ISSN 2523-0344

Volume 5, Issue 15 — July — December — 2021

Journal Industrial Engineering

ECORFAN®

Journal Industrial Engineering, Volume 5, Number 15, December, 2021, is a biannual magazine published by ECORFAN-República del Perú. AV. La Raza, No 1047 - Santa Ana, Cusco-Peru, CP: 11500. WEB: http://www.ecorfan.org/republicofperu/rj_ingenieria_industrial.php, revista@ecorfan.org. Editor in Chief: SERRUDO-GONZALES, Javier. BsC. ISSN: 2523-0344. Responsible for the last update of this issue Unidad Informática ECORFAN. Imelda Escamilla Bouchán, PhD. Vladimir Luna Soto, PhD. Updated December 31, 2021.

Journal Industrial Engineering

Definition of Research Journal

Scientific Objectives

Support the international scientific community in its written production Science, Technology and Innovation in the Field of Engineering and Technology, in Subdisciplines Production systems design, product quality management, operations research, computer simulation, supply chains, quality certification, hydrometeorology.

ECORFAN-Mexico, S.C. is a Scientific and Technological Company in contribution to the Human Resource training focused on the continuity in the critical analysis of International Research and is attached to CONACYT-RENIECYT number 1702902, its commitment is to disseminate research and contributions of the International Scientific Community, academic institutions, agencies and entities of the public and private sectors and contribute to the linking of researchers who carry out scientific activities, technological developments and training of specialized human resources with governments, companies and social organizations.

Encourage the interlocution of the International Scientific Community with other Study Centers in Mexico and abroad and promote a wide incorporation of academics, specialists and researchers to the publication in Science Structures of Autonomous Universities - State Public Universities - Federal IES - Polytechnic Universities - Technological Universities - Federal Technological Institutes - Normal Schools - Decentralized Technological Institutes - Intercultural Universities - S & T Councils - CONACYT Research Centers.

Scope, Coverage and Audience

Journal Industrial Engineering is a Journal edited by ECORFAN-Mexico, S.C. in its Holding with repository in Republic of Peru, is a scientific publication arbitrated and indexed with semester periods. It supports a wide range of contents that are evaluated by academic peers by the Double-Blind method, around subjects related to the theory and practice of Production systems design, product quality management, operations research, computer simulation, supply chains, quality certification, hydrometeorology with diverse approaches and perspectives , That contribute to the diffusion of the development of Science Technology and Innovation that allow the arguments related to the decision making and influence in the formulation of international policies in the Field of Engineering and Technology. The editorial horizon of ECORFAN-Mexico® extends beyond the academy and integrates other segments of research and analysis outside the scope, as long as they meet the requirements of rigorous argumentative and scientific, as well as addressing issues of general and current interest of the International Scientific Society.

Editorial Board

Arbitration Committee

Assignment of Rights

The sending of an Article to Journal Industrial Engineering emanates the commitment of the author not to submit it simultaneously to the consideration of other series publications for it must complement the Originality Format for its Article.

The authors sign the Authorization Format for their Article to be disseminated by means that ECORFAN-Mexico, S.C. In its Holding Republic of Peru considers pertinent for disclosure and diffusion of its Article its Rights of Work.

Declaration of Authorship

Indicate the Name of Author and Coauthors at most in the participation of the Article and indicate in extensive the Institutional Affiliation indicating the Department.

Identify the Name of Author and Coauthors at most with the CVU Scholarship Number-PNPC or SNI-CONACYT- Indicating the Researcher Level and their Google Scholar Profile to verify their Citation Level and H index.

Identify the Name of Author and Coauthors at most in the Science and Technology Profiles widely accepted by the International Scientific Community ORC ID - Researcher ID Thomson - arXiv Author ID - PubMed Author ID - Open ID respectively.

Indicate the contact for correspondence to the Author (Mail and Telephone) and indicate the Researcher who contributes as the first Author of the Article.

Plagiarism Detection

All Articles will be tested by plagiarism software PLAGSCAN if a plagiarism level is detected Positive will not be sent to arbitration and will be rescinded of the reception of the Article notifying the Authors responsible, claiming that academic plagiarism is criminalized in the Penal Code.

Arbitration Process

All Articles will be evaluated by academic peers by the Double Blind method, the Arbitration Approval is a requirement for the Editorial Board to make a final decision that will be final in all cases. MARVID® is a derivative brand of ECORFAN® specialized in providing the expert evaluators all of them with Doctorate degree and distinction of International Researchers in the respective Councils of Science and Technology the counterpart of CONACYT for the chapters of America-Europe-Asia- Africa and Oceania. The identification of the authorship should only appear on a first removable page, in order to ensure that the Arbitration process is anonymous and covers the following stages: Identification of the Research Journal with its author occupation rate - Identification of Authors and Coauthors - Detection of plagiarism PLAGSCAN - Review of Formats of Authorization and Originality-Allocation to the Editorial Board- Allocation of the pair of Expert Arbitrators-Notification of Arbitration -Declaration of observations to the Author-Verification of Article Modified for Editing-Publication.

Instructions for Scientific, Technological and Innovation Publication

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, *Design and construction of a Darrieus vertical axis turbine and analyzed by reverse engineering*, by GARCÍA-HERNÁNDEZ, Miguel Alejandro, CRUZ-GOMEZ, Marco Antonio, JUAREZ-ZERÓN, Tomás Aarón and SAAVEDRA-CRUZ, Nubia, with adscription in the Benemérita Universidad Autónoma de Puebla, as second article we present, *Performance indicators in the sustainable management of the company Metalyzinc*, by RAMÍREZ-ROMÁN, Adolfo, RODRÍGUEZ-RODRÍGUEZ, Luis Alberto, CHABAT-URANGA, Jacqueline and SUÁREZ-ÁLVAREZ, Ángel, with adscription in the Universidad Veracruzana, as third article we present, *Control system for parameter estimation in plastic injection for the automotive industry,* by ROMANO-RODRÍGUEZ, Ma. Natividad, MUÑOZ-RIOS, José Juan, PÉREZ-MARTÍNEZ, René and HERNÁNDEZ-MEDINA, José Juan, with adscription in the Instituto Tecnológico Superior de Tlaxco, as fourth article we present, *Microservices architecture as a viable option to support the organic growth of PYMEs*, by BENÍTEZ-QUECHA, Claribel, ALTAMIRANO-CABRERA, Marisol, LÓPEZ-GUZMÁN, Oscar Eduardo and MÉNDEZ-LÓPEZ, Minerva Donají, with adscription in the Tecnológico Nacional de México Campus Oaxaca.

Content

Article	Page

Article
Journal Industrial Engineering
December 2021, Vol.5 No.15 1-9

Design and construction of a Darrieus vertical axis turbine and analyzed by reverse engineering

Diseño y construcción de una turbina de eje vertical Darrieus y analizada por ingeniería inversa

GARCÍA-HERNÁNDEZ, Miguel Alejandro†, CRUZ-GOMEZ, Marco Antonio*, JUAREZ-ZERÓN, Tomás Aarón and SAAVEDRA-CRUZ, Nubia

Benemérita Universidad Autónoma de Puebla, Faculty of Engineering, Tribology and Transportation Group, Academic Body 189 (Disaster Prevention and Sustainable Development, Tribology, BUAP), Graduate Building, First Level, Cubicle No. 16, Blvd. Valsequillo esq. Av. San Claudio, Ciudad Universitaria, Col. San Manuel, CP. 72570, Puebla Mexico.

ID 1st Author: *Miguel Alejandro, García-Hernández* / **ORC ID**: 0000-0002-3813-8836, **Researcher ID Thomson:** AAM-3746-2021, **CVU CONACIT ID:** 1117920

ID 1st Co-author: *Marco Antonio, Cruz-Gómez* **/ ORC ID**: 0000-0003-1091-8133, **Researcher ID Thomson**: S-3098-2018, **CVU CONACYT ID**: 349626

ID 2nd Co-author: *Tomás Aarón, Juárez-Zerón* / **ORC ID:** 0000-0002-9796-0540, **Researcher ID Thomson**: S-3099-2018, **CVU CONACYT ID**: 295058

ID 3rd Co-author: *Nubia, Saavedra-Cruz* / **ORC ID:** 0000-0002-9606-6893, **Researcher ID Thomson:** AKK-8861-2021, **CVU CONACYT ID:** 1118065

DOI: 10.35429/JIE.2021.15.5.1.9 Received July 10, 2021; Accepted December 30, 2021

Abstract

The implementation of sustainable generation systems satisfying the demands of the electric power line has begun to become a necessity given the climatic consequences adjacent to the means of obtaining energy by burning fossil fuels. Today, Mexico has 30.14% of sustainable means installed as generators to the Electric Power System, but only as secondary feeders given their intermittency. However, wind farms have shown promise, being able to satisfy more than 30% of the Southeast Peninsula line at peak hours. Therefore, this research aimed to design and build a prototype of a reverse-engineered back-fed Darrieus vertical axis wind turbine. With the psychrometric chart data at 2135 masl, the parameters of angular velocity, tip speed ratio and wind rotor power were identified. In addition, the wind flow behavior was analyzed by means of a finite element modeling bounded by the K-Epsilon turbulence system and the boundary conditions pertinent to the State of Puebla. Finally, the results obtained will be discussed and based on these, how the implementation of this turbine in urban areas benefits.

Darrieus wind turbine, Reverse engineering, CFD

Resumen

La implementación de sistemas de generación sustentable satisfaciendo las demandas de la línea de potencia eléctrica ha comenzado a convertirse en una necesidad dadas las consecuencias climáticas adyacentes a los medios de obtención de energía mediante la quema de combustibles fósiles. Hoy en día, México cuenta con un 30.14% de medios sustentables instalados como generadores al Sistema Eléctrico de Potencia, pero únicamente como alimentadores secundarios dadas sus intermitencias. Sin embargo, los parques eólicos han demostrado ser prometedores, siendo capaces de satisfacer más del 30% de la línea de la Península Sureste en horas pico. Por lo tanto, esta investigación tuvo como objetivo diseñar y construir un prototipo de aerogenerador de eje vertical Darrieus retroalimentada con ingeniería inversa. Con los datos de la carta psicométrica a 2135 msnm, fueron identificados los parámetros de velocidad angular, Relación de Velocidad de Punta y potencia del rotor eólico. Además, el comportamiento de flujo de viento fue analizado mediante un modelado de elemento finito delimitado por el sistema de turbulencias K-Épsilon y las condiciones de frontera pertinentes al Estado de Puebla. Para finalizar, se discutirán los resultados obtenidos y en base a estos; como beneficia la implementación de esta turbina en zonas urbanas.

Turbina eólica Darrieus, Ingeniería inversa, CFD

Citation: GARCÍA-HERNÁNDEZ, Miguel Alejandro, CRUZ-GOMEZ, Marco Antonio, JUAREZ-ZERÓN, Tomás Aarón and SAAVEDRA-CRUZ, Nubia. Design and construction of a Darrieus vertical axis turbine and analyzed by reverse engineering. Journal Industrial Engineering. 2021. 5-15:1-9.

* Author Correspondence (Email: miguel.garciaher@alumno.buap.mx).
† Researcher contributing as first author.

Introduction

The generation of electrical energy through the excitation of the armature winding of a synchronous machine is a fundamental fact in any power system that seeks to satisfy a high load demand; however, 69.86% of the means to turn the rotors of the generators of the grid in Mexico are by burning fossil fuels, combined cycles, and nuclear power plants, which produce large amounts of carbon emissions and substances that degrade the integrity of the ozone layer. It is therefore advisable to explore the other remaining 30.14% of the excitation means for our generators: by sustainable means. *Centro Nacional de Control de Energía [CENACE]. (2021) y Programa de Desarrollo del Sistema Eléctrico Nacional 2017-2031 [PRODECEN]. (2020).*

Among the five means of sustainable energy generation used in Mexico (photovoltaic, wind, biomass, hydroelectric and geothermoelectric), this research focused on wind power, specifically on the Darrieus vertical axis designs, which consist of capturing the winds through the blades of this turbomachinery, which rotates perpendicularly to the direction of the air flows. However, the implementation of vertical wind turbines in Mexico are hardly implemented in comparison with horizontal axis, this is because they have lower aerodynamic efficiency and a higher drag coefficient, therefore, their area of study has also been reduced, despite everything, vertical axis designs have two great advantages: the first is that they do not have to be oriented in the direction of the wind and the second is that they can work in urban areas where air currents are turbulent. *Centro Nacional de Control de Energía [CENACE]. (2020) y el Instituto Tecnológico y de Estudios Superiores de Monterrey. (2020).* In this project, the design and construction of a Darrieus vertical axis turbine retrofitted through reverse engineering and the psychometric chart at 2135 meters above sea level, the calculation sheets of the parameters of angular velocity, Tip Speed Ratio, and power capacity that the rotor can generate with an average wind speed of 8.03 m/s radially were developed. In addition to corroborating each of these coefficients calculated through a CFD analysis, using the mathematical model K-Epsilon and the Navier-Stokes equations. *Benemérita Universidad Autónoma de Puebla [BUAP]. (2021).*

Methodology

This research has a mixed approach, applying both quantitative and qualitative technologies, using systematic processes as well as recorded and estimated data. The objective of this project is to design and build a prototype of a Darrieus H-type vertical axis turbine, from a selection of recycled and low-cost materials, capable of operating under the climatic conditions of the State of Puebla, Mexico, and to obtain the wind rotor operation data using a reverse engineering process. To this end, the application of the quantitative method was relevant to obtain the parameters of angular velocity, TSR, and project power through the figures provided by an anemometer, the data from the psychrometric chart at 2135 masl, and the geometric characteristics of the turbine, such as its outer radius (0.495 m) and the contact area (0.07081 m^2). The application of the qualitative method allowed the possibility of obtaining results from estimating the linear wind speed variable as a constant of the average air flow speed (8.03 m/s), in addition to a unit estimation of the drag coefficient; the operating data resulting from these estimates were an average angular velocity of 16.21632 rad/s and a projected power with the rotor assembled directly to the shaft of 22.45677 W. *Saavedra, A. et. al. (2019).* Finally, by the mixed method, a CFD analysis was performed to the CAD model of the turbine, through the ANSYS 2020 R2 Fluent simulator, where a control volume was implemented, in which a constant wind flow governed by the K-Epsilon model was made to observe how the fluid behaved with the wind rotor in operation. From the results obtained, a discussion of results was generated about the constructed design and its implications in the field of sustainable energy generation and sustainability.

Elaboration of the design and construction of the Darrieus vertical axis turbine

Generally, models of any turbomachinery are designed based on calculations developed concerning the physical conditions to which the system will be subjected. However, in this project; the calculations were approached through the reverse engineering process, so the wind turbine was first modeled based on previous designs.

ISSN: 2523-2517

A model of a Darrieus H-type vertical axis turbine with three blades was proposed, a schematic of the profile and blade dimensions is shown in Figure 1.

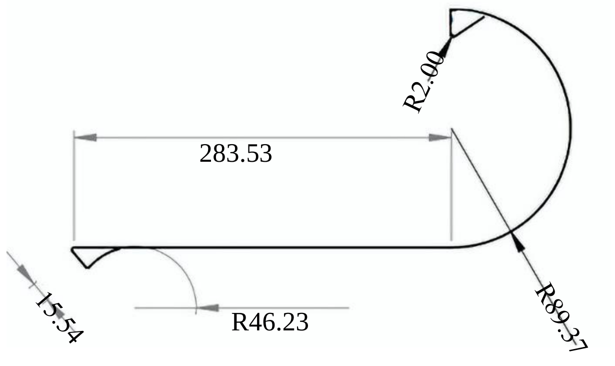


Figure 1 Diagram of the profile and blade dimensions in millimeters
Source: Tribology and Transport Group. Faculty of Engineering. BUAP; Solidworks 2018

From the above schematic, in the freely licensed CAD tool Solidworks 2018, as shown in Figure 2, the base plans for the rotor blades were carried out.

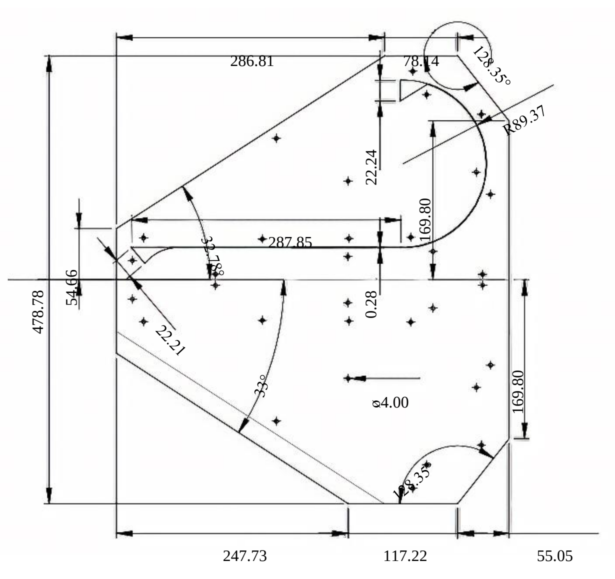


Figure 2 Base plane in millimeters
Source: Tribology and Transport Group. Faculty of Engineering. BUAP; Solidworks 2018

Using a commercial sheet plate of 664 x 510 mm, the angles of curvature of the turbine blades were proposed, as shown in Figure 3.

