trained staff
4. It will reduce the times in making the piece

DISADVANTAGES

1. The price of the machine
2. No assets will be generated at the time of staff training.

Phase 5, Control

This last phase corresponds to control, and its objective is not to lose the achievements made in the previous phases, that is, to maintain the stability of the processes and their capacity at a Six Sigma quality level. We say that a process is capable when it can be maintained within the tolerances in an interval of admissible variability; thus, a stable process may be available but not capable. (Pellegero, 2015)

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Check	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Total	%
Check leather cuts from the workers	///	//	//	//	//	//		14	21.2121
Check the status of the sewing machines								0	0
Check the stitched instep by hand								0	0
heat machine	///	///	//	////	/	/	//	17	25.7576
power test	///	///	//	//	/	//	//	15	22.7273
tensile test on dry and wet	//	//	///	//	//	/	//	14	21.2121
Check cycle test	/	/		/	/			4	6.06061
Check part quality		/		/				2	3.0303
Defects								**66**	**100**

Table 3 Operations checklist
Source: Own elaboration

These are the checklists of table 3 and table 4 that are regularly used to verify that everything is fine, but lately there were some errors that, as already mentioned in the problem, were so great that a few pairs of sneakers were presented in the client and therefore he complained, since the product was not well made by the heat machine, which is the most important, because, without it, the pieces cannot be correctly assembled from the top to the bottom. In addition, they did not even pass the most important tests, since if they do not pass them, the product cannot be sold to the customer.

Check	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Total	%
Check the state of the cutting machine	/	/	/	/	/	/	/	7	2.5
Check hand-stitched instep	/	/	/	/	/	/	/	7	12.5
Check the condition of the sewing machine	/	/	/	/	/	/	/	7	12.5
New heat machine	/	/	/	/	/	/	/	7	12.5
Power test	/	/	/	/	/	/	/	7	12.5
Wet and dry tensile test	/	/	/	/	/	/	/	7	12.5
Check cycle test	/	/	/	/	/	/	/	7	12.5
Check part quality	/	/	/	/	/	/	/	7	12.5
It worked properly								**56**	**100**

Table 4 Operations checklist
Source: Own elaboration

Here is another checklist of operations after applying the improvement. See table 4.

As can be seen in the verification sheet in table 2, after applying the improvement, the errors that caused the product to go wrong were reduced, so having applied this improvement that favors the moment it is delivered to the client where there will no longer be claims for not having finished the product.

Apart, as can be seen, the part of verifying workers' leather cuts by the cutting machine mentioned in phase 4 was eliminated, the name of the heat machine was also changed to a new heat machine to know how to differentiate which is the correct one.

Gratitude

I would like to thank the Paso del Norte Technological University, my career director Ángeles Holtzaimer Álvarez, Ing. Amado Tovar, Ing. Denisse Rivera Mojica, Ing. Ana Lorena Chávez Montelongo and all my friends and family who supported in the preparation of this article.

Conclusion

Carrying out a research project with the DMIC method is of great help, since you can find a problem, either directly in the product in the same process, in addition, it gives you the ability to plan and give orders to reach a solution. solution and increase efficiency, as well as your experience in the Labor field. Apart from that, the quality management system itself provides the ability to do things correctly in the product/service and look for possible solutions to the problem.

Finally, it was a success to have changed the workforce for a machine capable of making the cuts without fearing that it will do them wrong or that it will take time, apart from reducing labor costs and although labor continues to be used in the station of the new heat machine is because it is required because without them it cannot be handled automatically, since it is based on the measurements that will be given, but in the same way the product can be made correctly. Besides, there is data that affirms that it is being done correctly, as it can be seen in the checklist.

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Article
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Identification of the human-machine interaction process through the generation of a grammar based on automata theory, by means of a practical case

Identificación del proceso de interacción hombre-máquina a través de la generación de una gramática basada en teoría de autómatas, mediante un caso práctico

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Abstract

This project shows how the Automata Theory is a viable option for the process of defining the inputs and outputs that allow the design of a human-machine interface (HMI). In this case, it is applied to the design of a device that allows the "intelligent" control of a traffic light. For this purpose, the work is divided into an Introduction, a Theoretical Framework, a description of the Development, Results, and Conclusions. Objectives. General: To apply the automata theory to identify the input processes in a human-machine interface. Specific: Identification of the functionalities of the device, Formulation of Alphabet, Language, and Grammar, Creation of the automata. Methodology: The methodology followed is that of the Automata Theory, which defines the points mentioned in the specific objectives of this text. Contribution: To show how to apply Automata Theory in situations different from the development of compilers, as in this case to a process of implementation of the interface for human-machine interaction.

Grammar, Interface, Process

Resumen

En el presente proyecto se muestra la forma en cómo la Teoría de Autómatas es una opción viable para el proceso de definición de las entradas y salidas que permitan diseñar una interfaz hombre-máquina (HMI). En este caso se aplica al diseño de un dispositivo que permite controlar de forma ¨inteligente¨ un semáforo. Para tal efecto se divide el trabajo en una Introducción, un Marco Teórico, en la Identificación de Funcionalidades, Creación de la Gramática, Generación de los Autómatas, Resultados y Conclusiones. Objetivos. General. Aplicar la teoría de autómatas para identificar los procesos de entrada en una interfaz hombre-máquina. Específicos. Identificación de las funcionalidades del dispositivo, Formulación de: Alfabeto, Lenguaje y Gramática, Creación de los autómatas. Metodología. La metodología seguida es la de la Teoría de Autómatas, que define los puntos mencionados en la parte de objetivos específicos, de este texto. Contribución. Mostrar cómo aplicar Teoría de Autómatas, en situaciones diferentes al desarrollo de compiladores, como en este caso a un proceso de implementación de la interfaz para una interacción hombre-máquina.

Gramática, Interfaz, Proceso

Citation: BENÍTEZ-QUECHA, Claribel, ALTAMIRANO-CABRERA, Marisol, MÉNDEZ-LÓPEZ, Minerva Donají and SANTIAGO-APARICIO, Nallely Elizabeth. Identification of the human-machine interaction process through the generation of a grammar based on automata theory, by means of a practical case. Journal Industrial Engineering. 2022. 6-17:8-12.

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Introduction

In the field of engineering, the human-machine interface (HMI) is a highly demanded process nowadays, since there are more and more devices that allow automating daily life processes through technological environments where a certain response is expected from a mechanism or device to an action provided by man.

However, these interfaces are not totally manipulated by software, but have a high programming content at the hardware level or electronic functions. Therefore, software development methodologies are not as useful.

