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Journal of Mechanical Engineering

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Presentation of the Content

In the first chapter we present, *Analysis and Characterization of Organic Materials for Abrasive Sand-Blasting Process*, by García-Medina, Daniela & Montúfar, Jesús, with adscription in the Universidad Politécnica de Otzolotepec, as next article we present, *Implementation of a mechatronic system for the hydraulic automation of artificial wetlands*, by Becerril-Zarate, Bianca Paola, Mastache-Mastache, Jorge Edmundo and López-Ramírez, Roberto, with adscription in the Tecnológico Nacional de México - Tecnológico de Estudios Superiores de Jocotitlán, as next article we present, *Design and construction of a machine for destructive testing of reinforced concrete gantries based on rapid prototyping and AI*, by Rodríguez-González, José Miguel & Gómez-Arizmendi, Gabriela, with adscription in the Tecnológico Nacional de México/TES Valle de Bravo, as next article we present, *Polynomial regression model for the prediction of thermal efficiency in spark ignition engines operating with ethanol-water mixtures*, by Camacho-Catemaxca, Erik Guadalupe, Escobedo-Trujillo, Beatriz Adriana, Alaffita-Hernández, Francisco Alejandro and Herrera-Romero, José Vidal, with adscription in the Universidad Veracruzana, as next article we present, *Innovative design of a compact conveyor for medium loads and high production*, by Martínez-Torres, Rosa Elia, Mendoza-Razo, Juan Arturo, Alvarado Cano, Juan Antonio and Villalpando-Romo, Guillermo, with adscription in the Instituto Tecnológico de San Luis Potosí, TecNM, as next article we present, *Artisanal fabrication of prismatic concrete brick units using a modular mold covered by utility model MX 4516*, by Álvarez-Arellano, Juan Antonio, Lastra-González Isabel Christine, El-Hamzaoui Youness and Flores-Trujillo, Juan Gabriel, with adscription in the Universidad Autónoma del Carmen, as last article we present, *Feed pellet machine poultry*, by Mariscal-Navarro, Fidel Alejandro, Bravo-Cadena, Román, Cardon-Angeles, Asael Jesse and Tellez-Ramos, Jonathan Esau, with adscription in the Universidad Tecnológica del Valle del Mezquital

Content

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Article

Analysis and Characterization of Organic Materials for Abrasive Sand-Blasting Process

Estudio y Caracterización de Polvos Abrasivos Orgánicos para Proceso de Sand-Blast

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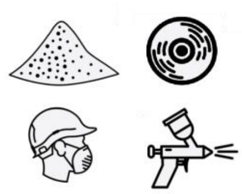
Abstract

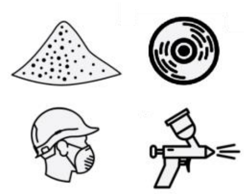
This article presents the results of research conducted at the Polytechnic University of Otzolotepec, focused on characterizing organic materials for abrasive applications. The study involved producing powders from walnut shells and orange peels, aiming to develop an organic abrasive for cleaning and material removal. The project successfully resulted in an environmentally friendly abrasive compatible with abrasive discs. The sandblasting process, using pressurized air and the organic abrasive, effectively cleans and removes impurities from various materials, including deep craters, with minimal material wear. Conducted in the Manufacturing Technology Engineering laboratory, the research emphasized identifying and processing locally available organic materials to minimize environmental impact and health risks for students and faculty. This article outlines the project's methodology, findings, and the critical factors contributing to its success, while highlighting the practical experiences and outcomes achieved during its implementation.

Objectives	Methodology	Contribution
Walnut and orange peels as eco-friendly abrasives, reducing synthetic waste and health risks. 	Walnut and orange peels were processed and sieved to optimize flow through a 3/8" nozzle. Orange peel removed paint in 2.5 min at 100 psi, while walnut was unsuitable. Organic abrasive powder was tested for sandblasting and discs. 	• Organic alternative to silica sand in sandblasting • Abrasives for manufacturing industry • Production of organic abrasive discs • University-driven innovation • Safer, sustainable practices 

Sand-blast, Organic, Dust, Abrasive

Resumen

Este artículo presenta los resultados de una investigación realizada en la Universidad Politécnica de Otzolotepec, centrada en la caracterización de materiales orgánicos para aplicaciones abrasivas. El estudio involucró la producción de polvos a partir de cáscaras de nuez y cáscaras de naranja, con el objetivo de desarrollar un abrasivo orgánico para limpieza y remoción de materiales. El proyecto logró producir un abrasivo ecológico compatible con discos abrasivos. El proceso de arenado, utilizando aire a presión y el abrasivo orgánico, limpia eficazmente y elimina impurezas de diversos materiales, incluso en cráteres profundos, con un desgaste mínimo del material. Realizada en el laboratorio de Ingeniería en Tecnología de Manufactura, la investigación enfatizó la identificación y procesamiento de materiales orgánicos locales para minimizar el impacto ambiental y los riesgos para la salud de estudiantes y docentes. Este artículo detalla la metodología, los hallazgos y los factores críticos que contribuyeron al éxito del proyecto.

Objetivos	Metodología	Contribución
Cáscaras de nuez y naranja como abrasivos ecológicos, reduciendo residuos sintéticos y riesgos para la salud. 	Las cáscaras de nuez y naranja fueron procesadas y tamizadas para optimizar el flujo en una boquilla de 3/8". La cáscara de naranja eliminó pintura en 2.5 min a 100 psi, mientras que la de nuez fue inadecuada. Se probó polvo abrasivo orgánico para arenado y discos. 	• Alternativa orgánica a la arena de sílice en arenado • Abrasivos para la industria manufacturera • Producción de discos abrasivos orgánicos • Innovación impulsada por la universidad • Prácticas más seguras y sostenibles. 

Polvos orgánicos, Abrasivos, Arenado

Area: Development of strategic leading-edge technologies and open innovation for social transformation

Citation: García-Medina, Daniela & Montúfar, Jesús. [2025]. Analysis and Characterization of Organic Materials for Abrasive Sand-Blasting Process. Journal of Mechanical Engineering. 9[22]1-11: e1922111.

Introduction

This article presents a study on the application of walnut and orange peels as organic abrasives, an alternative to reduce the use of synthetic abrasives, conducted at the Polytechnic University of Otzolotepec. Students carry out cleaning processes on corroded metal structures and etching on glass pieces using the sandblasting process and/or abrasive discs, within a commercial cabin and equipment. The process is conducted in the Manufacturing laboratory. When working with sand in the cabin, dust clouds form during cleaning or etching, causing visibility issues and posing environmental and health risks to the students.

The main objective is to characterize walnut and orange peels as organic materials that can be used as natural abrasives for the sandblasting process, as inorganic abrasives pose health risks to the students and have a significant environmental impact. As a sustainable university, efforts are made to reuse cutting discs by incorporating organic materials in their manufacture.

Set of issues

The development of this research is based on the problems caused by silica sand when it comes into contact with the respiratory tract and its environmental impact. Silica sand has been affecting health for several years, and the study aims to determine which organic product could potentially be used for this application. A natural abrasive is required to support the process in order to avoid environmental and health issues, benefiting the students of the Polytechnic University of Otzolotepec and improving the process by testing derivatives that can be adapted as abrasives.

For years, sand has been the only abrasive used for engraving or cleaning in the University's laboratory. So far, students have not encountered risks during the process; however, the effects become evident over the years [1].

Previous Work

The first known instance of sandblasting took place in England, United Kingdom, in August 1870, when Benjamin C. Tilghman invented a machine that he patented under the number 2147. This machine has been modified over time to fulfill different purposes, but the operating principle has always remained the same [2].

The term "sandblast" comes from the English words "sand," meaning sand, and "blast," meaning pressure, thus referring to the technique known as "sand under pressure." However, this system does not necessarily use sand for its operation and can employ various pressure abrasives [3].

Vegetable abrasives are those derived from living plants. The most commonly used ones are obtained from corn cobs, walnut shells, fruit pits, and rice husks.

Vegetable abrasives are mainly used to clean valves, turbine rotor blades, to remove grease from engines, and to remove sludge or other deposits from a layer of paint. They are also used to remove scale or pieces of paint, especially when repainting, whether on wood, fiberglass, or aluminium. Vegetable abrasives do not generate sparks, which is why they are used in hazardous areas where all parts to be cleaned are adequately placed on the ground and ventilated [4].

Some shells, such as walnut shells, contain oil or colouring substances that may not be suitable for some surfaces, especially when repainting. Within the university, sandblasting tests have been conducted using only silica sand, yielding satisfactory results, as sand is one of the best inorganic abrasives that can be used to clean corrosion from metallic materials [5].

Sand-Blast

The primary objective of this process is to safely perform maintenance and/or cleaning of equipment using organic sand-blasting on surfaces such as tanks, pipes, production vessels, sheets, compressors, and machinery that require this procedure for their presentation and preservation. This procedure is executed to remove rust, existing corrosion, metal impurities, and to achieve a surface with an anchor profile that meets the requirements for coating applications. It also applies to maintenance operations and surface preparation to achieve the necessary conditions and requirements in coating, finishing, and painting processes.

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Organic sandblasting is an advanced technique that uses eco-friendly and biodegradable materials, minimizing environ- mental impact compared to traditional sandblasting methods. This method is not only effective in removing contaminants but also safer for operators, reducing exposure to toxic sub- stances and decreasing the risk of health issues associated with hazardous dust particles [4].

During the execution of the process, specialized equipment is used to project the organic abrasive at high speed onto the surfaces to be treated. This controlled impact ensures thorough and uniform cleaning, completely removing dirt and oxidation layers without damaging the integrity of the base material.

Proper surface preparation through this method is crucial to ensuring the optimal adhesion of subsequent coatings. An ad- equate anchor profile enhances the durability and performance of the coating, extending the lifespan of the treated equipment and structures.

This process is essential in various industries, including petrochemical, maritime, construction, and manufacturing, where corrosion protection and surface preparation are vital for maintaining and efficiently operating equipment. Implementing this method significantly contributes to reducing long-term maintenance costs and increasing the reliability and safety of industrial operations.

This method is considered one of the best in the industry for removing any type of impurity and preparing surfaces for any final finishing process [6].

Sand-Blast Equipment

The sandblasting equipment generally consists of a com- pressor that reaches a minimum pressure of 100 psi [pounds per square inch]. In addition to having air and sandblasting ducts, it also has a sand tank where pressurized air is injected, producing the air-sand mixture. Finally, there is a nozzle that directs the flow toward the surface.

Air Compressor

A necessary part of the equipment for abrasive blasting is an air compressor.

The compressors regularly used are portable units without a storage tank; they are essentially the same equipment used for pneumatic breakers. These units differ in the air supply capacity and the pressure they can withstand. Occasionally, stationary units can be used, but this depends on their capacity since only a few can meet the required air demand. The air compressor used at the Polytechnic University in Otzolotepec as shown in Figure 1, it has a capacity of 20 litres, which is sufficient for conducting sandblasting tests at the laboratory level.

Box 1

Figure 1
Compressor 150lt-10 Bar
Image by author

Abrasive Container

All sandblasting containers serve the same essential function, which is to provide an amount of abrasive to a high- pressure stream; the difference between one setup and another lies in the abrasive storage capacity. The tanks range from 50 to 400 or more liters of storage [Figure 2]; sometimes they are classified by the kilograms of abrasive they can store, but this can be relative due to differences in volumetric weights. Therefore, classification by volume may be more accurate [2]. The issue is that only a medium capacity of the container can be added, although it may not seem so, but it is very useful for students, which is why it is necessary to find the correct organic abrasive so they don't have problems with the amount of abrasive.

Nozzle

Nozzle tips for blowtorching are manufactured in various materials, of which the most common are: ceramic, cast iron, and tungsten carbide.

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The first two are more economical but have a lifespan of approximately 2 to 4 hours of continuous service. Our nozzle is shown in Figure 3. The sandblasting gun is commonly used; its size is 3/8”, which allows us to work in the process without complications.

Sand blasting hoses

The hoses used in the process are reinforced with multiple layers of natural rubber without wires or reinforcements, usually prioritizing the prevention of electrostatic charges that could create sparks in potentially explosive environments. They are approximately 15m long with inner diameters of 1” or 1 ¼”, suitable for 3/8” nozzles. Using smaller diameters may result in pressure losses in the line unless smaller diameter nozzles are used. The inner diameter of the hose should be 3 to 4 times larger than the inner diameter of the nozzle.

Sand blasting cabin

The cabin was created within the University to mitigate the impact of the environment and potential illnesses caused by using any type of inorganic abrasive. The cabin prevents students from direct contact with the dust generated by sand or organic abrasive materials.

Box 2

Figure 2
Abrasive Container

Image by author

Box 3

Figure 3
Connection nozzle

Image by author

Types of Sandblasting

Wet blasting

Wet abrasive blasting [also known as vapor abrasive blast- ing] removes coatings, contaminants, corrosion, and residues

From hard surfaces. The main advantage of wet abrasive blasting over dry blasting is that it reduces dust. It provides a cleaner surface with a more uniform finish, ready for coating, without embedded particles or adhered dust [6].

For this, we need a compressor that, instead of assisting the abrasive with air pressure, does so with water. There are several types of commercial compressors that can be used in the process. This process is not viable for organic materials since moisture reduces the hardness of the dust, thus eliminating its removal capacity.

Dry blasting

This technique involves cleaning or removing materials from a surface by the action of granular abrasive material expelled by a compressed air machine through a nozzle. Sandblasting is used to remove rust or any type of coating on surfaces and prepare them for coating, but that’s not its sole function; there are many more functions of sandblasting besides the aforementioned [7].

Abrasives

Abrasives are tools used for polishing, grinding, and smoothing surfaces.

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They are widely employed across various industries to work on other materials. The use of abrasives involves the removal of material through the action of hard abrasive particles that are typically bonded. Grinding is the most significant abrasive process. Other traditional abrasive processes include honing, lapping, superfinishing, polishing, and buffing. Generally, abrasive machining processes are used as finishing operations [8].

Organic abrasives

These abrasives are composed of materials found in nature, such as walnut shells and corn residues. Because they are softer than other common materials, they are useful for delicate applications like polishing or cleaning, leaving surfaces largely intact. A significant advantage of this medium, besides being natural and non-toxic, is its reusability due to its resistance to decomposition [4].

Corundum: It is the most common abrasive in the metal industry. It is a fused aluminum oxide with an alpha aluminum structure and a Knoop hardness of between 2000- 2100 Kg/mm2. There is white corundum [harder and purer] and brown corundum, with a chemical composition including small percentages of titanium oxide and iron. Corundum is primarily used for shot blasting [removal of rust and scale on metal surfaces, discoloration, and material removal cleaning of surfaces], surface finishing, improvement of metal surface adhesion, deburring, glass matting, and treatment of highly hardened workpieces.

Quartz: Widely used and inexpensive, also known as silica sand. It is used in the manufacture of sandpapers, blocks, or discs, and primarily in abrasive blasting systems through pressure sandblasting.

Garnet: It is a mixture of various hard alkaline earth silicates. The purest variety is used in jewelry, while the smaller,more impure fragments are used as abrasives, especially for woodworking, water jet cutting, and sandblasting.

Corn Residues: Another sandblasting abrasive is corn residues. Since it is not very hard, it is mainly used for delicate surfaces like wood and glass, or to remove soft layers like grease or debris.

It is a biodegradable abrasive made from corn, its major advantages being completely safe for operators and resistant to breakage, making it reusable. It only comes in extra coarse size.

Walnut Shell: Walnuts are an organic and biodegradable abrasive. Because it is a soft abrasive, it is widely used for cleaning, polishing, or preparing wood and stripping car coatings. Some of the most important advantages of walnut shells are that they are non-toxic, pose no health risks, and are recyclable, making them a healthy and economical medium.

Synthetic Abrasives

Steel Grit: Another widely used sandblasting abrasive is steel. Steel shots are rounded, and steel grits are angular, but they are made of the same material: carbon steel.

They are mainly used for heavy-duty sandblasting tasks, such as epoxy coating preparation, hard coating removal, deburring, etc. Among the main advantages of this medium are high quality and the resulting smooth surface it produces. Additionally, there is a wide variety of sizes and hardness levels for this medium [9].

Plastics: Plastic abrasives are an excellent choice for strip- ping and cleaning applications involving aluminum compounds and other delicate materials.

If you need to remove organic coatings without damaging the underlying component surface, this is the sandblasting abrasive to choose. Some of the main advantages of plastic abrasives are that they are available in all standard sizes, hardness, shape, and density, and can even be manufactured to meet different needs.

Parameters for abrasives

Shape: Different shapes in abrasives will offer different profiles on the surface, with the two main abrasive configurations being angular and spherical. Angular abrasives work best when dealing with heavy layers of paint and corrosion. They are classified into four possible shapes: angular, sub-angular, round, and sub-rounded. As the designation describes, angular media have sharper edges than sub-angular ones, but both are used for aggressive abrasive blasting.

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Hardness: The hardness of the abrasive will determine its effect on the surface being cleaned or etched. Abrasive hardness is measured on the Mohs scale, with 1 being as soft as talc and 15 as hard as diamond. Abrasives such as boron carbide, silicon carbide, and aluminum oxide fall within the range of 10 to 13. Size: The size of abrasive particles is extremely important for achieving a consistent texture pattern when applying the abrasive blast on the surface. Abrasive manufacturers use various nomenclatures and numbering systems to define the size of their products [10].

Main benefits of sandblasting

Sandblasting offers numerous benefits beyond corrosion removal in metals. It has many advantages within the industry, improving cleanliness in materials such as glass, marble, slate, ceramic, tile, stainless steel, acrylic, concrete, wood, iron, aluminum, bronze, among others [2]. Removing impurities and leaving surfaces exactly as desired is one of the main functions that sandblasting benefits industries, helping to:

- Reduce labor costs.
- Improve part maintenance.
- Enhance the appearance of finished parts.
- Achieve efficient results with less effort.
- Optimize work time.
- Increase adhesion for coatings.
- Highlight material priorities.

Methodology

The current situation at the laboratory of the Polytechnic University of Otzolotepec is limited for research development due to equipment constraints. However, with support from COMECYT, equipment has been acquired to characterize the abrasives being developed. Considering relevant background and investigating key aspects related to health and the environment, it is known that silica sand causes significant pollution, and frequent inhalation can lead to silicosis.

Preparation of organic products

The products suitable for obtaining the abrasive underwent a series of processes before being ground, with the purpose of finding the shape, hardness, and size. The first step was cleaning, followed by drying, and finally grinding.

The initial option was corn husks. After consulting with individuals engaged in agriculture near the University's location, it was decided to primarily work with walnut and orange peels, as they are used as feed for livestock, as shown in Figures 4, 5 and 6.

Box 4

Figure 4
Harvested corn husk
Image by author

Box 5

Figure 5
Cleaned pecan shell
Image by author

Use and Integration of an Electric Mill into the Procedure

An electric mill is acquired to process seeds and dry products. Figure 7 shows a capacity of 2hp Electric Mill, resulting in the material having the grain size characteristics as shown in Figure 8 and 9.

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The resulting product is presented below.

Results

The results obtained after using the electric mill to reduce the size of the shells of three different types of natural products showed that the achieved fineness, measured with various instruments, allowed us to reach a valid conclusion.

Results of Sieving Test

A sieve was used to observe and analyze the particle size obtained for both walnut shells and orange peels. It was carefully observed that the grain size of each raw material achieved the necessary fineness to carry out the tests, thus demonstrating that any type of grain met the characteristics typical of sand. Subsequently, sandblasting tests were conducted using a 3/8" nozzle without encountering flow problems and maintaining a constant output, as with sand.

To evaluate the feasibility of using walnut shells and orange peels as abrasive materials in sandblasting processes, a detailed particle size analysis was conducted using a sieve. This procedure allowed for the determination that both types of shells broke down into grains fine enough to meet the necessary requirements for sandblasting tests. Observations showed that the grain size of each raw material met the granulometric characteristics typical of conventional sand used in these processes.

Box 6

Figure 6
Orange Peel Drying Process

Image by author

Once the adequacy of the particle size was confirmed, sandblasting tests were performed. For these tests, a standard 3/8" nozzle was used. During the sandblasting process, it was observed that there were no flow issues and that the output of the abrasive material remained constant, similar to what is experienced when using conventional sand. This suggests that both walnut shells and orange peels can be viable alternatives to traditional sand in sandblasting applications, potentially offering additional benefits such as waste reduction and the utilization of recycled organic materials.

Moreover, these alternative abrasive materials may present significant ecological advantages since they are biodegradable and do not produce the silica dust associated with sand, which can be harmful to health. This property makes them a safer option for operators and more environmentally friendly. In summary, the tests indicated that walnut shells and orange peels not only meet the necessary physical characteristics for sandblasting but also offer additional benefits, positioning them as promising alternatives in the surface cleaning and finishing industry.