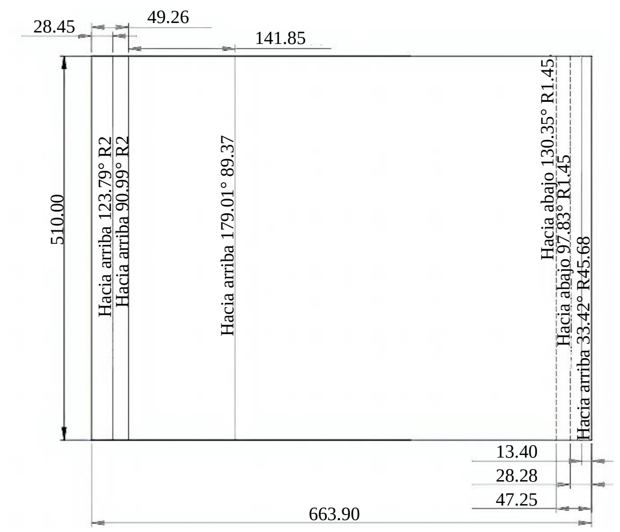


Figure 3 Drawings for the manufacture of blade curvatures in millimeter
Source: Tribology and Transport Group. Faculty of Engineering. BUAP; Solidworks 2018

Following the geometry in the previous drawings, Figure 4 shows the three-dimensional model of the turbine elements, proposing a thickness of 26 mm.

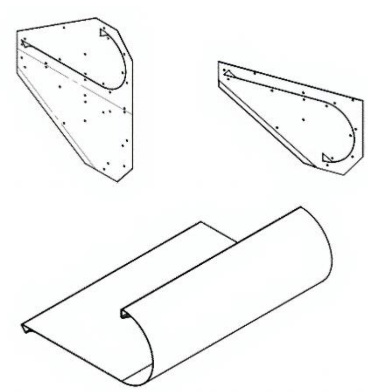


Figure 4 Three-dimensional models of the base and blade
Source: Tribology and Transport Group. Faculty of Engineering. BUAP; Solidworks 2018

As part of the material reuse plan, it was decided to use a bicycle rim with a 260 mm radius to allow the rotation of the turbine, so it was also modeled in the final design, as shown in Figure 5.

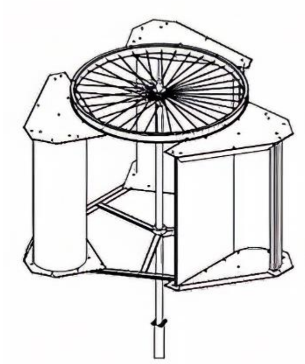


Figure 5 Final modeling of the Darrieus vertical axis turbine *Source: Tribology and transport group. BUAP; Solidworks 2018*

Using the design drawings of the Darrieus vertical axis turbine as a reference, the vertical rotor blades and bases were fabricated from a 26-gauge stainless steel sheet. Figure 6 shows the wind rotor assembled according to the above specifications.

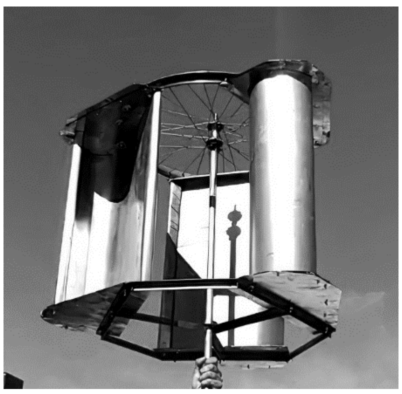


Figure 6 Darrieus vertical shaft turbine
Source: Tribology and Transport Group. Faculty of Engineering. BUAP

Theoretical analysis of the turbine

To allow the study of the Darrieus turbine, the average wind speed of Puebla (8.03 m/s) was declared to be constant. The rest of the wind rotor parameters were obtained through its geometry, the psychrometric chart data, and the formulas described below. *Benemérita Universidad Autónoma de Puebla [BUAP]. (2020).*

Identification of TSR rate

The Tip Speed Ratio or TSR was obtained through equation 1, which relates the linear speed of the turbine to the linear speed perpendicular to the wind flows.

$$\lambda = \frac{v}{V} = \frac{wr}{V} \quad (1)$$

Where:

- λ: Tip Speed Ratio.
- V: Linear wind speed (m/s).
- v: Turbine linear speed (m/s).
- w: Turbine angular velocity (rad/s).
- r: Turbine radius (m).

In which, the linear velocity of the turbine will be described by equation 2.

$$v = wr = 2\pi fr \quad (2)$$

Where:

- f: Frequency (Hz)

Substituting the data in equation 1.

$$\lambda = \frac{2\pi(60\ Hz)(0.495\ m)}{8.03\ {}^{m}/_{s}}$$

Therefore.

$$\lambda = 23.23917$$

However, given the design of the Darrieus vertical axis turbine generated and that it has three blades equidistant to its axis and the same contact area, the TSR coefficient is divided by three, as shown in equation 3.

$$\lambda_R = \frac{\lambda}{3} \quad (3)$$

Where:

- λ_R: Real Tip Speed Ratio

Substituting the data in equation 3.

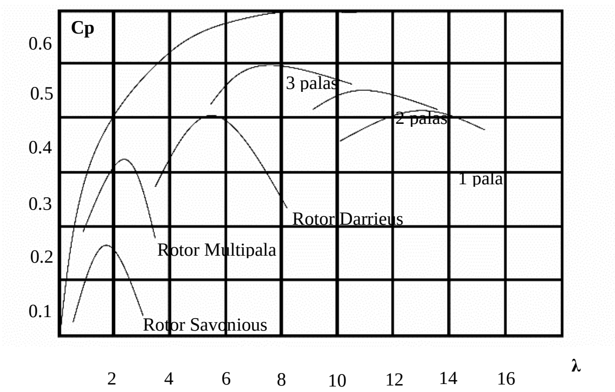
$$\lambda_R = \frac{23.23917}{3} = 7.74639$$

Power coefficient

The TSR allows us to measure the behavior of a body that rotates on its axis and is governed by aerodynamic drag and given the shape of the blades for wind capture are perpendicular to the wind flows and have a large contact area; a unit drag coefficient will be estimated.

ISSN: 2523-2517

Graphic 1 shows the power curves for the TSR of each of the designs. Therefore, we can estimate an approximate power coefficient of 0.35.



Graphic 1 Tip Speed Ratio Curves concerning power coefficients of different wind turbine designs
Source: Análisis matemático. Potencia Eólica. Hidrolate; Recovered from https://hidrolate.wordpress.com/tema/. (2021)

Force and power of the wind flow captured by the turbine

Based on the geometric characteristics of the wind rotor, the psychrometric chart of the State of Puebla (2135 masl) and the delimitation of the wind constant of 8.03 m/s, the equations of the force captured by the turbine and the power to be projected from it without mechanical transmissions were developed.

- Contact area = A = 0.07081 m^2
- Drag constant = C_A = 1
- Wind speed = v = 8.03 m/s
- Air density = ρ = 1.225 kg/m^3
- Turbine radius = r = 0.495 m

The force exerted by the air flows exerted on the turbine blades is defined by equation 4.

$$F_w = C_A \frac{1}{2} \rho A v^2 \quad (4)$$

Substituting the data in equation 4.

$$= (\frac{1}{2})(1.225\ {}^{kg}/_{m^3})(0.07081\ m^2)(8.03\ {}^{m}/_{s})^2$$

Therefore

$$F_w = 2.79661\ N$$

The power to be harnessed by the wind speed is described in equation 5.

$$P_w = C_A \frac{1}{2} \rho A v^3 \quad (5)$$

Substituting the data in equation 5.

$$= (\frac{1}{2})(1.2\ {}^{kg}/_{m^3})(0.07081\ m^2)(8.03\ {}^{m}/_{s})^3$$

Therefore

$$P_w = 22.45677\ W$$

CFD analysis of the Darrieus wind turbine

To observe the behavior of the wind flow while the wind turbine was rotating, the CAD model was imported into the ANSIS 2020 R2 CFD program.

As shown in Figure 7, a control volume was implemented to define the domain through which the wind flow would pass through the wind rotor. Likewise, a rotation domain was also declared to allow the model to rotate.

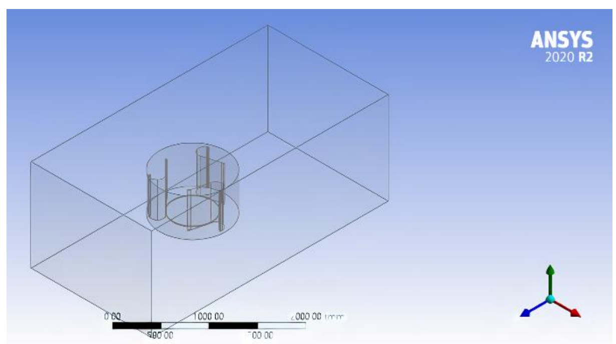


Figure 7 Implementation of control and rotation domains
Source: Tribology and transport group. Faculty of Engineering. BUAP; ANSYS R2 2020. Student license

The K-Epsilon viscosity model achievable with a near-wall treatment scalable to the wall was declared. In addition to programming the boundary parameters given in Table 1.

ISSN: 2523-2517

Parameters	Coefficients and Features
Fluid	Air Density = 1.225 kg/m³ Viscosity = 1.784e-05 kg/m·s
Inlet	8.03 m/s to -Z
Relative pressure in control volume openings (except Inlet)	1.00863 atm
The direction of rotation of the rotation domain	Y = 1
The maximum speed of rotation of the rotation domain	16.21632 rad/s
Number of Prandt TDR	1.2
Number of Prandt TKE	1

Table 1 Boundary parameters of CFD analysis
Source: Tribology and Transport Group. Faculty of Engineering. BUAP. (2021)

From these data, the simulation was developed in the CFX tool of ANSYS R2 2020, obtaining the results of pressure, the velocity of the air flows in the turbine.

Figure 8 shows how the first air flow intake exerts a relative pressure of 63.2 MPA which starts to push the blade concerning the turbine shaft, making it rotate.

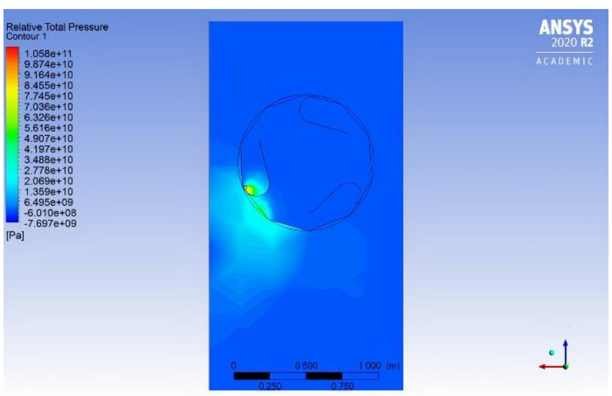


Figure 8 CFD relative pressure results of airflow in the Darrieus vertical axis turbine
Source: Tribology and Transport Group. Faculty of Engineering. BUAP; ANSYS R2 2020. CFX. Student license

In Figure 9, it can be observed how the wind flows take helical shapes when colliding with the internal walls of the blades at a relative velocity, generating those turbulences that are released to the environment at approximately 90° after the wind capture.

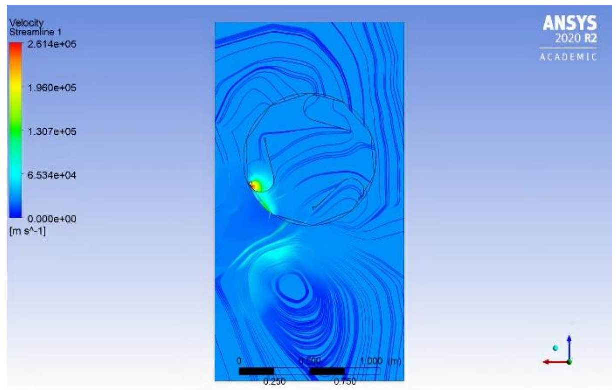


Figure 9 CFD linear velocity results of air flow in the Darrieus vertical axis turbine
Source: Tribology and Transport Group. Faculty of Engineering. BUAP. ANSYS R2 2020. Student license. (2021)

Rectification of the linear velocity results using the Navier-Stokes equations and the Galerkin approximation

Since the ANSYS R2 2020 CFX software obtains the results using the finite volume discretization method, the linear velocity data will be corroborated through the Navier-Stokes equations without fear of a large lag in the CFD analysis solutions.

For the analytical resolution described in equation 6, the effects of viscosity, density, pressure, and temperature were neglected to achieve simpler governing equations, leaving the steady-state velocity as the unknown. *Guanoluisa, E. (2011).*

$$\vec{P} = [K]\vec{\phi} \qquad (6)$$

Where:

- P: Elementary characteristic vectors.
- [K]: Elemental stiffness matrix.
- Φ: Node vectors for linear polynomial interpolation.

From Equation 6, we rename Φ as the velocity of the air currents, as shown in Equation 7.

$$\vec{\phi} = \vec{V} \qquad (7)$$

Therefore, by clearing V we obtain eq. 8.

$$\vec{V} = [K] \setminus \vec{P} \qquad (8)$$

Using the Galerkin approximation, triangular elements were drawn to discretize a section of the top view of the control volume, as shown in Figures 10, 11, and 12. *Guanoluisa, E. (2011).*

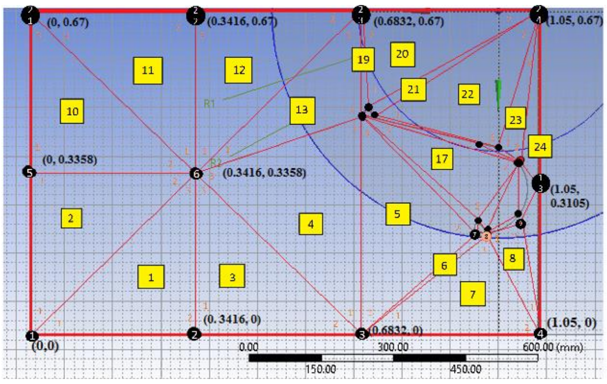


Figure 10 Analogous discretization with the numbering of elements and global and local nodes
Source: Tribology and transport group. Faculty of Engineering. BUAP. (2021)

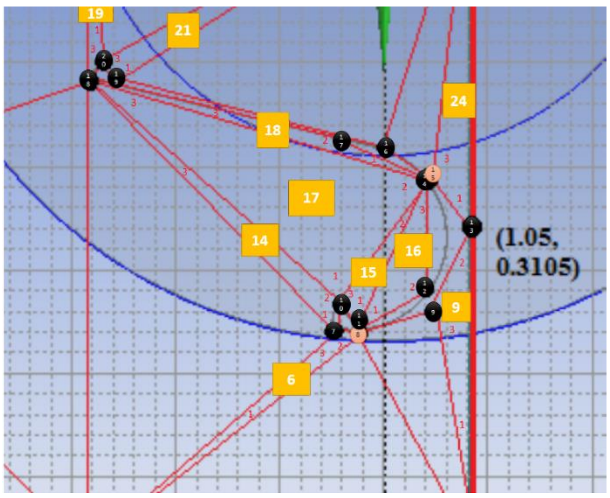


Figure 11 Analogous discretization of blade details with the numbering of elements and global and local nodes
Source: Tribology and transport group. Faculty of Engineering. BUAP. (2021)

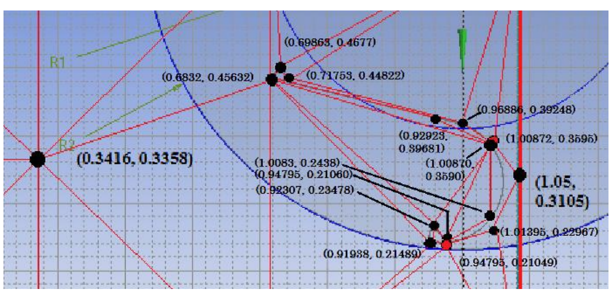


Figure 12 Coordinate system of the analog discretization, warp details
Source: Tribology and transport group. Faculty of Engineering. BUAP. (2021)

Using the coordinate system and the numbering of the twenty-four global and local nodes, the matrices and vectors of equation 6 were developed, whose data were displayed in Matlab R2019a software to obtain the velocity vector described by equation 8, the solutions of the clearance are shown in figure 13.