For a human-machine interface the communication is done with programmable logic controllers (PLC) and input/output sensors that allow obtaining and displaying information based on which a response is generated through technological means. These systems can be used for a variety of technological events, from simple ones such as monitoring or tracking to intelligent ones, to make decisions based on information gathered by sensors depending on how they are implemented.

So, it is necessary to specify unambiguous, mechanical responses to commands that may come from another machine or from man.

It is here where the usefulness of the Automata Theory is considered, since it defines in a methodical way a series of actions that end in a response or action (known as acceptance state), through a sequence of valid events.

Process that can be easily configured in PLCs, such as arduinos, or other models of electronic controllers.

Theoretical framework

HMI is the abbreviation for Human Machine Interface. An HMI system is basically the interface that allows a person to interact with a machine, system or device. It is also identified as a control panel. These systems allow to obtain operational information to carry out a process. It transmits information, data and commands between man and machine, and vice versa.

The theory of Automata was developed to define the sequence of actions to follow for an interaction between devices that "speak" different languages.

It is the study of abstract computational devices, i.e., of "machines" (Hopcroft).

It allows defining an interface based on areas of knowledge such as mathematics, linguistics, machine theory, among others.

The software developed from this theory is a compiler, which validates a common language between different devices.

Identification of functionalities

In the field of Systems Engineering, one of the basic disciplines is Systems Analysis, since it is essential to understand what we want to automate, so the first point to develop is the establishment of the functionalities of the system to be created.

This system is an intelligent traffic light, which allows the operation of a pair of traffic lights that must detect the presence or absence of cars, to manage the passage of the same in an intelligent way, that is if a traffic light is on red light but there are no cars formed, it checks if there are cars waiting for the pass in the lane controlled by the traffic light that is red. If so, it should turn green the traffic light that is red to allow cars to pass and turn red the traffic light that is green, but has no cars waiting to pass.

The solution to be implemented is that the traffic light, through the sensors, identifies if there are cars in a certain lane, if there are not, then it allows the passage to the lane that has cars waiting, turning it to green light in case it is on red. And turning the empty lane to red light.

Three states of acceptance are identified in the operation of the traffic light:

Green light, yellow light and red light.

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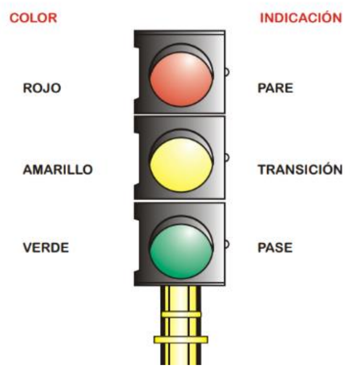

Figure 1 Acceptance states
Source: Own source

The control variable that allows detonating the defined states is the sensor, which has for this prototype, an approach value of the objects from 1 to 49cms.

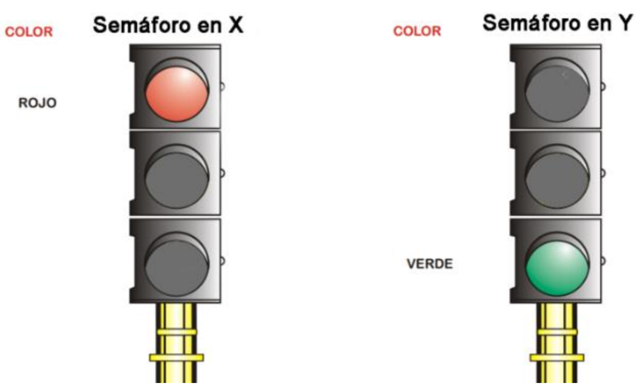

Figure 2 Identification of traffic lights
Source: Own source

The identified events (E1, E2, E3), which lead to the acceptance states are the following:

E1. The sensor checks if there are cars waiting in a lane with red light while in the other lane with green light there are no cars (Fig. 3).

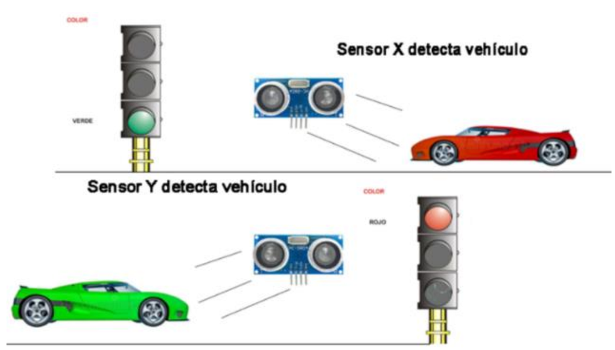

Figure 3 Event 1 (E1)
Source: Own source

E2. In the case of Event 1, the HMI modifies the lights in the traffic lights, the traffic light at X becomes green and the traffic light at Y becomes red (Fig. 4).

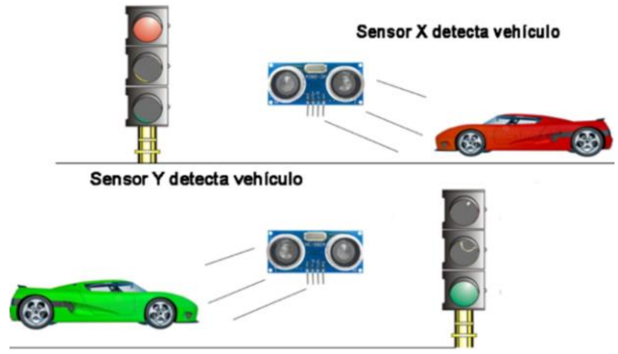

Figure 4 Event 2 (E2)
Source: Own source

E3.- Yellow light on at traffic light Y and red light on at traffic light X.

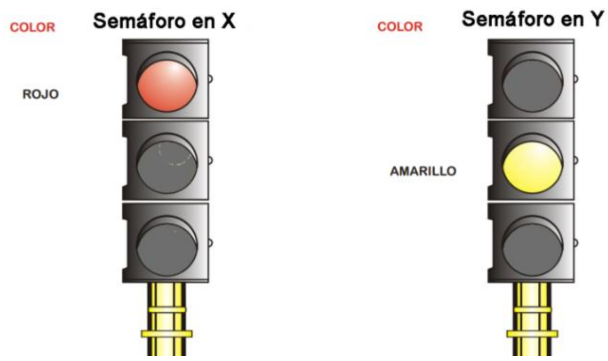

Figure 5 Event 3 (E3)
Source: Own source

From the above it is defined:

INPUTS.

Approximation of a car in X.

Approximation of a car in Y.

ACCEPTANCE STATUS (results of inputs).

