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Journal Innovative Design

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Presentation of the content

In the first article we present, *Design and characterization of a prototype anaerobic reactor for domestic wastewater treatment using fixed biomass*, by RODRIGUEZ-MORALES, José Alberto, RAMOS-LOPEZ, Miguel Angel, CAMPOS-GUILLEN, Juan and LEDESMA-GARCIA, Janet, in the next article we present, *Design and Construction of a rectangular section channel-prototype, to determine the specific energy in the three types of regimens: Critical, subcritical and supercritical* by CARO-BECERRA, Juan Luis, LUJÁN-GODÍNEZ, Ramiro, VIZCAÍNO-RODRÍGUEZ, Luz Adriana and REYES-BARRAGÁN, José Luis, with adscription in the Universidad Politécnica de la Zona Metropolitana de Guadalajara, in the next article we present, *Contingency Access Control COVID-19*, by RODRÍGUEZ-MIRANDA Gregorio, VALENCIA-GARCÍA, Alejandro Cesar, SANTOS-OSORIO, Rene and JUÁREZ-SANTIAGO, Brenda, with adscription in the Universidad Tecnológica de San Juan del Río, in the next article we present, *Optimal active yaw control for a wind turbine*, by VILLAFUERTE-ALTÚZAR, Eugenio, GURUBEL-TUN, Kelly Joel and HARO-FALCÓN, Nicolás, with adscription in the Universidad de Guadalajara.

Content

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Design and characterization of a prototype anaerobic reactor for domestic wastewater treatment using fixed biomass

Diseño y caracterizacion de un reactor anaerobio prototipo para tratamiento de aguas residuales domésticas utilizando biomasa fija

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Abstract

In developing countries, the RAFA (Anaerobic Upflow Reactor) reactor stands out as a viable alternative in wastewater treatment. In addition, biofilters are used in the biological reactors that have the objective of biofilm formation, by means of which effluents of better quality are obtained. An anaerobic reactor of 140 Liters was evaluated for the treatment of domestic wastewater. Granular activated carbon and cellulose fiber filters were placed outside. After the stabilization of the reactor (3-6 months), different volumes corresponding to 3, 5 and 7 liters / day of residual water were evaluated, with hydraulic retention times (HRT) of 47, 28 and 20 days, respectively. Percentages of reduction of BOD5, COD, SST and fecal coliforms were obtained for the 3 effluents. It was obtained for 3 liters / day: 90%, 66%, 90% and 99.9%. For 5 liters / day: 93%, 71%, 90% and 99.9%. For 7 liters / day: 80%, 65%, 91% and 99.9%. With these results and comparing them with the NOM-003-Ecol-1997. It is concluded that the treated wastewater can be reused to be reused in public services.

Wastewater, Hydraulic retention time, Biofilm, Biological reactor

Resumen

En los países en desarrollo, el reactor RAFA (Reactor anaerobio de flujo ascendente) resalta como una alternativa viable en el tratamiento de aguas residuales. Además, dentro de los reactores biológicos se emplean soportes que tienen como objetivo la formación de biopelícula, mediante la cual se obtienen efluentes de mejor calidad. Se evaluó un reactor anaerobio de 140 Litros para el tratamiento de aguas residuales domésticas. En el exterior se colocaron filtros de carbón activado granular y fibra de celulosa. Despues de la estabilización del reactor (3-6 meses), fueron evaluados diferentes volúmenes que correspondieron a 3, 5 y 7 Litros/dia de agua residual, con tiempos de retención hidráulica (TRH) de 47, 28 y 20 días, respectivamente. Se obtuvieron porcentajes de reducción de DBO_5, DQO, SST y coliformes fecales para los 3 efluentes. Se obtuvo para 3 Litros/dia: 90%, 66%, 90% y 99.9%. Para 5 Litros/dia: 93%, 71%, 90% y 99.9%. Para 7 Litros/dia: 80%, 65%, 91% y 99.9%. Con estos resultados y comparándolos con la NOM-003-Ecol-1997. Se concluye que se puede reutilizar el agua residual tratada para que se reusen en servicios al publico.