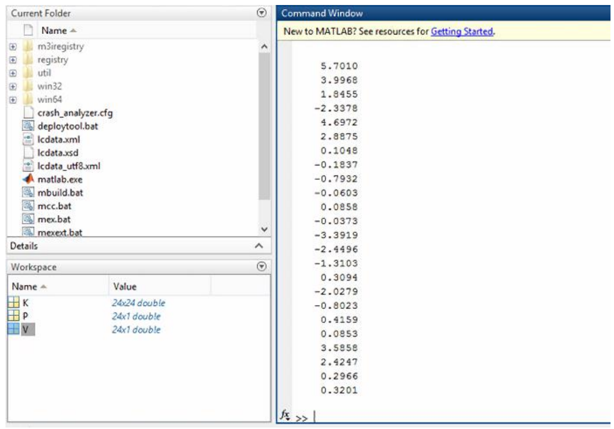


Figure 13 Vector V solution
Source: Tribology and transport group. Faculty of Engineering. BUAP; Matlab R2019a. (2021)

Since ANSYS indicates the direction of the results visually, the directions of the analog solution are defined by the sign corresponding to its result. So comparing; for example, element 16, which corresponds to the inner base of the blade, whose flow velocity is 1.3103 m/s according to the analog solution; is close to the 1.307 m/s of the ANSYS CFD solution, making the obtained results valid.

Results

Table 2 shows all the calculated data obtained from the turbine geometry and the corresponding psychrometric data.

Description	Literal	Calculated Value
Ratio Rate Tip Speed	TSR	7.74639
Power Coefficient	Cp	0.35
Calculated power	Pw	22.45677 W

Table 2 Calculated operating values
Source: Tribology and Transport Group. Faculty of Engineering. BUAP. (2021)

Regarding the airflow analysis, it can be interpreted that the wind intercepted by the turbine blades spreads out around the contact area, encapsulating the air eddies and releasing the greatest amount of kinetic energy by turbulence when reaching 90° after the first capture.

When comparing the steady-state velocity solutions obtained by the Navier-Stokes equations and the Galerkin approximation with the results obtained by the CFD analysis performed in ANSYS; it can be observed that there is a relatively pronounced lag, however, given the number and shape of the nodes and elements, this can be attributed to the accuracy of the study.

Discussion of results

The Darrieus vertical axis turbine design proposed in this research presents a medium-high tip speed ratio with good turbulence behavior of the air flows. Therefore, in terms of sustainability, it would be a great benefit for urban areas with high wind speeds, providing them with an affordable and environmentally friendly energy production alternative.

In the sustainable area, the implementation of this wind turbine design would begin to generate a culture committed to the integrity of its environment. It would also allow Mexican society to actively participate in international compliance with the Paris Agreement on climate change and the reduction of carbon emissions by 2050.

Conclusions

In this study, a three-bladed Darrieus H-type vertical axis design with a large contact area, capable of operating optimally under the psychrometric conditions of the State of Puebla in Mexico, was proposed for future implementation in different urban areas. However, the results obtained show low aerodynamic performance and pose a great challenge to meet the daily demands of city residences. In addition, safety measures must be considered for the inherent risks of this type of turbine, such as, for example, the use of tensioning cables at the top of the prototype to ensure its structural stability in the event of strong winds or a study to ensure that the building in which the installation will be carried out will be able to withstand the extra load. Even so, the Darrieus rotor represents a great advantage in the production of electrical energy in enclosed cities, where wind flows collide with buildings, forming air eddies; and since these designs do not need to be directed into the air currents; they become the appropriate wind generation devices for these environments.

References

(2018). Programa de Desarrollo del Sistema Eléctrico Nacional 2018-2032. Recuperado de: https://www.gob.mx/sener/acciones-y-programas/programa-de-desarrollo-del-sistema-electrico-nacional-33462

(2021). Análisis matemático, Potencia Eólica, Hidrolate. Recuperado de: https://hidrolate.wordpress.com/tema/.

(2021). Estadística de la Energía Generada Liquidada Agregada (MWh) Intermitente y Firme por Tipo de Tecnología. Sistema Eléctrico Nacional. Días de Operación del Mes de: febrero 2021. Proceso de Liquidación: Original (L0). https://www.cenace.gob.mx/SIM/VISTA/REPORTES/EnergiaGenLiqAgregada.aspx

(2021). Red Automática de Monitoreo Meteorológico 12: DIAU-BUAP. Benemérita Universidad Autónoma de Puebla. http://urban.diau.buap.mx/estaciones/ramm/ramm.html

ANSYS. (2021). https://www.ansys.com/

Barrera, J., Jurado, F., Razo, J., González, R. Aerogenerador de eje vertical para aplicaciones In-situ. Análisis y modelado de un aerogenerador de eje vertical. *Innovación y sustentabilidad Tecnológica. Instituto Tecnológico de Misantla.*

Batista, H. (2000). Las turbinas eólicas. Universidad Nacional de la Plata.

Battaglia, L. (2009). Elementos finitos estabilizados para flujos con superficie libre: Seguimiento y captura de interface. Universidad Nacional de Litoral. 24-26.

Canalejo, D. (2011). Generador eólico para uso doméstico. Escuela Universitaria Politécnica de Mataró. 5-7.

Estrella, B. (2008). Prototipo Experimental Turbina Eólica de Eje Vertical. Tecnológico de Monterrey. 8-19.

Guanoluisa, E. (2011). Aplicación del método de elementos finitos en la dinámica de fluidos. 38-50.

ISSN: 2523-2517

Gutiérrez, P. (2020). Sistemas de energía eólica y solar para la alimentación de luminarias. 44-47.

Huacuz, J. (2016). Tendencias en el Desarrollo de la Tecnología Eólica. *Premio Nacional de Tecnología e Innovación.*

Lucero, F. (2016). Diseño de un aerogenerador que apoye la demanda energética de un hogar promedio en Bogotá.

Matlab. (2021). https://www.mathworks.com/products/matlab.html

Saavedra, A., Alejos, R. (2019). Diseño de la geometría de un aerogenerador de eje vertical tipo Savonius. 2-3.

Sanchez, C. (1956). Cálculo aerodinámico de compresores y turbinas. Recuperado en: http://oa.upm.es/6418/

Sánchez, C. (2020). Simulación numérica de algunos modelos de turbulencia con aplicaciones a la aerodinámica de fluidos. Universidad Politécnica de Cartagena. 13-34.

Solidworks. (2021). https://www.solidworks.com/es

Stelee, J. (1977). Finite Element Analysis and Program for Stokes Fluid Flow. Instituro Rochester de Tecnología. Recuperado en: https://scholarworks.rit.edu/theses/?utm_source=scholarworks.rit.edu%2Ftheses%2F7384&utm_medium=PDF&utm_campaign=PDFCoverPages

Torres, A. (2015). Simulación y análisis de interacción fluido-estructura en alabe de turbina de motor a reacción mediante método por elemento finito. Instituto Politécnico Nacional.

Tseng, Y., Kuo, C. (2011). Engineering and construction torsional responses of glassfiber/Epoxy composite blade shaft for a small wind turbine. *Procedia Engineering 14.*

Vázquez, M. (2007). Diseño de una turbina eólica de eje vertical con rotor mixto.

Villanueva, J., Álvarez, R. (2007). Modelado del coeficiente de potencia de un aerogenerador por efecto de fricción. Universidad Nacional Autónoma de México.

Weht G., Giovachinni, J., Sacco C., D´Errico. Mario. (2011). Métodos de elementos finitos aplicado a flujo compresible con gas en equilibrio. *Mecánica Computacional,* Volumen 30. 547-562.

ISSN: 2523-2517

Performance indicators in the sustainable management of the company Metalyzinc

Desempeño de indicadores en la gestión sostenible de la empresa Metalyzinc

RAMÍREZ-ROMÁN, Adolfo†*, RODRÍGUEZ-RODRÍGUEZ, Luis Alberto, CHABAT-URANGA, Jacqueline and SUÁREZ-ÁLVAREZ, Ángel

Universidad Veracruzana, School of Mechanical Engineering and Naval Sciences, Mexico.

ID 1er Author: *Adolfo, Ramírez-Román* / **ORC ID:** 0000-0002-3820-8582, **Researcher ID Thomson:** S-5868-2018, **arXiv Author ID:** adolramirez, **PubMed Autor ID:** adolramirez, **CVU CONACYT ID:** 244749

ID 1er Co-author: *Luis Alberto, Rodríguez-Rodríguez* / **ORC ID:** 0000-0002-6118-040X, **Researcher ID Thomson:** W-9316-2019, **CVU CONACYT ID:** 1011993

ID 2do Co-author: *Jacqueline, Chabat-Uranga* / **ORC ID:** 0000-0003-2202-1032, **CVU CONACYT ID:** 464993

ID 3er Co-author: *Ángel, Suárez-Álvarez* / **ORC ID:** 0000-0002-0726-9630, **CVU CONACYT ID:** 946964

DOI: 10.35429/JIE.2021.15.5.10.23 Received July 15, 2021; Accepted December 30, 2021

Abstract

The research has been developed according to the result of the experimental study of the anti-corrosion protection service of the company Metalyzinc, in the period September 2020 - April 2021, where it is proposed that the performance of the indicators favors the competitiveness of the industrial service of the company of the COBOS Group founded in 1989, therefore, how is the sustainable impact by the management of the indicators in the service of the anti-corrosion protection system?; question that has allowed the content analysis of the reference framework of the context of the study, the knowledge of the operating process that involves the types of variables of the Galvanizinc System service, with the purpose of examining the impact of management, and the evaluation of the performance of the process with the support of diagnosis, application of statistical tools, innovation methodology and use of operational diagrams, contributing to the strengthening of strategic planning, the development of proposals for improvement and sustainable management.

Indicators, Galvanized, Management

Resumen

La investigación se ha desarrollado conforme al resultado del estudio experimental del servicio de protección anticorrosiva de la empresa Metalyzinc, en el periodo de Septiembre 2020 – Abril 2021, donde se plantea que el desempeño de los indicadores favorece la competitividad del servicio industrial de la empresa del Grupo COBOS fundada en 1989, por lo tanto, ¿Cómo es el impacto sostenible por la gestión de los indicadores en el servicio del sistema de protección anticorrosiva?; interrogante que ha permitido el análisis de contenido del marco referencial del contexto del estudio, el conocimiento del proceso operativo que involucra los tipos de variables del servicio Sistema Galvanizinc, con el propósito de examinar el impacto de la gestión, y la evaluación del desempeño del proceso con el apoyo de diagnóstico, aplicación de herramientas estadísticas, metodología de innovación y uso de diagramas de operaciones, contribuyendo en el fortalecimiento de la planeación estratégica, el desarrollo de propuestas de mejora y de la gestión sostenible.

Indicadores, Galvanizado, Gestión

Citation: RAMÍREZ-ROMÁN, Adolfo, RODRÍGUEZ-RODRÍGUEZ, Luis Alberto, CHABAT-URANGA, Jacqueline and SUÁREZ-ÁLVAREZ, Ángel. Performance indicators in the sustainable management of the company Metalyzinc. Journal Industrial Engineering. 2021. 5-15:10-23.

* Author's Correspondence (E-Mail: adolramirez@uv.mx)
† Researcher contributing as first author.

December 2021, Vol.5 No.15 10-23

Introduction

The company is in search of a quality improvement that allows the control of the service parameters, which is equivalent to generate products or services according to the standards established by the regulations or clients, which is the reason why in the last ten years quality has acquired transcendence in all levels of society (Verdoy et al., 2006).

The hot-dip galvanizing service is an advanced industry, dedicated to the protection against corrosion of iron and steel parts by immersing them in a crucible with molten zinc. As a result of the immersion, coatings are obtained that provide the parts with effective and long-lasting protection. These coatings have a much better adhesion than paints because they are alloyed with the base steel.

The control of indicators has become one of the key issues in organizations, since waste and losses caused by rejects, rework and returns can be very high, affecting the profitability of the business.

However, statistical control tools have evolved in the industries, but the use of statistical techniques is very low, often being considered very difficult, unnecessary and with high costs (Miró, 2005).

By means of statistical analysis and process design in particular, it is possible to reduce the number of critical variables. Since the application of statistical process control is governed by the concept of continuous improvement, the results obtained must be evaluated from time to time in order to, in a given case, re-evaluate from the lower and upper limits to the definition of KPI (Key Performance Indicator).

In the organization there are KPIs according to the areas within it, highlighting their use in areas such as logistics, quality, purchasing, sales, production.

The main objectives of the performance indicators are to measure the level of service, make a diagnosis of the situation, reporting its status, generating an environment of motivation to the teams responsible for meeting the objectives reflected in the KPI and, in general, to evaluate the progress constantly, that is why, the interest of promoting its importance within the business environment, and to promote the importance of this topic to engineering students, teachers and related professionals and also to companies that do not know the use of a KPI, which implies the characteristics, its use and impact on the performance of the organization through a methodology that can duplicate the effectiveness in innovation processes, also, that allows sustainable integration, stability, improvement and reduction of variability.

Planning and measurement are essential for a company to succeed. Carefully evaluating strategies and their results allows correcting mistakes, detecting new opportunities, anticipating consumer behavior and making better decisions. In order to carry out this continuous evaluation process, it is necessary to start from the key performance indicators, where the respective performance of the indicators favors the competitiveness of the industrial service, and the sustainable impact by the management of the indicators on the service of the corrosion protection system.

The sections of the article have been developed by blocks with the purpose of optimizing by demonstrating an option of impacting sustainability in the management of the indicators of the corrosion protection system, where, in the development part, listed in three parts, the topics are described in section one, the corrosion protection service, and in section two, the experimental work, where the methodology consisting of application of statistical tools is described in the section of general methodology of the study and innovation. Subsequently, the results, acknowledgements, conclusions of the research and its references are indicated.

Journal Industrial Engineering
December 2021, Vol.5 No.15 10-23

Figure 1 Facade of Metalyzinc, S.A. de C.V. facilities
Source: COBOS Group Marketing

Corrosion protection service

The Galvanizing process in the plant starts when we coat with Iron, Steel with Zinc or with alloys made of Zinc-Iron by immersing the part in molten Zinc, thus forming a long lasting protective layer with resistance in almost all natural environments.

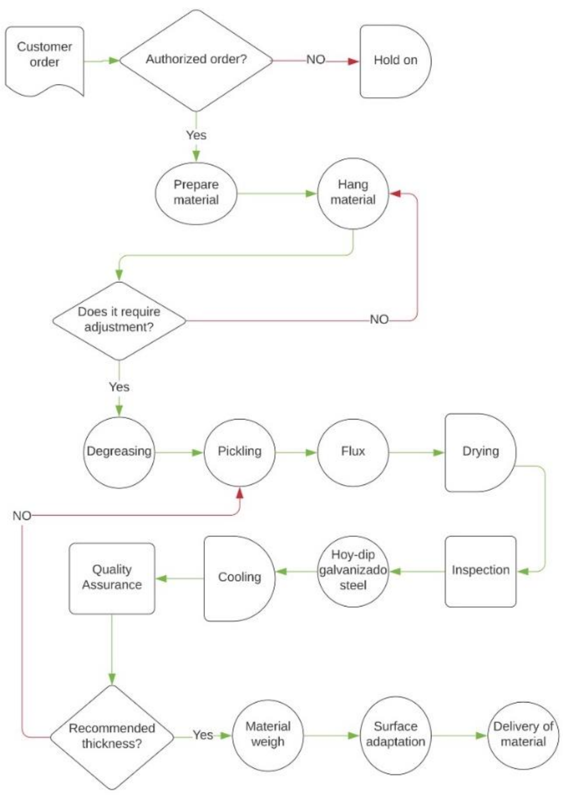


Figure 2 Flow chart of the operational process
Source: Thesis by Martínez Peña, Mª. Guadalupe

This diagram in figure 2, consists of the description of the following steps:

- At material reception, the conditions and weight of the material are inspected, as well as the initial service conditions are established.

- The process of hanging parts to be galvanized allows the parts to be sorted and clamped in relation to their weight and shape, also, the inclination and the object holder are determined so that the hot Zinc can flow properly.

- In the saline solution, the material is purified by eliminating grease or oil impregnated since its manufacture. It is very useful to eliminate organic contaminants such as grease, oil and dirt that adhere to the metal surface.

- In the rinsing stage, it avoids carrying impurities to the next stage of the process.

- With respect to the acid solution at room temperature, it allows the removal of rust and calamine, which are the most common surface contaminants.

- With the second rinsing stage, it prevents acid residues from passing to the next stages of the process.