Measurements were made using the sieving process, with the largest sieve being 2 mm and the smallest 250 microns. These tests concluded that, in terms of grain size, the materials met the standards compared to silica sand. The results obtained with the different materials are shown in Figure 10.

Box 7

Figure 7
Electric Mill

Image by author

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We started with an initial weight of 145 g for the three types of husks, in order to conduct the necessary measurements. Each sample undergoes a weight reduction with each subsequent sieving; for instance, after the first sieving, the weight decreases to 138 g, and so on.

These initial weights are crucial for subsequent calculations. On average, we observe a loss of 7 grams per product, which can be recycled to achieve a minimum size of 1 mm and fully utilize the material. The sieves used are standardized, ensuring precise results essential for accurate tabulation and obtaining concrete outcomes. Figure 11 depicts an image of the sieves with the sieved materials. The three types of husks were measured using six different mesh sizes, each with a different mesh opening. Measurements were conducted on the three types of powders obtained after grinding. Mesh sizes of 2mm, 1mm, 710 microns, 500 microns, 355 microns, and 250 microns were used. As mentioned previously, the weights decreased as the material passed through each sieve.

Referring to Table 2, which provides granulometric classification, we can compare the results obtained. The fineness of the silica sand ranges from 600 microns to 2mm in the table.

The highest final weight was obtained with the 500-micron mesh, indicating that the particle size of each husk is slightly finer than that of silica sand. Thus, the results obtained were as expected. Dividing the total weight by the three types of husks yields an 85% effectiveness rate for any powder as an abrasive. Tables 1, 2 and 3 present the results of the measurements conducted with the sieves for each of the powders derived from different husks.

Box 8

Figure 8
Sifted walnut shell

Image by author

Box 9

Figure 9
Dry orange peel

Image by author

After sieving the three types of grains used throughout the project and analyzing the results in a standardized manner, we conclude that none of the powders clog the sandblasting gun nozzle. This is because their fineness is finer than that of sand, making them ideal for the process. Taking into account the statistics from the tables and the measurements of silica sand grains, which theoretically range from 0.625 microns to up to 2 millimeters for compressor work, we can draw conclusions without conducting direct tests.

The final results regarding the weight of the different powders are as follows: orange peel weighed 4g, walnut shell weighed 2g, and pecan shell weighed 5g, all with a minimum grain size [less than 250 microns].

Box 10

Figure 10
Sieve used to measure grain size

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Box 11

Table 1

Orange Peel Measurements

Num	Opening	Initial weight	Sample Weight	Final weight
1	2.00mm	145g	145g	10g
2	1.00mm	138g	138g	10g
3	710mic	132g	133g	1g
4	500mic	127g	131g	4g
5	355mic	124g	127g	3g
6	250mic	122g	124g	2g
TOTAL		89g	91g	2g

Source by author

This indicates that both orange peel and pecan shell meet the grain size requirement. With the acquired mill, it is possible to obtain organic abrasive powder according to desired characteristics, adjusting analytically through trial and error.

For the Sand Blast process, orange peel, pecan shell, and walnut shell were used, all with a grain size of 1mm, compressor pressure set at 100 psi, and a time of 2.5 minutes. Orange peel efficiently cleaned an area of 3.5x3.5 cm. It was observed that both types of walnut shell presented flow difficulties and lacked hardness.

The results obtained with orange peel are shown in Figure 12.

Conclusions

Through thorough analysis and following the project's objectives step by step, we can confidently conclude that it has been completed satisfactorily. The material generated has exceeded expectations, meeting the granulometry specifications and exhibiting the characteristic properties of an abrasive material.

Box 12

Table 2

Measurements of the Shell of the Castilian Walnut

Num	Opening	Initial weight	Sample Weight	Final weight
1	2.00mm	145g	145g	0.0417g
2	1.00mm	138g	138g	0.0010g
3	710mic	132g	133g	1g
4	500mic	127g	129g	2g
5	355mic	124g	127g	3g
6	250mic	122g	124g	2g
TOTAL		89g	93g	4g

Source by author

Box 13

Table 3

Measurements of Pecan Nutshell

Num	Opening	Initial weight	Sample Weight	Final weight
1	2.00mm	145g	145g	1.3438g
2	1.00mm	138g	138.5g	0.5g
3	710mic	132g	136g	4g
4	500mic	127g	132g	5g
5	355mic	124g	126g	2g
6	250mic	122g	123g	1g
TOTAL		89g	91g	2g

Source by author

This achievement brings positive benefits to the students of the Polytechnic University of Otzolotepec, who are the primary users of the material during their laboratory hours. It also significantly contributes to reducing environmental pollution and helps prevent respiratory problems that may arise from long-term exposure to silica sand.

In conclusion, this project was successfully concluded, the development of an organic abrasive powder for the Sand Blast process is fully usable, meeting the established objectives and making a positive impact on both the student community and the environment.

Box 14

Figure 11

Measurement of Pecan Shell Granules Using Seven Different Sieves

Image by author

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Box 15

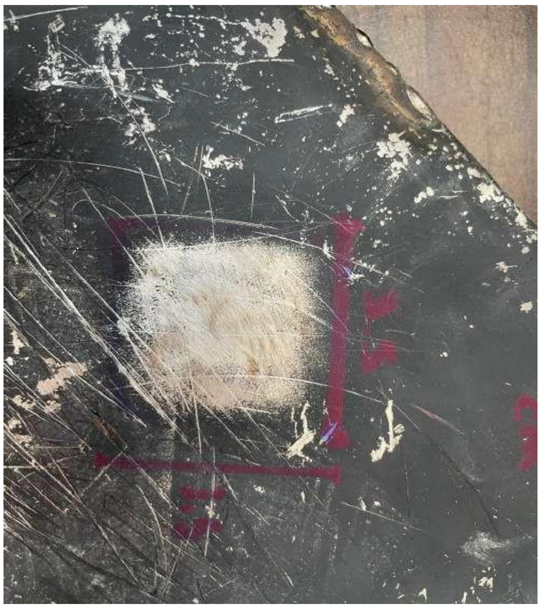

Figure 12
Sand-Blasting Results

Image by author

Declarations

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

García-Medina, Daniela: Contributed to the project idea, research method and technique.

Montúfar, Jesús: Contributed to experimentation and writing.

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Article

Implementation of a mechatronic system for the hydraulic automation of artificial wetlands

Implementación de un sistema mecatrónico para la automatización hidráulica de humedales artificiales

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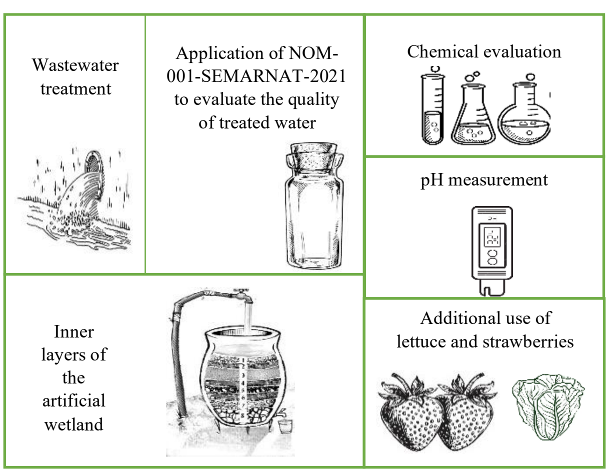
Abstract

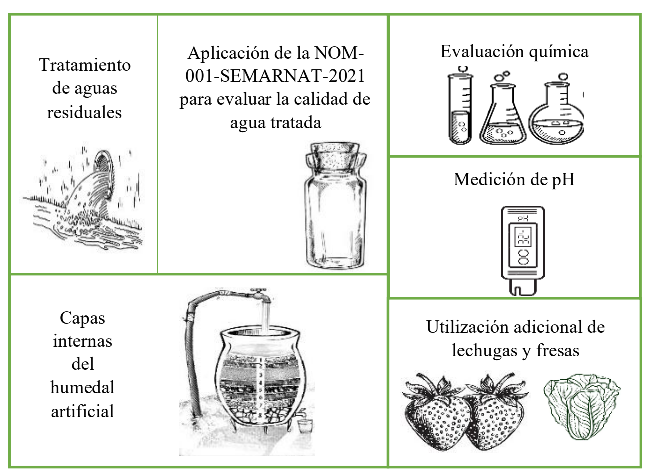
This paper presents the design and construction of a mechatronic system for the hydraulic automation of portable artificial wetlands. For the control system, on-off solenoid valves were used for hydraulic distribution, which were controlled by proportional-type sensors that provide a voltage level in relation to the moisture of the container. The system is based on three stages, composed of seven layers of filtering materials that retain solid sediments; simultaneously, the use of plants enabled the execution of the phytoremediation process, which integrally contributed not only to absorbing heavy metals and other water contaminants but also those present in the soil. The analysis conducted allowed for the evaluation of the performance of each plant within the artificial wetlands system. Additionally, the artificial wetlands were designed and conditioned with the intention of returning these treated waters to the environment. The water recovered from the treatment was evaluated based on the NOM-001-SEMARNAT standards, and the quality of the recovered water was determined according to various parameters and pH strips.



Mechatronic systems, Hydraulic, Artificial wetlands

Resumen

En este trabajo se presenta el diseño y construcción de un sistema mecatrónico para la automatización hidráulica de humedales artificiales portátiles. Para el sistema de control se usaron electroválvulas tipo on-off para la distribución hidráulica, las cuales fueron controladas por sensores del tipo proporcional, que entregan un nivel de voltaje con relación a la humedad del recipiente. El sistema está basado en tres etapas, compuestas por siete capas de materiales filtrantes que retienen los sedimentos solidos; simultáneamente, el uso de plantas permitió ejecutar el proceso de fitorremediación, lo que integralmente contribuyó no solo a absorber metales pesados y otros contaminantes del agua, sino también de aquellos presentes en el suelo. El análisis realizado permitió evaluar el funcionamiento de cada una de las plantas en conjunto de los humedales artificiales. También, se diseñó y se acondicionaron los humedales artificiales con la intención de devolver estas aguas tratadas al ambiente. El agua recuperada del tratamiento fue evaluada con base en la NOM-001-SEMARNAT y se determinó de acuerdo con varios parámetros la calidad de agua recuperada y con tiras de pH.



Sistemas mecatrónicos, Hidráulico, Humedales artificiales

Area: Advocacy and attention to national problems

Citation: Becerril-Zarate, Bianca Paola, Mastache-Mastache, Jorge Edmundo and López-Ramírez, Roberto. [2025]. Implementation of a mechatronic system for the hydraulic automation of artificial wetlands. Journal of Mechanical Engineering. 9[22]1-10: e2922110.

Introduction

Currently, in Mexico as in the world, there is a problem of water scarcity due to different factors such as the overexploitation of resources, the unequal distribution of the natural resources, climate change, as well as overpopulation, whose situation affects the quality of life of the society.

Nowadays, according to the water available in the world, 97.216% correspond to saltwater in seas and oceans, 2.135% to ice caps and 0.611% in the earth's crust. The percentage used for human activities is that found in the earth's crust; that is, it is fresh water that is used for human consumption [Guerrero, 2024]. Therefore, treating wastewater is a vital issue both in Mexico and in the world.

Domestic wastewater is that from human activity; that is, water from bathrooms and laboratories, which is a mixture of physical, chemical, and biological components [Osorio-Rivera, 2021]. Wastewater has the following characteristics: a dark gray or black color, unpleasant odor, surfactants that form foams, oils and fats [Ramos-Jiménez, 2021]. In Mexico there are 2,540 wastewater treatment plants which treate only 65.7% of the water collected throughout the country. This is due to factors such as the high cost of operation and maintenance [Casiano-Flores, 2022].

When facing the problem of water scarcity, natural wetlands are often an alternative for wastewater treatment. According to UNESCO, wetlands are defined as extensions of marshes, swamps, peat bogs, or surfaces covered with water, whose depth is not greater than six meters [Arteaga-Cortez, 2019]. On the other hand, HA are systems that aim to use the natural processes that occur in the environment, mainly involving the use of vegetation and supporting materials [Asprilla, 2020].

Phytoremediation is defined as a series of technologies that are based on the use of plants to clean or restore contaminated soils and waters; that is, damage is remedied by means of plants or vegetables [López-Hernández, 2022].

This project presents the creation of an artificial wetland, together with the use of phytoremediation.

The wastewater treatment was used to feed wetlands and then, the treated water was returned to the environment. This process was performed according to the NOM-001-SEMARNAT-2021 standard.

Materials and methods

This work was developed at the Technological Institute of Higher Studies of Jocotitlán, taking control samples from a septic tank whose water comes from bathrooms and laboratories of the institute.

Figure 1 Set of systems that make up the artificial wetlands system.

Box 1

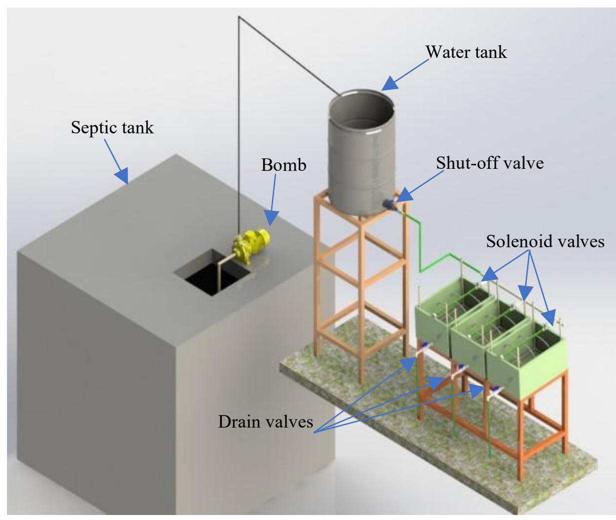


Figure 1
Structural design

Source: Own elaboration

Wastewater was obtained by pumping out it from the septic tank to a water tank by using a commercial ½ HP peripheral pump.

Storage tanks

The septic tank has a storage capacity of 1000 m^3. The tank that supplies the wastewater to the wetlands has a capacity of 200 liters and was placed at a height of 2.54 m from ground level.

The HA were made up of 3 containers with a capacity of 114 L, which also contain the set of layers that allow the treatment of wastewater.

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Irrigation system

To distribute the water within the wetlands, a drip irrigation system that prevents unnecessary losses of the liquid and focuses on distributing the water to the plants in a homogeneous way was fabricated. This system is shown in figure 2, which exhibits each component of it, where a ½” diameter pipe in all pipes that make up the system, as well as the connections that are required are shown.

Box 2

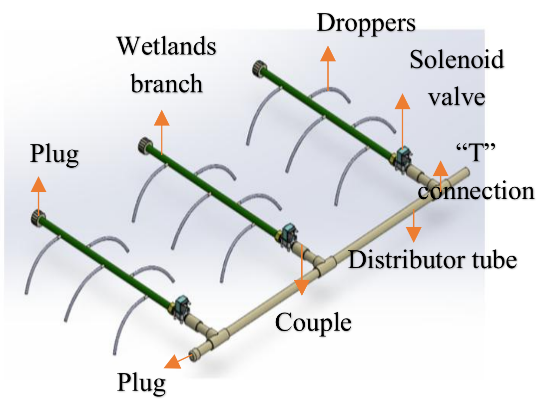

Figure 2
Wetlands Branch

Source: Own elaboration

The distribution pipe has the function of passing the water from the tank to the containers of the wetlands. Solenoid valves were used to have autonomous control in the system, allowing to regulate the incoming water and thus having a flow control within the wetlands.

The distribution of water inside of the wetland container was carried out by implementing a system that we called drip branches, whose function is to distribute, drop by drop, the water inside the container. The design of the drip branches was made using a flexible hose, perforating it along every 7 cm, to place in each hole a thin hose of 0.6 cm in diameter and 15 cm length. An internal pipe system was placed at the inside of the boxes where the HA was implemented. The purpose was to distribute the water that entered the HA and providing an outlet to the first layer of the wetland.

Figure 3 shows the parts that make up this pipe system, as well as the measurements used for its development.

Box 3

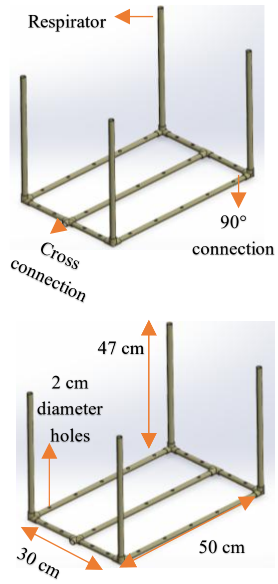

Figure 3
Lower pipe system

Source: Own elaboration

Likewise, this pipe has four vents with a height of 47 cm, whose function is to ventilate the layers that internally integrate the HA, and also, these layers filtered and separate organic waste.

Control system

An automatic electronic control circuit was developed to supply the wetlands with wastewater through an arrangement of solenoid valves that connect the drip system to the storage tank. For this, humidity sensors and a microcontroller were used to compare the reference voltage levels and achieve automatic activation of the system. This system is composed of the electrical elements shown in Figure 4, which are: power supply, control, humidity sensors, power system, interface and motor control.

Box 4

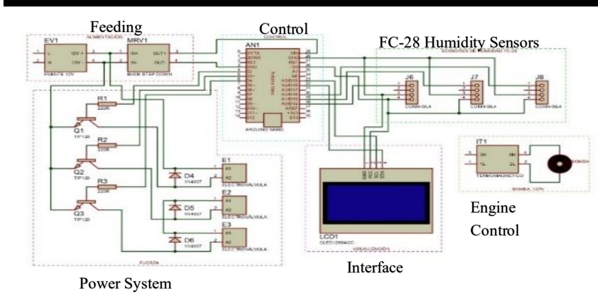

Figure 4
Electronic circuit of the control system

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Each of the elements that make up the electrical circuit are described below.

- ***Power Supply***

A switched power supply with thermal-magnetic isolation was used.

This transforms the 127 V AC line voltage to a 12 V DC voltage through a buck step down converter that delivers a voltage of 4 to 35 V with an electrical current of 3 A, which maintained a fixed voltage value of 5 V to feed the control devices.

- ***Control system***

The control system was developed by implementing an Arduino Nano programmable electronic board, allowing for an interconnection of the entire system, controlling the three signals emitted by the humidity sensors to the solenoid valves.

Electromechanical relays were used to control the solenoid valves, activating and deactivating them every time the humidity level drops to the reference level.

The humidity sensors were activated when they detected a low level of humidity in the layers that make up the artificial wetlands, allowing water to enter the wetlands.

Operation of the wastewater treatment system is described in the flow diagram shown in Figure 5.

The diagram begins with a starting point when the system is connected to the electric power; then the three humidity sensors are conditioned in an individual reading value less than 650 [in hexadecimal system].

According to the program, the humidity sensor exhibiting the lowest value will activate the solenoid valve.

The cycle will be repeated indefinitely until the humidity sensors reach the maximum humidity level.

Box 5

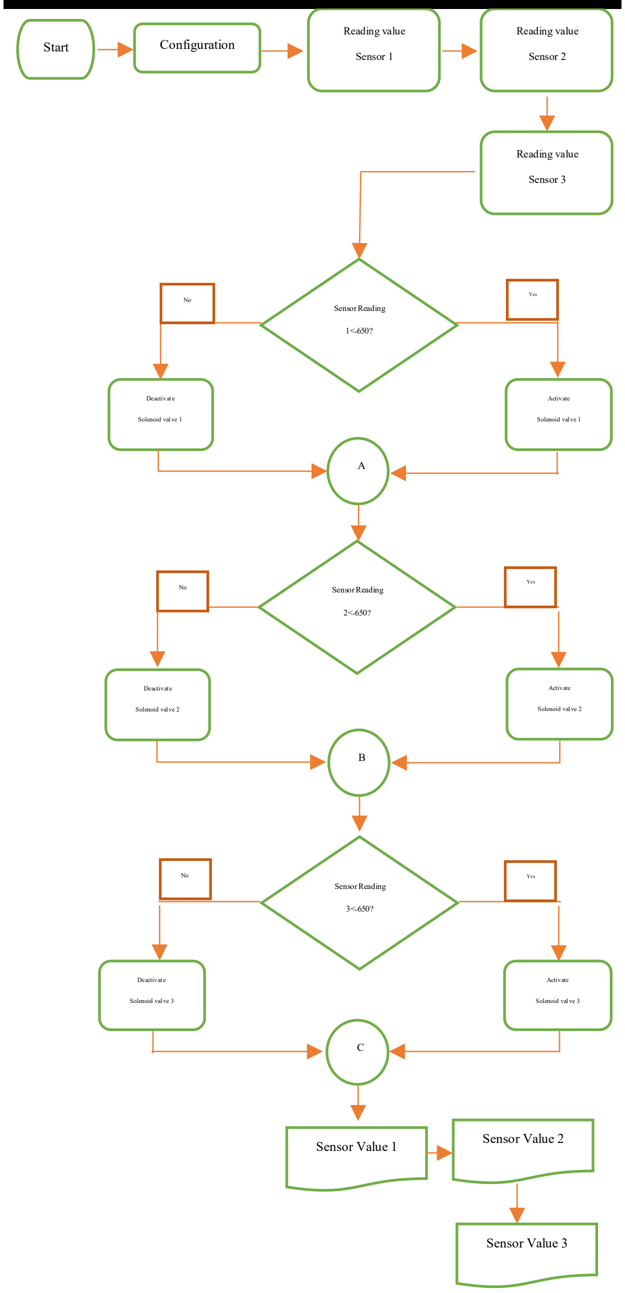

Figure 5

Arduino program flowchart

Source: Own elaboration

Construction of the artificial wetland

The internal composition of the HA filters consists of eight layers of various materials that allow the treatment of wastewater. These materials were selected to eliminate organic waste in wastewater treatment.