Green light on from traffic light X.

Yellow light on from traffic light X.

Red light on from traffic light X.

Traffic light green light on Y.

Yellow light on for traffic light Y.

Red light on for traffic light Y.

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Creation of the grammar

General alphabet

$\sum_1$ = {Números enteros}

Language = {dx_1, dx_2, dy_1, dy_2}

dx_1 € dx_1 = [1cm - 49 cm] → Green light on from traffic light X and red light on from traffic light Y.

dy_1 € dy_1 = [1cm - 49 cm] → Green light on for traffic light Y and red light on for traffic light X.

dx_2 € dx_2 = [50cm - 99cm] → Yellow light on for traffic light X and red light on for traffic light Y.

dy_2 € dy_2 = [50cm – 99cm] → Yellow light on for traffic light Y and red light on for traffic light X.

Production rules

dx_1 → [1-4][0-9] | [1-9] (1)

dy_1 → [1-4][0-9] | [1-9] (2)

dx_2 → [5-9][0-9] (3)

dy_2 → [5-9][0-9] (4)

Generation of automata

Event 1 (E1)

Acceptance states = Green light on for traffic light X and red light on for traffic light Y.

Grammar

$G_1 = (\Sigma_1, N, S, P)$ (5)

N = {q0, q1, q2, q3}

S = q0

P = dx_1 → [1-4][0-9] | [1-9] (6)

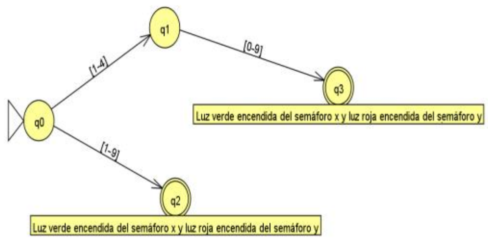

Figure 6 Event 1 automaton

Event 2 (E2)

Acceptance states = green light on for traffic light Y and red light on for traffic light X.

Grammar

$G_1 = (\Sigma_1, N, S, P)$

N = {q0, q1, q2, q3}

S = q0

P = dy_1 → [1-4][0-9] | [1-9] (7)

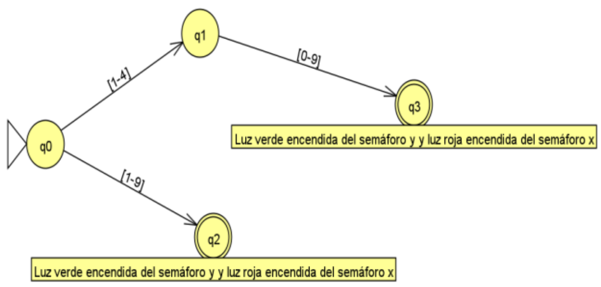

Figure 7 Event 2 automaton

Event 3 (E3)

Acceptance states = Yellow light on for traffic light Y and red light on for traffic light X.

Grammar

G1 = (Σ1, N, S, P)

N = {q0, q1, q2}

S = q0

P = dy2 → [5-9][0-9] (8)

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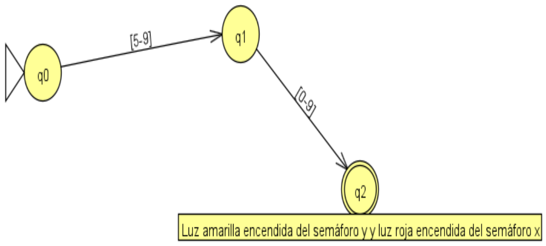

Figure 8 Automaton Event 3

The next step would be the coding itself. Which is done in the PLC (using Arduino) and sensors.

Results

As we can see, through the use of the Automata Theory, it was possible to specify precisely the events to be considered in an HMI interface.

Since there is no intensive use of software to program PLC's, but only basic code to generate an action through a given input, the relevant thing was to identify the sequence of events to obtain a specific response.

Therefore, it was not necessary to carry out all the actions of the analysis phase of the software development methodologies.

Acknowledgement

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Conclusions

When creating interfaces for manipulation of technological devices, without the use of a computer, but through microcontrollers (PLC), the use of methodologies for software development is not so useful. Since they are simpler processes, where the number of actions is smaller than in an administrative type software.

Since what needs to be defined is a sequence of events that lead to an answer, the Automata Theory is a much more useful tool. The Automata Theory, the models associated with it, as well as the algorithms inherent to the compilers, can be very useful in a variety of software development, including, as we can see in this project, in software for programming devices in HMI interfaces, regardless of the source language or the target machine.

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Article

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Operational innovation in the performance of the anti-corrosive protection process

Innovación operativa en el desempeño del proceso de protección anticorrosiva

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Abstract

The present research is a study developed in corrosion protection operations with the use of chemical treatments, which consist of the transformation of steel corrosion products into more stable oxides, an alternative to protect against corrosion in materials that have already begun to degrade avoiding mechanical cleaning, in order to present the results of the experimental study generated in the factory laboratory, which consists of the analysis of the solution of the oxide converter, of the sealing substance and their respective photographic representations of the application, for the chemical development of an oxide converter generator against the deterioration of the metal by minimising the cleaning effort, improving the aesthetics of the affected surface of the metal by the phenomenon of corrosion for its domestic and industrial use in the field of innovation of the corrosion protection of technological services.

Industrial, Experimental, Innovation

Resumen

La presente investigación, es un estudio desarrollado en las operaciones de protección anticorrosiva con el uso de tratamientos químicos, que consisten en la transformación los productos de corrosión del acero en óxidos más estables, una alternativa de protección contra la corrosión en materiales que ya han comenzado a degradarse evitando limpieza mecánica, por el cual, se tiene el objetivo de presentar los resultados del estudio experimental generados en el laboratorio de la fábrica que consiste en el análisis de la solución del convertidor de óxido, de la sustancia de sellado y sus respectivas representaciones fotográficas de la aplicación, para el desarrollo químico de un generador de convertidor de óxido contra el deterioro del metal minimizando el esfuerzo en la limpieza, mejorando la estética de la superficie afectada del metal por el fenómeno de la corrosión para su uso doméstico e industrial en el ámbito de la innovación de la protección anticorrosiva de los servicios tecnológicos.

Industrial, Experimento, Innovación

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Introduction

In an environmentally sensitive environment, the use of oxide converters has been widely recognized in different sectors of daily life. The developed product (rust converter) will represent a sustainable saving for the customer, also, the implementation of the product will represent a technological improvement for the company, placing it in a market of greater opportunity and competitiveness. It is proposed to the consumer an alternative protection against corrosion in materials that have already begun to degrade in industrial, domestic or construction operations.