- In the salt bath process, it favors the impregnation of the molten zinc on the steel surface.

Figure 3 Steel in salt bath
Source: Ruiz, E. (2016) Practical guide for hot dip galvanizing. Retrieved from https://www.idu.gov.co/web/content/7423/guia_galvanizado_24nov14+(1).pdf

- In the hot air-drying option, the parts are transferred to a hot air drying pit before immersion in the molten zinc bath.

- Being the heart of the process, the galvanizing area, the parts are immersed in a bath of molten zinc, at temperatures between 440ºC and 460ºC, this temperature will depend on the type of material structure to be protected.

- And, as a stage prior to delivery or storage as an accepted product, the thicknesses are sampled and appearance is checked to comply with the standard requested by the customer, when necessary, it is taken to the finishing area to remove burrs, sharp drops and surface adhesions of ashes or salt residues, to later perform a final inspection.

This protection is stronger than steel itself and is capable of protecting small bare areas (by means of galvanic protection) and is extremely economical. For small parts, on the other hand, we apply centrifugation after immersion. We also perform the process of galvanizing only on the outside, to power radiators, coils and other parts.

The hot-dip galvanizing layer is formed by Zn-Fe alloys, which is made with the Zinc and Iron bath of the parts. The thickness and appearance of this protective layer depend on multiple factors, some of which are specific to the part itself and others to the bath.

Hot dip galvanizing (Galvanizinc System) is one of the best options for corrosion protection of iron and steel.

Figure 4 Galvanized parts over molten zinc
Source: Metalyzinc Quality

The barrier protection occurs because a thin layer of zinc oxides is created on the zinc surface, due to the fact that carbon dioxide CO_2 from the atmosphere reacts with the zinc resulting in zinc carbonate $ZnCO_3$ which is insoluble in water and prevents the formation of corrosion products. Through a process of diffusion saturation of the steel surface with zinc, as a rule, in the range of 300-550ºC in a suitable medium.

Experimental work

Collection of information

The selection of the service was made in conjunction with the company's quality manager, considering the impact on delivery time due to rework or reprocessing. Considering the process of immersion of parts in molten zinc. The information for the year 2020 was recorded, specifically for the type of structural material, in order to have sufficient data for the analysis. This analysis was developed in the period from December 2020 to February 2021. The critical variable is the time of immersion in molten zinc, which has the following classification of defects found during the analysis period, which depends on the quality of chemical cleaning.

Category	Type of defect	
Zinc-related	Zinc lumps	Zinc splashes
Appearance	Welding spatter	Ungalvanized surfaces
Superficial	Blisters (air bubbles)	Clogged threads

Table 1 Defect category
Source: Metalyzinc Quality Area

As can be seen, the different types of defects that were studied were mainly six, where, when grouped together, they are concentrated in only three categories, related to zinc, appearance and surface.

And, according to the type of performance indicator, they were analyzed with a financial, customer, process, learning and growth perspective, as part of the good practices of the balanced scorecard.

With reference to the use of the indicator, they were determined by their duration, quality and effectiveness.

General methodology of the study

The steps developed in the research were through the following items in conjunction with the innovation methodology subsequently characterized:

- Diagnosis of the company: Knowledge of the process, identification of areas of opportunity and key indicators.

- Information gathering: Search for records of operations, selection and analysis through statistical tools (Pareto Chart, Statistical Process Control CEP, Bayes Theorem).

- Development of the indicators model according to the opportunities and weaknesses determined in the production line.

- Implementation through the follow-up of the operations with the support of a flow chart generated by guided tours, interviews and observation logs.

- Analysis of the results with statistics, incorporated in each area of the production line, reaching great importance in the process, being an essential tool for decision making through data summary, sampling plan, control, design and research.

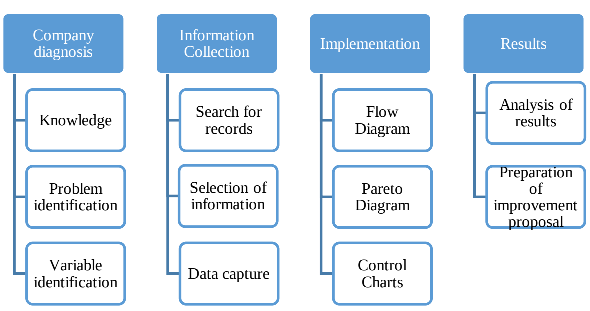


Figure 5 Methodology scheme
Source: Thesis of Martínez Peña, Mª. Guadalupe

It highlights, Statistical Process Control, is a statistical approach to help operators, supervisors and managers manage quality and eliminate the causes of variability in the process (Berthe and Gidey 2016).

Innovation methodology

The experimental study applied the steps of the Forth Innovation methodology, proposed by consultant Patricia Galiana in 2017, created by Gijs van Wulfen, is a methodology dedicated to doubling the effectiveness in customer-focused innovation processes that helps develop and improve products, services and business models. Forth helps to improve processes through innovation improvements that work effectively through three of the most useful trends of our time: design thinking, creativity and business reality.

Its name comes from an acronym taken from the first letter of each of the steps that must be followed to develop this methodology. Thus, the nickname FORTH comes from:

- Full steam ahead.

- Observe&Learn (observe and learn).

- Raise Ideas (generate ideas).

- Test Ideas.

- Homecoming.

With this, the FORTH methodology aims to sort out the chaotic state of innovation and foster a culture for innovation in a 20-week expedition.

The results of this innovation expedition are 3-5 mini new business cases for innovative ideas, which are in line with the reality of the organization (Galiana, Patricia; Van Wulfen, Gijs. 2017).

And, with statistical thinking in the methodology, it has contributed at the three levels of the organization, involving the strategic, managerial, and operational area. (See figure 6):

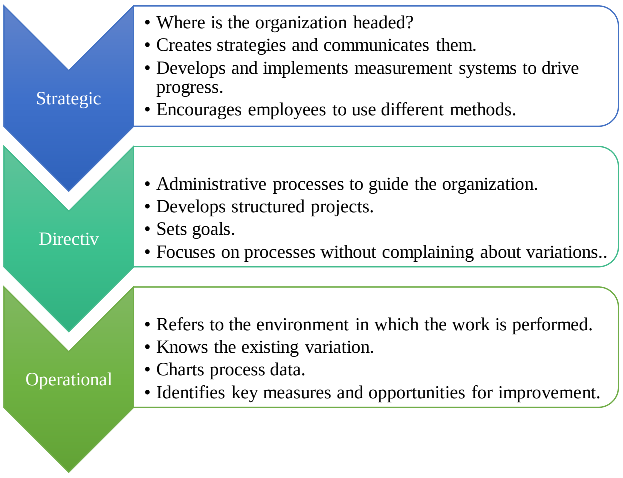


Figure 6 Diagram of statistical thinking
Source: Gutiérrez and De la Vara (2009)

Results

The operational indicators were aligned with the strategic objectives considering the context, the level, the data, their interpretation and the generation of the action plan. Therefore, the indicator has been considered to influence by being specific, measurable, achievable, real and just in time. And the following scheme simplifies the steps for the design of a KPI used for the galvanizing production line.

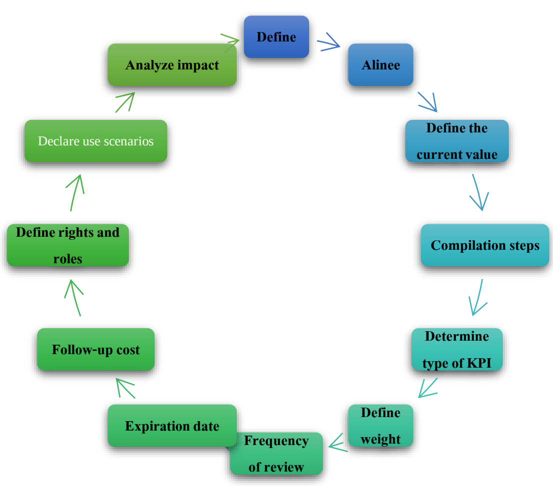


Figure 7 KPI Template: 12 steps to achieve a perfect KPI
Source: BSC Designer.

Hereby, the steps of the KPI template, applied in the research, are described:

1. The name of the indicator is defined, avoiding combining the objective, time scope and units of measurement.

2. The indicator is aligned with a strategic objective, where it does not imply doing a little better than what was previously done.

3. The current value is defined through questions, from the reference point and the objective, which implies reaching or staying within the tolerance level.

4. The information is collected by identifying the data recorded through the network (connected) or manually.

5. The classification of performance indicators related to success factors or results (achievement of the goal) is performed.

6. The weighting weight (percentage value) is defined with respect to its impact and relevance.

7. The updating periods are defined to avoid the excess of performance metrics and high measurement costs.

8. Establish dates of evaluation or expiration of the indicator for changes in tolerance or focus in the business strategy.

9. A budget is determined for monitoring the indicator, identifying the types of costs.

10. The privileges of the organization's personnel are determined, which implies the level of visualization of the behavior, collection or consultation of results of the indicator of a certain process or work area.

11. The reasons for assigning the indicator and the way of using the data in reports, follow-up or self-monitoring are established.

12. The results or performance of the indicator are analyzed through statistical tools suitable to the understanding of the organization, involving the description of operational and administrative changes.

Subsequently, the following table, as part of the study of a given period and type of material, shows the ordered frequencies of the classification by type of defect in the hot dip galvanizing process as part of one of the indicators identified in the study.

Immersion	Defect Appearance	Defect Surface	Thickness defect
419	4	12	9
241	2	17	12
326	0	11	8
260	0	9	7
474	0	5	5
242	1	7	2
278	1	5	4
436	2	7	5
381	3	2	1
536	4	5	2
380	2	2	2
412	7	1	4

Table 2 Frequency of immersion and category of defects.
Source: Metalyzinc 2020 Quality Area.

The analysis of the data in table 2 allowed determining key indicators for productivity, safety and quality with the support of IBM SPSS Statistics Software, analyzing the variety of correlation to determine a standard control or improvement of the service or operation in the next orders that influences the immersion time and delivery time scheduling.

It is indicated as a sample of the analysis of the study, three tables with their respective graph with reference to the proportion of statistical control defects where the sample size (immersions) is variable and application of the Pareto diagram:

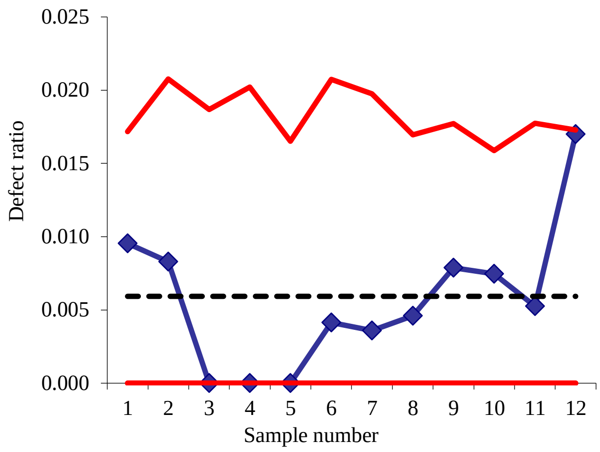
Input: Sigma limit = 3

Output: $\bar{p} = 4385 / 26 = 0.006$

Defect Appearance

Sample	Sample size	Number of defects	Proportion Defects	p	Upper Limit	Lower limit
1	419	4	0.010	0.006	0.01718	0.000
2	241	2	0.008	0.006	0.02077	0.000
3	326	0	0.000	0.006	0.01869	0.000
4	260	0	0.000	0.006	0.02021	0.000
5	474	0	0.000	0.006	0.01651	0.000
6	242	1	0.004	0.006	0.02073	0.000
7	278	1	0.004	0.006	0.01974	0.000
8	436	2	0.005	0.006	0.01696	0.000
9	381	3	0.008	0.006	0.01773	0.000
10	536	4	0.007	0.006	0.01588	0.000
11	380	2	0.005	0.006	0.01774	0.000
12	412	7	0.017	0.006	0.01728	0.000
Total (Di)	4385	26				

Table 3 Calculation of appearance defect ratio
Source: Own elaboration



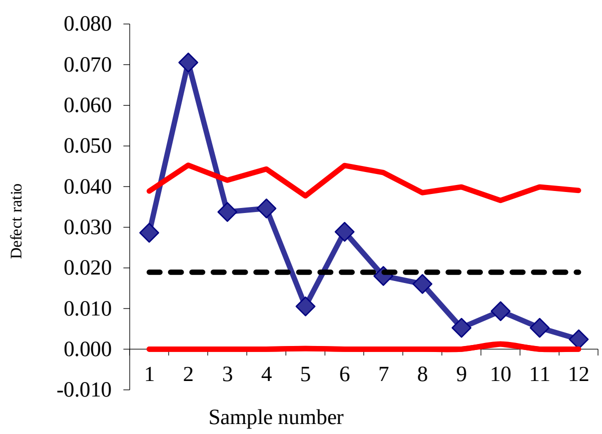
Graphic 1 Number of sample with respect to the proportion of appearance defects
Source: Own elaboration

Input: Sigma limit = 3
Output: $\bar{p} = 4385 / 83 = 0.019$

Superficial defect

Sample	Sample size	Number of defects	Proportion Defects	p	Upper Limit	Lower limit
1	419	12	0.029	0.019	0.03890	0.000
2	241	17	0.071	0.019	0.04526	0.000
3	326	11	0.034	0.019	0.04157	0.000
4	260	9	0.035	0.019	0.04428	0.000
5	474	5	0.011	0.019	0.03771	0.000
6	242	7	0.029	0.019	0.04521	0.000
7	278	5	0.018	0.019	0.04345	0.000
8	436	7	0.016	0.019	0.03851	0.000
9	381	2	0.005	0.019	0.03987	0.000
10	536	5	0.009	0.019	0.03659	0.001
11	380	2	0.005	0.019	0.03990	0.000
12	412	1	0.002	0.019	0.03907	0.000
Total (Di)	4385	83				

Table 4 Calculation of surface defect ratio
Source: Own elaboration



Graphic 2 Number of samples with respect to the proportion of surface defects
Source: Own elaboration

Input: Sigma limit = 3
Output: $\bar{p} = 4385 / 61 = 0.014$

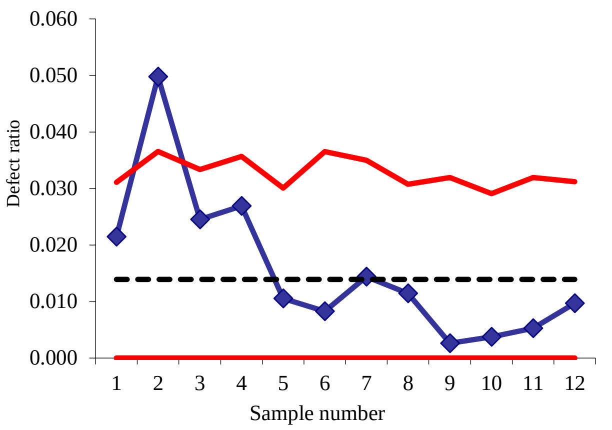
Thickness defect

ISSN 2523-0344

Journal Industrial Engineering
December 2021, Vol.5 No.15 10-23

Sample	Sample size	Number of defects	Proportion Defects	p	Upper Limit	Lower limit
1	419	9	0.021	0.014	0.03108	0.000
2	241	12	0.050	0.014	0.03654	0.000
3	326	8	0.025	0.014	0.03337	0.000
4	260	7	0.027	0.014	0.03570	0.000
5	474	5	0.011	0.014	0.03005	0.000
6	242	2	0.008	0.014	0.03650	0.000
7	278	4	0.014	0.014	0.03498	0.000
8	436	5	0.011	0.014	0.03074	0.000
9	381	1	0.003	0.014	0.03191	0.000
10	536	2	0.004	0.014	0.02909	0.000
11	380	2	0.005	0.014	0.03194	0.000
12	412	4	0.010	0.014	0.03122	0.000
Total (Di)	4385	61				

Table 5 Calculation of defect ratio by thickness
Source: Own elaboration



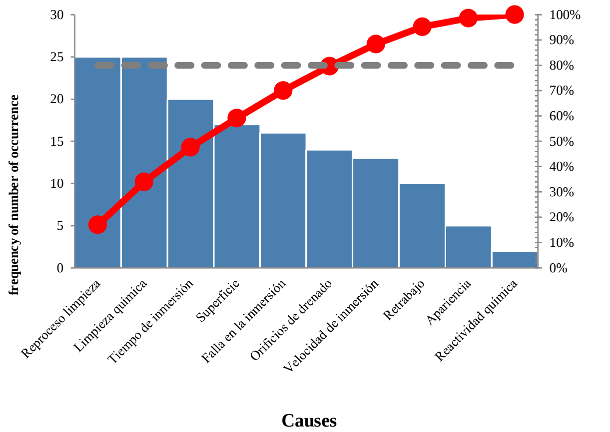
Graphic 3 Number of sample with respect to defect to thickness ratio
Source: Own elaboration

With reference to the detection of the main defects, they were analyzed by the frequency indicated in the Pareto diagram.