These layers are described in Figure 6, as well as listed from bottom to top, considering each section as a controlled separation process, with the following heights inside the vessels: layer 1-2: 1.5 cm, layer 3-6: 3.5 cm, layer 7: 20 cm and layer 8: up to the top of the vessel.

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Box 6

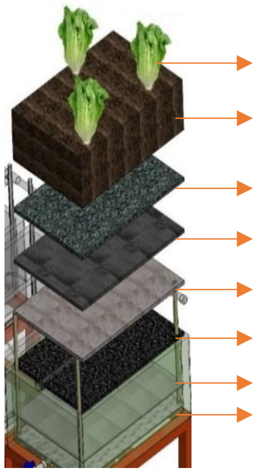

Figure 6
Internal composition of the HA
Source: Own elaboration

The function of each of the layers is described below:

Layer number 1. Cotton:

As shown in Figure 7, a layer of cotton is placed at the bottom of the container of the HA, which serves for retaining small particles, trapping impurities and suspended solids that remained from the above layers, thus improving the filtering process of water.

Box 7

Figure 7
Cotton cape
Source: Own elaboration

Layer number 2. Scalloped flannel:

A layer of scalloped flannel was placed inside the HA containers as shown in Figure 8, retaining particles and sediments that were not removed in the previous layers and avoiding to enter the last cotton layer. This is possible due flannel has porosities that stop entry of these contaminants, performing a deeper filtering.

Box 8

Figure 8
Scalloped flannel cape
Source: Own elaboration

Layer number 3. Activated carbon:

As shown in Figure 9, the activated carbon used in this layer was manually crushed to a dimension with a particle size of 20 mm. This layer aims to absorb organic compounds and various contaminants that can be toxic or produce color, odor or taste to the water, and also removes dyes [Vásquez-Gómez, 2024].

Box 9

Figure 9
Activated carbon layer
Source: Own elaboration

Layer number 4. Fine sand:

This layer is composed of fine sifted sand. The sifting process performed to the fine sand was based on separating commercial gravel on a mesh with particle size of 0.02 mm to 0.5 mm. The purpose of this layer is to retain solids that were not caught by the coarse sand layer, since the particles in this layer are smaller [Décima, 2024].

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Box 10

Figure 10
Layer of fine sand
Source: Own elaboration

Layer number 5. Coarse sand:

Figure 11 shows the layer of coarse sand that was placed inside the HA container. This layer is considered to form a mesh composed by particles in the range of 2-5 mm, which eliminate large particles and sediments [Décima, 2024].

Box 11

Figure 11
Layer of coarse sand.
Source: Own elaboration

Layer number 6. Gravel:

A layer of gravel was placed inside the HA as shown in Figure 12, with a particle size between 2-64 mm, responsible for retaining the contaminants that have passed from the soil layer and the plant roots [Décima, 2024].

Box 12

Figure 12
Gravel layer
Source: Own elaboration

Layer number 7. Soil:

The function of this layer is to retain suspended solid waste such as organic compounds, as well as heavy metals, as is in the process where sludge are employed. In future research, it is intended to perform chemical analysis on this layer. Commercial soil known as "milpa-soil", consisting of a proportion of a mixture of 70% black soil and 30% leaf soil was employed, providing nutrient-rich and well-drained soil, which also retains the necessary moisture, which benefits plant growth. Placing this layer depended on the characteristics of the plants to be planted.

Layer number 8. Plants:

Strawberry and lettuce seed were planted, plants for phytoremediation of the sludge with the aim of cleaning and restoring the residual water that remains on the surface of the wetland. It should be noted that these plants are not for human consumption, since they are being used to carry out the phytoremediation treatment.

A container with lettuce was used because it is a plant that is normally watered by a drip system, since it only requires water in its roots and not in the leaves [Loachamín-Oña, 2019].

According to research carried out on crops in Hidalgo, fecal coliforms enter the lettuce through the roots, absorbing from the sludge all those metals found in wastewater [Mejía-Peréz, 2023]. To carry out the planting of the lettuce, the seeds were placed 18 cm above layer number 6 and covered by 2 cm more soil.

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Two containers with strawberries were also included, considering that they are normally watered by keeping moist the soil and with the developed dripping system, this condition was met. Strawberries, having their roots or stems submerged, serve first as a substrate for the microbial community, significantly reducing the content of suspended solids, nitrogen levels and oxygen consumption. Subsequently, the plants themselves are responsible for assimilating, transforming and accumulating the different types of contaminants [Caballero-Castaño, 2022].

To plant the strawberry seeds inside the containers, they were placed at a height of 15 cm after layer number 6, to be subsequently covered by soil until completing 20 cm.

Box 13

Figure 13
Soil layer
Source: Own elaboration

Results

The physical construction of each of the artificial wetlands was starting by planting the lettuce and strawberry plants, respectively. It should be noted that wastewater was also used to irrigate the plants in an automated manner, as shown in Figure 14.

Box 14

Figure 14
Artificial Wetland System
Source: Own elaboration

The lettuces that were planted 12 along the container, which germinated in 7 days after planting; the growth of these leaves or seedlings developed in 14 days, for the vegetative growth 50 days were waited and the maturation period took 80 days. This was with the purpose of having mature plants as a control parameter within the HA.

The planting of strawberries per container was 6 days, the process was carried out 15 days after germinating them inside external flowerpots, to then put them inside the wetland containers. The transplant of the strawberries to the containers was carried out on day 16, to wait for the flowering that occurred 60 days after planting. The formation of fruits is understood as a maturation process and was 20 days corresponding to the flowering, lasting approximately 4 weeks.

Once the two types of plants were already in the maturation process, the HA were evaluated.

This process was carried out by collecting the water that entered the HA containers for a period of two consecutive weeks daily. The automatic control system was activated during a period of time from 09:00 am to 05:00 pm, noting that 10 liters of wastewater entered the wetlands daily at different times depending on the environmental conditions and the amount of humidity contained in the containers.

Each wetland processed the wastewater, producing 2 liters of treated water. In their sum, it was observed that the three wetlands together produced 6 liters of filtered water that exhibited a naked-eye clarification of the water samples, with respect to the original one, safeguarding a sample for each one, as well as the one at the entrance in previously disinfected and sterilized glass jars.

Figure 15 shows the collected samples, where the color of the three wetlands shows a light brown color corresponding to that of the sludge or sand layers of the wetland's active filter. The control water that enters the wetland is also shown, which has a greenish color, reflecting a high contamination of organic waste, the presence of algae or microorganisms that proliferate in wastewater.

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Box 15

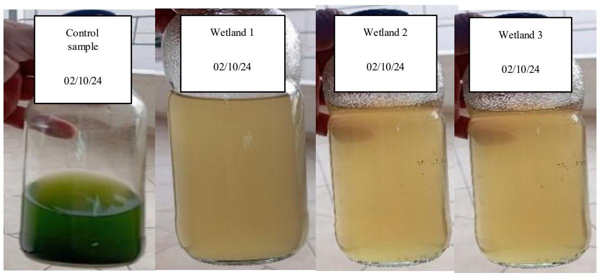

Figure 15
Control samples and samples recovered from artificial wetlands.
Source: Own elaboration

Below are the results of the tests carried out on the samples obtained from the artificial wetlands.

pH tests

pH measurement tests were carried out with indicative strips and with the Redlemon brand digital meter.

Table 1 shows the comparative tests carried out on both the wastewater as a control sample and the output from the artificial wetlands, which is the filtered water of one day.

Box 16
Table 1
pH measurements

	pH strips	Digital meter	Result
Control sample			9.41
Wetland 1			7.09
Wetland 2			6.75
Wetland 3			8.47

Source: Own elaboration

The control sample of the residual water presents a colorimetry corresponding to the bluish-green color on the pH indicator scale, corresponding to the pH level between 9 and 10.

Likewise, the test was carried out with the digital meter that corresponds to a value of 9.41 validating the synchrony of the results, this reflects that the water is in an alkaline state.

The sample collected from wetland 1 presents a corresponding colorimetry on the pH indicator scale between green, which corresponds to the pH level 7 according to the strip indicator.

Likewise, the test was carried out with the digital meter that corresponds to a value of 7.09 validating the synchrony of the results, reflecting that the water is in a neutral state.

The sample collected from wetland 2 shows a corresponding colorimetry on the pH indicator scale of light orange, which corresponds to the pH level 6. Likewise, the test was carried out with the digital meter that corresponds to a value of 6.75 validating the synchrony of the results, reflecting that the water is slightly acidic.

The sample collected from wetland 3 shows a corresponding colorimetry on the pH indicator scale of light green, which corresponds to the pH level 8. Likewise, the test was carried out with the digital meter that corresponds to a value of 8.47 validating the synchrony of the results, reflecting that the water is in a slightly alkaline state.

Chemical Analysis

This analysis was carried out in collaboration with the Chemical Engineering department of the Technological Institute of Higher Education of Jilotepec.

It was performed in accordance to the parameters established by the Mexican Official Standard NOM-001-SEMARNAT-2021, evaluating the elements of Phosphate, pH, COD and Nitrates.

Table 2 shows the results that were made both to the wastewater and to the control sample.

Box 17

Table 2

Chemical test result

ITEMS	Control sample	Wetland 1	Wetland 2	Wetland 3	Maximum permissible limit NOM-001-SEMARNAT 2021
Phosphate	20	22.7	12.1	16	21 mg/l
DQO	262	50	95	138	210 mg/l
Nitrates	150	30	57	40	10 mg/l

Source: Own

The Mexican Official Standard establishes within its parameters that the maximum permissible limit of Phosphate is 21 mg/l, in the case of the control sample the value obtained is 20 mg/l, in wetland 1 it is 22.7 mg/l, in wetland 2 it is 12.1 mg/l, in wetland 3 it is 16 mg/l, which denotes that the water recovered from wetland 1 is the one that is above the maximum permissible limit according to the Standard, exceeding contaminants.

The chemical demand of oxygen parameter [DQO], has a maximum permissible limit according to the NOM of 210 mg/l. In the case of the control sample, the value is 262 mg/l, which exceeds the amount of permitted contaminants; In the case of treated water from wetland 1, it is 50 mg/l, wetland 2 95 mg/l, wetland 3 138 mg/l, which means that the values obtained meet the standards established by the norm.

The parameter of Nitrates according to the Norm establishes that they must be found at a value of 10 mg/l, in the case of the control sample the value is 150 mg/l, in wetland 1 it is 30 mg/l, wetland 2 57 mg/l, wetland 3 40 mg/l, obtaining a removal of this parameter in wetland 1 of 80%, in wetland 2 of 62%, in wetland 3 of 73%, which indicates that according to the norm the permissible limit is not met, for which reason another filtering process must be considered to continue reducing the removal of Nitrates.

In addition, the analysis carried out deduces that the removal efficiency of the proposed treatment train is close to 80%, which shows that the wastewater treatment is efficient, but several parameters can be modified to improve the treatment.

Conflict of interest

The authors declare that they have no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the work described in this article.

Authors' contribution

Becerril-Zarate, Bianca Paola: Contributed with the idea of the project, the method and the research technique. Supported in the design of the field instrument. Performed the data analysis and systematization of results, as well as the writing of the article.

Mastache-Mastache, Jorge Edmundo: Corresponding author and analyzed samples, contributed to the writing of the article.

López-Ramírez, Roberto: Provided guidance on the approach, method, writing and sample collection.

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Abbreviations

A	Ampere
AM	Before noon
CM	Centimeters
DQO	Chemical Oxygen Demand
HA	Artificial Wetlands
HP	Horsepower
Mg/l	Milligrams per liter
MM	Millimeters
pH	Hydrogen Potential
PM	After noon
UNESCO	United Nations Educational, Scientific and Cultural Organization
V	Voltage
V AC	Alternating Current Voltage
V DC	Direct Current Voltage

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Article

Design and construction of a machine for destructive testing of reinforced concrete gantries based on rapid prototyping and AI

Diseño y construcción de una máquina para ensayos destructivos de marcos de concreto reforzado con base en prototipado rápido e IA

Rodríguez-González, José Miguel * [a] & Gómez-Arizmendi, Gabriela [b]

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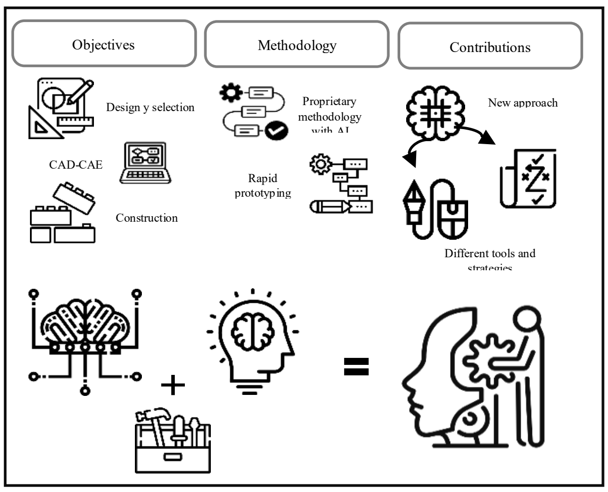
Abstract

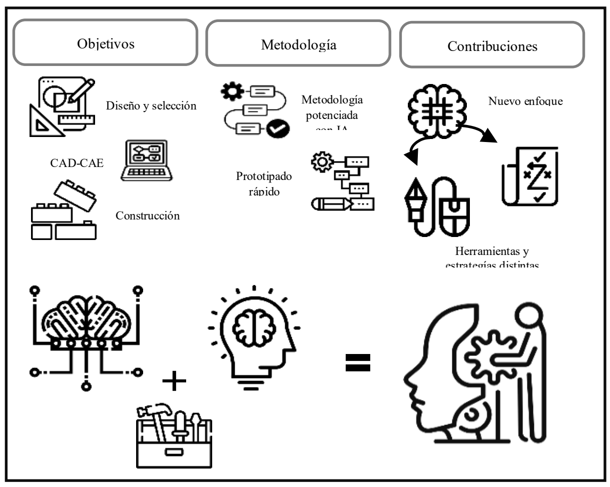
The study of the structural behavior of reinforced concrete is crucial in civil engineering to optimize designs and regulations. However, destructive testing machines present economic and operational limitations, making access difficult for institutions with limited resources. This work proposes the design and construction of a machine fabrication of modular and accessible components, while AI optimizes the methodology and provides possible application scenarios. This proposal aims to promote institutional research and improve academic experimentation processes for destructive testing of reinforced concrete frames, integrating rapid prototyping and artificial intelligence. Prototyping allows for the fabrication of modular and accessible components, while AI optimizes the methodology and provides possible application scenarios. This proposal aims to promote institutional research and improve academic experimentation processes.



Design, Method, Testing

Resumen

El estudio del comportamiento estructural del concreto reforzado es crucial en la ingeniería civil para optimizar diseños y normativas. Sin embargo, las máquinas de ensayo destructivo presentan limitaciones económicas y operativas, dificultando su acceso en instituciones con recursos limitados. Este trabajo propone el diseño y construcción de una máquina para ensayos destructivos de marcos de concreto reforzado, integrando prototipado rápido e inteligencia artificial. El prototipado permite fabricar componentes modulares y accesibles, mientras que la IA optimiza la metodología y brinda escenarios posibles de aplicación. Esta propuesta busca impulsar la investigación institucional y mejora los procesos de la experimentación académica.



Diseño, Método, Pruebas

Area: Promotion of frontier research and basic science in all fields of knowledge.

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Introduction

The study of the structural behaviour of reinforced concrete is a fundamental pillar in civil engineering, specifically in the design and analysis of resilient structures [Musab, et al., 2022].

Destructive testing of concrete structural frames allows the evaluation of critical parameters such as failure modes, ultimate strength and ductility, providing basic information for the development of standards and the optimisation of structural designs [Ebensperger & Donoso, 2021]. However, the machines used in these tests have limitations in terms of cost, size and versatility, making them difficult to access in academic and research institutions with limited resources, as is the case of the Tecnológico de Estudios Superiores de Valle de Bravo.

The development of advanced technologies, such as rapid prototyping and artificial intelligence [AI], are exploring new horizons to overcome these challenges. Rapid prototyping enables the agile manufacturing of components using techniques such as 3D modelling [CAD], 3D printing and CNC machining, significantly reducing production times and costs. These technologies not only make it possible to create customised models adapted to the specific needs of a project but also encourage the search for innovative geometries and designs [Khan, et al., 2023].

Artificial intelligence has proven to be a powerful tool for optimising design and operation processes [Habeeb, et al., 2023]. In the context of destructive testing machines, AI can be used to simulate loading scenarios, analysis and prediction of complex structural data and behaviour. This allows for improved testing accuracy, as well as optimising the performance and functionality of the equipment, adapting with the principles of sustainability and efficiency [Adewale, et al., 2024].

This work focuses on the design and construction of a machine for destructive testing of reinforced concrete frames that combine these emerging technologies, but with traditional manufacturing methods provided by the context.

While using rapid prototyping, it seeks to develop a modular and accessible design, while AI is incorporated to improve methodological accuracy, configured through a step-by-step analysis exercise for optimisation of the design process, reported in previous work by the authors. This comprehensive approach aims to provide a practical solution that facilitates structural research, especially in academic and laboratory settings. The development of this machine will promote an accessible and scalable approach to civil engineering research. Furthermore, by integrating modern technological tools, this project hopes to set a precedent in the evolution of testing equipment, contributing to scientific advancement and the improvement of structural safety in a context of increasing urbanization and construction demands [Muneeb, et al., 2021].

Background

In the field of structural engineering, destructive testing is a fundamental tool in the evaluation of the mechanical performance and strength of reinforced concrete under critical loading conditions. They not only allow the identification of structural capacity limits, but also facilitate the validation of theoretical models and the development of standards

The convergence of traditional design methodologies, rapid prototyping and the use of AI, establishes a new paradigm in the design and operation of machines in any field, with applications ranging from the validation of innovative materials to the study of the behaviour of complex structures, marking a significant advance in civil engineering research [Vishwanatha, et al., 2024; Rashid & Karim Kausik, 2024].

When studies must be carried out due to lack of specialised machinery, they can be subject to certain regulations that, while not strict in some areas, help to ensure that studies can be carried out with elements that can be constructed without much difficulty. In a study by Shu et al. [2020], they used field elements such as hydraulic jacks and steel anchors with concrete and ultrasonic sensors to obtain failure data for large-scale destructive testing of a reinforced concrete bridge slab, reporting accurate results, but doing a finite element analysis [FEA] with various types of context can help to further predict some of the results of the study.

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At BAUET in Bangladesh, they reported a concrete evaluation study using a combined methodology of standardised destructive and non-destructive techniques with field elements in a building, although they did not compare them using an integrative approach, forming a test method that improves and gives effective results [Mohshin, 2023].

In a study by Marquez and Meza [2020], they adapted a device for direct shear testing of concrete with a universal testing machine. Although the design does not show the machine capacity, they redefined the experiment to be able to test concrete in shear tests despite the limitations of the laboratory.

However, the current facilities of the institution do not have the elements, equipment, machinery, or adequate space for installation, the techniques discussed in the literature require tests that show accurate data, in which support is obtained based on the above, on the other hand the inspection of elements using guides with recommendations can be a way to strengthen the knowledge acquired, the intention of the design is to provide specimens that once fractured show flaws that can be identified through visual inspection, relying on the accepted and standardised processes [ACI, 2007; ACI, 2008; Ebensperger & Donoso, 2019].

Materials and Method

This paper shows the design and construction process of a machine for destructive testing of reinforced concrete frames. Rapid prototyping was used as the main methodology for the creation of components, which allowed to reduce the time and costs associated with traditional design. Materials such as structural steel were used for the main elements of the machine, along with accessible and easy-to-use components to ensure durability and accuracy during testing. Visual inspection of the elements using ACI-R8.1-07 was also considered.

The machine design process included simulation of the stresses to which the machine's load cell would be subjected, using computer aided structural analysis [CAE] tools. This approach allowed the proper selection of materials and component dimensions, ensuring component stability and efficiency, a methodology developed from Shigley and fed from AI [Figure 1].