It is important for the contribution of technical knowledge of coatings to retard corrosion on metallic surfaces, being an electrochemical application in research. Incorporating equipment for the development of laboratory tests to ensure compliance with customer requirements, improve the competitiveness of the organization and contribute to increased customer satisfaction, as well as reducing the cost of maintenance and wear of parts or steel structures, to take advantage of the consequences of oxidation of metals in synergy for self-protection and allow customers to propose alternative corrosion protection systems. And, development of sustainable strategies to reduce the number of maintenance, and mitigate contamination with the use of other chemical products that deteriorate natural resources such as soil and water, contributing to maintain a sustainable environment in the coastal and industrial zone.

Therefore, this article mentions the studies related to the research, also, describes the benefits of the research study, the importance of innovation through the innovative environment section, then the images of the interior of the laboratory are identified, describing the laboratory META section, also, in the results section, the sequential process of the experimental study is described through images, and finally there are the acknowledgements, conclusions and references of the research.

Environment of disciplinary studies

The studies that are related to the present investigation, their contributions are briefly mentioned as part of the basis for the development of the experimental work:

For example, Integrating knowledge is the fundamental task of chemical education and it is in this context in which the research in corrosion inhibition of steel gives us the opportunity to integrate the knowledge of electrochemical kinetics with organic chemistry, instrumental analytical chemistry and electronics via the construction of a low-cost potentiostat and the use of this in the study of the anticorrosive properties of atropine sulfate against carbon steel in solution (Alfaro, M., 2017).

It is considered that, it lives in a world surrounded by moisture, being found free in a solid without difficulty, it is then established that it is a non-hygroscopic material as happens in glass (Ananías, R., 2020).

In an environment of steel corrosion in concrete, the determination of the corrosion rate of reinforcement is of fundamental importance when making a diagnosis and assessing the service life of a reinforced concrete structure (Arva, 2002).

Therefore, the term corrosion comes from the Latin word "corrodere" which means to gnaw. This term is commonly used to describe the process of deterioration by natural oxidation of metallic materials, manifested through their visible degradation that, in external cases, can be total.... (Godínez, 2003). And, new materials are sought to improve corrosion levels in its different types involving uniform corrosion, intergranular corrosion, galvanic corrosion, possible stress corrosion cracking, pitting and fatigue (Plaza Torres, 2015).

On the inhibitors side, the evaluation of the anticorrosive effect of an oxide converter obtained from an extract of the Mimosa Tenuiflora plant, applied on 1018 steel corrosion products, has been documented (Enrique Arceo-Gómez, 2021). However, corrosion studies have been carried out with a mathematical approach that allows the development of the discipline in the field of innovation in the industrial sector of corrosion protection (Escobar Jiménez, 2022).

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> ...it is important to have a risk management plan with a methodology, along with a format to take into account the different events and how to generate a solution to these, after this in case of any unforeseen event it is necessary to make an assessment of the situation either through regulations, contracts, project schedules and generate a risk report to have concise information according to the needs already identified in the risk plan. From this plan, the probabilities and priorities can be seen, in order to generate a response to the problem in order to improve or mitigate, and to have a follow-up of the problem with records, updates and lessons (Ayma, 2022).

However, poor organization of materials, spare parts and tools in the area leads to setbacks, unsynchronized work and delays in delivering work to customers, who are dissatisfied with the lack of punctuality and commitment to them, thus creating mistrust and a poor image of the companies (Castillo Rivas, 2022).

It is considered that, in 1905 Tafel discovered an empirical relationship between the increase of power and the total current intensity with which the curtain of the corrosion mechanism began to be drawn, but it was not until 1938 when Wagner and Traud with the publication of their article "Concerning the evaluation of corrosion reactions by superposition of electrochemical partial reactions and concerning the potential formation on mixed electrodes", laid the foundations of the mixed potential theory, which postulates that even without assuming the existence of local anodes and cathodes, corrosion reactions can be explained by assuming that partial oxidation and reduction reactions occur at the metal/electrolyte interface and that these reactions are constantly changing under a statistical distribution of time position (Yunny Meas, 1991). Subsequently, evaluation studies were developed through the electrochemical modular frequency technique (Esra Kus, 2006); and, velocity study in steels for construction (Martí, Marc., 2011).

Also, there are analyses of corrosion products of steel, zinc, copper and aluminum formed in the Antarctic polar climate, analyzing the influence of the singular characteristics of this climate on the formation of these products (Fuente, 2002). Also, there are the applications of electrochemical techniques (González-Masí, 2014), as a complement, there are velocity analyses through the studies of the description of the electrochemical frequency modulation (M. Mora, 2007). Likewise, with the studies of the determination of the corrosion rate in AISI SAE 1010, 1020 and 1045 steels implanted with titanium ions around the hydrocarbon industry (Valbuena N., 2012).

It is highlighted that Ni coatings present better resistance to corrosion-erosion than the steel substrate, the most corrosion resistant coatings and with higher microhardness were those obtained at higher agitation speed (Henao, Johny, 2011).

Regarding innovation to preserve materials from corrosion, there is a feasibility study where a series of strategies are established which would mitigate this impact in order to achieve a successful painting process and also help preserve the environment and generate different competitive capabilities about environmental care through the different production processes within the company (Castro Garzon, 2022). Therefore, it is important to study localized corrosion and passivation phenomena (Gómez, 2021).

Benefits of an anticorrosive system

An anticorrosive system that could be conformed by a plastic, chemical or metallic coating has the function of preserving the useful life in a time proportional to the quality of the cleaning and thickness of the coating. Therefore, they could provide ten benefits, according to the studies carried out and indicated by the company Metalyzinc (Cobo-Losey, A. 1989) in their systems of Hot Dip Galvanizing, Thermorroding among other industrial coatings, we have that:

- For the most part, they assure corrosion-free durations from 10 to more than 100 years.

- They can achieve that corrosion does not lower their productivity from 100%.

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- They have produced maintenance savings of up to 90%.

- They have achieved a return on investment with real rates of more than 50%.

- They can reduce their level of hidden corrosion insecurity to 0%.

- They can extend rod life in concrete by more than 500%.

- Most of them can protect even after some abuse.

- Many of them are compatible with each other, mutually reinforcing and repairable.

- They are applied with attention to detail by qualified personnel.

- They are applicable in thousands of different cases and parts.