Cause	Frequency
Drainage orifices	14
Appearance	5
Chemical reactivity	2
Failure to dive	16
Reworking	10
Reprocess cleaning	25
Immersion time	20
Immersion speed	13
Chemical cleaning	25
Surface	17

Table 6 Frequencies of defect causes
Source: Own elaboration

The causes shown in Table 6 and represented in Pareto Chart 4 are the result of holding work meetings applying brainstorming, prioritizing the causes with their respective analysis through the Ishikawa diagram with respect to the times of the stages of the forth innovation methodology.



Graphic 4 Pareto diagram of defect causes
Source: Own elaboration

Finally, Bayes' Theorem was applied to the operations by type of defects and their respective cause, and the following example is presented as evidence of the experimental work:

In the Hot Dip Galvanizing production line. It is assumed that the probability of presence of defect in the zinc coating on the steel structural surface (sill and angles of ¾" thickness). After the chemical cleaning process and its immersion in the molten zinc bath at 450 degrees Celsius is 2.5%.

Also, it is assumed that, given that a batch of 20 pieces has low coating thickness, the probability of inspection sampling yielding an acceptance result is 95%. In addition, it is assumed that a lot of 20 parts has no defects, upon inspection of the parts, the probability of being rejected by the quality inspector is 8%.

A random lot selected from a customer with a structural roof construction job, selected from the population of customer material received and inspected, generates a rejected coating result. What is the probability that the lot is effectively rejected by the quality area?

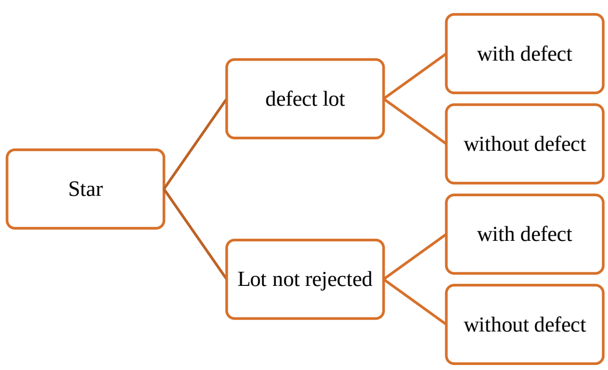


Figure 8 Tree diagram of application of Bayes' Theorem
Source: Own elaboration

ISSN 2523-0344

P (presence of defect in coating / lot with defect) =

A = Event: Defective lot

B = Event: Batch rejected

P(A) = 0.025

P(B) = 0.02375 + 0.078 = 0.10175

P(B/A) = 0.95

P(A/B) = (0.025 * 0.95) / 0.10175 = 0.2334 = approximately 23.34 %.

Data that have allowed the training and evaluation of the results in the meetings with the personnel for the establishment of indicators.

Thanks

The management and support of Metalyzinc company personnel through its internal resources, the members of the Academic Body UV-CA-470 Innovation in Management Systems, as well as the participation of the students María Guadalupe Martínez Peña (ZS16001478) and Milca Deyli Hernández Morán (ZS16001471) for their contribution to the development of the project.

Conclusions

A KPI, also known as a key performance indicator or key performance indicator, is a measure of the performance level of a process. The value of the indicator is directly related to a previously set target and is expressed in percentage values. A KPI is designed to show how progress is in a particular process or product, making it a reliable performance indicator.

The analysis of the data with SPSS software has allowed visualizing the generation of combination of variables with respect to regression, Pearson correlation, Curvilinear estimation, and their respective scatter plots, contributing in the improvement of the parameters and their adequate relationship of the variables of the hot dip galvanized production line with molten zinc in structural type parts.

The importance of monitoring and combining different variables is identified as a sample of the options to analyze through the software that allows the quality personnel to establish improvement proposals in the formats for recording the performance of the process and to consider the critical variables as the data is analyzed.

However, the specific variables evaluated according to the analysis samples have been as follows:

- Clogged threads.
- Blisters.
- Zinc splashes.
- Dips.
- Delivery delays.

These variables were obtained from the following causes:

- Drainage holes.
- Appearance.
- Chemical reactivity.
- Immersion failure.
- Rework.
- Reprocess cleaning.
- Immersion time.
- Immersion speed.

Also, the optimization of the management model was determined with the determination of three categories of production performance which are:

1. Duration time in rework,

2. Delays in deliveries by type of material, and 3.

3. Zinc coating thickness quality according to material type or specification.

These indicators are part of the management model, and three are highlighted as defects out of five by management authorization in the results section.

The innovation methodology was the axis that moved the technical and statistical part, optimizing the types of duration of each stage of the study, where, currently, innovation management is being developed in accordance with the ISO 56000 family of standards in Metalyzinc's strategic management system.

Based on the results of the application of the statistical tools, five questions were asked as part of the contextual study:

a) Why is innovation important to Metalyzinc?

b) Does innovation in anti-corrosion systems make business sense?

c) What are the main challenges Metalyzinc faces in developing new products or services?

d) Is Metalyzinc adopting an innovation model in its strategic planning?

e) What changes do you envision in innovating the management system or organizational structure?

It is key to develop a statistical analysis project with an axis-type guide, as proposed by the Forth Innovation methodology, which guarantees the impact of the study on the sustainable development of operations with relevant performance indicators that are consistent with strategic planning.

The combination of innovation with statistical analysis has fostered a diversity of options to address the optimization or improvement of the areas of opportunity of hot dip galvanizing operations, being the gateway to the development of Big Data analytics topics.

As expectations and challenges of the research, are new challenges to develop a sustainable organization that contributes to the objectives of sustainable development by transforming the organization according to the good practices of the sustainable goals proposed by the United Nations in the final document, entitled "transforming our world: the 2030 Agenda for sustainable development", strengthening the context of Metalyzinc, and its impact on stakeholders by promoting a culture of corrosion protection in a framework of law and cooperation of the human resource.

Maintaining synergies alliance of COBOS Group, and its effectiveness in the application of anticorrosive systems, as well as, the integral management system with the use of process innovation tools, performance analysis, and opportunity for consolidation in the growth of the industrial sector of the anticorrosive protection service through training and participation in the promotion of the anticorrosive protection culture through associations and institutions. Developing a strategy to promote the culture of corrosion protection and to offer protection services for new products such as hydro-pneumatic water tanks, gas tanks, boats, and in the construction and energy sectors.

There is a tendency of the personnel to achieve the strategic goals for decision making contributing in the consolidation of the challenges with the development of three processes in the management system according to the scheme shown in figure 9. Scheme of processes of the management system that involves the areas of Purchasing, Warehouse, Sales, Marketing, Quality, Human Resources, Training, Production, Maintenance, Management, Direction, Technical Support, Transportation.

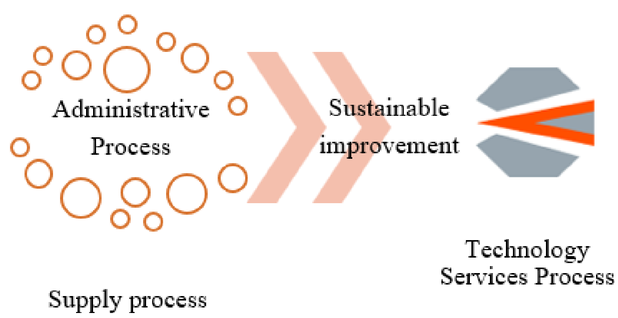


Figure 9 Process schematic diagram
Source: Own elaboration 2020

An organizational structure with solid perspectives in general; however, in relation to each job position, job descriptions can cause confusion at times of audit, a competency-based development approach is essential.

And the type of management leadership that has consolidated the organization in its first 30 years of operation has been developed with situational and transformational strategies forging the delegation of activities and trust of skills for the achievement of objectives and with the establishment of KPI performance indicators as the basis for sustainable structural development.

References

Acosta, I. de las M. C., & Martínez, O. Q. (2008). Propuesta de metodología para elaborar la estrategia de gestión de la innovación tecnológica en las empresas cubanas. ACIMED, 18(6), 1–17.

Acosta, L., Castañeda, A., Corvo, F., & Berardo, L. (2010). Estudio de la influencia del clima tropical insular de Cuba en la corrosión del acero galvanizado. Resultados preliminares. Revista CENIC Ciencias Quimicas, 41, 1–11.

Aldeanueva Fernández, I., & Cervantes Rosas, M. de los Á. (2019). El desarrollo sostenible como imperativo estratégico: el contexto de la pequeña y mediana empresa latinoamericana. Revista Lasallista de Investigación, 16 (2), 28 – 43. https://doi.org.ezproxy.uv.mx/10.22507/rli.v16n2a3

Arango Serna, M. D., Moreno, S. R., Ortiz Vásquez, L. F., & Zapata Cortes, J. A. (2017). Indicadores de desempeño para empresas del sector logístico: Un enfoque desde el transporte de carga terrestre. INGENIARE - Revista Chilena de Ingeniería, 25(4), 707–720.

Arroyo-Garrido, A. (2021). Monitoreo de indicadores en la gestión pública: Caso del Sistema de Monitoreo de Indicadores del Desarrollo, MIDE Jalisco.

Arundel, A., Kanerva, M., Van Cruyaen, A., Hollanders, H. Innovation statistics for the European service sector (2007) Final Draft, PRO INNO Europe: Inno Metrics, UNU-MERIT.

Ballesteros, D. Y. P., Amador, A. S., Durán, H. A. E., Fajardo, D. S., & Ascanio, L. Q. (2015). Corrosión de acero galvanizado en un ambiente que contiene cloruros y sulfatos mediante técnicas electroquímicas. Informador Técnico, 79(2), 127–136. https://doi.org.ezproxy.uv.mx/10.23850/22565035.157

Berenguer de Vasconcelos, Renata Braga; Gois de Oliveira, Marcos Roberto. 2018. Determinantes de la innovación en micro y pequeñas empresas: Un enfoque de gestión gerencial. DOI: http://dx.doi.org/10.1590/S0034-759020180402. RAE | São Paulo | 58(4) | July-August 2018 | 349-364. ISSN 0034-7590

Candía, J. G., Coliñanco, L. G., Caro, C. L., & Hernández, N. R. (2014). Estrategia y cultura de innovación, gestión de los recursos y generación de ideas: prácticas para gestionar la innovación en empresas. Pensamiento & Gestión, 36, 107–133. https://doi.org.ezproxy.uv.mx/10.14482/pege.36.5567

Castañeda, A., Fernández, D., Valdés, C., & Corvo, F. (2015). Estudio de la corrosión atmosférica en una zona estratégica de Cuba. Revista CENIC Ciencias Quimicas, 46, 14–25.

Castillo Romero, J. A. (2018). Big Data IFCT128PO. Málaga: IC Editorial.

Crespi, G., Zuniga, P. Innoación y productividad: Evidencia de seis países latinoamericanos (2012) World Development, 40 (2), pp. 273-290.

Chamba Macas, J. R. (2021). Gestión administrativa y el desempeño pedagógico en las escuelas unidocentes del circuito El Limo, Ecuador, 2020.

Djellal, F., Gallouj, F. El desafío de la productividad en los servicios: Medición y perspectivas estratégicas (2013) Service Industries Journal, 33 (3-4), pp. 282-299

Deloitte. (2013). Innovación impulsada por la sostenibilidad: aprovechar la capacidad de la sostenibilidad para generar innovación. Obtenido de https://www.mvovlaan-deren.be/sites/default/files/media/Rapport%20Deloitte.pdf

Doctum, Software de Contratos, Documental, Desarrollo Blockchain. La importancia de las KPIs como herramienta de gestión en la empresa. 20/Septeimbre/2020. Sitio web https://www.doctum.cl/la-importancia-de-las-kpis-como-herramienta-de-gestion-en-la-empresa/

Evans, U. R. (2018). Corrosiones metálicas. (J. Company Bueno, Trans.) Barcelona, España: Editorial Reverté. Retrieved from https://elibro.net/es/lc/bibliotecauv/titulos/105682

Fajardo, C. E. V., Vaca, L. M. F., Fajardo, X. A. V., Núñez, D. W. T., Arroyo, F. G. M., Toalombo, R. A. E., & Hinojosa, D. J. M. (2019). Key Performance Indicator (Kpi) “La Satisfacción Del Cliente” Y La Competitividad en Las Operadoras De Transporte Terrestre Intraprovincial De Pasajeros. Investigación Operacional, 40(5), 652–657.

Garrido Raad, D. R. (2021). Diseño y validación del diplomado en gestión sostenible y sustentable en seguridad y salud en el trabajo para la Corporación Universitaria Minuto De Dios.

Galiana, Patricia; Van Wulfen, Gijs. (2017). ¿Qué es la metodología Forth? Funcionamiento y Ventajas. 16/Julio/2020, de IEBS Business School Sitio web: https://www.iebschool.com/blog/metodologia-forth-digital-business/

Gallego, J. M., Gutiérrez, L.H., Taborda, R. Innovación y productividad en las industrias de servicios y manufacturas colombianas (2015) Mercados Emergentes Finanzas y Comercio, 51 (3), pp. 612-634. Cited 13 times.

González-Diaz, Y., Pires-Araújo, L., & Domingos António-Simão, Z. (2016). Propuesta de mejora ambiental en el proyecto de una Planta de Producción de Acero Galvanizado en Angola. Tecnología Química, 36(2), 281–291.

Gonzalez, V.H., Tapia, K.C.M., Tapia, M.C.M., Villacreses, K.B., Sabando-Vera, D. 2018. Diagnóstico empresarial y capacidad de Absorción e innovación de las pymes del Sector industrial farmacéutico de Guayaquil. Actas de la Conferencia Internacional de Ingeniería, Educación y Tecnología de LACCEI, 2018-July. (DOI): http://dx.doi.org/10.18687/LACCEI2018.1.1.100

Grisales, N. M., & Ramírez, R. D. M. (2019). Decisiones estratégicas de operaciones en la producción sostenible: análisis de tendencias en investigación. Revista Lasallista de Investigación, 16(1), 228–243. https://doi.org.ezproxy.uv.mx/10.22507/rli.v16n1a4

Guzmán-Villavicencio, M., González-Suárez, E., & Marlén Morales-Zamora II, C. (2019). Metodología para Gestionar la Innovación Tecnológica con Integración del Análisis Complejo de Proceso en la Industria Ronera Cubana. Tecnología Química, 39(2), 370–383.

Lara, R. A. O., & Peralta, L. G. (2011). Mejoramiento del servicio de galvanizado Mediante Seis Sigma y el análisis de la información. Revista Ingeniería Industrial, 10(2), 81–102.

López Salazar, Alejandra. 2020. Capacidad de innovación en la mype: impacto en el crecimiento y desarrollo de las ventajas competitivas. Fontamara.

Martínez, J. P., Hernández, M. E. F., & de la Nuez Hernández, D. (2021). Criterios e indicadores de gestión forestal por la excelencia. Cooperativismo y Desarrollo, 9 (1).

Molina-Molina, Silvia; Álvarez-Argaez, Sol; Estrada-Hernández, Jovanny; Estrada-Hernández, Margarita (2020). Indicadores de ciencia, tecnología e innovación: hacia la configuración de un sistema de medición. Revista Interamericana de Bibliotecología, 43(3), eI9. https://doi.org/10.17533/udea.rib.v43n3eI9

ISSN 2523-0344

More Espinoza, R. A., & Morey Guevara, M. O. (2021). Gestión del clima institucional y desempeño del personal docente de la Institución Educativa N° 7044 San Martín de Porres, Chorrillos. Dilemas contemporáneos: educación, política y valores, 8(SPE2).

Nica, I., Chirită, N., & Ionescu, Ștefan. (2021). Uso de KPIs y Dashboard en el análisis de la gestión del rendimiento de la empresa Nike. Theoretical & Applied Economics, 28(1), 61–84.

Norma Oficial Mexicana NMX-H-004-SCFI-2008. (2008). Industria siderúrgica-productos de hierro y acero recubiertos con cinc. galvanizados por inmersión en caliente - especificaciones y métodos de prueba. Secretaría de Economía.

Núñez Peña, N., Segura Sánchez, E., & Bofill, P. (2020). Diseño de un sistema informatizado basado en inteligencia de negocios en el Astillero Mariel. 12, 1, 404-412. Universidad y Sociedad.