The machine was designed to perform bending and compression tests, with the ability to withstand an impact load of approximately 310 N, but the impact energy can vary according to the height and if the weight of the element changes [steel cylinder] allowing its use on a wide variety of specimens and adjustable geometries [Xiao, 2020].

Box 1

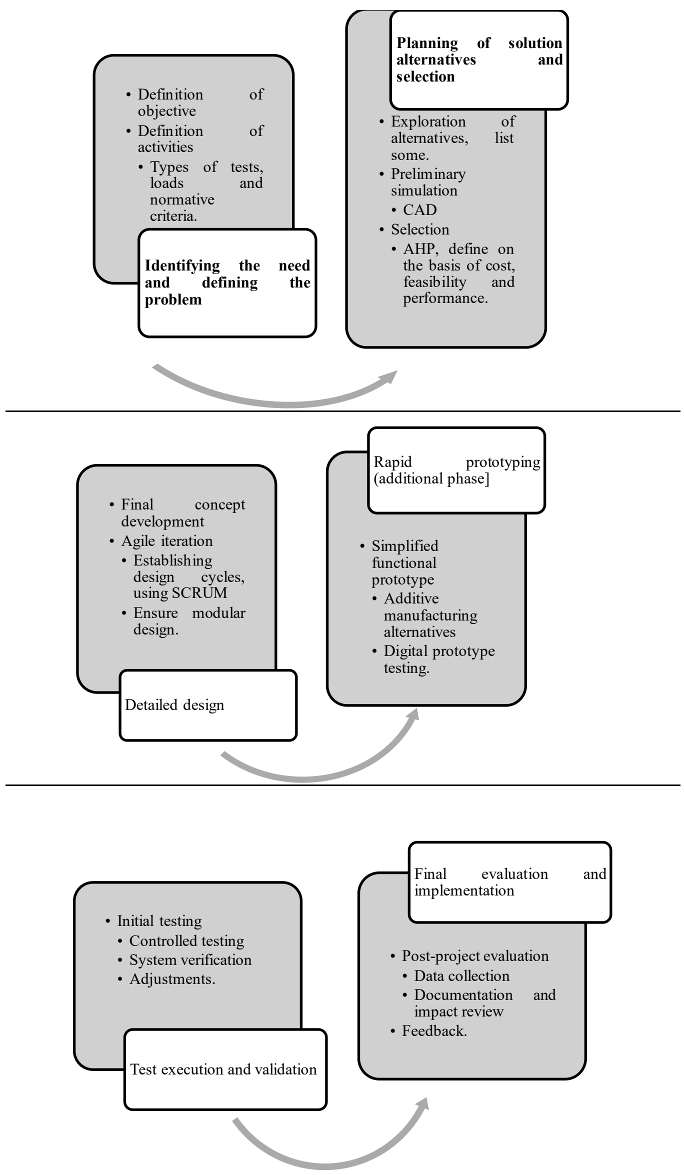

Figure 1
Design methodology adapted from Shigley and enhanced through GPT 4.0 based on designer feedback.

The elements that make up the machine were modelled using CAD software, SolidWorks 2024, the main support base [Figure 2] and the upper base to contain the load cell [Figure 3], once this was done, the load cell was modelled with elements accessible for construction and a pulley mechanism [Figure 4].

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Box 2

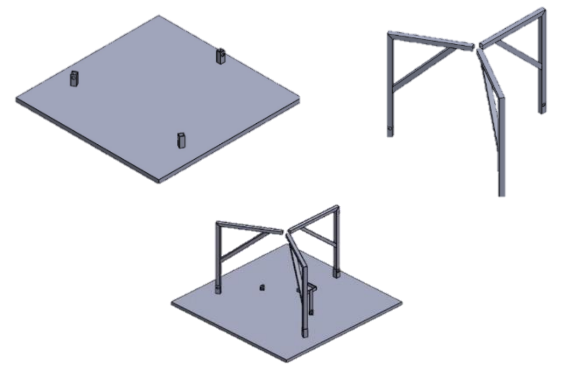

Figure 2
Main base and supporting structure
Source: Own elaboration

Box 3

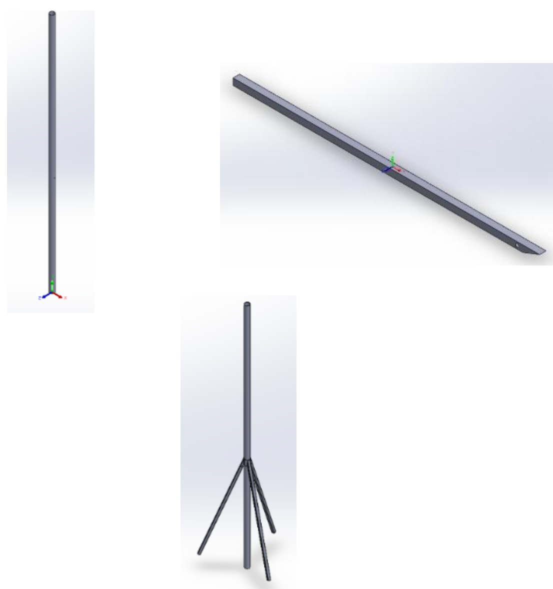

Figure 3
Top base of the load cell
Source: Own elaboration

Box 4

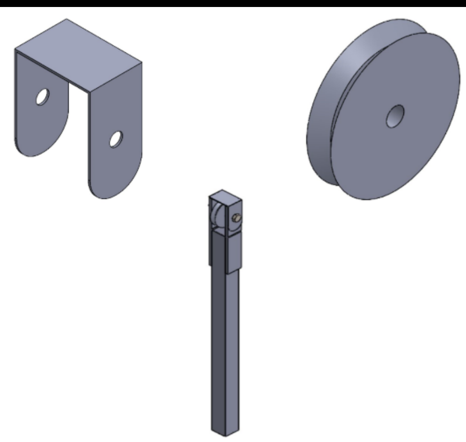

Figure 4
Load cell elements [pulley and upper support]
Source: Own elaboration

The selection of the material was ASTM A513 steel due to its easy accessibility and malleability to obtain the pieces, it was acquired in the following presentations for what was to be done [Table 1]:

Box 5

Table 1
Characteristics of selected materials

Element	Material
Base of the device	1in plate, with dimensions of 1x1m
Supporting and fastening elements between base and load cell	1in square PTR profile, different sizes
Fasteners between PTR profile, plate and tube	Sill of $\frac{3}{16}$ in
Upper load cell	Tubular of $60mm$, a stretch of $3m$
Load cell pulleys	2 pulleys of $2x\frac{1}{2}in$
Load cylinder	Steel cylinder of $50mm$, section of $500mm$.
Clamping bolts	Screws of $\frac{1}{4}x2$ in long

Source: Own elaboration

Subsequently, at the designer's discretion, a more unfavorable element was chosen because it would be in contact with the elements of the load cell subjected to elementary loads, so a finite element analysis [FEA] was performed in the same way in SolidWorks 2024, obtaining positive results, the selected material is ASTM A513 steel, taking as reference the equivalent AISI 1020, weldable structural steel, supported the reported loads of 100kg of the upper load cell, i.e. 981N, distributed in three supports uniformly, we have 327N, referenced to the equivalent area of 1 m2, so 327 N/m2, this element is embedding the fastening element, the steel plate of 1 in [Figure 5].

Results

The results obtained are translated into the reported maximum displacement of 6.547 mm, however, after this was made the addition of a tubular interior that makes up the load cell, which simulated is reflected in the embedment of the element at the other end, performing a second analysis [Figure 6], where the maximum displacement becomes 2.575x10-2mm, reducing 99.6% the displacement is exaggerated to locate where the element will be affected, however, it is minimal given the stresses to which it will be subjected.

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Box 6

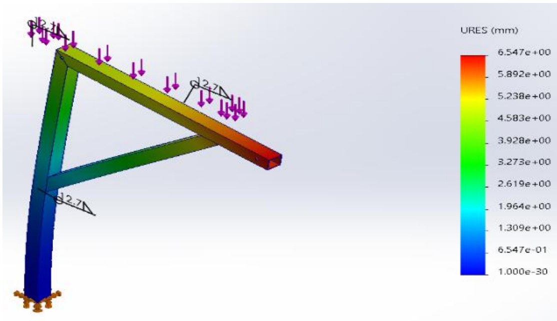

Figure 5

FEA of the worst-case element, displacement analysis

Source: Own elaboration

Box 7

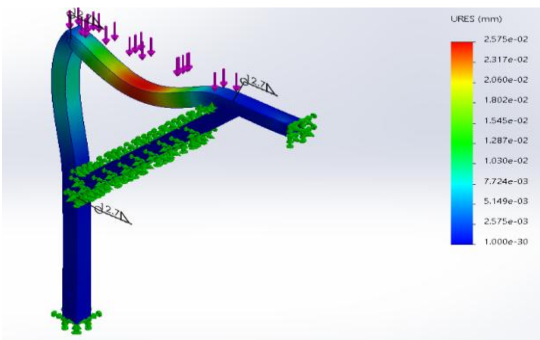

Figure 6

FEA of the worst-case element with new fasteners to improve the displacement condition

Source: Own elaboration

The elements developed for the assembly of the machine were manufactured using conventional processes, cutting and welding, in addition to including bolted joints to achieve disassembly and versatility of the elements.

The fabricated elements are shown in the design sequence, the base and elements for supporting and holding the specimens [Figure 7] and their assembly [Figure 8], the load cell elements, pulley and load cylinder [Figure 9] and the load cell assembly [Figure 10], and finally the assembly of the complete device [Figure 11]. Once assembled, different non-significant tests were performed with some concrete frames, only to evaluate the functionality of the machine and the elements that integrate it, so the fractures of the frames were not evaluated based on the standard, this will be reported in a later work, and a DoE and controlled variables will be used, which will deepen the adaptability of the machine to an environment of greater control, parametric evaluation of variable and normative standardization.

Box 8

Figure 7

Lower support elements

Source: Own elaboration

Box 9

Figure 8

Lower set of elements integrated into the base of the structure

Source: Own elaboration

Box 10

Figure 9
Set of load cell elements
Source: Own elaboration

Box 11

Figure 10
Assembled load cell with integrated elements
Source: Own elaboration

Box 12

Figure 11
Assembled device
Source: Own elaboration

Conclusions

The design and construction of a machine for destructive testing of reinforced concrete frames represents a significant advance in structural research, especially in academic environments with limited resources.

The integration of emerging technologies such as rapid prototyping and artificial intelligence allows not only optimising production times and costs, but also improving the accuracy and functionality of the equipment [Gao, et al., 2024].

Combining traditional manufacturing methods with technological innovations offers an accessible and scalable approach, promoting civil engineering research. It is also the precursor to having the ability to perform bending and compression tests in various geometries ensures its versatility and applicability in different experimental contexts. This development not only contributes a step forward in academic and educational advancement, but also sets a precedent in the evolution of testing equipment, encouraging a more efficient and sustainable approach to structural analysis, using traditional methods and combining emerging technology at appropriate stages [Rane, et al. 2024].

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The next step of the research will be to conduct a DoE that tests the versatility of the device with reinforced concrete specimens and where each variable provided is observable and measurable.

Declarations

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

Rodríguez-González, José Miguel: Contributed with the original idea, planning of activities and design, manufacture and construction of the machine.

Gómez-Arizmendi, Gabriela: Contributed with the original idea of operation, selection of elements, verification of the quality of the elements and improvement work.

Availability of data and materials

The data generated are in the custody of the Tecnológico Nacional de México/TES Valle de Bravo, where they can be made available on request to the corresponding author's email address.

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Abbreviations

ACI	American Concrete Institute
AI	Artificial intelligence
AISI	American Iron and Steel Institute
ASTM	American Society for Testing and Materials
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CNC	Computer Numerical Control
DoE	Diseño de Experimentos
FEA	Finite Element Analysis
TESVB	Tecnológico de Estudios Superiores de Valle de Bravo

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Article

Polynomial regression model for the prediction of thermal efficiency in spark ignition engines operating with ethanol-water mixtures

Modelo de regresión polinomial para la predicción de eficiencia térmica en motores de encendido por chispa operando con mezclas de etanol y agua

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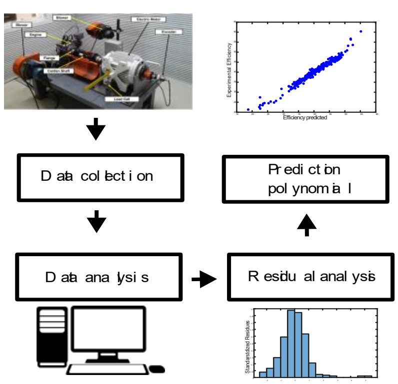
Abstract

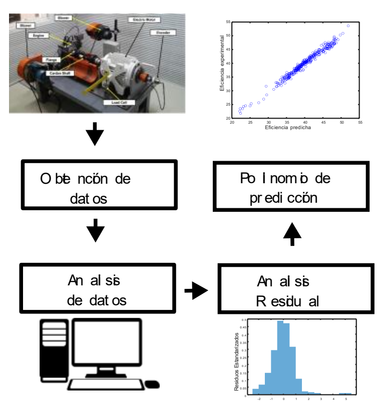
The present work aims to propose a polynomial model $y = P(V_1, V_2, \ldots, V_n)$ capable of predicting the thermal efficiency $[y]$ of a single cylinder spark ignition reciprocating engine that uses ethanol and water mixed as fuel at various proportions and speeds. The independent variables used in the development of the polynomial model are: V_1= water fraction, V_2 = rotation speed [rpm], V_3 = compression ratio, V_4 = ignition advance angle [°BTDC], V_5 = fuel temperature [°C], V_6=exhaust temperature [°C], V_7=oil temperature [°C], V_8=engine torque [Nm], V_9=fuel consumption [g/s] and V_{10}=power [kW] and V_{11}=specific fuel consumption [g/kWh]. A determination coefficient R^2= 0.9785 was obtained, which indicates that the polynomial model obtained can predict the behavior of thermal efficiency with an accuracy of 97.85%. The database used in this work is from the authors Torres, Mendes and Alburquerque [2024].



Polynomial model, Hydrated ethanol, Thermal efficiency

Resumen

El presente trabajo tiene como objetivo proponer un modelo polinomial $y = P(V1, V2, \ldots, Vn)$ capaz de predecir la eficiencia térmica $[y]$ de un motor reciprocante de encendido por chispa de un solo cilindro que utiliza etanol y agua mezclados como combustible en diversas proporciones y velocidades. Las variables independientes usadas en el desarrollo del modelo polinomial son: V_1 =fracción de agua, V_2= velocidad de rotación [rpm], V_3 = relación de compresión, V_4 = ángulo de avance del encendido [°BTDC], V_5 = temperatura del combustible [°C], V_6 = temperatura del escape [°C], V_7 =temperatura del aceite [°C], V_8 = par motor [Nm], V_9 =consumo de combustible [g/s] y V_{10}= potencia [kW] y V_{11} =consumo específico de combustible [g/kWh]. Se logro obtener un coeficiente determinación R^2 = 0.9785, lo que indica que el modelo polinómico obtenido puede predecir el comportamiento de la eficiencia térmica con una exactitud de 97.85%. La base de datos ocupada en este trabajo es de los autores Torres, Mendes y Alburquerque [2024].



Modelo polinomial, Etanol hidratado, Eficiencia térmica

Area: Promotion of frontier research and basic science in all fields of knowledge.

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Introduction

Growing demand for fuels, combined with environmental care efforts, has led to study, creation, and improvement of petroleum-based and alternative fuels. In order to reduce environmental impact and, in turn, improve efficiency [Secretaría de Energía, 2024].

[El-Faroug et al., 2016]. It states that a high ethanol content in gasoline-ethanol blend produces positive results in combustion duration, temperature, and engine performance. This was achieved by blending ethanol in a 70% ethanol, 30% water [E70W30] ratio, which was added to primary fuel.

Similarly, an experimental analysis conducted by [Chaudhary & Subramanian, 2022] used pure ethanol [E100W0] as primary fuel, without blending with water, ethanol showed superior thermal behavior compared to another fuel [methanol], highlighting its higher cumulative heat release and higher calorific value, which has a direct impact on engine's energy performance.

Increasing interest in alternative fuels presents a problem when analyzing the behavior of spark ignition engines, technical complexity of experimental work limits data collection, predictive models [regression models and statistical methods] are an effective method to determine states of experimental systems in extreme or non-replicable conditions as referred to by authors, [Torres, Mendes, & Albuquerque, 2024, El-Faroug et al., 2016]

Complexity in replicating experimental analyses leads to the creation of methods to predict behavior of fuels in different states, Dey, Singh, Gajghate, Pal, Saha, Deb and Das [2023], using statistical regression methods.

Altınışık, Nigiz, Gürdal et al [2025] conducted a study for creation of bioethanol from molasses under different conditions, determined a polynomial model from multivariate regression. Using determination constant [R^2] and response analysis methodology [RMS], a polynomial is found that predicts bioethanol production efficiency under different conditions.

In a compression-ignition engine, Dey, Singh, Gajghate, Pal, Saha, Deb and Das [2023] obtained a polynomial model that predicts thermal efficiency of blends of biodiesel and various alcohols, like ethanol, and concluded that it yields a positive impact on emissions and performance.

In Mądziel [2024], prediction of emissions from old cars is validated using similar methods, including plots of actual and predicted values, histograms of residuals, and Q-Q [quartilequantile] plots.

Experimental equipment

This analysis is based on experimental equipment presented by Torres, Mendes, and Albuquerque [2024], which describes a series of modifications to fuel mixture by adding water fractions, speeds, and compression factors to a stationary single-cylinder Otto cycle engine. Figure 1 shows the position of the sensors and configuration of equipment used for measurement.

Experimental analysis was conducted employing tests on a Honda GX160 OHV single-cylinder spark ignition engine, which was modified by installing an electronic injection system to perform tests.

In the engine assembly, a 19-tooth phonic wheel and a throttle position sensor were installed. Two thermocouples and a gravimetric scale were placed on the engine injection line to measure fuel temperature and consumption.

Dynamometer bench with an enconder was installed on the crankshaft, moreover, an intake air installed temperature sensor and two oil temperature sensors were positioned on the engine crankcase and Lambda sensor, via a probe, was installed near exhaust outlet, and a thermocouple sensor was installed to measure temperature at an emission outlet.

All above sensors were connected to the experimental controller.

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Box 1

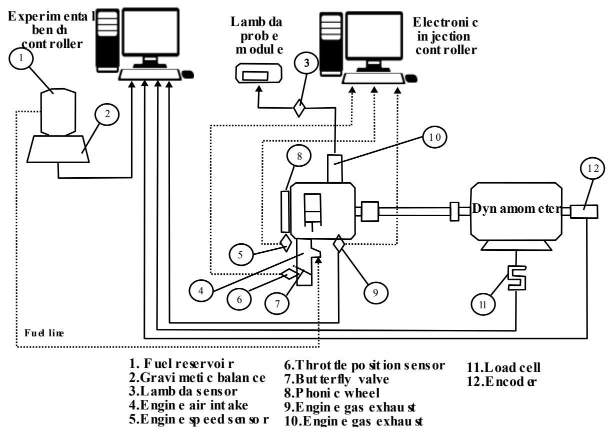

Figure 1

Schematic experimental bench

Source: Torres, D. J. G., Mendes, A. de S., & Albuquerque, C. [2024]. Performance and emissions data of an internal combustion engine operating with different ethanol/water mixtures and compression ratios

The general description of the parameters can be divided into three sections: controlled, measured, and calculated parameters. Controlled parameters, which directly affect the system measurements are

- Water Fraction: Proportion water-fuel mixed, [0-1].
- Compression Ratio: ratio of the maximum volume of the combustion chamber to the minimum volumen, [7.4 – 9.4].
- Rotacional speed: number of engine crankshaft revolutions per minute, [RPM].

Parameters measured by sensors are

- Ignition avance angle [BTDC]: Moment of combustion of fuel when it comes into contact with spark plug and before it reaches end of stroke [°BTCD].
- Fuel temperature: fuel mixture temperature,[°C].
- Exhaust Temperature: engine exhaust gas outlet temperatura, [°C] .
- Oil Temperature: Engine oil temperature during operation, [°C].
- Torque: Engine crankshaft torque, [N·m].
- Fuel Consumption: Fuel consumption rate [g/s]

Parameters are calculated through the measured independent variables.

- Power: Mechanical power generated by motor [kW].
- Specific Fuel Consumption: Amount of fuel consumed by engine to produce one kilowatt-hour, [g/kW].
- Efficiency: Useful work produced and total energy contributed by fuel-water mixture, [%].