Benefits of an oxide converter

According to the technical data sheet of CORTEC Corporation (Cortec vci, 2022), in one of its products, CorrVerter®, allows sustainable and innovative savings by taking advantage of the degree of oxidation of the parts as part of its protective layer, stopping pitting corrosion (hole by deterioration of the degraded surface). These applications are subjected to Salt Fog tests (ASTM B 117) 1000 hours (see figure 1), as a characteristic is non-toxic, water based, as well as a permanent anticorrosive.

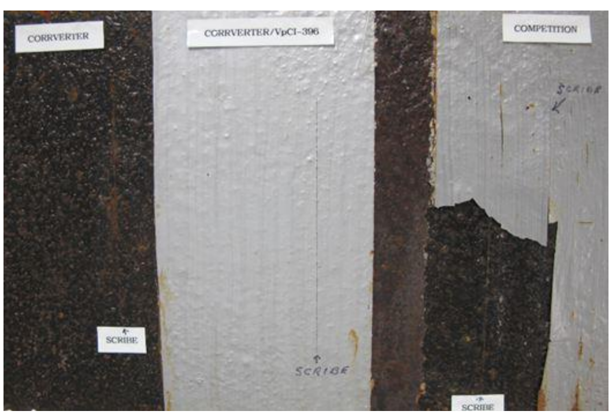

Figure 1 Salt fog test
Source: CORTEC Corporate

Figure 2 Corrverter inhibitor
Source: CORTEC Corporate

For example, image of a product type and with a sample applied is indicated, where it is CorrVerter, which is a fast-drying water-based one-coat primer system that converts rusted surfaces into a hydrophobic passive layer and prevents further rusting (Cortec vci, 2022).

Innovative environment

An industrial and substantial precept in the development of new alternatives to achieve increased customer satisfaction, where ISO 9001:2015 raises in its chapter 9.1.2 the aspects related to customer satisfaction, for this the standard cites that: The organization shall monitor the perception of customers on the degree of compliance with the requirements, and the organization shall monitor the perception of customers on the degree of compliance with the requirements. Therefore, the development of the experimental study generates an economical and viable alternative in domestic and industrial applications.

Also, because of the applications of the organization's own methodology with respect to the standards and requirements of the client, supported by its sustainable management indicators.

META Laboratory

The following three figures identify the basic equipment/instruments of the META laboratory for the development of its tests and control of the chemical production process. It is META, by the first four letters of the company's name, as part of any validation before starting the service of a corrosion protection system in the market.

Figure 3 Laboratory equipment
Source: Metalyzinc

Figure 4 Laboratory cleaning area
Source: Metalyzinc

Figure 5 Laboratory equipment
Source: Metalyzinc

Where, the application of the electrochemical technique was developed through chemical analysis and observation of the results of each parameter or type of sample with an experimental study in the company's laboratory.

Results

In the development of the research work, the following potential equipment was identified to ensure the reliability of future studies, which are:

Potentiostat / Galvanostat Biologic sp 150, which determines the corrosion rate and evaluate the electrochemical behavior of the oxide converter.

Compact porosity detector, for the surface of the protective film. Commonly known as Holiday jeepers detectors or spark testers. Conforms to the requirements of As3894.1-1991. CE Smart. Identifies the porosity in protective film on the metal surface and allows to determine the type of coating with reference to the consistency and concentration of the protective solution.

X-ray diffractometer, with the function of determining the elemental composition of the treated surface.

Optical Emission Spectrometer, for the analysis of the chemical composition of the coating.

FT-IR, which is a functional group identifier. Surface characterization of the treated metal substrate by possible techniques such as Raman Spectroscopy, Fourier Transform Infrared (FT-IR), Raman Spectroscopy, which is a functional group identifier.

Raman Spectroscopy, which identifies iron oxides, present in the conversion film.

Therefore, in the experimental study, the following figures are identified in sequence as part of the research work at the company's facilities, where the time is indicated in parentheses, whereby, the experiment has had a duration of its process of approximately 24 hrs, which has allowed to visually identify the reaction of the converter substance on the oxidized metal surface.

With a commercial solution developed by the company, as part of the copyright process, the formulation and physical and chemical characteristics are under validation for subsequent commercial publication and contribution to the research. However, the market has.

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Figure 6 Presentation of the sheet-type sample with oxide present (8:00 AM)
Source: Metalyzinc Laboratory

Figure 7 Cleaning of sample sheet with presence of rust (10:00 AM)
Source: Metalyzinc Laboratory

Figure 8 Beginning of converter application by sections on sample sheet with oxide present (15:07 PM)
Source: Metalyzinc Laboratory

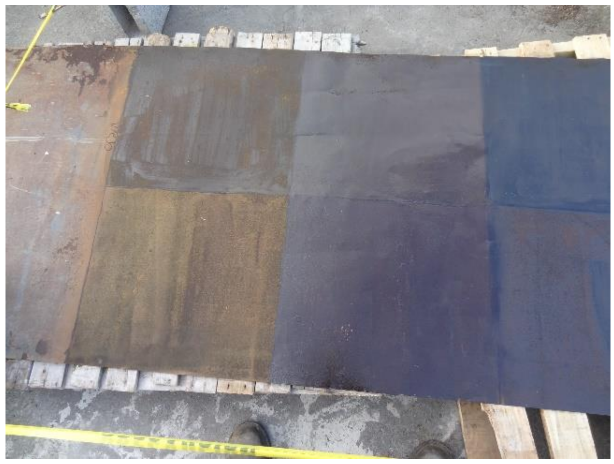

Figure 9 With sections of converter application on sample sheet with presence of oxide (16:49 PM)
Source: Metalyzinc Laboratory

Figure 10 Sample film with the converter after 15 hrs (07:50 AM)
Source: Metalyzinc Laboratory

Figure 11 Sample of coating substances
Source: Metalyzinc Laboratory

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Where, the developed product (oxide converter) will represent a benefit for the consumer (general public as well as for the industrial sector) likewise, the implementation of the developed product will represent a technological improvement for the company, placing it in a market of greater opportunity and competitiveness. And, a virtual corrosion laboratory allows the development of tests minimizing the costs of materials and operation time (Bethencourt M., et al., 2004).

Acknowledgement

The support of the company Metalyzinc through the use of its internal resources, as well as to the laboratory personnel for their support in the analysis of the results, and also to the members of the Academic Body UV-CA-470 Innovation in Management Systems for the compilation of the evidence of the study.

Conclusions

The study monitored the comparative of experimental parameters in the preparation of samples and performance of laboratory tests. The effectiveness of the application of the methodology and use of the equipment and inputs was ensured, generating reliable results for the development of the prototype, through the control of the parameters to validate the coating. Definition of the intellectual and industrial property protection strategy. Analysis of market needs and description of value proposition with reference to product cost and positive impact on the environment. Also, tracking of reactions to various environmental exposures in the field in the logbook and reports according to the parameters of the coating application. Verify compliance with the applicable regulations of the functional prototype, according to the inspection stages in accordance with the coating application parameters, compliance with the applicable regulations of the functional prototype.