Osorio, O. G., Quintero, J. Q., & Arias-Pérez, J. (2014). Capacidades De Innovación, Desempeño Innovador Y Desempeño Organizacional en Empresas Del Sector Servicios. Cuadernos de Administración (01203592), 27(49), 87–108. https://doi.org.ezproxy.uv.mx/10.11144/Javeriana.cao27-49.cidi

Pajić, V., Andrejić, M., & Kilibarda, M. (2021). Evaluación y Selección de Kpi en Logística de Compras y Distribución usando el Enfoque Swara-Qfd. International Journal for Traffic & Transport Engineering, 11(2), 267–279. https://doi.org.ezproxy.uv.mx/10.7708/ijtte2021.11(2).07

Pedroza, A., Ortiz, S. Gestión estratégica de la tecnología en el predesarrollo de nuevos productos (2008) Journal of Technology Management & Innovation, 3 (3), pp. 112-122.

Pérez - Uribe R., Nieto P. M., Velásquez C. A., Castellanos G., Garzón G. M., Vargas H. A., Alfonso N., Calixto N., Rodríguez A., Palacio S. M. R., López L. G., Vidal A. y López De Mesa J. (2013). Modelo de modernización para la gestión de organizaciones (MMGO). Agosto. Universidad EAN. Libro: 624 p. ISBN 958-8153-61-2. En: http://edicionesean.ean.edu.co/index.php/es/productos-de-investigacion1/libros/libros-impresos/27-libros-impresos/83-modelo-de-modernizacion-para-la-gestion-organizacional-mmgo

Pérez - Uribe R., Ramírez – Salazar, María del P. (2016) Modelo de innovación para la sostenibilidad de las pequeñas y medianas empresas – MISpymes: Análisis preliminar. Ponencia en Segundo congreso iberoamericano de investigación en pymes. San Jose de Costa Rica. 20 a 22 de Abril de 2017. FAEDPYME y Universidad Estatal a Distancia (UNED). En: http://iicongresoiberoamericano.upct.es/sites/default/files/sitio/documentos/memoriaiiiberoamericanoinvestigacionpyme.pdf

Piñero, A., Monroy, C. R., & Arzola, M. (2010). Análisis de las capacidades de la I+D+i en las PYMIS del Estado de Bolívar, Venezuela, para la aplicación de una metodología de Política de Innovación. Revista de Administración e Innovación - RAI, 7(3), 21–43.

Rybin, M. V., Guliev, I. A., Lobov, D. S., & Fokina, N. Y. (2020). KPI de innovación como como indicadores de la responsabilidad ambiental de las empresas rusas de petróleo y gas. EurAsian Journal of Biosciences, 14(2), 6923–6929.

Shohet, I. M., & Nobili, L. (2017). Aplicación de indicadores clave de desempeño para la gestión del mantenimiento de las clínicas. International Journal of Strategic Property Management, 21 (1), 58–71. https://doi.org.ezproxy.uv.mx/10.3846/1648715X.2016.1245684

Sociedad Americana para pruebas y materiales, ASTM Internacional. (2015). Especificación estándar para revestimientos de zinc (galvanizado en caliente) en productos de hierro y acero. Especificación internacional. ASTM.

Stricker, N., Echsler Minguillon, F., & Lanza, G. (2017). Selección de indicadores clave de rendimiento para la producción con un enfoque de programación lineal. International Journal of Production Research, 55(19), 5537–5549. https://doi.org.ezproxy.uv.mx/10.1080/00207543.2017.1287444

Tundidor Diaz, Alberto. 2016. Como innovar en las pymes manual de mejora a través de la innovación. Alfaomega / Marge Books.

Valencia-Rodríguez, O., Olivar-Tost, G., & Redondo, J. M. (2019). Metodología para el Modelado de algunos Aspectos Asociados a la Sostenibilidad Empresarial y su Aplicación en una Empresa Manufacturera. Información Tecnológica, 30(4), 103–125. https://doi.org.ezproxy.uv.mx/10.4067/S0718-07642019000400103

Žižek, S. Š., Nedelko, Z., & Mulej, M. (2020). Indicadores clave de rendimiento e industria 4.0 - Una perspectiva socialmente responsable. Our Economy (Nase Gospodarstvo), 66(3), 22–35.

Article

Journal Industrial Engineering

December 2021, Vol.5 No.15 24-29

Control system for parameter estimation in plastic injection for the automotive industry

Sistema de Control para la estimación de parámetros en la inyección de plásticos para la industria automotriz

ROMANO-RODRÍGUEZ, Ma. Natividad†*, MUÑOZ-RIOS, José Juan, PÉREZ-MARTÍNEZ, René and HERNÁNDEZ-MEDINA, José Juan

Instituto Tecnológico Superior de Tlaxco. División de Ingeniería Electromecánica. Mexico.

ID 1st Author: *Ma. Natividad, Romano-Rodríguez* / **ORC ID:** 0000-0002-3415-8629, **CVU CONACYT ID**: 640296

ID 1st Co-author: *José Juan, Muñoz-Rios* / **ORC ID:** 0000-0003-2162-8131

ID 2nd Co-author: *René, Pérez-Martínez* / **ORC ID:** 0000-0001-5981-8403, **CVU CONACYT ID**: 669754

ID 3rd Co-author: *José Juan, Hernández-Medina* / **ORC ID:** 0000-0003-4625-2660, **CVU CONACYT ID:** 5227576

DOI: 10.35429/JIE.2021.15.5.24.29 Received July 20, 2021; Accepted December 30, 2021

Abstract

In this work, a basic control system is established for the estimation of parameters in the injection of molds to cover product quality standards in the automotive industry. Estimates are made through mathematical tools and error analysis to determine the starting parameters for the injection process and that feed the injector program and then proceed to the adjustment of such parameters in a heuristic way. Establishing a control system to establish the initial injection parameters or those involved in the injection process would avoid waste of material, production times and the scope of the quality standards established by the IATF 16949 2016 standard.

Control, Injection, Parameters

Resumen

En este trabajo se establece un sistema de control básico para la estimación de parámetros en la inyección de moldes para cubrir estándares de calidad del producto en la industria automotriz. Se realizan estimaciones a través de herramientas matemáticas y análisis de errores para determinar los parámetros de inicio para el proceso de inyección y que alimentan el programa de la inyectora y luego pasar al ajuste de tales parámetros de una manera heurística. El establecer un sistema de control para establecer los parámetros de inyección iniciales o de los involucrados en el proceso de la inyección evitaría desperdicio de material, tiempos de producción y el alcance de los estándares de calidad establecidos por la norma IATF 16949 2016.

Control, Inyección, Parámetros

Citation: ROMANO-RODRÍGUEZ, Ma. Natividad, MUÑOZ-RIOS, José Juan, PÉREZ-MARTÍNEZ, René and HERNÁNDEZ-MEDINA, José Juan. Control system for parameter estimation in plastic injection for the automotive industry. Journal Industrial Engineering. 2021. 5-15:24-29.

* Author's Correspondence (E-mail: manatividadromanorgz@gmail.com)
† Researcher contributing as first author.

Introduction

The injection process cycle has four well-characterized stages: (1) the heating of the thermoplastic, (2) the entry of polymeric material into the mold, (3) the transfer of heat or cooling and (4) the demoulding of the part. The properties and quality of the molds determine the productivity of the process, since the production rate, that is, the cycle time, will depend on the speed with which the material can be heated, injected, solidified and expelled. Among these stages, cooling is the one that requires the longest time, so a good system project is essential not only to reduce the process cycle time, but also to improve the quality of the product (Corazza et al., 2012).

The parts of an injector are illustrated in figure 1, according to (Jurado, et al, 2019):

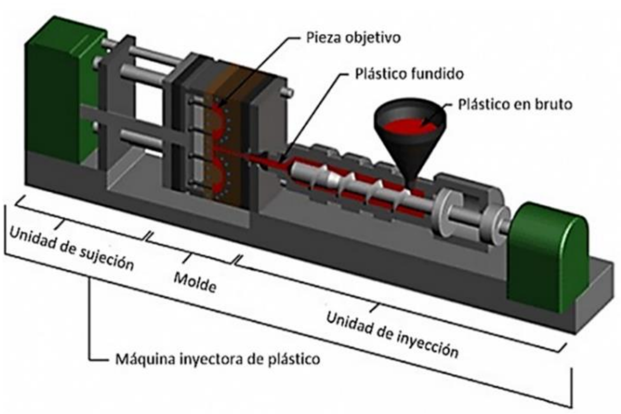


Figure 1 General injection process

Once the mold is placed in the injector, the process parameters are prepared and established to feed the injection machine program, in order to obtain a product that meets the quality standards established in the automotive industry of according to the IATF 16949 2016 standard. This will allow automotive companies to acquire injection products with the standard established to be part of the automotive models produced by these.

If a mold is to be used for the first time, it will be important to analyze factors such as: the technical data sheet of the material and the test parameters of the manufacturer or customer. However, a parameter review is performed to begin the molding tests.

Generally, parameters such as: cooling time, closing force, cycle time, among others, are calculated prior to the injection phase and at the end of this phase, the characteristics of the ejected part are verified, such as: lengths, finish, weight and other elements or tests requested by the customer or manufacturer, above all, the scope of the quality standard for automotive parts.

When they are already run molds, previously used, tested or improved, it is only valued that they comply with the established parameters of the process but that the required quality conditions are guaranteed within the standards established by the IATF 16949 2016 standard.

Within the process parameters the following are considered critical: injection time, mass cushion, maximum injection pressure. But they are also continuously monitored: The cycle time, the cooling time, the mold temperatures, the weight of the piece and the temperature of the dough.

In this work it is proposed to establish a control system of three parameters such as the closing force, the cooling time and the cycle time, in order to have them as a starting point to feed the injector program and start the injection process, we consider basic geometric structures such as circles, rectangles, and squares.

Justification

According to (Jurado, 2019), the importance of the injection process has caused various authors to have carried out a large amount of work and research to understand the effects of the injection process variables on the final properties of the molded part, among from which the works of Juárez, D., Balart, Peydró & Ferrándiz (2012) can be compiled, who coincide in the existence of previous studies that try to understand the injection process by analyzing the influence of certain process parameters with regarding certain effects that affect the injected parts. (Prada, 2017)

In (Boroat, 2019), they propose a model to quantify the interactions between several parameters, such as: the mold, the melting temperature of the polymer, the thickness of the geometry and the compaction pressure applied on the residual stresses and the contraction of flat pieces.

In (Bushko, 1995) they characterize the influence of four process parameters on the roughness of the final pieces obtained by injection, as a control parameter to guarantee the functionality and integrity of a surface.

With the fourth industrial revolution called 4.0, the use of digital technologies in industrial processes to make them more efficient is established, in this work a control system is proposed that allows to calculate three established parameters and with them make a first approximation to the data that they will feed the injector program, and then proceed to make adjustments to such parameters based on a basic interpolation process and acquire a "good" quality ejected part.

Description of the method

For the development of this work, a Battlenfeld PLUS 35/75 unilog B injection molding machine was used (figure 2). And a mold for the injection of a miniaturized set of wheels (figure 2a and 2b):

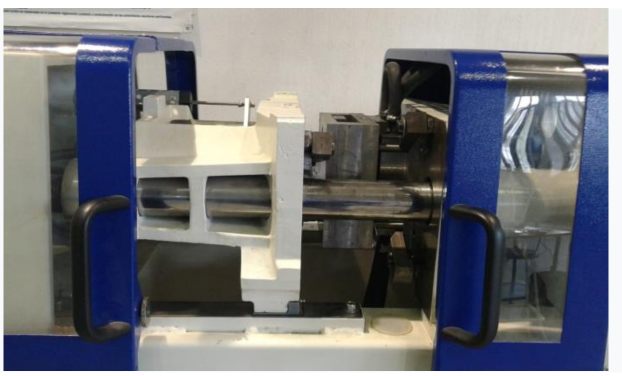


Figure 2 Battlenfeld injector mold

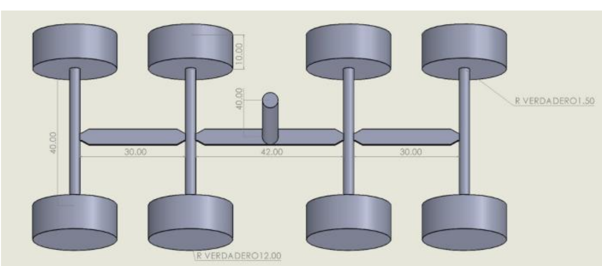


Figure 2a Miniaturized car tires design

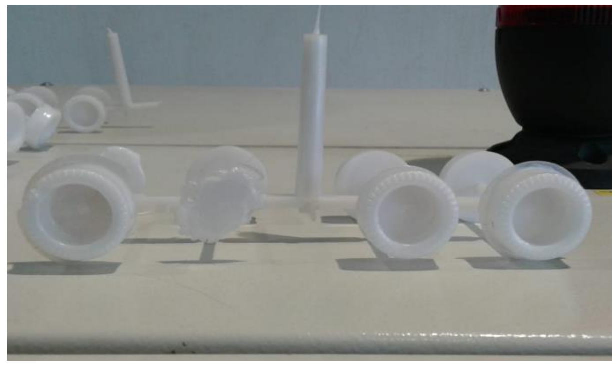


Figure 2b Ejected model in tests

Development

According to (Bigerelle, 2008) there are also some mathematical models to determine the number of cavities in a mold based on machine-dependent magnitudes, such as the closing force, the maximum injection capacity and the physical dimensions of the machine.

Next, the calculation of the closing force is established from the following formula:

$$Fc = Ap \cdot Pi \tag{1}$$

Where:

Fc is the closing force.
Ap is the surface area of element to be injected.
Pi is the internal pressure of the mold.

For the mold used in this work, the following data are considered (figure 3):

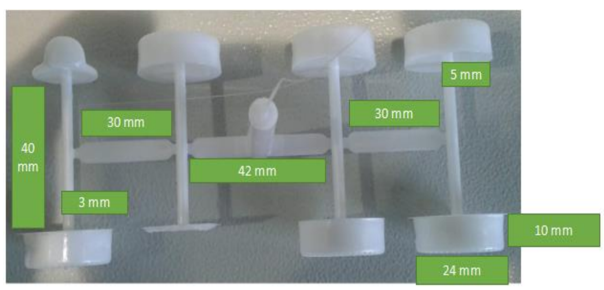


Figure 3 Considerations for surface area.

The projected area of the four sets of tires corresponds to four times 600 mm^2 plus the area of the casting, which was considered 510 mm^2, thus obtaining the value of:

$$Ap = 2910mm^2 = 29.1cm^2$$

The material used for injection into the tire mold is polystyrene (PS), which is why it is established:

ISSN 2523-0344

$Pi = 400bar$

according to the specific properties for the injector Battlenfeld.

Then the closing force is calculated:

$$Fc = Ap \cdot Pi$$

$$Fc = (29.1cm^2)(400bar) = 11640kgf$$

Considering the empirical recommendation that the maximum closing force of the machine is approximately 20% higher than that necessary for the injection of the part in question. We will have the following:

$$Fc = 11640 + 2328 = 13{,}968kg$$

Now we will proceed to calculate the cooling time, using the formula:

$$t_k = \frac{s^2}{\pi^2 - \alpha_{eff}} \ln\left\{\frac{4}{\pi}\left(\frac{T_{melt} - T_{mold}}{T_{eject} - T_{mold}}\right)\right\}$$

Where:

t_k is the cooling time
s is the thickness of the wall
α_{eff} the thermal diffusivity
T_{melt} is the temperature of the dough
T_{mold} is the temperature of the mold.
T_{eject} the draft temperature

For the case of the mold of miniaturized rims, this boils down to:

$$T_k = (2.82)(16mm^2) = 45.12seg$$

We consider in the formula the constant 2.82 associated with the material used for the process, in this case, that of polystyrene (PS) and the thickness corresponding to 4mm.

Finally, we calculate the third associated parameter: the cycle time, defined as triple the cooling time.

$$T_c = 3(45.12) = 135.36seg = 2.256\min$$

With the values obtained through the formulas of the parameters: cooling time, closing force and cycle time, the injector program is fed to start the injection process of the miniaturized tires: (figure 4).

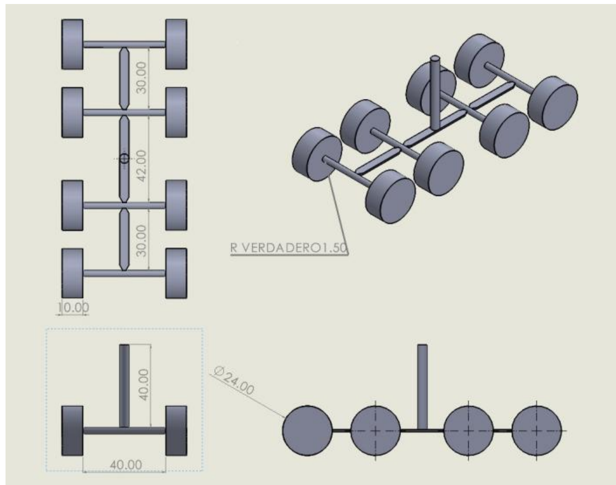


Figure 4 Different views of the injection model

Results

Once referenced to the start parameters, the first ejection tests are carried out. (Figure 5a and 5b).