Aguas residuales, Tiempo retención hidráulica, Biofilm, Reactor biológico

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Introduction

This work presents the evluation of a prototype for the treatment of domestic wastewater through anaerobic digestion, which does not use any type of energy and easy maintenance, which makes the prototype sustainable.
Introducción

Problem in the availability of water

Globally, the volume of renewable water per capita has decreased by 40% in the last 22 years [1]. This is a consequence of significant population growth and changes in lifestyles due to rapid economic growth that generate high demands for water to supply agriculture, industry and cities [2, 3] In addition, the inadequate treatment of the large volumes of water generated by the different economic sectors has caused diseases and environmental pollution [4]. In addition, the lag in municipal wastewater treatment infrastructure in most countries of the Latin American and Caribbean region is a matter that has not received due attention from the competent authorities. In the case of wastewater collection and drainage systems that do not have a treatment plant, a common situation in developing countries, the wastewater is discharged directly into the natural environment (body of water or soil). With a UASB type anaerobic reactor fed with typical municipal wastewater, removal efficiencies in Chemical Oxygen Demand (COD) of the order of 60 to 70% and biochemical oxygen demand (BOD_5) of 70 to 80% can be achieved [5].

Anaerobic wastewater treatment

In anaerobic systems, bacteria, both strict and facultative anaerobic, are involved; which, through a series of stages and in the absence of oxygen, degrade organic compounds, producing methane and carbon dioxide, mainly.

Anaerobic digestion is carried out in four successive stages. In the first stage, called hydrolysis, complex organic substrates are degraded into soluble monomers. In the second stage, known as acidogenesis, soluble monomers are transformed into organic acids, alcohols, carbon dioxide and hydrogen. In acetogenesis, organic acids are transformed into acetic acid, hydrogen and carbon dioxide.

Finally, in methanogenesis, methane is produced in two ways: the first from the degradation of acetic acid and the second, through the reaction between carbon dioxide and hydrogen produced in the previous stages. Methanogenesis is the slowest stage and determines the overall dynamics of the process; likewise, it is the most sensitive to changes in operating conditions. Therefore, it is considered as the limiting stage and the most interesting from the point of view of automatic control. Thus, this type of process brings benefits in the environmental sector and in the energy sector. The hypothesis raised in the present work is the effect of the application of hydraulic retention time conditions in a UASB type reactor and the interaction of anaerobic microorganisms fixed in the form of a biofilm in a polymeric material, which will reduce the organic load of domestic wastewater.

Some requirements of anaerobic systems in general

The start-up period of anaerobic reactors is a critical and relatively slow stage because a sufficient and balanced microbial population must be developed that often determines the efficiency of reactor operation. Biomass activity depends on many factors; in relation to micronutrients, one's deficiency can limit the biological process. Anaerobic digestion is very sensitive to certain parameters and certain operating conditions, such as pH, temperature, overloads, etc. [7, 8,9]. The growth rate is approximately doubled with an increase of 10°C until the optimum temperature is reached. The typical optimal temperature ranges for bacteria are: 12-18 °C for psychrophilic bacteria, 25-40 °C for mesophilic bacteria and 45-65 °C for thermophilic bacteria. In the case of pH, methanogen organisms effectively work between pH range of 6.5-8.2, with an optimal pH of 7.0. Although it has been shown that the optimal pH range for maximum gas performance is 6.5- 7.5 [10].

Importance of supports for the formation of biofilm in wastewater treatment

Currently, bioreactors with continuous biomass mixing have been built. In addition, they have a retention time based on organic load and inflow rate.

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However, this can be a problem because active bacteria, which could be used for wastewater treatment, can leave the reactor causing longer retention times and a decrease inactive microorganisms. To solve this problem, immobilization of bacteria on a solid surface is necessary in order to increase the contact surface in bioreactors.

Due to the formation of biofilms, the hydraulic retention time is independent of the cell retention time. In this way the washing effect is decreased in the bioreactor and biogas production increases [11]. A biofilm is an association of microorganisms attached to a surface, which are trapped within an extracellular polymeric substance [12]. Biofilms have the capacity for the effective elimination of organic compounds and the production of methane [13,14].

The importance of using plastic (such as PET) when employing it as a support material for water treatment is mentioned below: Plastic is used as an indispensable material for modern life. Plastics production has increased production from 0.6 million metric tons in 1950 to 2.5 million tons in 2010, with an average annual growth of about 10%.

Due to human neglect, plastics are found in rivers and oceans. Plastics in the ocean are thought to be increasing. Lightweight plastics such as polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), and foamed polystyrene (PS) are frequently found on the ocean surface around the world. Ingestion of plastics by marine animals has been widely reported.

With regard to the use of plastics, the vast majority of researchers have found that microorganisms are incorporated much faster on hydrophobic surfaces such as Teflon and other plastics than on hydrophilic supports [15].