Therefore, the possibility of improvement in the study, consolidates the application of tests in salt spray chamber according to ASTM B117-02, electrochemical analysis of the reaction mechanism of the anticorrosive system, surface characterization of the treated metal substrate by possible techniques such as Raman Spectroscopy, Fourier Transform Infrared (FT-IR) or X-Ray diffraction, and adhesion tests on the sheet type samples with the presence of oxide.

And the applicable standards for the cleaning of steel surfaces are considered the Swedish Standard SIS 055900, British Standard BS 4232, Surface Preparation Specification of the Steel, Surface Preparation of the National Association of Corrosion Engineers, (NACE), and the Colombian Institute of Technical Standards.

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Automation of a horizontal electrospinning system to obtain polymeric nanofibers at low cost

Automatización de un sistema de electrohilado horizontal para obtención de nanofibras poliméricas a bajo costo

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Abstract

The objective of this research is to automate the horizontal electrospinning system to obtain nanofibers with polymeric solutions. The open loop system was designed and implemented for the electromechanical system of the horizontal electrospinning machine to control the speed of injection, distribution and storage of the polymeric solution and the control of the distance between the capillary and collector, and the display of the temperature at through a human-machine interface. The control system is made up of the reference value, control, correction and process stages, in other words, in the reference value the desired values of each of the variables to be controlled are assigned, in the control stage decision making and send the signals to the correction stage to make the changes and maintain the desired value and the process is where the physical variables are controlled, it was carried out with the LabView software and the ATMega 2560 microcontroller. With the automation of the horizontal electrospinning system, they will determine the conditions of the process and environmental parameters for obtaining nanofibers from different polymer solutions for use in the area of catalysis and biomaterials.

Automation, Horizontal electrospinning, Variables

Resumen

El objetivo de esta investigación es automatizar el sistema de electrohilado horizontal, para la obtención de nanofibras con soluciones poliméricas. Se diseñó e implemento el sistema de lazo abierto para el sistema electromecánico de la electrohiladora horizontal, para controlar la velocidad de inyección, distribución y almacenamiento de la solución polimérica y el control de la distancia ente el capilar y colector, la visualización de la temperatura a través de una interfaz hombre máquina. El sistema de control está constituido por las etapas valor de referencia, control, corrección y el proceso; en otras palabras, el valor de referencia asigna los valores deseados de cada una de las variables a controlar, en la etapa de control se toma decisiones y envía las señales a la etapa de corrección para que realice los cambios, así se mantiene el valor deseado; en el proceso se controlan las variables físicas, se realizó con el software de LabView y microcontrolador ATMega 2560. Con la automatización del sistema de electrohilado horizontal se determinan las condiciones de los parámetros del proceso y ambientales para la obtención de las nanofibras a partir de diferentes soluciones poliméricas para su uso en el área de catálisis y biomateriales.

Automatización, Electrohilado horizontal, Variables

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Introduction

According to Arbones (Arbones, 2009) an automated system is a set of components that interact with each other, after receiving instructions provided by the operator, decides and acts, thus substituting man. Such substitution produces faster execution, better regulation of the results and avoids the man the painful and repetitive tasks.

In the field of industrial and process production, automation has become a necessary and indispensable working tool to optimize production processes and increase competitiveness. Therefore, automation has the mission to achieve added value in manufactured products, varying their characteristics and carrying out a transformation of materials or goods until reaching a finished product (Pardo, 2012).

Production involves repetitive tasks, where a set of magnitudes of physical variables (pressure, temperature, humidity, speed, voltage, current, etc.) must be maintained within pre-established margins (desired value or reference). The application of electromechanical and electronic systems in the industrial area allowed automating repetitive tasks, increasing production levels, and controlling the magnitudes of physical variables more precisely (Daneri, 2008).

Electrospinning is one of the most used and economic techniques, for obtaining nanofibers, where an electric field is generated between the two parallel plates with a high voltage source with positive or negative polarity, an injection or tubular pump to carry the solution from the plunger or pipette to the spinneret and a conductive aluminum collector (Fahimirad, Ajalloueian, & Ghorbanpour, 2019).

The diameters of nanofibers are in the submicron to nanometer range, it contains unique characteristics in which are: very large surface area relative to volume (Tong, Zhang, & Wang, 2012) and superior mechanical performance compared to other already known forms of the material, these characteristics make nanofibers, candidates for a variety of applications including: tissue engineering (Dersch, Steinhart, Boudriot, Greiner, & Wendorff, 2005) (Jayaraman, Kotaki, Zhang, Mo, & Ramakrishna, 2014); with nanofibers different materials are obtained with properties and characteristics that improve products or new ones are created, with applications in areas: medicine, environmental (Antúnez García, Maytorena Córdova, Petranovskii, & Raymond Herrera, 2000), textile (Jayaraman, Kotaki, Zhang, Mo, & Ramakrishna, 2014), (Srinivasan & Reneker , 1995) (Xue, Chen, Yin, Jia, & Ma, 2012), tissue engineering, biosensors, filtration, wound dressings, drug delivery and enzyme immobilization (Travis, 2008).

Figure 1 shows the electrospinning system, which consists of a capillary injector through which the polymer solution is expelled; a high voltage source containing two positive and negative electrodes are connected to the capillary and to the collector (Ju, Laurencin, Caterson, Tuan, & Ko, 2002), where the fibers are deposited after evaporation.

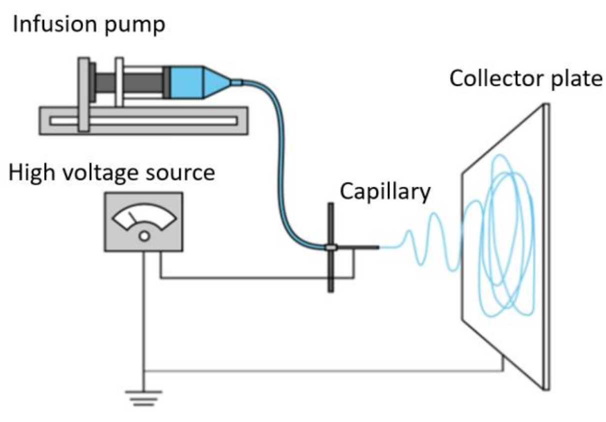

Figure 1 Assembly of the electrospinning system
Source: (Duque, Rodríguez, & López, 2012)

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There are several variables that are related to the properties and characteristics of the electrospun fibers; therefore, their control during the execution of the process is necessary. It is important to consider the parameters of the solution, such as: concentration, surface tension, conductivity, dielectric effect of the solvent, process parameters: voltage, output flow, distance between the needle tip and the collector plate (Ju, Laurencin, Caterson, Tuan, & Ko, 2002) and environmental parameters: humidity and temperature.