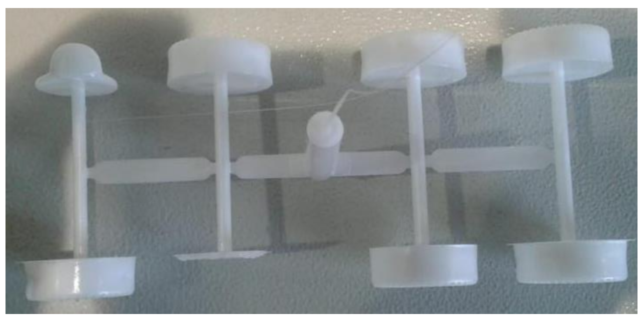


Figure 5a Part ejected during tests.

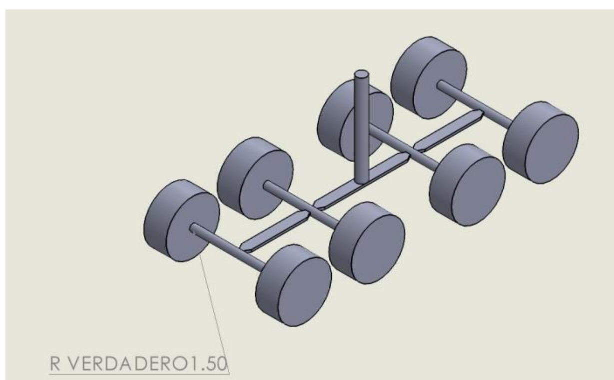


Figure 5b Final ejected part.

The parameters are adjusted through interpolation until the part is finished (see table 1).

ISSN 2523-0344

Closing Force	Cooling time	Cycle time
13,968 Kg	45.12 seg	2.256 min
14,000	45.00	2.000
13,990	43.00	1.500
13,970	40.00	1.250
13,950	38.00	1.000

Table 1 Variation of injection parameters for miniaturized tires

As a test of this control system to establish a starting approximation of the three parameters established in this work, a test was carried out with a part_X, in a company_X dedicated to the injection of plastics for the automotive sector, such a part is of geometry basic.

In the first row, the starting values are placed and other values are provided that approximate the real values required to obtain the ejected parts with the quality requirements under the IATF 16949 2016 standard (table 2).

Closing Force	Cooling time	Cycle time
2420 kN	43.12seg	2.5 min
2415	38.00	2.0
2400	35.00	1.5
2396	30.00	0.83

Table 2 Variation of injection parameters for part_x

Conclusions

In both processes, it has been seen that the parameters obtained by the formulas that define the closing force and the cooling time represent a good approximation in terms of their proximity to the real values required for the injection process, which avoids doing numerous heuristic tests. and material waste.

Regarding the cycle time, significant differences are seen with the real time of the process, especially in the practice in the injection of pieces within the company.

An important advantage of the proposed control system is not having a starting blind spot, but a better approximation to the values of the three parameters established in this work.

The control system was programmed, considering data such as the geometry of the part and using an interpolation method with two references, however it is proposed to carry out the program in a more robust way with a number of significant tests and using a Lagrange or interpolation type. It allows them to improve the estimation of the injection parameters established in this work, as well as to consider others that facilitate having a sufficiently precise approach to minimize times, avoid significant material waste and above all cover the quality indicators of automotive parts standardized by the IATF 16949 2016 standard, which for companies in the plastic injection industry, especially micro-companies, would be a competitive advantage to position themselves in the market.

References

Corazza, E., Sacchelli, C.,Marangoni, C.. (2012). *Reducción del Tiempo de Ciclo de Inyección de Termoplásticos con el uso de Moldes con Tratamiento Superficial por Nitruración.* Información Tecnológica, 23(3), 51-58. 2021, 25 Mayo, De SciElo Base de datos.

Jurado, P., Reveles, J., Plascencia, H.,& Aguilera, E.,. (2020). *Análisis de un proceso de inyección de plástico por interacción fluido estructural y cambio de estado.* Acta Universitaria, 29, s/n. 2021, Mayo 25, De SciElo Base de datos.

Prada, R., Acosta, J.. (Junio 2017). El moldeo en el proceso de inyección de plásticos para el logro de objetivos empresariales. Dimensión Empresarial, 15, 169-182. 2021,Mayo 25, De SciElo Base de datos.

Hassan, H., N. Regnier, C. Lebot, C. Pujos y G. Defaye, *Effect of cooling system on the polymer temperature and solidification during injection molding, Applied Thermal Engineering*: 29, 1786-1791 (2009).

Boroat, T. (2009). *Estudio y modelización de la procesabilidad mediante moldeo por inyección de materiales termoplásticos reciclados. Tesis Doctoral Universidad. Politécnica de Valencia (España).* 2009-05-21, doi:10.4995/Thesis/10251/5024.

Bushko, W.C. & V.K. Stokes (1995). *Solidification of thermoviscoelastic melts. Part II: Effects of processing conditions on shrinkage and residual stresses.* Polymer Engineering & Science, 35 (4), 365-383, doi: 10.1002/pen.760350410

Bigerelle, M. A. Van Gorp & A. Lost (2008). *Multiscale roughness analysis in injection-molding process. Polymer Engineering & Science*, 48 (9), 1725-1736, doi: 10.1002/pen.21131.

Isaza, E., E. Salazar & Y. Moreno (2010). *Modelo para la determinación del número óptimo de cavidades en moldes de inyección de* plásticos. Revista Scientia et Technica, X (200), 1-6.

Zavaleta, M. (2019, Septiembre 11). Moldeo por inyección. 2021, Septiembre 03, de https://moldeoporinyeccion.com/ Sitio web: https://www.facebook.com/moldeoporinyeccion/photos/a.1816212621978862/2368366213430164/.

Microservices architecture as a viable option to support the organic growth of PYMEs

La arquitectura de microservicios como una opción viable para apoyar el crecimiento orgánico de las PYMEs

BENÍTEZ-QUECHA, Claribel†*, ALTAMIRANO-CABRERA, Marisol, LÓPEZ-GUZMÁN, Oscar Eduardo and MÉNDEZ-LÓPEZ, Minerva Donají

Tecnológico Nacional de México Campus Oaxaca, Mexico.

ID 1st Author: *Claribel, Benítez-Quecha* / **ORC ID:** 0000-0001-6516-5760, **CVU CONACYT ID:** 657582

ID 1st Co-author: *Marisol, Altamirano-Cabrera* / **ORC ID:** 0000-0001-5800-9655, **CVU CONACYT ID:** 657390

ID 2nd Co-author: *Oscar Eduardo, López-Guzmán* / **ORC ID:** 0000-0003-2427-4850

ID 3rd Co-author: *Minerva Donají, Méndez-López* / **ORC ID:** 0000-0001-5336-1772

DOI: 10.35429/JIE.2021.15.5.30.33 Received July 25, 2021; Accepted December 30, 2021

Abstract

Generally, computer developments for business activities are focused on systematizing data processing. Activities that as the company grows or changes, they also undergo changes.However, computer systems are not easy to modify when they are done through traditional methodologies. The microservices architecture is characterized by being a modular development, specifically it is divided into independent services that communicate with each other through APIs. These services run independently and autonomously, so if an PYME changes its needs, only new services are added that can interact with the existing ones. Therefore, the ability to respond to changes is increased. Objective: General: Implementation of a Computational System based on Microservices for the management of a PYME. Specific: Identification of horizontal and vertical scalability needs, Identification of technologies and services. Development and testing of services, Coupling and testing.Methodology used: SCRUM is designed for projects with a high level of uncertainty. In this project, it was not known at the outset which technologies should be implemented.Contribution: Serve as a guide in the identification of viable technologies to implement microservices, focused on scalability in PYMEs.

PYME, microservices, scalability

Resumen

Generalmente los desarrollos computacionales para actividades empresariales están enfocados a sistematizar procesamiento de datos. Actividades que conforme la empresa crece o se modifica, éstas también sufren cambios. Sin embargo, los sistemas computacionales no son fáciles de modificar cuando se realizan a través de metodologías tradicionales. La arquitectura de microservicios se caracteriza por ser un desarrollo modular, específicamente se divide en servicios independientes que se comunican entre sí mediante API. Estos servicios se ejecutan de forma independiente y autónoma, por lo que, si una PYME cambia sus necesidades, sólo se agregan nuevos servicios que pueden interactuar con los ya existentes. Por lo que se incrementa la capacidad de respuesta a los cambios. Objetivo: General: Implementación de un Sistema Computacional basado en Microservicios para la gestión de una PYME. Específicos: Identificación de necesidades de escalabilidad horizontal y vertical, Identificación de tecnologías y servicios. Desarrollo y pruebas de servicios, Acoplamiento y pruebas. Metodología usada: SCRUM está diseñado para proyectos de alto nivel de incertidumbre. En este proyecto, no se sabía de inicio qué tecnologías debían implementarse. Contribución: Servir de guía en la identificación de las tecnologías viables para implementar microservicios, enfocados a la escalabilidad en PYMEs.

PYME, microservicios, escalabilidad

Citation: BENÍTEZ-QUECHA, Claribel, ALTAMIRANO-CABRERA, Marisol, LÓPEZ-GUZMÁN, Oscar Eduardo and MÉNDEZ-LÓPEZ, Minerva Donají. Microservices architecture as a viable option to support the organic growth of PYMEs. Journal Industrial Engineering. 2021. 5-15:30-33.

* Author's Correspondence (E-mail: claribelbk@hotmail.com)
† Researcher contributing as first author.

Introduction

In recent years, when a scalability problem is addressed in software development, two main pillars have been erected, the first being the integration into cloud computing platforms and secondly the selection of clean architectures, such as hexagonal and based on microservices. Although microservices architectures are scalable in nature, it must be considered that said scalability responds to a solution that is growing in the solution and not necessarily the growth of the company that implements it. When a Computer System is developed based on the current needs of the company or in the best of cases, with some future considerations, it happens that the company modifies its operations and these may not be the ones considered in the future. This implies that the Computer System is no longer viable and must be modified, which results in the original developer being the one who modifies it or having exhaustive documentation for a new developer to update it, so that always ends up doing a new system. As a proposed solution, it is considered that the fact of segmenting the Computational System based on the services required, presents the possibility of carrying out the scaling required by the SME, over time. Since each service is independent and autonomous with respect to the others, and new services can be coupled as required without having to rewrite the entire code.

In this work, each of the development phases and the technology used are exposed, according to tests based on response times, security and coupling capacity.

Theoretical framework

We can define electronic commerce that is carried out through the internet as the exchange of commercial information using this data transmission network as a medium in order to acquire goods or services. Microservices architecture is an approach to developing software solutions by dividing it into different modules or low-coupling services, each of them executing a process independent of the rest. Cloud computing is a scheme for the provision of computing resources through a distributed computing system that are dynamically supplied to the consumer.

A continuous integration and deployment chain refers to the process of automating operational tasks when building and deploying software. CI (Continuous Integration) covers the operations of building applications from source code while CD (Continuous Deployment) involves those operations referring to the start-up of the built software.

Development

11 microservices were developed grouped into 2 modules (Providers and clients) using the Java Spring Boot framework that consist of a secure session handler (Provider / Client security), an event handler for each module (Events Provider / Client), administrators of business information (Business Management), of the client (Clients management), and of products and services (Products / Services management), a manager of the purchase and sale process (Purchase / Sale) a point of consumption of product information and services (Products / services) and finally a microservice for registering customer, supplier and business information (Onboarding). The selection of Spring Boot is based on the robustness of the framework and the ease with which unit and integration tests can be automated, a key step in the development of services that must maintain a low coupling. For information management, MongoDB was integrated in order to store and retrieve the information of the actors. The main use of a non-relational database responds to specific needs of the solution, such as the ability to consult coordinate information in real time, and to perform searches based on parameters. The nature of a non-relational database helps to improve the experience in these specific processes that are the main part of the solution. The session management was implemented using Redis, this database engine not only allows a more advanced administration of the sessions, but also acts as a general information dashboard in which all the microservices can obtain information in common, becoming a channel more efficient communication than an event queue for certain actions.

ISSN 2523-0344

Journal Industrial Engineering
December 2021, Vol.5 No.15 30-33

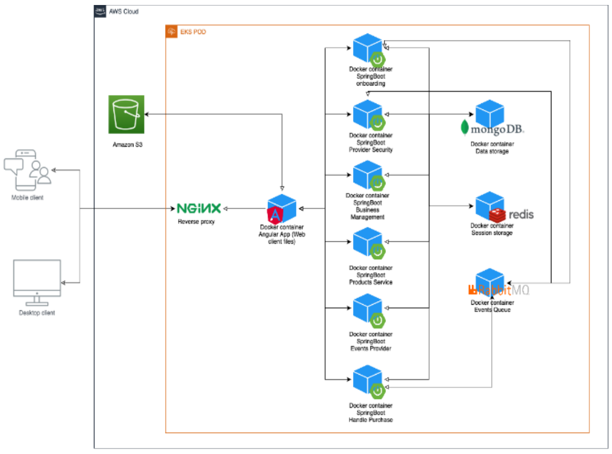


Figure 1 Microservices architecture for providers module
Source: Own elaboration

RabbitMQ was also implemented to manage event queues in communication between microservices, and with the outside world. When an architecture of this style is designed, it is necessary to implement different communication channels where it is possible to report or consult events that are of common interest for one or more microservices. 2 Angular Web clients were also developed for consumption from the end devices, both modules were designed with easy integration with microservices in mind, allowing to enable and disable functionalities in a simple way.

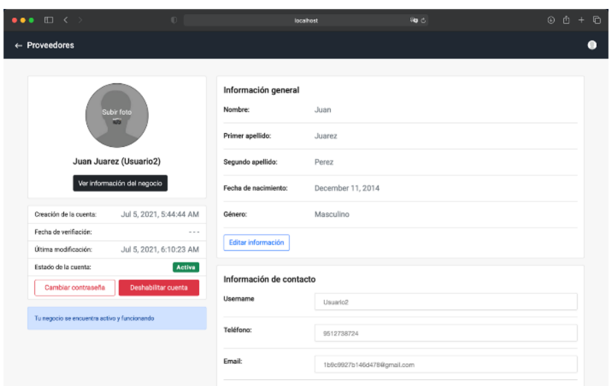


Figure 2 Suppliers module, profile editing functionality
Source: Own elaboration

Angular was selected as the frontend development framework because it allows more robust and less casual development. Although the decision of frontend technologies are not usually influenced by the architecture of the solution, they are influenced by the size of the project, and when an architecture is designed to improve scalability, it is useful to have technologies that allow this scalability in a organic, especially when it comes to SMEs, since they benefit from being able to invest their resources in maintaining an infrastructure that corresponds to their volume of sales or traffic.

As more traffic is generated, the cost of maintenance will increase as well. For the deployment of all the elements, it was necessary to use docker containers and in this way facilitate the maintenance of the microservices, as well as Kubernetes to improve monitoring and ensure their response.

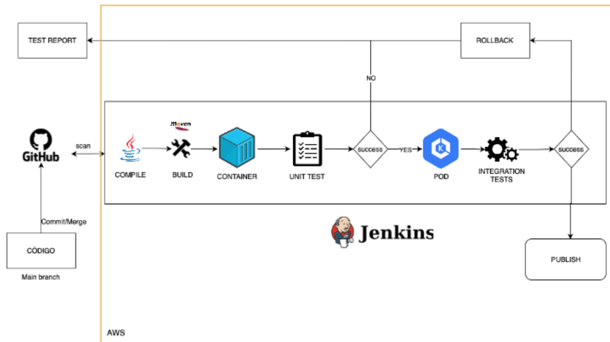


Figure 3 Continuous integration and deployment scheme (CI / CD)
Source: Own elaboration

Finally, by designing a continuous integration and deployment model using the Jenkins tool, it was possible to automate all the tasks corresponding to the packaging, dockerization and deployment of the microservices on the AWS cloud, this integration and deployment process also contributes to the scalability of the solution, as it allows making changes more efficiently.

Choosing a cloud computing service provider like AWS is perhaps the most obvious step an SMB can take to deploy a software project. These types of providers offer payment schemes based on traffic, that is, the use that the solution is having, in this way the company will not have to make a large investment in hosting until this solution has high traffic.