Box 2

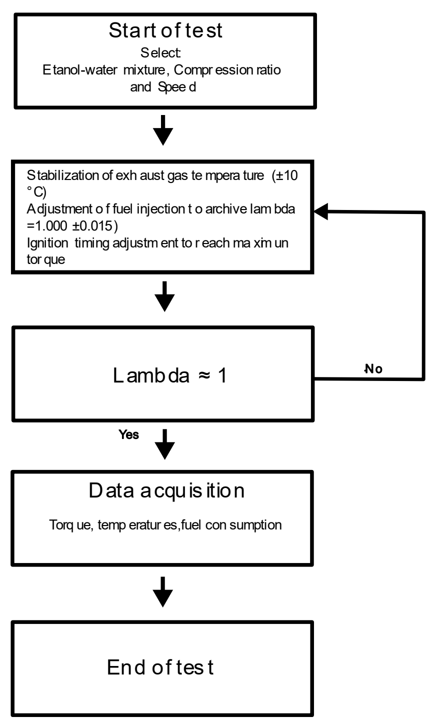

Figure 2

Operation flowchart

Source: Own elaboration

In Figure 2 a flowchart illustrates data collection mode used in this configuration. In this study we will focus on the thermal efficiency of engine emissions data except for temperature will be discarded. A comprehensive description of the procedure can be found in Torres, Mendes, and Albuquerque [2024] .

Methodology

Data obtained from experimental analysis are presented in Table 1, which includes notations and ranges of each variable

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Box 3

Table 1

Variables and intervals obtained from experimental analysis.

Variable	Interval	Notation
Water Fraction	0:0.50	V_1
Rotational Speed [rpm]	2000:4000	V_2
Compression Ratio	7.4400:9.4400	V_3
Ignition Advance angle [°BTDC]	20:75	V_4
Fuel Temperature[°C]	29.50:37.50	V_5
Exhaust Temperature[°C]	435.80:767.50	V_6
Oil Temperature [°C]	63.90:166.10	V_7
Torque [Nm]	5.70:12.50	V_8
Fuel Consumption [g/s]	0.2100:1.2600	V_9
Power [kW]	1.7593:5.2360	V_{10}
Specific Fuel Consumption [g/kWh]	309.7069:1.8048e^3	V_{11}

Source: Own elaboration

To determine a polynomial $y = P[V_1, V_2, \dots, V_n]$ that describes behavior of thermal efficiency $[y]$ of a single cylinder spark ignition reciprocating engine that uses anhydrous ethanol when it is subjected to variations such as fractions of water mixed with fuel [0%-50%], rotational speeds [2000- 4000 rpm], and compression ratios [7.44:1 and 9.44:1] several combinations of the independent variables $V_1, V_2, \dots, V_n$ are performed to determine model coefficients and degree, which can represent a polynomial. In our case, we consider that the polynomial model is of the form

$$y = E_f = P(V_1, V_2, \dots, V_n) + \varepsilon \qquad [1]$$

Where E_f is experimental thermal efficiency, P is a polynomial described by the independent variables $[V_1, V_2, \dots, V_{11}]$ shown in Table 1, and ε are residuals or measurements error which are considered a random variable with a standard normal distribution, i.e., with a mean of zero and constant variance. This assumption will be substantiated in residual analysis section.

Methodology is analogous to that proposed by Escobedo-Trujillo et al. [2014], in which a polynomial was determined using system operating variables to predict the energy yield or coefficient of performance [COP]. Quality of the regression was assessed using the determination coefficient R 2 following same hypothesis proposed in this study. Polynomial obtained is described by the set of predictor variables A defined in our case of the following manner

$$A = \{V_1, \dots, V_{11}, V_iV_j, V_iV_jV_k, V_iV_jV_kV_l, V_iV_jV_kV_lV_m | i = 1, \dots, 11; j = i, \dots, 11; k = j, \dots, 11; = k, \dots, 11; m = l, \dots, 11\} \qquad [2]$$

The procedure consists of empirically testing different combinations of elements of the set A to construct a polynomial, then the coefficient of determination R^2 is calculated between the polynomial $y = P[V1, V2, V3, \dots, V11]$ obtained and the experimental thermal efficiency E_f, seeking that the coefficient of determination has a value greater than 0.96 and the residual error ε converges to zero since this would imply that the thermal efficiency is modeled by the polynomial P, i.e., $E_f = P[V1, V2, V3, \dots, V11]$. In fact, note that if $\boldsymbol{E}$ denote the expected value, then taking expected value in both sides of [1] it obtained

$$y = E_f = \boldsymbol{E}[P(V_1, V_2, \dots, V_{11})] + \boldsymbol{E}[\varepsilon]$$

$$= P(V_1, V_2, \dots, V_{11}) + \boldsymbol{E}[\varepsilon]$$

Since the expected value of a constant is the same constant. Therefore, if $\boldsymbol{E}[\varepsilon]$ converges to zero

$$y = E_f = P(V_1, V_2, \dots, V_{11})$$

Results

The polynomial model with a coefficient of determination R^2 value higher than 0.96 found using the procedure mentioned in the methodology section is

$$E_f = 54.8401(V_1V_2) + 0.0123(V_1^2V_2^2V_5^2) - 6.3836x10^{-6}(V_1V_5V_7)^2 + 3.9437x10^{-6}(V_3^4V_6V_{10}) - 2.1825x10^{-7}(V_3V_7V_{11}) - 6.0404x10^{-5}(V_3^4V_8)^2 + 1.4041x10^{-9}(V_9V_{10}) - 3.2762(V_7V_{10}) + 0.0205(V_8V_9V_{11})^3 + \varepsilon \qquad [3]$$

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With a coefficient of determination, $R^2 = 0.9785$, indicates that the polynomial model explains 97.85% of variation in thermal efficiency of fuel and its variables. Figure 4 shows the thermal efficiency modeled by the polynomial [3] and the experimental thermal efficiency. As can be note the E_f modeled by the polynomial vs experimental E_f form a line indicating a good fit.

Box 4

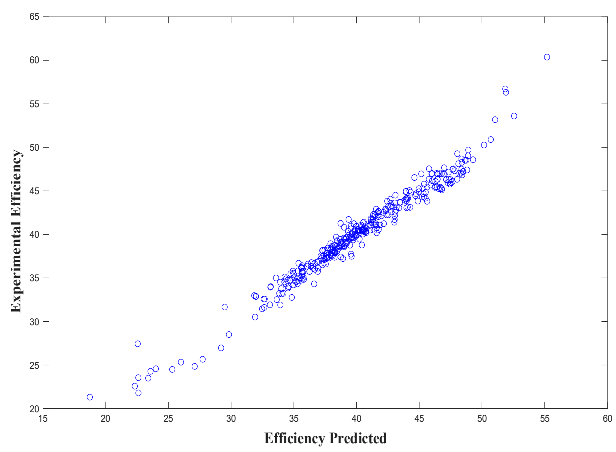

Figure 3
Predicted vs. Experimental effciency
Source: Own elaboration

Residual analysis

Residual analysis method enables us to determine variability of ε, which allows us to assess the quality of regression used.

To check that $\boldsymbol{E}[\ \varepsilon]$ is approximately zero, the standardized residuals with and without outliers were graphic in Figure 4. Outliers are points that are ± 3 standard deviations away from mean.

As can be seen in Figure 4[a], there are outliers outside three positive standard deviations which found only represent 1% of points, without, these are considerable for the increase of R^2, when debugged, show that all localized residuals are within three standard deviations, as shown in Figure 4[b].

Box 5

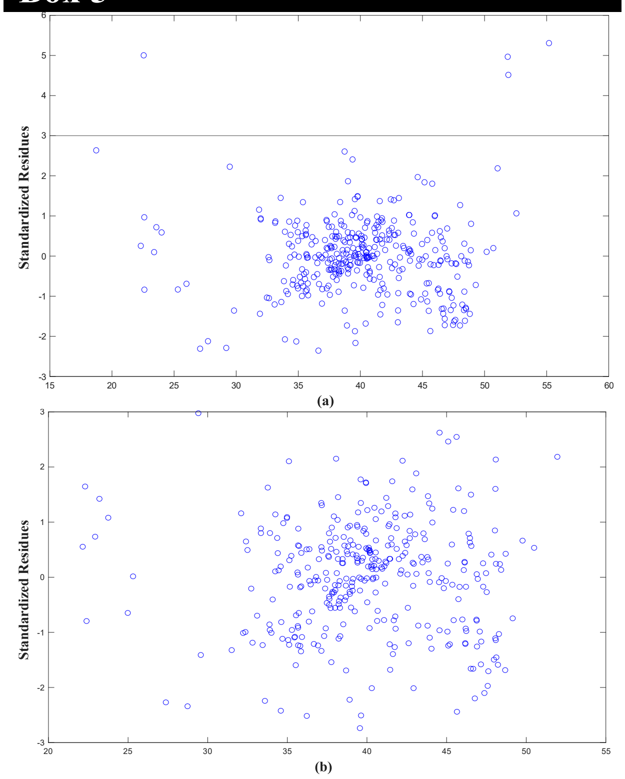

Figure 4
Standardized residuals with [a] and without [b] outliers
Source: Own elaboration

Mean and variance obtained also showed changes; when presenting outliers in residuals, mean and variance were -2.9606e-17 and 0.9548, respectively.

Even so, the $\boldsymbol{E}[\ \varepsilon]$ is approximately zero ensuring that the proposed polynomial model [3] fits well to the experimental thermal efficiency data.

Graphically also it was obtained the standardized residuals histogram [a] with and [b] without outliers. Figure 5 [a] shows the standardized residuals histogram with outliers and Figure 5 [b] shows the standardized residuals histogram without outliers, in both cases the histograms can represent characteristic shape of a standard normal distribution, this supports assumptions about what ε is a random variable with normal distribution, i.e., $\boldsymbol{E}[\ \varepsilon] = 0$ and variance of ε approximately 1.

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Box 6

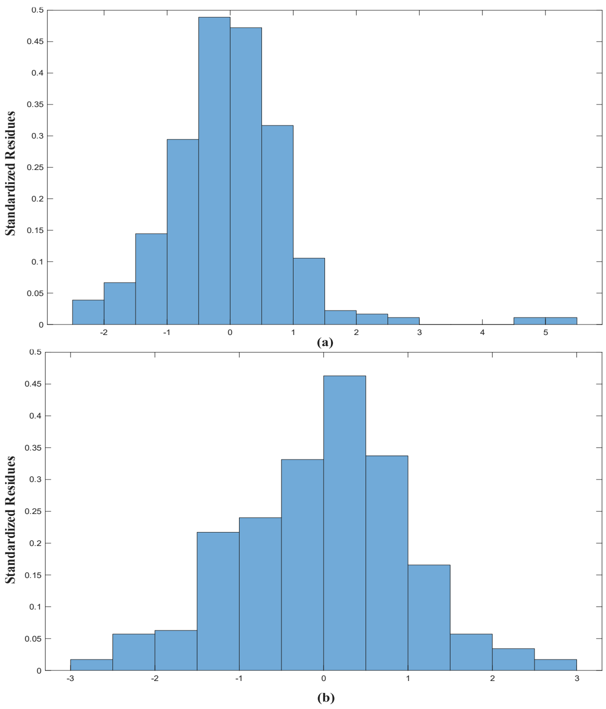

Figure 5
Standardized residuals histogram [a] with and [b] without outliers
Source: Own elaboration

Conclusions

This study proposed a polynomial model that predicts thermal efficiency of ethanol-water mixes in a spark ignition engine. The goodness of fit was obtained with the coefficient of determination with a value of $R^2 = 0.9785$ and graphically. Was found that E_f modeled by the polynomial vs experimental E_f form a line in and that ε is a random variable with normal distribution, i.e., $\boldsymbol{E}[\varepsilon] = 0$ and variance of ε approximately 1.

Results enables us to determinate the state of ethanol efficiency by varying the thermal and mechanical data both the mixed fuel and speed variations, allowing for manipulation of variables, thus managing to determine greater efficiency results for a more exhaustive study. allowing a study of both limitations and scopes of alternative fuel used, the method can be replicated to know same state applied to various alternative fuels such as methanol.

This study was limited by quantity and quality of measurements obtained in experimental analysis; replication of method with more fuels and alternatives fuels is encouraged.

Declarations

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article

Author contribution

Camacho-Catemaxca, Erik G: Was responsible for results interpretation, figure preparation, and drafting the initial manuscript.

Escobedo-Trujillo, Beatris A: Participated in style correction, grammatical review, and final text adaptation to editorial guidelines.

Alaffita-Hernandez, Francisco A: Implemented the algorithm programming, study conceptualization, contributed to methodological development, and participated in results validation.

Herrera-Romero, Jose Vidal: Contributed to manuscript editing, technical content review, and methodological coherence.

Availability of data and materials

Given the nature of this work, the data collected were made available.

Funding

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Abbreviations

R^2	Coefficient of determination
$\boldsymbol{E}$	Expected value
ε	Residuals
E_f	Thermal efficiency

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Antecedents.

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Basics

Torres, D. J. G., Mendes, A. de S., & Albuquerque, C. [2024]. Performance and emissions data of an internal combustion engine operating with different ethanol/water mixtures and compression ratios. *Data in Brief, 54*, 110390.

Supports

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Article

Innovative design of a compact conveyor for medium loads and high production

Diseño innovador de transportador compacto para cargas medias y alta producción

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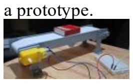
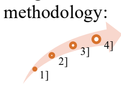
Abstract

This work develops and validates the mechanical design of a conveyor belt for loads up to 50 kg, considering real-world conditions and specific dimensions. Structural calculations were performed to ensure strength and stability. Finally, a functional prototype confirmed the design's viability, reinforcing the practical application of mechanical design knowledge.

Diseño innovador de transportador compacto para cargas medias y alta producción

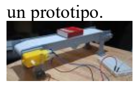
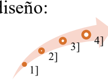
Objetives	Methodology	Contribution
Perform the mechanical design of a conveyor belt for handling loads up to 50 kg, considering normative, structural and functional criteria; validated through the construction of a prototype. 	Applied research, with a mixed-methods approach and explanatory information management. The project was developed using the following design methodology:  1] Problem clarification, 2] Conceptual design, 3] Preliminary design, 4] Detailed design.	Technological contribution in the area of mechanics and mechatronics, integrating CEMA-DIN standards, structural analysis, fatigue, energy efficiency and advanced detection, validated with a prototype, significantly improving reliability and industrial productivity.

Compact conveyor, automation, mechanical design.

Resumen

Este trabajo desarrolla y valida el diseño mecánico de una banda transportadora para cargas de hasta 50 kg, considerando condiciones reales y dimensiones específicas. Se realizaron cálculos estructurales para asegurar resistencia y estabilidad. Finalmente, un prototipo funcional confirmó la viabilidad del diseño, fortaleciendo la aplicación práctica de conocimientos en diseño mecánico.

Diseño innovador de transportador compacto para cargas medias y alta producción

Objetivos	Metodología	Contribución
Realizar el diseño mecánico de una banda transportadora para el manejo de cargas de hasta 50 kg, considerando criterios normativos, estructurales y funcionales; validados mediante la construcción de un prototipo. 	Investigación aplicada, con enfoque mixto y manejo de información explicativo. El proyecto se desarrolló con la metodología de diseño:  1] Clarificación del problema, 2] Diseño conceptual, 3] Diseño preliminar, 4] Diseño detallado.	Aportación tecnológica en el área de la mecánica y mecatrónica, integrando normativas CEMA-DIN, análisis estructural, fatiga, eficiencia energética y detección avanzada, validada con un prototipo, mejorando significativamente la confiabilidad y productividad industrial.

Transportador compacto, automatización, diseño mecánico.

Area: Promotion of frontier research and basic science in all fields of knowledge.

Citation: Martínez-Torres, Rosa Elia, Mendoza-Razo, Juan Arturo, Alvarado Cano, Juan Antonio and Villalpando-Romo, Guillermo. [2025]. Innovative design of a compact conveyor for medium loads and high production. Journal of Mechanical Engineering. 9[22]1-7: e5922107.

Introduction

Conveyor belts are one of the most widely used continuous transport systems in modern industry, due to their ability to move materials and products efficiently, safely and consistently. Their use is essential in sectors such as mining, the food industry, manufacturing, logistics and bulk material handling, where they optimise production processes, reduce transport times and minimise human intervention [1].

From a mechanical design perspective, a conveyor belt should be considered as an integrated system consisting of the belt, rollers, drums, support structure and drive system. The correct operation of the conveyor belt depends directly on the design and appropriate selection of each of its components, taking into account fundamental working parameters such as the load carried, the operating speed, the length and the characteristics of the material [2].

The dynamic behaviour of these systems directly influences energy consumption and the service life of the belt. The importance of the energy balance associated with dynamic stresses is highlighted in order to avoid unnecessary power losses and accelerated component wear [3].

In this context, this article describes the mechanical design of a conveyor belt intended for handling unit loads of 50 kg, with a length of 2 m, a width of 0.90 m and an operating speed of 30 m/min, which are non-standard requirements for commercial conveyor belts.

Clarification of the task

In industrial processes where the continuous transfer of materials and unit loads is required, the use of manual methods or inadequate transport systems generates risks to personnel safety, low operational efficiency and limitations in productivity. Conveyor belts have established themselves as one of the most efficient solutions for the continuous handling of materials, allowing safe, constant transport with less human intervention [1]. However, the design of a conveyor belt cannot be done empirically, as incorrect selection of its components can lead to premature failure, accelerated belt wear, slippage on the drums, overload of the drive system and structural failure, compromising the safety and performance of the system.

According to the design guidelines established by the CEMA [Conveyor Equipment Manufacturers Association], it is essential to carry out an adequate analysis of the operating conditions, load, speed and length of the system to ensure safe and efficient operation [2].

Recent studies show that inadequate analysis of the energy balance can lead to considerable power losses and premature wear of the conveyor system components [3].
This project identifies the need to design a transport system that allows the continuous movement of 50 kg unit loads, considering regulatory, structural and functional criteria, to ensure efficient, safe and reliable operation through the construction of a functional prototype.

Theoretical background

Conveyor belts are one of the most important continuous transport systems in modern industry due to their ability to move materials and products efficiently, safely and consistently [1].The design of conveyor belts must be based on international technical standards that guarantee their safety, durability and mechanical performance. CEMA establishes the main guidelines for calculating the required power, roller selection, drum diameter, belt strength and operating conditions [2]. Similarly, DIN 22101 provides criteria for calculating stresses, movement resistance and the dimensions of the main elements of the belt conveyor system [4].

Shigley, Budynas and Nisbett point out that systems subjected to cyclic loads, such as conveyor belts, must be designed taking into account criteria such as material strength, fatigue, efficient power transmission and adequate safety factors [5]. During operation, dynamic stresses are generated by the acceleration of the system and load variations. The energy balance of these stresses directly influences the power required and the wear on the belt [5, 7].

The correct selection of the type of belt directly influences the energy efficiency of the system. Lateral deviation of the belt is one of the most frequent problems in these systems. The use of artificial vision and deep learning models allows this phenomenon to be detected with high precision, facilitating its timely correction [8].

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Recent research shows that poor design increases resistance to movement and energy consumption. The coefficient of friction is also a determining factor in the design of the drive system [9, 10]. Structural analysis ensures that the support structure is safe to withstand the loads acting on it. The use of simulation software allows stresses, deformations and safety factors to be evaluated prior to manufacture [11].

Development

For the development of the conveyor belt design, the systematic design methodology proposed by Pahl and Beitz [6] was applied, beginning with a clear definition of the main function of the system, which was established as the continuous transport of unit loads of up to 50 kg, ensuring safe, stable and controlled movement. Based on this function, the minimum requirements of the system were defined, considering fundamental aspects such as the total length of the conveyor, the width of the belt, the operating speed, the load capacity and the need for an adequate mechanism to support the belt and transmit movement. Subsequently, the final requirements were established, incorporating criteria related to system safety, structural stability, correct belt tensioning, component durability, and ease of operation and maintenance.

In order to properly structure all the necessary functions of the system, a function diagram was used, as shown in Figure 1, which allowed the main function to be divided into partial functions such as supporting the load, transmitting movement, guiding the belt, maintaining adequate tension and ensuring structural stability, serving as the basis for the subsequent development of the design.

Box 1

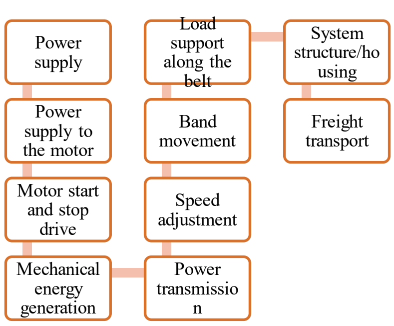

Figure 1

Function diagram

Own elaboration

Once the functions had been defined, tables were developed with a format as shown in Table 1, each table corresponding to each function, evaluating advantages and disadvantages based on the fundamental aspects for each function.