The objective of the work is to develop an anaerobic system for the reduction of the organic load in domestic wastewater by fixing microorganisms in the form of a biofilm in the PET support.

Methodology

Conditioning of the UASB type reactor

The design of the prototype was carried out as shown in Figure 1. Subsequently, the 140-liter UASB type reactor was built, as shown in Figure 2. 15 PET columns were placed at the bottom of the reactor. For the formation of the PET columns, the 0.5, 1 and 2 liter bottles were collected and cut from the base. In addition, a cellulose filter (acting as a solid-liquid separator) and a lid were placed on top to completely cover the reactor. A granular activated carbon filter and a cellulose fiber filter were attached to the outside of the reactor. The prototype consists of influent inlet tubes (raw wastewater), effluent outlet (treated water), sludge meter and sludge purge. The prototype was operated outdoors at room temperature.

Physicochemical characterization of the influencer

Within the adaptation and growth phase, 3 random samples of the influencer were taken (which were carried out in triplicate), in 3 different months and physicochemical tests were carried out in the Hydraulics Laboratory of the Cerro de las Campanas Campus of the UAQ. It was based on the methodologies proposed in NOM-003-SEMARNAT-1997 to perform the following analyses: Fecal coliforms (C.F.), Helminth Eggs (H. H), Fats and Oils (G and A) and Total Suspended Solids (SST). For the determination of the parameters, they were sent to a certified laboratory for analysis.

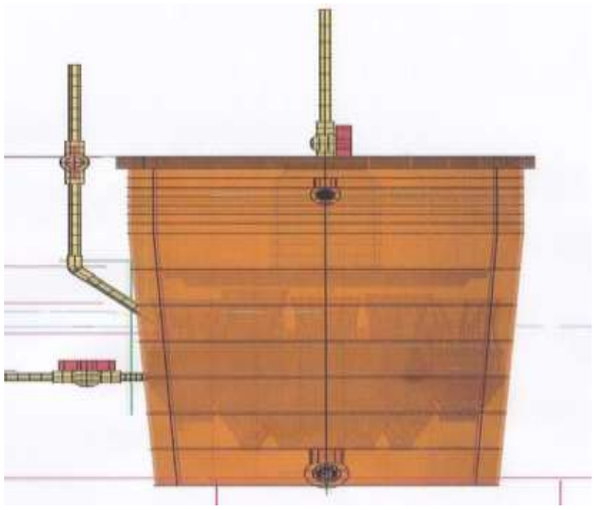

Figure 1 Design of the UASB reactor prototype

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Stabilization of the UASB type system

Initially 40 liters of sludge from a storage pit were introduced into the interior of the UASB reactor. During a period of 3 months the reactor was fed with 1 Liter of wastewater per day, after this time it was proceeded for another 3 months to feed the reactor with 2 Liters of wastewater per day for acclimatization, adaptation and growth of the sludge (the wastewater came from the carcamo of the aerobic water treatment plant of the Multidisciplinary Building Campus Airport of the UAQ). The measurement of the volume of sludge was carried out in a 1 liter specimen to see the growth, the pH value and temperature during this period was also obtained. The turbidity of the treated wastewater was obtained to check the stabilization of the system during this period (1 time each month), in order to proceed to the variation of the flow of the influent.

Figure 2 Construction of the prototype of the UASB type reactor with 2 filters placed on the outside of the reactor (cellulose and granular activated carbon filter)

Analysis of the flow variation of the influent (obtaining the physicochemical analyses of the 3 flows)

Once the system was stabilized, the flows of the influent were varied, where 3 volumes were tested, which corresponded to 3, 5 and 7 liters of wastewater per day. Hydraulic retention times (HRT) were 47, 28 and 20 days respectively. Each volume was added per day until first reaching the HRT of 47, then that of 28 and 20 days respectively to obtain each effluent (3, 5 and 7 liters per day). After each HRT of each volume, 9 effluents corresponding to each flow rate (3, 5 and 7 liters per day) were sampled to perform the physicochemical analyses based on NOM-003-SEMARNAT-1997.

Fixation of the biofilm to the PET and its respective analysis by Scanning Electron Microscopy

After the treatment of the 3 effluents and once it was possible to visually observe the anaerobic sludge adhered to the PET support as shown in Figure 3.

The evidentiary analysis of the fixation of the biofilm was carried out. This analysis was performed by Scanning Electron Microscopy, where small pieces of PET were cut, as shown in Figure 4, which were taken for analysis at the Center for Applied Physics and Advanced Technology (CFATA), Electron Microscopy Laboratory of the UNAM Juriquilla campus located in Juriquilla, Querétaro.