Voltage is one of the most important parameters within the electrospinning process; i.e., applying high voltages decreases the diameter of nanofibers (Sencadas, et al., 2012), or increasing the voltage decreases the diameter of nanofibers (Lee, et al., 2004), increases the probability of obtaining defective fibers (Deitzel, Kleinmeyer, Harris, & Tan B., 2001) (Sencadas, et al., 2012); a lower outflow the solvent would have more time to evaporate avoiding the formation of defects in the fibers (Yuan, Zhang, Dong, & Sheng, 2004), when the outflow increases the diameter of the fibers and possibly in the size of the defects (Zong, et al., 2002) (Ribeiro, Sencadas, Gomez, & Lanceros, 2010); the distance between the needle tip and the collector plate depends on the properties of the solution. It can have an effect on the morphology of the fibers, with very large distances the electrospun fibers may break under their own weight, especially if the fibers are small in diameter (Li, Wang, & Xia, 2003), a minimum distance is required to give the fibers enough time for the solvent to evaporate before it reaches the collector, with very large or too small distances the appearance of beads has been observed (Ki, et al., 2005).

Aligned or oriented nanofibers have been obtained with rotating or parallel collectors (Jayaraman, Kotaki, Zhang, Mo, & Ramakrishna, 2014) and random ones with lamellar collectors inside the membrane that configure the movement according to each collector; i.e., without movement. The development of the collectors, influence by the membranes that can be obtained, by the control of the process, in other words, the magnitudes of the variables that converge for an optimal preparation of nanofibers (Suárez, Goméz, & Muñoz , 2015).

Therefore, this work explains the automation of the electromechanical system of the horizontal electrospinning, implementing an open loop system, for the control of injection (injection speed of the polymeric solution), distribution (horizontal distribution speed of the polymeric solution) and collector (storage speed of the polymeric solution); It also controls the positioning of the platform (distance between the capillary and the collector) and temperature monitoring, i.e., the desired value for each of the process parameters is assigned through the human machine interface (HMI) to obtain nanofibers, which can be used as biomaterials or in catalysis for the removal of organic dyes in effluents.

Methodology to be developed

The mechanical system of horizontal electrospinning was automated to obtain nanofibers; that is, an open loop system was implemented to control the magnitudes of the physical variables of the horizontal electrospinning process (injection speed, distribution and storage of nanofibers); manipulate the separation between the capillary and the collector, monitor the temperature in the process and finally test the operation of the equipment.

Results

Control system

An open loop control system was implemented, because the magnitudes of the reference values are not compared with the magnitudes of controlled variables, these systems are only calibrated to obtain a precision, the block diagram of the control system for horizontal electrospinning, is shown in Figure 2.

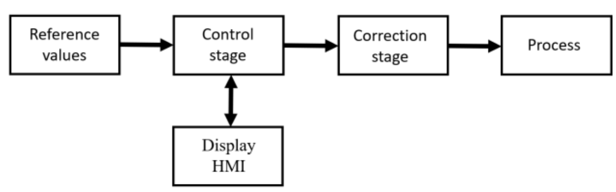

Figure 2 Block diagram of the control system for the electromechanical horizontal electrospinning system
Source: Own elaboration

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Reference values: The magnitudes of the physical variables that are controlled are: injection speed, distribution and storage of the polymeric solution; the distance between the needle and the roller is manually manipulated, and the temperature is monitored.

The control of injection speed, distribution and storage of the polymeric solution and the separation between the capillary and the collector were implemented direct current motors manipulated by pulse width modulator (PWM) at a frequency range of 0 to 970 Hertz (Hz) and the ATMega 2560 microcontroller.

Control stage

Manual and autonomous control of the injection system: The direction of rotation of the motor is manipulated with the digital outputs 11 and 12 of the ATMega 2560 microcontroller; i.e., it is controlled manually by enabling the "Close" button actuates the electromechanical system with which a force is applied to the syringe plunger that injects the solution and the "Open" button releases the syringe plunger and autonomous control of the injection system sets the injection time then sets the speed of the DC motor in the range of 0 to 255 related to the frequency of 0 to 1. 942 KHz with the knob "injection motor control" and finally the buttons "intermittent" and "close" are activated and the electric actuator rotates clockwise and with the buttons "intermittent" and "open" the rotation of the direct current motor is inverted, in other words the electromechanical system will return to its initial state; meter 3" is an indicator instrument that shows the percentage of the duty cycle of the pulse width modulator that controls the speed of the DC motor and the indicator light if deactivated indicates that the electromechanical system is in manual mode.

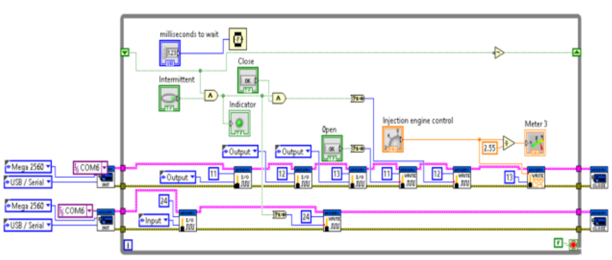

Figure 3 Injection control system for the mechanical horizontal electrospinning system
Source: Own elaboration

Oscillation speed control: The speed of the oscillation system is set with the slider "oscillation motor control" with values from 0 to 255, duty cycle of the pulse width modulator from 0 to 100% is displayed on the indicator instrument "meter 2" and the frequency range is 0 to 970 Hz (pin 7); The DC motor rotation control of the electromechanical oscillation or distribution system uses pins 5 and 6 to reverse the rotation of the electric actuator automatically in conjunction with two slot sensors (pins 24 and 26) placed at the ends of the mechanical system; that is to say, if the light beam of the slot sensor emitter is not interrupted in the receiver a logical 1 is obtained and therefore the mechanical system moves to the left or right otherwise when it reaches the limit the slot sensor changes state from 1 to 0 and therefore, the rotation of the motor changes direction and also with two indicator lamps shows at which end is the mechanism, shown in Figure 4.