Tables such as the one shown in Table 1 were used to evaluate each of the functions defined in the diagram in Figure 1. This was followed by the creation of evaluation matrices such as the one shown in Table 2, which considered the main aspects for each option proposed in the tables of advantages and disadvantages. Each matrix was weighted from 1 to 5 to select the best option through a holistic evaluation. After evaluating all the functions and selecting the most appropriate option to fulfil each function, the elements to be used were defined. The list of resulting elements is presented below:

Box 2

Table 1

Advantages and disadvantages of electric motor options

No	Image	Name	Advantages	Disadvantages
1		Three-phase AC induction motor	Durable. Low maintenance. High energy efficiency. Safe [no sparks or brushes]. High power capacity and good torque. [maximum 500HP] Reliable in industrial applications.	Installation cost. Heavier and bulkier. Not suitable for single-phase installations..
2		Single-phase AC motor	Initial cost. Easy installation. Requires little maintenance. Suitable for small or medium power ratings.	Less durable than a three-phase system. Lower efficiency. Frequent overheating during prolonged use. Limited power. [7.5HP]
3		Motor Brushless	High efficiency. Durable and requires minimal maintenance. Compact and lightweight. Safe and quiet operation. Excellent speed and torque control.	Cost. Requires additional components for operation [driver]. More complex installation. Power limited to 20HP.
4		Brush motor.	Cost. Easy to obtain. Good starting torque. Simple installation with DC power supply. Simple speed control..	Low durability [brush wear]. Lower efficiency due to friction. Risk of sparks and overheating. Requires frequent maintenance. Power limited to 10HP.

Own elaboration

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- Three-phase power supply
- 10-12 AWG wiring
- Start/stop switch with interlock
- Three-phase motor
- Steel tension roller
- Gear motor
- Chain-sprocket transmission system
- Steel structure
- Steel support roller
- Rubber belt

Box 3

Table 2

Assessment for the selection of control interface

No.	Option	Cost	First of all	Efficiency	Safety	Potency	Installation	Sum
1	Three-phase AC induction motor	2	3	3	3	3	2	16
2	Single-phase AC motor	3	2	2	2	1	3	13
3	Motor Brush-less	1	3	3	2	3	2	14
4	Motor with brushes.	3	1	1	1	2	3	11

Once the components were defined, an initial sketch was made, which is shown in Figure 2.

Box 4

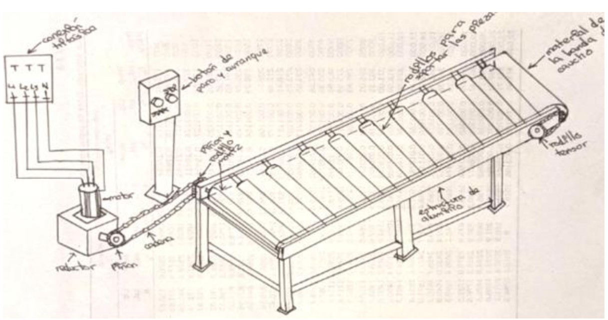

Figure 2

Initial outline

Own elaboration

Calculations

The corresponding calculations were performed before selecting the mechanical elements of the conveyor belt, in order to ensure a safe, functional design in accordance with the established operating conditions.

These calculations made it possible to determine the parameters necessary for the correct selection of the drive system, rollers, belt and structure, ensuring that the system meets the load, speed and stability requirements defined for the project.

Analysis 1: Calculation of roller diameters.

The minimum diameter of the rollers was determined based on the permissible belt deflection criteria established by CEMA regulations, which relate the roller diameter to the belt thickness using the flexibility factor K. In general, the criterion is expressed by Equation 1.

$$D\_min=K\cdot s \quad [1]$$

Where:
Dmin - is the minimum roller diameter,
K - is the flexibility factor of the belt, and
s - is the thickness of the belt.

A belt with a thickness of 3 mm was considered, and Table 3 was used to determine the value of K. This table establishes the typical values of K for each type of roller based on CEMA/DIN industry standards.

Box 5

Table 3

Typical K values

Roller type	Location	Belt tension level	K value [vulcanised]
Drive roller	Head	high [100%]	30
Return roller	Return final	high [100%]	25
Support roller	Load roller	Low-zero [support only]	15-20

CEMA, Belt Conveyors for Bulk Materials

Based on this criterion, minimum diameters of 90 mm were obtained for the drive roller, 75 mm for the return roller and 60 mm for the support rollers. With the aim of using commercial components and increasing the safety margin, rollers with a diameter of 100 mm were selected.

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Analysis 2: Calculation of belt length.

Once the diameters of the rollers to be used had been determined, the length of the belt was calculated using Equation 2.

$$L = 2 \cdot C \cdot \pi \cdot d \quad [2]$$

In Equation 2, L is the length of the belt, C is the centre-to-centre distance, and d is the diameter of the rollers; the length of the belt was calculated to be 4.11 m.

Analysis 3: Calculation for the selection of the motor and gear motor.
We begin by calculating the friction force using Equation 3.

$$F_{friction} = \mu \cdot M_t \cdot g \quad [3]$$

In this equation, μ is the coefficient of friction, Mt is the total mass of the belt, and g is gravity.

The total mass of the belt was calculated using Equations 4 and 5:

$$Belt\ area = 2 \cdot length\ \cdot wide \quad [4]$$

$$M_t = Belt\ area + Belt\ density \quad [5]$$

Combining the results of the above equations, a total mass of 25.2 kg was obtained. Substituting all the values in Equation 3, a friction force of 295 N was determined.

With this data, it is possible to calculate the power using Equation 6.

$$P = F \cdot v \quad [6]$$

This results in a required power of 147.5 Nm/sec. Considering that 1 Nm/sec is equivalent to 1W and that 1 Hp is equivalent to 746 W, a relationship between these values is established, yielding a required power of 0.197 Hp. To calculate the design power, i.e., the power required by the motor, Equation 7 is used.

$$P = FS \cdot HP \quad [7]$$

In this calculation, a safety factor FS of 2 is considered, and the minimum power required is obtained to be 0.395 HP.

Once the power was obtained, the necessary torque was calculated. To do this, the circumference of the roller was first calculated, giving a result of 0.314 m.

From this, the necessary rotation speed was determined, giving a result of 95.5 rpm. This value was converted to rad/s to have consistent units and use Equation 8 to calculate the torque.

$$Torque = \frac{Power}{Angular\ velocity} \quad [8]$$

By substituting the values, a power of 14.75 Nm was obtained. With this data, a three-phase motor of 0.5 HP at 1500 rpm was considered, resulting in the requirement for a gear motor with a transformation ratio of 1:15.
Analysis 4: Verification of the roller shaft.

Based on the maximum bending moment obtained of 36.79 Nm using Equation 10.

$$M_{max} = \frac{P \cdot L}{4} \quad [10]$$

Using Equation 11, a normal stress of 46.8 MPa was calculated for the shaft, considering that it will be manufactured in SAE 1018 steel, whose yield strength is 370 MPa. This resulted in a safety factor of 7.9, which guarantees a mechanically safe design.

$$\sigma_{real} = \frac{M_{max} \cdot \frac{d}{2}}{I} \quad [11]$$

Analysis 5: Verification of the structure.

For the structure made of ASTM A36 steel, a total load of 2,229 N was considered and the maximum stress of 17.7 MPa was determined. Given that the yield strength of the material is 250 MPa, a safety factor of 14.1 was obtained, confirming the structural stability of the system.

Results

The final selection of conveyor belt components was made based on the results of the design calculations. A 3 mm thick vulcanised rubber belt with a surface density of 3.5 kg/m² was selected. For the support system, 100 mm diameter steel rollers were chosen for the drive, return and support rollers, with shafts made of SAE 1018 steel. The drive system consisted of a 4-pole three-phase motor coupled to a gear motor with a reduction ratio of 15:1, which meets the speed and torque requirements of the system.

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The supporting structure was manufactured in ASTM A36 structural steel, ensuring the strength and stability of the assembly. This selection ensures the correct mechanical operation, safety and reliability of the system under the established operating conditions.

Construction plans

The plan for the conveyor belt assembly was drawn up using SolidWorks software, integrating all the elements defined in the mechanical design, such as the structure, rollers, transmission system, gear motor and belt. This plan made it possible to verify the correct layout of the components and the overall dimensions of the prototype, serving as the basis for the construction of the prototype, Figure 3.

Box 6

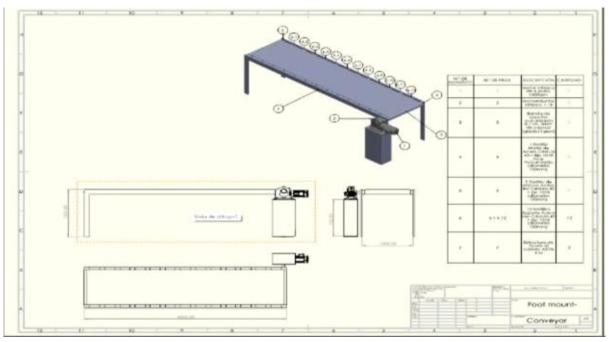

Figure 3
Overall plan

Prototype construction

Based on the results obtained in the previous phases, a scale prototype was manufactured and assembled to demonstrate the functionality of the design. Figures 4 and 5 illustrate this process..

Box 7

a] Structure with drive roller and return roller

b] Structure with all rollers

Figure 4
Assembly of the structure

Own elaboration

Box 8

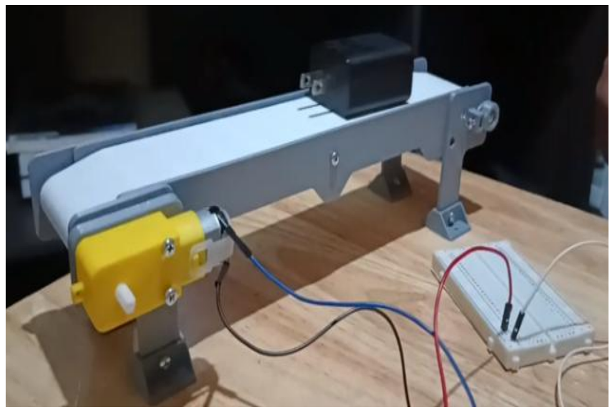

Figure 5
Assembled prototype

Own elaboration

Conclusions

The development of this project enabled us to achieve the objective of designing and experimentally validating a conveyor belt for handling unit loads of up to 50 kg, adequately integrating the principles of mechanical design, component selection and structural verification.

The results obtained through the construction and testing of the prototype demonstrate that the system operates efficiently, safely, and stably under the established operating conditions. Furthermore, it is confirmed that the proposed design is a viable solution for continuous transport applications in small and medium-scale systems.

Declarations

Conflict of interest

The authors declare that they have no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Contribution of the authors

The contribution of authors a and b focuses on the scientific and technical direction of the research project, the assignment of methodologies and tools, as well as inter-institutional management for its dissemination and publication. They developed the conceptual idea and enabled the manufacture of the device.

On the other hand, authors c and d participated in the process of construction,

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assembly, and control of the prototype: author c was responsible for control programming and assembly, while author d performed 3D modelling, controlled the construction phase, and also participated in the assembly.

Availability of data and materials

The data obtained in this research are available through the technical report of the San Luis Potosí Institute of Technology, whose authors participate in it.

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Article

Artisanal fabrication of prismatic concrete brick units using a modular mold covered by utility model MX 4516

Fabricación artesanal de tabiques prismáticos de concreto a través de molde modular de modelo de utilidad MX 4516

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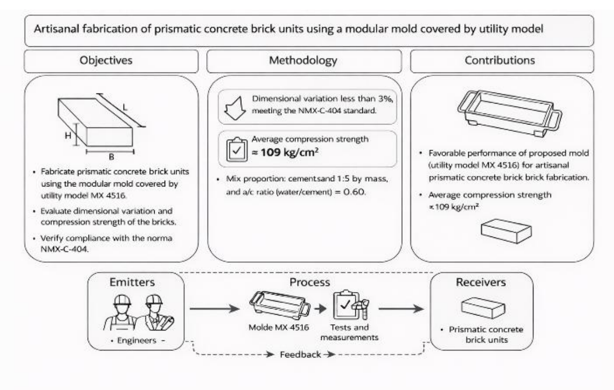
Abstract

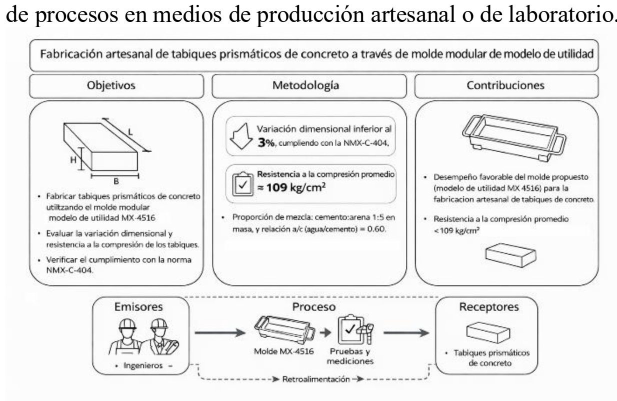
The study evaluates the performance of a proposed mold [utility model MX 4516] for the artisanal production of concrete bricks with nominal dimensions of 24 × 10.1 × 6.2 cm. Dimensional measurements exhibit variations lower than 3%, complying with standard NMX-C-404. Using a cement-to-sand ratio of 1:5 and a water–cement ratio of 0.6, the bricks achieve average compressive strengths close to 109 kg/cm², exceeding the structural requirements of NMX-C-441. It is demonstrated that 5 × 5 × 5 cm cubic specimens adequately represent the material behavior of the full unit for compressive strength testing, facilitating quality control and process standardization in artisanal or laboratory-scale production.



Brick, Mold, Masonry, Utility model

Resumen

El estudio evalúa el desempeño de un molde propuesto [modelo de utilidad MX 4516] para la fabricación artesanal de tabiques de concreto de 24 × 10.1 × 6.2 cm. Las mediciones dimensionales muestran variaciones menores al 3 %, cumpliendo la norma NMX-C-404. Con una dosificación cemento:arena 1:5 y relación a/c = 0.6, los tabiques alcanzan resistencias promedio cercanas a 109 kg/cm², superiores a lo establecido en la norma NMX-C-441 para uso estructural. Se demuestra que probetas cúbicas de 5×5x5 cm representan adecuadamente al material de la pieza completa para fines de ensaye de resistencia a compresión, facilitando el control de calidad y la estandarización de procesos en medios de producción artesanal o de laboratorio.



Tabique, Molde, Mampostería, Modelo de utilidad

Area: Development of strategic leading-edge technologies and open innovation for social transformation

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Introduction

Self-build is the main form of housing construction in Mexico, accounting for more than 54.5% of the housing sector's GDP in 2023 and 57.3% of the national housing stock SEDATU [2021]. This model allows families to make fundamental decisions on aspects such as design, material selection and construction, representing an alternative to exclusion from the formal housing market. However, this informality creates significant structural challenges, with 44.2% of homes suffering from damp or leaks and 40.8% showing cracks, particularly in south-eastern states such as Tabasco, Campeche and Chiapas INEGI [2021].

In addition, 83.9% of these homes lack formal financing, which limits their quality, safety, and durability. In response, the federal government has implemented the National Self-Build Strategy, aimed at promoting technical assistance, accessible financing, and regularisation processes SEDATU [2021]. Consequently, strengthening technically adequate self-construction represents a strategic way to reduce the housing backlog and boost the national economy.

The representative structural system in the above context is structural masonry, which, in addition to the availability of skilled labour, must be adapted to the country's diverse regions. To achieve uniformity in both the quality of construction processes and the materials used in them, numerous standards have been instituted in Mexico, including NMX-C-038 [2014], NMX-C-073 [2004] and NMX-C-077 [1997], among others, together with technical regulations such as NTC-DM [2023]. Compliance with the requirements mentioned in these standards is difficult to achieve because the procedures involved are artisanal, from the production of the pieces that make up the masonry to the construction process of the dwelling. This document refers to a proposed mould that meets the geometric requirements for the manufacture of bricks, which are generally produced by hand without any control over the quality of the materials or the geometric aspects. In this context, Frasson Jr. et al. [2012] propose a methodology for designing mixtures for structural concrete blocks that incorporates the use of cylindrical laboratory moulds to evaluate key properties such as cohesion, surface texture and compressive strength.

This methodology highlights the relevance of the geometric aspects of both the moulds and the blocks, given that the density and final texture of the moulded unit are directly related to the compaction energy and the optimum moisture content of the mix. The moulds used have three curved panels, which allow for a uniform distribution of loads during the layer compaction process, simulating industrial production conditions. Consequently, this proposal represents a technical and economical alternative for optimising the quality of concrete blocks from the laboratory stage onwards.

Complementarily, Malavika et al. [2017] report results related to the manufacture of interconnected blocks, where the design of the mould plays a fundamental role, as it directly influences the geometry, functionality and quality of the pieces obtained. In their study, a steel mould was used to configure blocks with a male-female system, facilitating interconnection and alignment without the need for mortar in the horizontal joints. This geometric configuration, which includes a tongue-type projection and a groove-type recess, provides structural stability by limiting lateral displacement, especially in seismic areas. The experimental results demonstrated that the shape of the mould not only improves the interconnection between elements, but also optimises the use of materials and reduces construction times.

On the other hand, Quiroz Carranza et al. [2021] report results from studies related to the artisanal production of bricks, in which the use of moulds plays a crucial role in ensuring the dimensional uniformity and mechanical quality of the manufactured pieces. These moulds, usually made of wood or metal, define the basic geometric dimensions of the bricks, which commonly measure 6 × 12 × 24 cm. However, variations were identified depending on the producer, which directly affects the strength and structural behaviour of the final product.

The traditional methodology involves manually pouring mixtures of clay and organic aggregates into individual moulds, followed by natural drying and subsequent firing in rudimentary kilns. This practice, although functional, lacks precise dimensional controls and standardisation, which affects both construction efficiency and modular compatibility.

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Addressing this issue, Álvarez-Arellano and Lastra-González [2021] proposed a device aimed at improving the dimensional accuracy and efficiency of the block manufacturing process. In addition, the mould allows for the production of pieces with standardised geometry, which is crucial for structural stability and ease of assembly on site. Likewise, its implementation reduces the dimensional variability that often occurs in artisanal processes, which results in lower quality and durability of the elements produced. Furthermore, its design facilitates adoption in communities with limited resources, as it does not require complex machinery for its operation. As a result, it promotes improved local productivity, technical training, and standardisation of block production, which are key aspects for sustainable development in rural regions. This type of technological solution demonstrates the value of utility models as tools for appropriate innovation in the construction sector.

In addition, Escamirosa Montalvo and Molina Narváez [2022] identified that a critical factor influencing the mechanical performance of block pieces is the use of moulds during their manufacture. Moulds not only define the geometry of the blocks, but also ensure dimensional consistency and surface regularity, which are essential for proper load distribution and structural integrity. Furthermore, the geometric properties of blocks, such as length, width, height, and wall thickness, play a fundamental role in determining the net resistant area and, therefore, the overall compressive capacity. Therefore, improving mould design and standardising geometric parameters is essential not only to optimise structural performance but also to promote environmental sustainability.

For their part, Cajamarca-Zuniga et al. [2023] report that the use of moulds plays a fundamental role in the manufacture of ceramic bricks, as it defines the shape, dimensions and consistency of the pieces. These researchers conducted several studies in Ecuador, where they identified that brick production is predominantly artisanal, which generates high geometric variability. This heterogeneity directly influences the quality of constructions, as it prevents standardisation in structural design.

In addition, the study shows that 98% of factories do not comply with technical regulations, which reinforces the need to control geometric parameters from the moulding stage. In this context, the geometric characterisation methodology used included direct measurement of dimensions in the field. Consequently, the design and proper use of standardised moulds is a key step in improving the quality and uniformity of masonry elements.

Fernandez-Baqueiro [2024] and, more recently, Pahl & Feldman [2025] report in their studies that the geometry of the cores of masonry pieces is a structural safety parameter, as it can cause the shear capacity outside the plane to be significantly lower than estimated and, therefore, increase the probability of shear failure under wind and seismic actions.

In line with the above, Ruales and Tupiza [2025] conducted studies related to an alternative structural shear reinforcement for masonry walls made of pumice blocks and fired clay bricks, where they report that, based on the geometric analysis of bricks and blocks, the former showed greater variability in width, which is associated with low quality control in the artisanal process, while more consistent values were observed in the blocks, associated with the use of prefabricated moulds.For his part, Punín [2025] reports the results of studies related to the analysis of material used for earth plaster, resistant to the disintegration of its fine particles.

In this work, the plaster material is analysed using cubes made with 5×5×5 cm moulds, which allowed mechanical resistance studies to be carried out. However, this study focused on the plaster material and not on the bricks or blocks used in traditional construction; even so, this element of the structural masonry system also requires specific analysis, which is addressed in the work reported by the researcher.Likewise, Ticsihua, R. [2025] conducted studies on bricks pressed from a combination of hardened cement and clay, evaluating the possible improvement in brick strength by adding hardened cement.

In this process, dimensional variation [length, width, and height] was evaluated using an explicit procedure and calculation, using maximum/minimum criteria to obtain the variation.