Figure. 3 Adhesion of the sludge visually to the PET material. To the PET columns inside the reactor after 6 months of acclimatization

Figure 4 Trimmed pieces of PET columns

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Results

Physicochemical characterization of the influencer

The physicochemical characterization of the influencer in the 4 different samples is shown in Table 1. These results determined the characteristics of the wastewater during the treatment and in this way to be able to compare with the effluents after the treatment (which will be mentioned later), in such a way it was possible to determine the efficiency of the treatment in the anaerobic system. The pH and temperature conditions of the influent in the different samples were in a pH range of 7.0 to 8 and Temperature range of 15 to 26 °C.

No. sample	Fecal Coliforms NMP/100 mL	Fats and oils mg/L	SST mg/L	BOD_5 mg/L	H H (h/L)
Prom.Total4 muestreos	≥2,400,000	3.3	299	270.3	<1

Table 1 Average results of chemical analyses of the influencer

Stability of the UASB type system.

In a period of 3-6 months, the system was stabilized. It was observed that the supernatant was clarified and no scattered flocs were observed in it, which indicated that it had changed from scattered to flocculent mud. What reinforced the above was the comparison that was made in a sampling obtained inside the reactor with respect to that of the influent. The pH and temperature conditions during the selection stage were: pH between 7.0 - 8 and temperature range between 10 - 20 °C. The results of turbidity in 6 different months are shown in Table 2, both of the influent and the effluent (samples obtained at random), which corroborated the stabilization stage of the anaerobic system, due to the difference in the measurement of turbidity of the different influents and effluents according to time.

The filtration system

The coupling of the granular activated carbon filter and the cellulose fiber filter contributed to the elimination of the color of the treated wastewater, which is expressed in nephelometric units of turbidity (NTU), is a unit used to measure turbidity, as can be seen in Table 2.

Sample number/No. of Month	Influencers (UNT)	Effluents (UNT)
1	250	130
2	240	139
3	230	136
4	270	129
5	245	125
6	220	115
Average	243	129

Table 2 Results of the measurement of turbidity of the influents and effluents in different months with influents of 1 and 2 L

Physicochemical analysis of the 3 flows and obtaining the percentages of reduction.

During the treatment of the 3 different effluents (3, 5 and 7 Liters), the pH and temperature conditions of the sludge were as follows: pH of 7.2 – 8.0 and temperature range of 11 – 28 °C. These conditions are within an acceptable range for treatment in anaerobic systems, so it was not necessary to add reagent to neutralize the pH or heat to increase the temperature. It should be noted that the optimal conditions in this treatment are: temperature > 35 ° C and pH between 7-7.5, but it could be shown that an efficient reduction of contaminants was possible, even without operating at the optimal conditions for these systems. Table 3 shows the averages of the results of the analysis of effluents of 3, 5 and 7 liters and compares them with the values specified with NOM-003-SEMARNAT-1997. Table 3 shows that for effluents of 3 and 5 Liters the standard was met and for the effluent of 7 Liters, only the BOD_5 was not complied with.

The percentages of reduction of the pollutants indicated in the same regulations of the 3 effluents are indicated in table 4.

	Fecal Coliforms NMP/ 100 mL	H H (h/L)	Fats and oils mg/L	BOD_5 mg/L	SST mg/L
Values of NOM-003-SEMARNAT-1997	1,000	1	15	30	30
Vol. de 3 L	3	< 1	3.0	27	29
Vol. de 5 L	25	<1	3.6	19	30
Vol. de 7 L	435	<1	1.2	55	26

Table 3 Comparison of the parameters obtained from the effluents with the values indicated in the nom-003-SEMARNAT-1997 regulation

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This was achieved by further stabilizing the system. Finally, it was observed that by increasing the flow and therefore the organic load of 3-5 Liters, an increase in the reduction of these contaminants was obtained, due to the increase in the stability of the system. On the contrary, by increasing the flow to 7 Liters, although for BOD_5, COD, and fecal coliforms the reduction did not increase with respect to the effluent of 5 Liters, still a similar reduction difference was obtained between these two effluents of 5 and 7 Liters (Table 4).