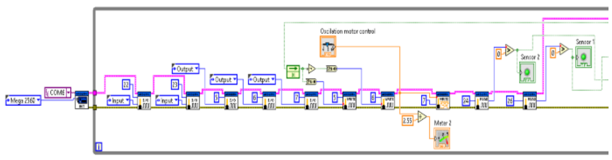

Figure 4 Horizontal electrospinning distribution system control system
Source: Own elaboration

Speed control of the collector (roller): The direction of rotation of the direct current motor of the electromechanical system of the fiber collector is manipulated; In other words, clockwise direction of rotation of the electric actuator is used pin 9, which is assigned a Boolean value equal to one, a voltage is supplied and otherwise a voltage is provided to the direct current motor and with pin 8 the counterclockwise direction of rotation is inverted, the Boolean value is set equal to zero, therefore, a potential differential is applied to it, a potential differential is applied and otherwise no voltage is applied to the direct current motor and the speed is controlled with pin 10, with the pulse width modulator (PWM) technique at a frequency from 0 to 487 Hz, the values are from -100 to 100, for positive values a high pulse is sent to pin 9 and a low pulse to pin 8 and negative values a logic zero is sent to pin 9 and a logic one to pin 8, as shown in Figure 5.

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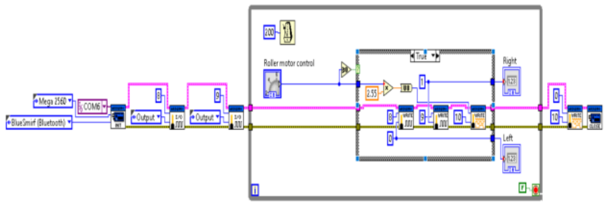

Figure 5 Horizontal electrospinning roller control system
Source: Own elaboration

Platform control: To control the separation distance between the capillary and the collector is used an electromechanical system that is manipulated with a direct current motor, for the displacement of the platform forward is manipulated with pin 3 if it is assigned the Boolean value of 1 with an event of a click of the button "forward" and backward is done with the push button "back" and the displacement speed with manipulated with the knob "platform control", The "meter" display instrument shows the duty cycle of the rotating machine or 100% is controlled by the pulse width modulator technique, see figure 6.

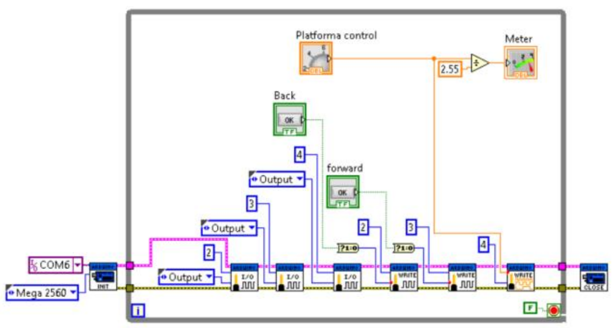

Figure 6 Horizontal electrospinning platform control system
Source: Own elaboration

Temperature: the temperature reading is made by means of a thermocouple, which sends an analog signal to pin A0 of the ATmega 2560 Microcontroller. This signal is processed passing first through a difference, then the result to a division by 0.0255 and the magnitude of the temperature of the process is obtained, as shown in Figure 7.

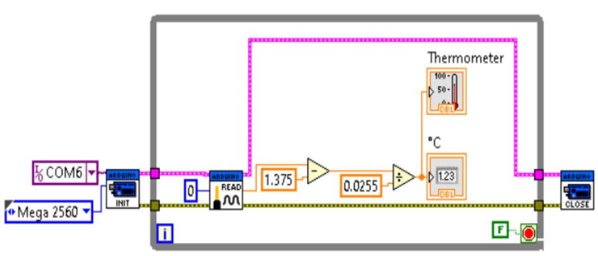

Figure 7 Horizontal electrospinning platform control system
Source: Own elaboration

Conclusions

The control system of the variables of distribution, injection of the polymeric solution and storage of the nanofibers, the speed was manipulated with a pulse width modulator, and the control of the separation between the capillary and the collector and the temperature of the process was visualized, and the operation was checked by performing tests with a polymeric solution under different reference values of voltage, injection speed, distribution and storage, with the man-machine interface (see figure 8).

With the automation of the electrospinning system, the feasibility conditions of polymeric solutions for obtaining fibers are being sought.

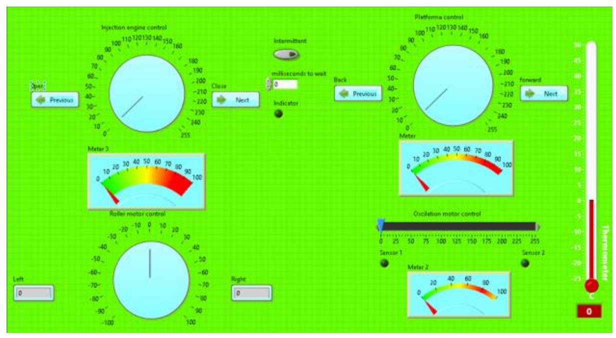

Figure 8 Man-machine interface of the horizontal electrospinning system
Source: Own authorship

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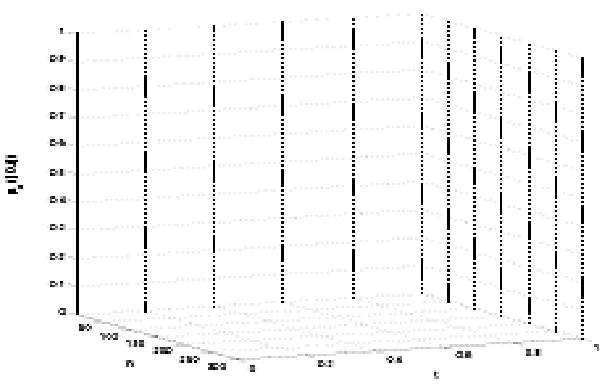

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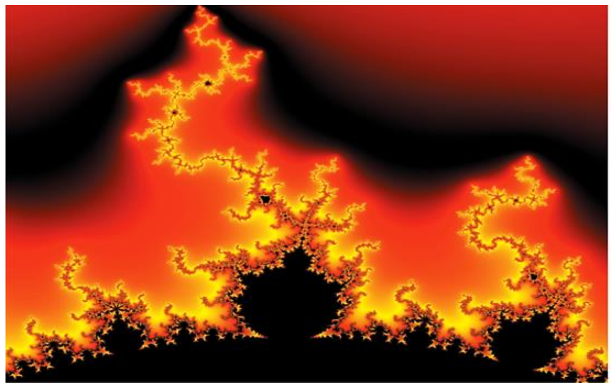

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