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Although the importance of the geometric aspects of the pieces is not highlighted, due to the pressing process, it was assumed that the brick pieces were constructed with prefabricated moulds, which reduces geometric uncertainty.Complementarily, in the research reported by Guerrero et al. [2025], related to the cost analysis for the production of mechanised earth adobe, the researchers used mechanised procedures for the production of bricks, as well as general methods for classifying the materials available on site.

In this sense, this initiative represents a positive aspect due to the use of standardised moulds, as they reduce uncertainty in the production of pieces in the face of possible geometric dimensional errors in the bricks.Finally, Rubio-Carpio et al. [2025] developed an automated system for volumetric dosing and mixing of materials in block manufacturing, highlighting the importance of standardising processes that are commonly performed manually. In this context, the design of moulds and dosing devices plays a crucial role, as their internal dimensions precisely determine the volume of material required per cycle.

Thus, the geometry of the dosing cup was calculated to contain exactly 5% of the total mixture volume, equivalent to 1000 cm^3, ensuring uniform and repeatable dosing. This demonstrates that the geometric precision of the moulds and automated control not only optimise the process, but also improve the quality of the blocks obtained, facilitating their adoption by small producers in controlled environments.

Taken together, all these studies support the assertion that the standardisation of moulds and the comprehensive improvement of the manufacturing process are essential for reducing environmental impact and ensuring technical quality in the production of masonry materials. Thus, the geometric design of the mould and a controlled manufacturing process are key factors in the mechanical, functional and economic performance of the blocks.

Consequently, the proper integration of geometric design, mould type and construction system is essential to maximise structural efficiency and move towards sustainable and technologically appropriate building models.

Methodology

The first stage of the research consisted of developing a mould for the manufacture of concrete blocks, the design of which was based on the collection of technical information and field verification of the dimensions most commonly used in regional production.

The mould was made of A36 steel plates, reinforced with 1/8" soles and 9 mm diameter rounds, materials that guarantee the strength and durability necessary to withstand the loads during the pouring and compaction of the mixture. This construction arrangement ensured proper functioning for obtaining homogeneous and reproducible pieces, suitable for subsequent evaluation under laboratory conditions.

With regard to the production of the partitions, it was observed that the process begins with the selection and dosing of materials, based on previous experiences that have shown favourable results in terms of workability and strength. However, the availability of economic resources is a determining factor, since at the industrial level there is more standardised equipment and procedures, while in smaller-scale scenarios it is necessary to consider alternatives adapted to local conditions.

Subsequently, the proposed dosages were subjected to laboratory tests by preparing representative test specimens, which allowed their technical feasibility to be validated. Once manufactured, the partitions underwent a controlled curing process, which is essential to ensure the proper development of the concrete's strength. Finally, tests were carried out on compressive strength, absorption and geometric variability, the results of which were compared with the limits established in current Mexican regulations, specifically NMX-C-441 [2013] for non-structural partitions, with a minimum strength of 35 kg/cm^2, and NMX-C-404 [2012] for structural partitions, which requires a minimum of 60 kg/cm^2.

Although the current stage of the studies does not include the design of a target strength, the values achieved were verified and will serve as a reference for further studies once the proposed mould has been validated for larger-scale production.

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In this way, a systematic procedure was established that allowed the mould design to be linked to the production, curing and evaluation of the blocks under recognised technical standards.

Selection of material for blocks

At this stage of the project, performance tests were carried out on the mould described above. For this purpose, a mixture of materials commonly used in the manufacture of handmade blocks was used, consisting of a cement:sand ratio of 1:5. It should be noted that in the municipality of Carmen, Campeche, there is no identified materials bank that meets the technical requirements for the production of blocks. Consequently, the material used in the tests and in the preparation of the specimens was purchased from a commercial establishment specialising in construction products.

Geometry of the partition wall pieces

The results obtained in the solid partition walls manufactured with the proposed mould are highly relevant and are related to three recent contributions and the NMX guidelines on the subject. Rafi et al. [2024] show that the compressive response of masonry prisms is highly sensitive to the geometry of the specimen and the support conditions, so that preparation and alignment in the construction process are precise and decisive in avoiding eccentricities that modify the hypotheses established for behaviour in the corresponding regulations. Asteris et al. [2025] integrate evidence and models that relate shape and tolerances to the variability of masonry strength, supporting the need to report geometric parameters along with strength.

The modular mould proposed by Álvarez-Arellano and Lastra-González [utility model MX 4516, 2021] is made up of rigid plates and guides that ensure parallelism and target dimensions, allowing partitions to be manufactured within the tolerances and geometries established in the specifications of NMX-C-404 [2013], as well as preparing specimens in accordance with NMX-C-036 [2013] [geometry and test procedure]. The general geometric data of the proposed modular mould are shown in Figure 1, and the partition obtained is shown in Figure 2.

Box 1

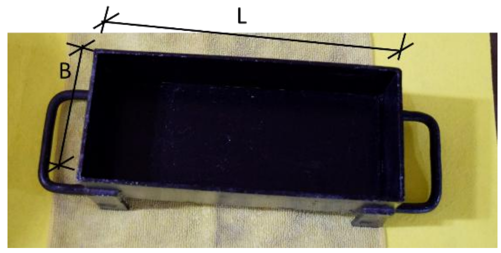

Figure 1
Internal dimensions of the mould for handmade bricks

Box 2

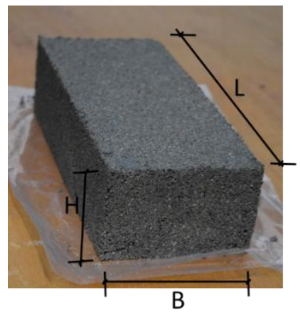

Figure 2
Geometry of manufactured partition pieces.

LThe geometric requirements were evaluated in accordance with the current NMX-C-404 [2013] standard. For this purpose, the reference values indicated in Figure 3 will be used, which establishes that the maximum deviations of the edges from a straight line perpendicular to the adjacent side must not exceed 3%. This deviation "d" is calculated as the quotient of the distance that the edge deviates measured perpendicularly to the reference line "e" between the distance to the measured point.

Box 3

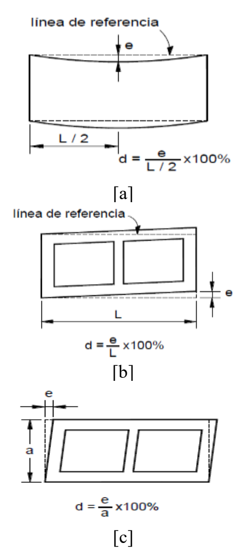

Figure 3
Tolerances established for block and partition wall components [NMX-C-404, 2013].
Source: NMX-C-404 [2013]

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Box 4

Table 1

Calculated deviations in blocks manufactured using the proposed modular mould Álvarez-Arellano and Lastra-González [2021].

ID piece	Figure 3a			Figure 3b		Figure 3c		
	L [mm]	e[mm]	d_1[%]	e[mm]	d_2[%]	a[mm]	e[mm]	d_3[%]
Mbase01-04	241.35	0.80	0.66	0.57	0.24	101.57	1.54	1.51
Mbase01-05	242.02	1.80	1.49	0.55	0.23	101.55	1.93	1.90
Mbase02-01	242.76	1.10	0.91	0.40	0.16	101.40	1.73	1.69
Mbase02-02	242.46	1.00	0.82	0.77	0.32	101.77	2.04	2.00
Mbase02-03	241.58	2.92	2.40	0.35	0.14	101.35	2.14	2.06
Mbase02-04	242.25	2.80	2.31	0.99	0.41	101.99	2.32	2.29
Mbase02-05	242.02	1.80	1.49	0.55	0.23	101.55	1.93	1.90

In Table 1, L refers to the length of the septum with respect to Figure 1, Figure 2, and Figure 3a, while B is the width in Figure 1, Figure 2, and the value "a" in Figure 3c. The values of d1, d2, and d3 refer to the tolerances calculated with respect to Figure 3a, Figure 3b, and Figure 3c, respectively. In all cases established by equations [1], [2], and [3], d1, d2, and d3 must not exceed 3%.

$$d_1 = \frac{e}{\frac{L}{2}} x100\% \quad [1]$$

$$d_2 = \frac{e}{L} x100\% \quad [2]$$

$$d_3 = \frac{e}{a} x100\% \quad [3]$$

Based on Table 1, values of less than 3% were obtained, confirming that the proposed mould significantly reduces the geometric errors of the parts produced using the proposed modular mould [utility model MX 4516].

Material particle size

The particle size of the material was considered an important aspect to evaluate, since the final geometry of the partition also depends on this critical parameter for the design of mixtures, because it conditions the compactness, workability and, consequently, mechanical performance; in addition, its determination is governed by national technical standards. In particular, NMX-C-073 [2004] establishes the procedure for quantifying the volumetric mass of fine, coarse or combined aggregates, NMX-C-077 [1997] describes the method of granulometric analysis by screening in order to obtain the size distribution, and NMX-C-164 [2014] specifies the determination of the relative density and absorption of coarse aggregate.

In this context, the proposed model for the manufacture of partitions that complies with current regulations was subjected to experimental validation in this study, since the mixtures tested were formulated with commercial materials commonly used in the artisanal manufacture of parts and were characterised in accordance with these standards; thus, the aim is to corroborate that the mould allows for the production of elements whose production and properties are consistent with the required granulometric and quality control criteria.

The granulometric analysis of the sand for the manufacture of the partitions provided the results shown in Table 2. The analysis considered a tare mass [Mt] of 344 g, a tare mass plus sample [M_t+M_{mi}] of 2344 g, and an initial sample mass [M_{mi}] of 2000 g. Using the same process, the values shown in Table 2 were calculated for the percentage of gravel [0.00%], sand [100%] and fines [0%].

From Table 2, the effective diameter values D_{10} = 0.33, D_{30} = 0.50, D_{60} = 0.83 were calculated using the interpolation expression suggested by Bardet [1997]. Subsequently, the uniformity coefficients defined by $C_u = D_{60}/ D_{10}$ were estimated with a value of 2.469, $C_c = [D_{30}]^2/[D_{60}xD_{10}]$ curvature coefficient equal to 0.92. According to the results, if $C_u{}^{3}6$ and $1^{3}C_c$£3, it is well-graded sand. In the case studied, C_u = 2.469 and C_c = 0.92, the material is classified as poorly graded sand.

The fineness modulus was calculated by dividing the cumulative % retained in sieves 9.5, 4.75, 2.36, 1.18, 0.6, 0.30 and 0.15 mm and dividing that amount by 100, resulting in 2.758.

Box 6

Table 2

Sand particle size distribution.

Soil Types	Clean No.	Opening [mm]	Retained weight [g]	Percentage retained [%]	Percentage passing [%]
Important	3/8	9.500	0.00	0.00	100.00
	4	4.750	9.00	0.45	99.55
	8	2.360	50.00	2.51	97.04
Sands	16	1.180	263.00	13.20	83.84
	30	0.600	900.00	45.16	38.69
	50	0.300	678.00	3402	4.67
	100	0.150	84.00	4.21	0.45
FINE	Fondo		9.00	0.45	0.00
		Mmf =	1,993.0		

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Proportions used in the mixture design

The proportions considered for the manufacture of the blocks were estimated based on the dimensions in Figure 1, corresponding to 24x10.1x6.2 cm, with a volume of 1502.88 cm3. In this case, no target strength was proposed because mixtures were only being prepared to validate the use of the block referred to in this publication. However, calculated values are reported in the following section. With this data, material was dosed for five blocks with a cement:sand ratio of 1:5, and the results shown in Table 4 were obtained.

Box 5

Table 3

Proposed dosage for 5 solid blocks.

Material	Quantity
Cement [kg]	2.43
Fine aggregate, sand [kg]	12.15
Water [ml]	1.45

Source: Own elaboration

A 10% loss or waste was considered, with a water/cement ratio of 0.6 and an apparent density of sand of 1600 kg/m^3.

Compression testing of the pieces

To check the compressive strength of the partition material, a 5x5 cm cube was made and a 24x10.1x6.2 cm partition piece was also tested.

These were tested in a Shimadzu universal testing machine with a capacity of 100 tonnes.

The pieces were placed in the centre of the test plate as shown in Figure 3.

Box 7

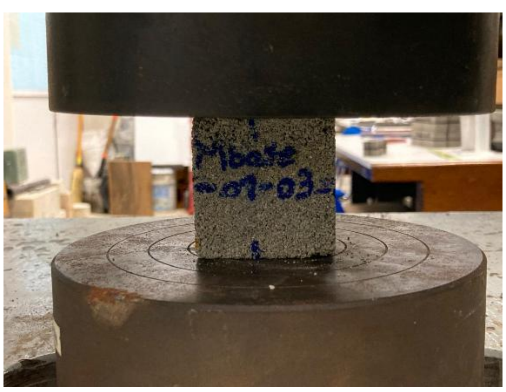

Figure 4

Placement of cube for compression testing.

Source: Own work

The compressive strength [fp, in kg/cm²] was calculated following the procedure in standard NMX-C-036 [2013], where P[kg] is the maximum load, substituting in equation [5], considering A [cm²] as the gross cross-sectional area of each 25 cm² block.

$$f_p = \frac{P}{A} \quad [5]$$

Where P is the load to failure applied in kg and A is the cross-sectional area in cm².

The corresponding values for each proposed dosage are shown in Table 5.

Box 8

Table 4

Summary of compressive strength for the samples tested.

ID exhibit	a/c	F_{max}[kg]	A[cm^2]	f_p[kg/cm^2]
Mbase-02-01	0.6	23885.92	242.4	98.53
Mbase-02-02		29226.86	242.4	120.57
Mbase-02-03		24527.46	242.4	101.18
Mbase-02-07		3151.15	25	126.05
Mbase-02-08		2644.31	25	105.77
Mbase-02-09		2616.58	25	104.66

Source: Own elaboration

Discussion of results

This study focuses on the implementation of a mould for the manufacture of concrete blocks, associated with the proposed utility model MX 4516 [Álvarez-Arellano and Lastra-González, 2021]. This mould was used to manufacture pieces measuring 24 × 10.1 × 6.2 cm. In the first stage, seven test pieces were produced to verify possible geometric variations, taking into account the recommendations of standards NMX-C-404 [2013] and NMX-C-441 [2013]. The results of applying equations [1], [2], and [3] indicate that, in all cases, the tolerances obtained are less than the maximum permitted value of 3%, as reported in Table 1, where it can be seen that all measurements remain within the regulatory limits, with a maximum value of 2.40% for d1.

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Figure 4 shows the values of d1, d2 and d3. The cases designated as Mbase01-04 and Mbase01-05 were prepared with the same dosage, but on a different date from cases Mbase02-01, Mbase02-02, Mbase02-03, Mbase02-04 and Mbase02-05. Although the latter show slightly higher deformation percentages, these remain within the limit established by the standard [3% maximum], which confirms that the proposed mould, together with the dosage used, allows the production of partitions that, from a geometric point of view, comply with the tolerance relationships defined in the current NMX-C-404 [2013]

Box 9

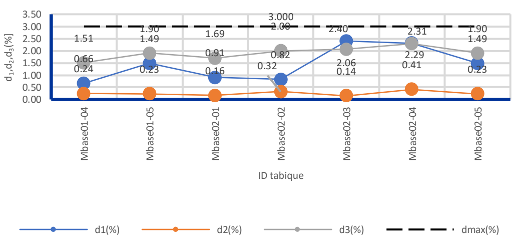

Figure 5

Relationship between tolerances d1, d2 and d3 vs. $ID_{tabiques}$.

The test tubes were prepared using a traditional dosage used in artisanal production, which, although not usually expressed in technical terms, was formalised in this study as a cement:sand ratio of 1:5. In the case analysed, this ratio was translated into a weight dosage, as indicated in Table 4, even though in artisanal practice it is customary to work with volumetric dosages. Additionally, a water/cement [w/c] ratio of 0.6 was adopted, which was kept constant for all the reported blocks produced.

The samples were tested at 14 days of age, obtaining the compressive strength values shown in Table 5. The actual stresses were calculated considering the gross area of the sections, determined from the dimensions of the block mould and the mortar test mould. This procedure made it possible to verify the consistency between the results of the cubic test specimens and those corresponding to the complete block for the 1:5 dosage. The results indicate that 5 × 5 cm test specimens can be used, whose stress values are sufficiently representative of those obtained in a complete piece, which facilitates the evaluation of the compressive strength of the mixture and saves concrete material during sample collection.

Figure 5 was constructed from the results in Table 5, incorporating the minimum strength reference values established in NMX-C-441 [2013] for non-structural elements [35 kg/cm²] and structural elements [60 kg/cm²]. In all cases, the measured strengths exceed these minimum values, so the manufactured pieces can be classified as structural. In particular, an average stress of 109.46 kg/cm² was obtained, with a standard deviation of 11.16 kg/cm², which shows favourable mechanical performance and relatively limited variability in the results.

Box 10

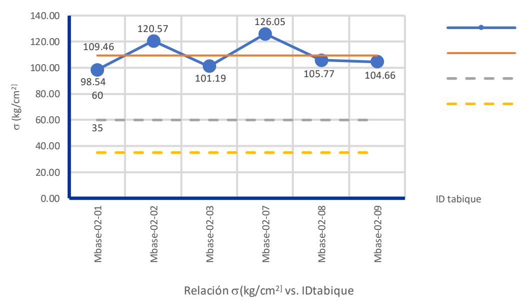

Figure 6

Relationship $\sigma[kg/cm^2]$ vs. $ID_{tabique}$

Source: Own elaboration

The benefits of the results obtained demonstrate that the proposed MX 4516 mould [Álvarez-Arellano and Lastra-González, 2021], combined with a traditional cement dosage of sand 1:5 and a w/c ratio of 0.6, allows the manufacture of partitions that also comply with the geometric tolerances established by NMX-C-404 [2013] and achieve compressive strengths above the thresholds established in NMX-C-441 [2013] for structural use.

This promotes the artisanal production of pieces with dimensional and mechanical quality that can be verified under regulations, facilitates quality control through representative cubic test specimens, and contributes to standardising a process that is usually carried out empirically, improving the reliability of the partitions obtained through the proposed mould.

Conclusions

The results related to the manufacture of bricks using the MX 4516 utility model were presented, and the following conclusions were drawn:

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1. Geometric performance of the MX 4516 mould. The proposed MX 4516 mould allows the manufacture of blocks with dimensions of 24 × 10.1 × 6.2 cm, whose geometric variations remain below the 3% established by NMX-C-404 [2013], confirming its ability to guarantee acceptable dimensional tolerances, thereby improving artisanal production conditions.

2. Structural classification of the manufactured blocks. With a cement:sand ratio of 1:5 and a w/c ratio of 0.6, the blocks achieve compressive strengths that exceed the minimum values of NMX-C-441 [2013] for structural pieces [60 kg/cm²], obtaining an average stress of around 109 kg/cm², which supports their use in applications with even higher applied load demands.

3. Use of cubic test specimens as a quality control tool. The results show that 5 × 5 cm cubic test specimens provide compressive stresses representative of those obtained in the complete partition wall, making them a practical and reliable alternative for quality control of the mixture in contexts where the availability of instrumentation and resources are limited. As a first alternative, complete partition walls or cubic test specimens such as those mentioned above could be tested.

4. Practical benefits for artisanal block production. The combination of the MX 4516 mould [Álvarez-Arellano and Lastra-González, 2021] with traditional dosing [1:5 by weight] and a constant w/c ratio helps to standardise a traditionally empirical process, improves the reproducibility of geometric and mechanical properties, and facilitates the verification of the quality of the bricks, generating direct benefits for potential artisanal producers seeking to improve the performance and reliability of their products, most of whom make the pieces using wooden moulds with wide geometric variations and mix dosages based on volumes and prior knowledge of the physical properties of the aggregates.

Summarising conclusions

The results obtained confirm that the MX 4516 mould [Álvarez-Arellano and Lastra-González, 2021] guarantees geometric tolerances within NMX-C-404 [2013] and, with a 1:5 dosage and a w/c ratio of 0.6, produces blocks with a strength greater than that required by NMX-C-441 [2013].

Likewise, the 5×5 cm cubic test specimens are representative and viable for quality control in standardised artisanal production for the dimensions of the partitions studied.

Declarations

Conflict of interest

The authors declare that there is no conflict of interest. They have no competing financial interests or personal relationships that could have influenced, or appear to influence, the content presented in this article.

Contribution of the authors

The first author and first co-author carried out experimental studies and drafted the paper, the second co-author contributed to the analysis of results and comparison with existing regulations, and the third co-author carried out the literature review and exhaustive review of the entire document.

Availability of data and materials

The data presented in this research are available for consultation if required.