Sample	BOD_5 % of decrease	DQO % of decrease	SST % of decrease	Fecal Coliforms % of decrease	H H % of decrease	Fats and oils % of decrease
3 L	90	66	90	99.9	100	9
5 L	93	71	90	99.9	100	0
7 L	80	65	91	99.9	100	64

Table 4 Percentage of removal of organic and microbial load in the treated wastewater (effluent) compared to the influent

Analysis of the fixation of the biofilm to the PET by Scanning Electron Microscopy

The fixation of the anaerobic sludge biofilm to the PET columns after 6 months was carried out as shown in Figure 5.

Figure 5 Adhesion of the biofilm in an anaerobic system after 6 months

The pH and temperature conditions during the biofilm fixation stage were: pH 7.2 – 8 and temperature range 12 – 27 °C. The analyses of the biofilm by Scanning Electron Microscopy are shown as shown in Figure 6, which served as a verification of the adhesion of this, in order to confirm that the anaerobic microorganisms adhere to the PET and therefore improve the treatment by being in a greater area of contact.

It is claimed that the biofilm is mostly made up of bacteria, by the size ranging from 0.5-5 μm and the shapes of these. Therefore, this set of microorganisms-biofilm, interact to be fixed to the PET, improving the treatment.

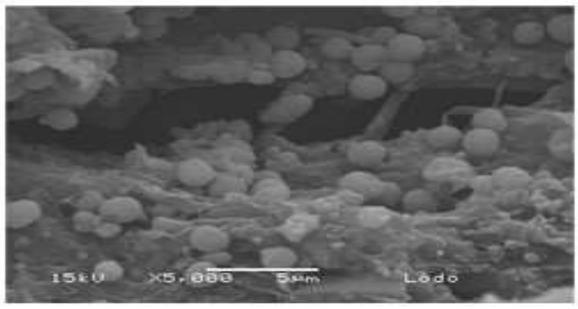

Figure 6 Analysis by Scanning Electron Microscopy (15 kV, X 5,000 and 5μm)

Gratitude

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Conclusions

The fixation of the biofilm to the PET after 6 months was achieved, which is a suitable material for its fixation, to the conditions under which the system was operated (temperature, pH and volume of wastewater) and percentages of removal of the evaluated parameters similar to those obtained in anaerobic systems in general (UASB and among other anaerobic systems) and with aerobic systems were obtained.

The fixation of the biofilm by scanning electron microscopy.

The stabilization of the system was achieved after 3-6 months of adaptation of the inoculum to the influent, with the pH and temperature conditions obtained.

Granular activated carbon was chosen as the filter medium of the effluent according to the results obtained from turbidity and COD in the filtered with granular activated carbon and zeolite.

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The percentage of removal increased for the parameters of BOD_5, COD, SST, fecal coliforms and fats and oils, in the effluents of 3 and 5 Liters, this due to the increase in the stability of the system, as well as the increase in the organic load. With respect to the effluent of 7 Liters there was no significant increase in the decrease of these parameters, but the percentages of decrease were similar to these effluents.

The UASB type system using, brings economic benefits by not using reagents or energy compared to other systems of the same type obtaining important percentages of removal compared to biological systems. The environmental regulations NOM-SEMARNAT-1997 were complied with for effluents of 3 and 5 Liters, with the exception of the effluent of 7 Liters, where only the boD5 parameter did not meet.

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Design and Construction of a rectangular section channel-prototype, to determine the specific energy in the three types of regimens: Critical, subcritical and supercritical

Diseño y Construcción de un canal-prototipo de sección rectangular, para determinar la energía especifica en los tres tipos de regímenes: Crítico, subcrítico y supercrítico

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Abstract

The problem of water scarcity is not a transient issue, but to solve it has been a long lasting endeavor for humanity. Many human societies have tried diverse solutions to solve this problem and one of them was to efficiently move water for the subsistence of all people. For this purpose, civil and agricultural engineers seek to find novel ways to conduct water as close as possible to where it is needed, e.g., cultivated fields and water supply reservoirs, or to build up infrastructure to greatly reduce the immense problem of floods generated by high intensity rains. The main goal of this paper is to determine the water specific energies occurring in critical, subcritical and supercritical flow regimes, by means of a prototype rectangular section channel operation. Application of Bernoulli´s equation for uniform flow conditions is the adopted methodology. As final conclusions we can state that development of new channel prototypes facilitates the experimentation of fluids, allowing to a great extent the stabilization of flow, thus, optimizing the measurement of different types of key water variables.