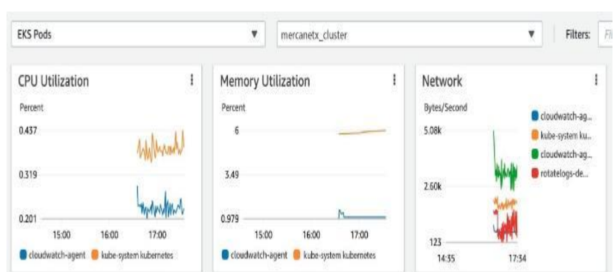


Figure 4 Kubernetes pod monitoring on AWS
Source: Generated with the Amazon Cloudwatch tool

ISSN 2523-0344

All of the above was proposed as an initial development, since within the general design of the solution, 2 additional modules (administrators and dispatchers) are contemplated whose implementation would require 7 microservices and 2 additional Web clients.

Results

In addition to all the advantages that a non-monolithic infrastructure brings with it, such as the low level of coupling between the functionalities, for the SME, having a development where the architecture is completely modularized also represents a possibility of implementing small parts of the solution and freeing up functionalities progressively as your infrastructure as a company and economic condition can allow it.

Gratitude

We thank the Tecnológico Nacional de México Campus Oaxaca for its support in carrying out this work.

Conclusions

Current technologies respond satisfactorily in computational development through architectures based on microservices. With regard to database managers, programming languages and container platforms. However, not all of them do, it is necessary to carry out tests of response times, security in the transactions and coupling. Factors such as resources, time and personnel influenced the design procedure of the following architecture, as well as the selection of the technologies to be used within it. For the development of MercanetXpress (Registration in process), a solution for an SME dedicated to connecting product and service providers with customers and distributors, vertical and horizontal scalability needs were identified for both the solution (platform) and the company, as that part of his business plan consisted of implementing the solution in certain geographical locations and replicating it following the organic growth of the company.

References

Alfaro Azofeifqa, Cindy. Alfaro Chamberlain, José I. Monge González, Ricardo. ICTs in Central American SMEs: Impact of the Adoption of Information and Communication Technologies on the performance of companies. Ed. Tecnológica de Costa Rica. 2005.

Arias, Á. (2015). Cloud Computing: 2nd Edition. IT Campus Academy. Berenguel Gómez, José Luis. Development of distributed web applications. Ed. Editions Paraninfo. 2016. Married, Sergio. How to take your backend in Node to the next level? Introduction to NestJS. Retrieved from https://www.paradigmadigital.com/dev/introduccion-nestjs / on May 7, 2021.

Dadoo, Maya. The need to implement technology in an SME. Retrieved from https://expansion.mx/opinion/2018/10/03/opinion-la-necesidad-de-implementar-tecnologia-en-una-pyme, on February 10, 2021.

Llopis, Joan. Lighten the Monolith: Miniservices and Microservices. Retrieved from https://clouddistrict.com/aligerar-monolitominiservicios-microservicios/ on May 11, 2021.

López, D., & Maya, E. (2017). Software Architecture based on Microservices for Web Application Development.

Ortega Candel, José Manuel. Technologies for microservices-based architectures: Patterns and solutions for applications deployed in containers. Ed. José Manuel Ortega. June 30, 2020.

Ruiz, A. D. L. Á. R. (2015). Analysis and perspectives of electronic commerce in Mexico. Profiles of Social Sciences, 3 (5).

[Title in Times New Roman and Bold No. 14 in English and Spanish]

Surname (IN UPPERCASE), Name 1st Author†*, Surname (IN UPPERCASE), Name 1st Coauthor, Surname (IN UPPERCASE), Name 2nd Coauthor and Surname (IN UPPERCASE), Name 3rd Coauthor

Institutional Affiliation of Author including Dependency (No.10 Times New Roman and Italic)

International Identification of Science - Technology and Innovation

ID 1st Author: (ORC ID - Researcher ID Thomson, arXiv Author ID - PubMed Author ID - Open ID) and CVU 1st author: (Scholar-PNPC or SNI-CONACYT) (No.10 Times New Roman)

ID 1st Coauthor: (ORC ID - Researcher ID Thomson, arXiv Author ID - PubMed Author ID - Open ID) and CVU 1st coauthor: (Scholar or SNI) (No.10 Times New Roman)

ID 2nd Coauthor: (ORC ID - Researcher ID Thomson, arXiv Author ID - PubMed Author ID - Open ID) and CVU 2nd coauthor: (Scholar or SNI) (No.10 Times New Roman)

ID 3rd Coauthor: (ORC ID - Researcher ID Thomson, arXiv Author ID - PubMed Author ID - Open ID) and CVU 3rd coauthor: (Scholar or SNI) (No.10 Times New Roman)

(Report Submission Date: Month, Day, and Year); Accepted (Insert date of Acceptance: Use Only ECORFAN)

Abstract (In English, 150-200 words)

Objectives
Methodology
Contribution

Keywords (In English)

Indicate 3 keywords in Times New Roman and Bold No. 10

Abstract (In Spanish, 150-200 words)

Objectives
Methodology
Contribution

Keywords (In Spanish)

Indicate 3 keywords in Times New Roman and Bold No. 10

Citation: Surname (IN UPPERCASE), Name 1st Author, Surname (IN UPPERCASE), Name 1st Coauthor, Surname (IN UPPERCASE), Name 2nd Coauthor and Surname (IN UPPERCASE), Name 3rd Coauthor. Paper Title. Journal Industrial Engineering. Year 1-1: 1-11 [Times New Roman No.10]

* Correspondence to Author (example@example.org)
† Researcher contributing as first author.

Introduction

Text in Times New Roman No.12, single space.

General explanation of the subject and explain why it is important.

What is your added value with respect to other techniques?

Clearly focus each of its features

Clearly explain the problem to be solved and the central hypothesis.

Explanation of sections Article.

Development of headings and subheadings of the article with subsequent numbers

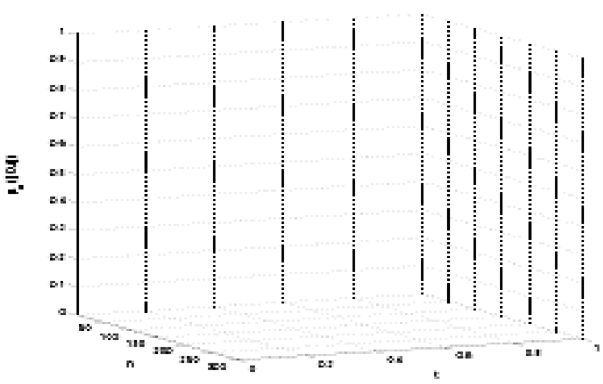
[Title No.12 in Times New Roman, single spaced and bold]

Products in development No.12 Times New Roman, single spaced.

Including graphs, figures and tables-Editable

In the article content any graphic, table and figure should be editable formats that can change size, type and number of letter, for the purposes of edition, these must be high quality, not pixelated and should be noticeable even reducing image scale.

[Indicating the title at the bottom with No.10 and Times New Roman Bold]



Graphic 1 Title and *Source (in italics)*

Should not be images-everything must be editable.

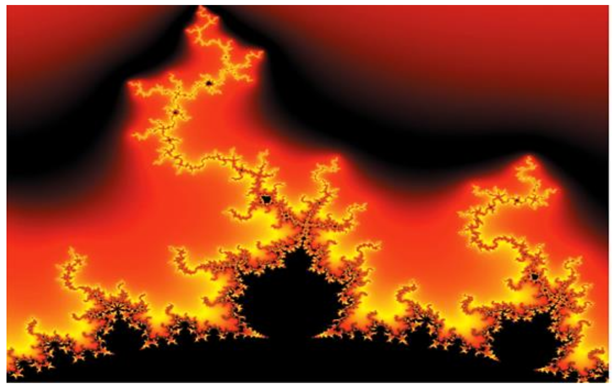


Figure 1 Title and *Source (in italics)*

Should not be images-everything must be editable.

Table 1 Title and *Source (in italics)*

Should not be images-everything must be editable.

Each article shall present separately in **3 folders**: a) Figures, b) Charts and c) Tables in .JPG format, indicating the number and sequential Bold Title.

For the use of equations, noted as follows:

$$Y_{ij} = \alpha + \sum_{h=1}^{r} \beta_h X_{hij} + u_j + e_{ij} \quad (1)$$

Must be editable and number aligned on the right side.

Methodology

Develop give the meaning of the variables in linear writing and important is the comparison of the used criteria.

Results

The results shall be by section of the article.

Annexes

Tables and adequate sources

Thanks

Indicate if they were financed by any institution, University or company.

ISSN 2523-0344

Conclusions

Explain clearly the results and possibilities of improvement.

References

Use APA system. Should not be numbered, nor with bullets, however if necessary numbering will be because reference or mention is made somewhere in the Article.

Use Roman Alphabet, all references you have used must be in the Roman Alphabet, even if you have quoted an Article, book in any of the official languages of the United Nations (English, French, German, Chinese, Russian, Portuguese, Italian, Spanish, Arabic), you must write the reference in Roman script and not in any of the official languages.

Technical Specifications

Each article must submit your dates into a Word document (.docx):

Journal Name
Article title
Abstract
Keywords
Article sections, for example:

1. Introduction
2. Description of the method
3. Analysis from the regression demand curve
4. Results
5. Thanks
6. Conclusions
7. References

Author Name (s)
Email Correspondence to Author
References

Intellectual Property Requirements for editing:

- Authentic Signature in Colour of Originality Format Author and Co-authors.

- Authentic Signature in Colour of the Acceptance Format of Author and Co-authors.

Reservation to Editorial Policy

Journal Industrial Engineering reserves the right to make editorial changes required to adapt the Articles to the Editorial Policy of the Research Journal. Once the Article is accepted in its final version, the Research Journal will send the author the proofs for review. ECORFAN® will only accept the correction of errata and errors or omissions arising from the editing process of the Research Journal, reserving in full the copyrights and content dissemination. No deletions, substitutions or additions that alter the formation of the Article will be accepted.

Code of Ethics - Good Practices and Declaration of Solution to Editorial Conflicts

Declaration of Originality and unpublished character of the Article, of Authors, on the obtaining of data and interpretation of results, Acknowledgments, Conflict of interests, Assignment of rights and Distribution

The ECORFAN-Mexico, S.C Management claims to Authors of Articles that its content must be original, unpublished and of Scientific, Technological and Innovation content to be submitted for evaluation.

The Authors signing the Article must be the same that have contributed to its conception, realization and development, as well as obtaining the data, interpreting the results, drafting and reviewing it. The Corresponding Author of the proposed Article will request the form that follows.

Article title:

– The sending of an Article to Journal Industrial Engineering emanates the commitment of the author not to submit it simultaneously to the consideration of other series publications for it must complement the Format of Originality for its Article, unless it is rejected by the Arbitration Committee, it may be withdrawn.

– None of the data presented in this article has been plagiarized or invented. The original data are clearly distinguished from those already published. And it is known of the test in PLAGSCAN if a level of plagiarism is detected Positive will not proceed to arbitrate.

– References are cited on which the information contained in the Article is based, as well as theories and data from other previously published Articles.

– The authors sign the Format of Authorization for their Article to be disseminated by means that ECORFAN-Mexico, S.C. In its Holding Republic of Peru considers pertinent for disclosure and diffusion of its Article its Rights of Work.

– Consent has been obtained from those who have contributed unpublished data obtained through verbal or written communication, and such communication and Authorship are adequately identified.

– The Author and Co-Authors who sign this work have participated in its planning, design and execution, as well as in the interpretation of the results. They also critically reviewed the paper, approved its final version and agreed with its publication.

– No signature responsible for the work has been omitted and the criteria of Scientific Authorization are satisfied.

– The results of this Article have been interpreted objectively. Any results contrary to the point of view of those who sign are exposed and discussed in the Article.

Copyright and Access

The publication of this Article supposes the transfer of the copyright to ECORFAN-Mexico, SC in its Holding Republic of Peru for its Journal Industrial Engineering, which reserves the right to distribute on the Web the published version of the Article and the making available of the Article in This format supposes for its Authors the fulfilment of what is established in the Law of Science and Technology of the United Mexican States, regarding the obligation to allow access to the results of Scientific Research.

Article Title:

Name and Surnames of the Contact Author and the Co-authors	Signature
1.	
2.	
3.	
4.	

Principles of Ethics and Declaration of Solution to Editorial Conflicts

Editor Responsibilities

The Publisher undertakes to guarantee the confidentiality of the evaluation process, it may not disclose to the Arbitrators the identity of the Authors, nor may it reveal the identity of the Arbitrators at any time.

The Editor assumes the responsibility to properly inform the Author of the stage of the editorial process in which the text is sent, as well as the resolutions of Double-Blind Review.

The Editor should evaluate manuscripts and their intellectual content without distinction of race, gender, sexual orientation, religious beliefs, ethnicity, nationality, or the political philosophy of the Authors.

The Editor and his editing team of ECORFAN® Holdings will not disclose any information about Articles submitted to anyone other than the corresponding Author.

The Editor should make fair and impartial decisions and ensure a fair Double-Blind Review.

Responsibilities of the Editorial Board

The description of the peer review processes is made known by the Editorial Board in order that the Authors know what the evaluation criteria are and will always be willing to justify any controversy in the evaluation process. In case of Plagiarism Detection to the Article the Committee notifies the Authors for Violation to the Right of Scientific, Technological and Innovation Authorization.

Responsibilities of the Arbitration Committee

The Arbitrators undertake to notify about any unethical conduct by the Authors and to indicate all the information that may be reason to reject the publication of the Articles. In addition, they must undertake to keep confidential information related to the Articles they evaluate.

Any manuscript received for your arbitration must be treated as confidential, should not be displayed or discussed with other experts, except with the permission of the Editor.

The Arbitrators must be conducted objectively, any personal criticism of the Author is inappropriate.

The Arbitrators must express their points of view with clarity and with valid arguments that contribute to the Scientific, Technological and Innovation of the Author.

The Arbitrators should not evaluate manuscripts in which they have conflicts of interest and have been notified to the Editor before submitting the Article for Double-Blind Review.

Responsibilities of the Authors

Authors must guarantee that their articles are the product of their original work and that the data has been obtained ethically.

Authors must ensure that they have not been previously published or that they are not considered in another serial publication.

Authors must strictly follow the rules for the publication of Defined Articles by the Editorial Board.

The authors have requested that the text in all its forms be an unethical editorial behaviour and is unacceptable, consequently, any manuscript that incurs in plagiarism is eliminated and not considered for publication.

Authors should cite publications that have been influential in the nature of the Article submitted to arbitration.

Information services

Indexation - Bases and Repositories

RESEARCH GATE (Germany)
GOOGLE SCHOLAR (Citation indices-Google)
MENDELEY (Bibliographic References Manager)
HISPANA (Information and Bibliographic Orientation-Spain)

Publishing Services

Citation and Index Identification H
Management of Originality Format and Authorization
Testing Article with PLAGSCAN
Article Evaluation
Certificate of Double-Blind Review
Article Edition
Web layout
Indexing and Repository
ArticleTranslation
Article Publication
Certificate of Article
Service Billing

Editorial Policy and Management

1047 La Raza Avenue -Santa Ana, Cusco-Peru. Phones: +52 1 55 6159 2296, +52 1 55 1260 0355, +52 1 55 6034 9181; Email: contact@ecorfan.org www.ecorfan.org

Journal Industrial Engineering

“Design and construction of a Darrieus vertical axis turbine and analyzed by reverse engineering”

GARCÍA-HERNÁNDEZ, Miguel Alejandro, CRUZ-GOMEZ, Marco Antonio, JUAREZ-ZERÓN, Tomás Aarón and SAAVEDRA-CRUZ, Nubia

Benemérita Universidad Autónoma de Puebla

“Performance indicators in the sustainable management of the company Metalyzinc”

RAMÍREZ-ROMÁN, Adolfo, RODRÍGUEZ-RODRÍGUEZ, Luis Alberto, CHABAT-URANGA, Jacqueline and SUÁREZ-ÁLVAREZ, Ángel

Universidad Veracruzana

“Control system for parameter estimation in plastic injection for the automotive industry”

ROMANO-RODRÍGUEZ, Ma. Natividad, MUÑOZ-RIOS, José Juan, PÉREZ-MARTÍNEZ, René and HERNÁNDEZ-MEDINA, José Juan

Instituto Tecnológico Superior de Tlaxco

“Microservices architecture as a viable option to support the organic growth of PYMEs”

BENÍTEZ-QUECHA, Claribel, ALTAMIRANO-CABRERA, Marisol, LÓPEZ-GUZMÁN, Oscar Eduardo and MÉNDEZ-LÓPEZ, Minerva Donají

Tecnológico Nacional de México Campus Oaxaca

2523 0344

ISSN 2523-0344

www.ecorfan.org