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Abbreviations

INEGI	National Institute of Statistics, Geography and Informatics
SEDATU	Secretariat of Agrarian, Territorial and Urban Development
NMX	Mexican Standard
NTC	Complementary Technical Standard
NTC-DM	Complementary Technical Standard for the Design and Construction of Masonry
f_p	Compressive strength of block piece obtained from the experiment
M_t	Tare mass
M_{mi}	Sample mass
M_{mf}	Final mass of the sample
C_c	Coefficient of curvature
C_u	Coefficient of uniformity
P	Axial load applied
A	Gross cross-sectional area of the block piece
L	Partition length
B	Partition width
H	Partition camber
$ID_{tabiques}$	Partition piece identifier
F_{max}	Maximum force applied
d_1,d_2,d_3	Partition piece deflection
e	Distance that the edge deviates measured perpendicular to the reference line
c/a	Cement/sand ratio
a/c	Water/cement ratio

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Article

Feed pellet machine poultry

Peletizadora de alimento avícola

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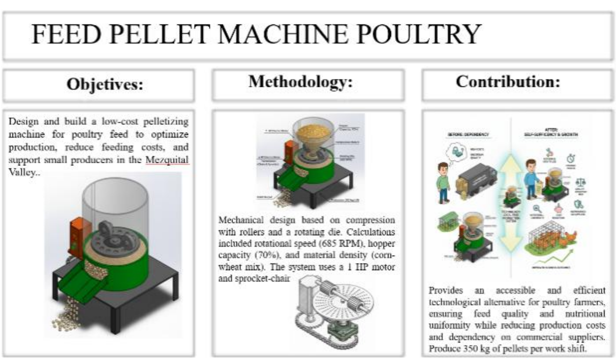
Abstract

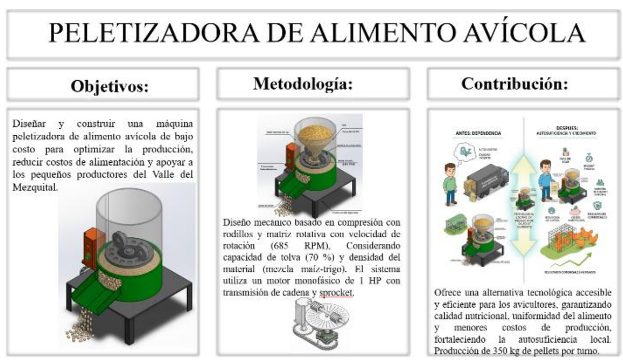
The production of poultry feed is a key process in the poultry industry, as it requires proper nutrition to ensure the growth and welfare of the birds. In this regard, the manufacturing of poultry feed pellets represents a fundamental stage to guarantee both quality and efficiency in bird feeding.This study focuses on the design and construction of a poultry feed pelletizing machine, with the purpose of developing an efficient and effective solution for the production of high-quality pellets. The different components that make up the machine are analyzed, evaluating their characteristics and performance to identify potential opportunities for optimization.



Pellet mill, Production processes, Poultry industry

Resumen

La producción de alimento para pollo constituye un proceso esencial dentro de la industria avícola, ya que requiere una nutrición adecuada para garantizar el crecimiento y el bienestar de las aves. En este sentido, la fabricación de pellets de alimento para pollo representa una etapa fundamental para asegurar la calidad y la eficiencia en su alimentación. El presente trabajo aborda el diseño y la construcción de una máquina peletizadora de alimento para pollo, con el propósito de desarrollar una solución eficiente y efectiva para la producción de pellets de alta calidad. Se analizan los diferentes componentes que integran la máquina, evaluando sus características y desempeño con el fin de identificar oportunidades de optimización.



Peletizadora, Procesos productivos, Industria avícola

Area: Promotion of frontier research and basic science in all fields of knowledge.

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I. Introduction

During the past decade, global chicken meat production maintained an average annual growth rate of 2.1%, reaching a record high volume of 103.5 million tons [mdt] in 2023.

In Mexico, chicken meat production in 2023 reached a historic high of 3.89 million tons. According to data from the Secretariat of Agriculture and Rural Development in Mexico, for 2024, national production is estimated to grow by 2.4%, reaching a new high of 3.98 million tons.

Chicken meat is the most produced type of meat in Mexico, representing nearly half of the total volume. Chicken meat accounts for 48.1% of meat consumption in Mexico, as it continues to be the most affordable source of meat compared to pork and beef. [FIRA. 2024]. For the Mezquital Valley, in the state of Hidalgo, Mexico, in a study conducted in 2021 for one of its communities, the population considers poultry farming as the most important activity compared to other activities in their family production units, reaching a 63% importance rate, compared to 25.9% for dairy cattle and the rest for sheep and rabbits. [Romero, 2021].

In the Sectoral Program for Agricultural and Rural Development, Hidalgo 2023 – 2028, the results indicate a repetitive need for technological equipment [Gobierno del Estado de Hidalgo 2023], this being one of the main reasons for this work.

The demand for nutritionally quality food is concerning, because the supply becomes insufficient, leading to the need to accelerate, modernize, and improve the meat production process.

In the state of Hidalgo, according to the 2022 agricultural census, it is reported that, of the total cost of poultry production, feed represents 66.99% of the expenses [SAGARPA 2012], a situation that directly affects small producers.

These producers seek new alternatives for animal feed, which allow them to reduce costs and obtain greater profits from their production system.

As the demand for animal feed increased, many farmers are having problems acquiring feed with the right quality, cost, and sustainability. Furthermore, considering that a 5-kilogram bag of poultry feed costs between $200 and $250 pesos, small farm owners do not have access to a reliable source nor the financial means to acquire feed that meets their specific needs. The manufacturing of a pelletizing machine aims to minimize costs and increase feed productivity.

Today, more than 60% of farmers in the Mezquital Valley do not have access to these machines due to their high market price, which ranges from $50,000.00 to $72,000.00 pesos.

2. Methodology

2.1. The pellet and the characteristics of a pelletizer

Currently, if a poultry or swine company wants to improve its productive parameters and profitability, it must optimize feed use, since this represents 60–70% of the total production cost. For this reason, the use of pelleted feed in the animal industry has become very important in recent decades, as studies indicate that it leads to better feed efficiency.

Pelleting is defined as a process that uses pressure, moisture, and heat to cause small feed particles to agglomerate with each other to form a larger granule or "pellet," making it sufficiently moldable to be compacted to achieve greater density. [Loor 2016].

Depending on the physical characteristics of the balanced feed, greater or lesser compression is used. For example, if the formula contains a high level of fibrous ingredients such as bagasse, bran, or ground alfalfa, the pelletizer will spend a large amount of energy compressing the meal to the pellet density. On the other hand, for a relatively dense feed, such as one high in grains and soybean meal, the pelletizer will spend less energy on compression and a greater amount on production. [Behnke, 2010]. A pelletizer is a machine whose job or activity is to transform and/or convert raw material into pellets, which are smaller pieces, roughly spherical or cylindrical in shape. There are various types of pelletizers, for example, ring die pelletizer, disc pelletizer, and counterflow pelletizer.

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This means that pelletizing is the process that allows us to shape the mixture of ingredients, which are compacted through given holes to turn it into cylinders or spheres; these are also agglomerated foods. This form is achieved through a mechanical process with moisture, pressure, and temperature. [Loor 2016].

For the design of a pelletizer, it is necessary to consider a series of factors such as:

- Production Capacity: amount of pellets per hour or per day
- Size and Shape of the Pellets
- Feeding System• Cooling System
- Motor and Power
- Construction Materials: usually made of high-strength steel to withstand wear
- Adjustments and Control
- Pellet Ejection System
- Maintenance and Cleaning.

As is to be expected, the construction must be based on standards. For this work, the Mexican Official Standard NOM-Y-121-A-1979, the CEN/TS 14691 standard, and the ENplus standard, which is the European standard for pellet manufacturing, will be taken into account.

Therefore, there are three types of pelletizers: flat pellet mill, vertical ring mill, and horizontal ring mill. It has been decided to implement a compression pelletizing system using rollers and a rotating die, with a working capacity of 350 kg per shift. See Table 1.

Box 1

Table 1

Technical data sheet of the pelletizing machine

Chicken feed pellet	
Work capacity	350 kg/day
Rotation speed	685 rpm
Pelletizing system	Compression using rollers and a rotating die
Transmission system	1 HP single-phase electric motor with sprocket-chain
Dimensions	Height 0.5m, width 0.35m, length 0.35m
Net weight	35kg

Source: Table made by the authors

2.2 design of the pelletizing machine

For the machine design, the capacity per shift is calculated. A shift of 6.5 hours and a production of 54 kg of pellets per hour is considered. Therefore, with 54 kg per hour and considering 6.5 hours, we have 350 kg per shift. With a hopper capacity of 70%, it is obtained:

$V = \pi r^2 h$ [2.2.1]

With a height of 22.1 cm, a radius of 12.5 cm, replacing in [2.2.1]:

$$V = (3.14.16)[12.5cm]^2[22.10\ cm][0.7]$$
$$V = 7594.5cm^3$$
$$\frac{343cm^3}{1{,}000{,}000} = 7.5945x10^{-3}\ m^3$$

For the Volume of the dough we use:

$V_r = \frac{m}{\rho a}$ [2.2.2]

$$\frac{m}{\rho a} = \frac{food\ mass\ [kg]}{density\ of\ balanced\ feed}$$

On the other hand, the apparent densities of corn [450 kg/m³] and wheat [750 kg/m³] obtained from the density table published by the FAO [De Lucia, 1993] and considering a mixture with a proportion of 60% corn and 40% wheat:

$$corn\ by\ 60\% = 450kg/m^3[.6] = 270\frac{kg}{m^3}$$
$$Wheat\ at\ 40\% = 750kg/m^3[.4]$$
$$= 300kg/m^3$$
$$total\ density = 570\frac{kg}{m^3}$$
$$Vr = \frac{54kg}{570kg/m^3} = 0.094kg/m^3$$

The rotation speed with respect to the transmission system by means of pinion-chain is given by the following equation:

$VG = Rpm\frac{PE}{PM}$ [2.2.4]

If RPM = 1500 and PE = 16 [Number of pinions from the motor shaft] and PM = 35 [Number of pinions from the die shaft]

Then

$$VG = 1500\frac{16}{35}$$

VG=685.71 Rpm

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The angular velocity is related to the rotation speed of the machine, and is calculated using [2.2.5].

$$\omega = \frac{2\pi Rpm}{60} \qquad [2.2.5]$$

$$\omega = \frac{2\pi(685Rpm)}{60}$$

So:
$\omega = 71.73\ rads/s.$

Now, regarding the pellet, according to the CEN/TS 14691 standard, the desired diameter of the pellet is chosen.

$$V = \pi r^2 h \qquad [2.2.6]$$

$$d = 4.76\ mm$$
$$r = 2.38\ mm$$
$$h = 6.35mm$$
$$\pi = 3.1416$$
$$V = 3.1416[2.38mm]^2[6.35mm]$$
$$V = 112.999mm^3$$

To obtain the pellet density, it was weighed on an electronic scale, yielding a result of 50 grams.

To calculate the density of a pellet, use [2.2.7].

$$\rho = \frac{mass}{volume} \qquad [2.2.7]$$

Of [2.2.7], The volume is 112.999 $mm^{3,}$ becomes to cm^3

$$112.990mm^3 = 0.113cm^3$$

Therefore.

$$\rho = 50gr/0.113cm^3$$
$$\rho = 442.477gr/cm^3$$

The force of the rollers is calculated..

$$Fr = f\ x\ Fb \qquad [2.2.8]$$

Where:

Fr=Friction force [N], Fb=Balancing load [N], f=Friction coefficient.

The roller design was calculated considering the following parameters:

$$Fr = f\ x\ Fb \qquad [2.2.9]$$

Where Fr = Friction force [N], Fb = Balancing load [N], f = Coefficient of friction.

According to the coefficients of static and dynamic friction of steel with steel [Serway& Jewett, 2008] and considering [2.2.10]

$$Fb = \sigma_s x\ A_c \qquad [2.2.10]$$

σs = Coefficient of breaking strength [N/mm$^{2]}$
Ac = Contact area of the roller with the food[m^2]

$$\sigma_{s=10N/mm^2}$$

To calculate the contact area, the following was used: [2.2.11].

$$Ac = tm\ x\ lr \qquad [2.2.11]$$

Where tm = Average width of the corn size; tm=1 cm

Ac = Contact area of the roller with the feed
Lr = Roller length [m]
$Ac = 0.01m\ x\ 0.05$
$Ac = 0.0005m^2$

Therefore,

$$Fb = \frac{1x10^7N}{m^2} x\ 0.0005m^2$$
$$Fb = 5000N$$

Then the friction force.

$$Fr = 0.57x\ 5000 = 2050N$$

Considering four vertical supports, made with 2"X1/82 steel angle and a weight to support of 30kg, there is a total force of 295 N, divided into each support, so in each one we have a force of 73N.

Results

With the information obtained, the design is carried out, thus making a subassembly 1 for the base as shown in figure 3.1.

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Box 2

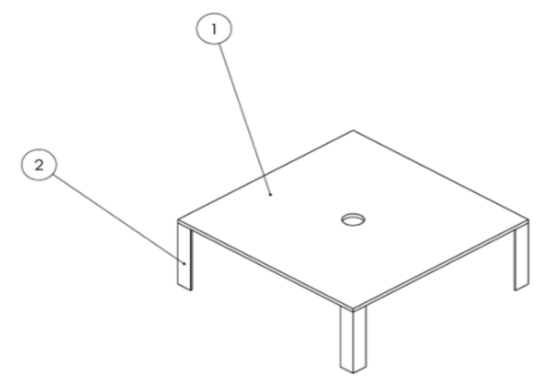

Figure 1

Base for the pellet mill, Number one represents the support and number 2 is the base

Source: Figure created by the authors

The subassembly 2 of the motor [7], the sprockets [1] [model 15T-520-S-Z, WEYINGSI], the chain [2] [525-Z8-H, DID brand], the transmission shaft [3] is carried out, likewise a bearing system [4] was added [F205-LDK wall bearing, FAG brand], the extractor plate with its respective matrix [5] and the rollers [6] [150-250-MKFD00P, MELKO brand]. This subassembly can be seen in figure 3.2.

Box 3

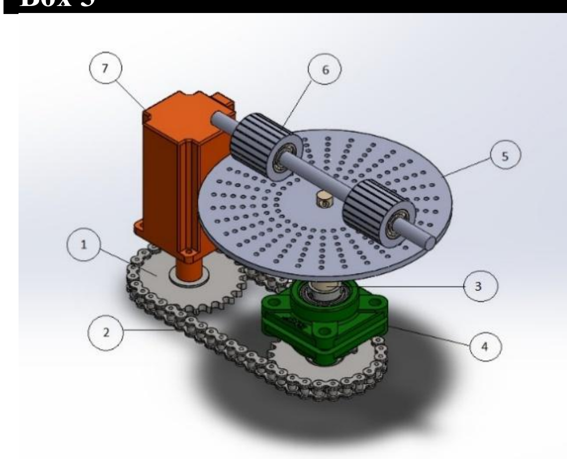

Figure 2

Subassembly 2. Motor, transmission system, rollers and extractor plate.

Source: Figure created by the authors

Once subassembly 2 is completed, proceed to complete subassembly 3, see figure 3.3, which consists of the discharge hopper [1], the pelletizing chamber [2], with its respective Grainger brand adjuster [3] [5-9-10] with nut.

Box 4

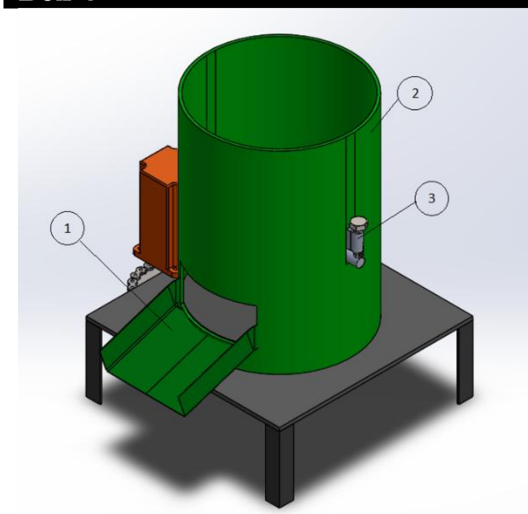

Figure 3

Subassembly 3. Pelletizing chamber, adjuster with nut and discharge Hopper.

Source: Figure created by the authors

With the last subassembly, all the elements are integrated, leaving the design of the pelletizing machine as can be seen in figure 3.4.

Box 5

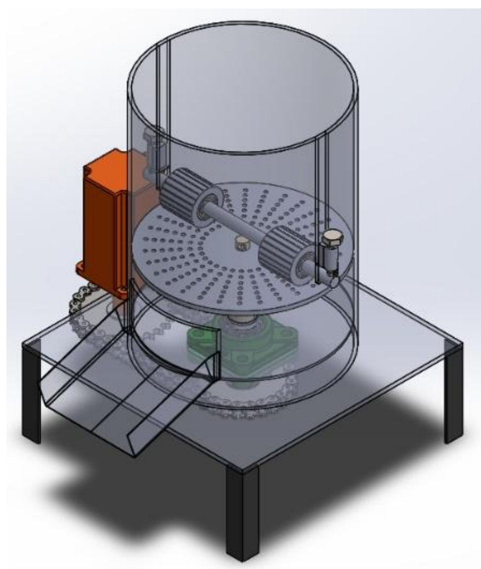

Figure 3.4

Pelletizing machine

Source: Figure created by the authors

3. Conclusions

The final product, the pellets, is characterized by their hardness and greater durability, as well as added value: when compressed, they become a more compact and balanced product, providing animals with nutritionally balanced feed. It also simplifies the distribution of rations based on the birds' nutritional consumption.

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The rotary die pelletizing machine has the advantage of being able to be installed anywhere; it does not require extensive space, which facilitates its operation and maintenance, thus ensuring lower operating costs for each owner.

This machine can benefit over 8,750 small and medium-sized chicken producers in the state of Hidalgo, generating an average of 350 kg of pellets per day.

Declarations

Conflict of interest

The authors declare that they have no conflicts of interest. They have no financial interests or personal relationships that could have influenced this work.

Author contribution:

Mariscal-Navarro, Fidel Alejandro: Contributed to the research technique, as well as the development and observations for future design recommendations.

Bravo-Cadena, Román: Contributed to the implementation of the research method for the study object.

Cardon-Angeles, Asael Jesse: Contributed to the idea and design of the project.

Téllez-Ramos, Jonathan Esaú: Provided fieldwork and advice on data processing.

Funding.

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Abbreviations

FIRA. Fideicomisos Instituidos en Relación con la Agricultura. México

SAGARPA. Secretaría de Agricultura, ganadería, desarrollo Rural, Pesca, México.

UNAM. Universidad Nacional Autónoma de México.

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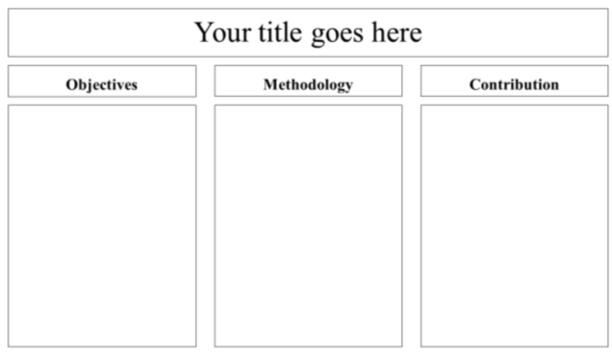

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General explanation of the subject and explain why it is important.

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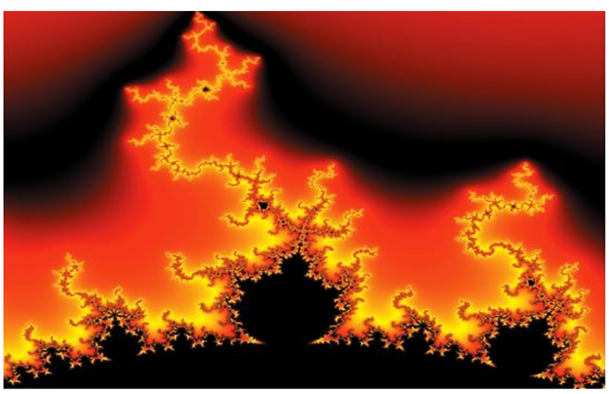

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Table 1
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$$Y_{ij} = \alpha + \sum_{h=1}^{r} \beta_h X_{hij} + u_j + e_{ij} \quad [1]$$

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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.

Conclusions

Clearly explain the results and possibilities of improvement.

Annexes

Tables and adequate sources.
<u>The international standard is 7 pages minimum and 14 pages maximum.</u>
Declarations

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

Specify the contribution of each researcher in each of the points developed in this research.

Prot-
Benoit-Pauleter, Gerard: Contributed to the project idea, research method and technique.

Availability of data and materials

Indicate the availability of the data obtained in this research.

Funding

Indicate if the research received some financing.

Acknowledgements

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

Abbreviations

List abbreviations in alphabetical order.

Prot-

ANN	Artificial Neural Network

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