Conduction, Flooding, Specific energy

Resumen

El problema de la escasez del agua no es tema de actualidad. Muchas sociedades han tratado de solucionar este problema y uno de ellos fue trasladar eficientemente el agua para la subsistencia de todas las personas, se han construido canales lo más cerca posible de donde sea necesitada el agua, en sitios tales como sembradíos y embalses, o la infraestructura para aliviar en gran medida el inmenso problema de las inundaciones generados por lluvias de alta intensidad. El objetivo es determinar las energías específicas del agua en los siguientes regímenes: crítico, subcrítico y supercrítico, mediante la operación de un prototipo-canal de sección rectangular. La metodología empleada consiste en la aplicación de la ecuación de Bernoulli para condiciones de flujo uniforme. Como conclusiones podemos afirmar que el desarrollo de nuevos prototipos de canales facilita la experimentación de fluidos permitiendo en gran medida la estabilización de flujos, por lo que optimiza la medición de los diferentes tipos de importantes variables del agua.

Conducción, Inundaciones, Energía específica

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1. Introduction

Fluids are liquid or gaseous substances that having low cohesion, adopt the shape of the bowl that contains them. Some of these containers can be classified either channels or pipelines. In channels, the fluid presents a surface open atmosphere and flows under the action of gravity, on the contrary, inside the latter the fluid is totally confined causing it to exert gravity, pressure and viscosity forces on the surrounding walls. Furthermore, in channels surface tension is present as well as other forces that can cause sediment dragging and accumulation, thus affecting the initial flow conditions (Sotelo, 2002).

Channels also have specific characteristics that must be considered in order to fully understand fluid dynamics. One of such characteristic is freeboard, which is defined as the distance or height from the free surface of the water to the top of the channel (the allowable limit before overflow occurs). Another characteristic is the longitudinal slope of the channel bottom, which is necessary for water to flow downstream (Chow, 2004). These and other characteristics should be taken into account for the design and construction of channels as conduction works. Despite the similarity between the two kinds of conduits, it is much more difficult to describe water flow along open channels than in pressurized pipelines. The flow conditions in open channels are complex due to the fact the position of the free surface can change with respect to time and space, as well as water depth, flow rate and longitudinal slope of the channel (Chow, 1994).

Examples of complex and detailed water works are the following: navigation channels, spillways, diversion tunnels hydroelectric inlet conduits, irrigation and drainage waterways and weirs, as well as channels constructed and operated at research laboratories as prototypes for experimental procedures.

The main objective of this paper is to characterize the three types of regimens occurring during the design and construction phases of a rectangular section prototype channel: critical, subcritical and supercritical flows by means of Froude number calculations, a number which represent the relation between the mean velocity of the uniform flow regime and the relative wave speed.

2. Background

Channels can be either natural or artificial depending on their origin. The former is usually created by aquatic ecosystems to conduct and drain water, forming rivers or streams. On the other hand, artificial channels are manmade, built by civil engineers, either for navigation purposes of defense works to prevent flooding. One of the main characteristics of natural channels is the irregularity of their shape, something which causes dimension and depth variations along the channel. In contrast, Artificial channels have a well-defined geometric shape, and in several sections the dimensions may remain constant.

Hydraulic engineering is as old as civilization itself, this fact is evident if we think of man´s long struggle for survival and to achieve better living conditions, something which has driven societies to learn how to better use and control water.

The history of hydraulic engineering in Mexico dates back to pre-Hispanic times and can be described through its hydraulic works. These works have solved to the needs of catchment, conduction, storage, distribution and irrigation during the different periods through which the country has passed (Peña Santana, 1989).

The Mexica people, one of the most representative pre-Hispanic societies, had a close relationship with their water resources. As a proof of this, there exist data about the fact that their cities were designed to have efficient irrigation systems through a network of aquatic communication schemes, formed by “chinampas”, a local nahuatl word for a type man-made floating farming rafts, water channels and irrigation ditches; a novel solution with which they were able to solve a recurring problem of Mesoamerica cultures: water use and transportation (Villagómez, 2013).

Besides the water use and transportation purposes of channels, flood prevention and protection are some additional and important objectives for efficient design and construction of these kind of water works. Every year and all over the world occur frequent and severe flood episodes that inflict material and personal damages to human settlements and existing environmental conditions.

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There are numerous cases of many Mexican cities that suffer severe flooding caused episodes by high intensity rains, such as several cities located in the state of Tabasco that experienced extreme flooding events during the 2016 and 2021, rainy season when the city streets became water became channels (Cama-Pinto *et al*, 2016)

Furthermore, floods are frequently accompanied by water channel clogging caused by solid material coming down from the upper parts of watersheds, the quantity of which depends on the intensity of runoff, vegetation cover, soil type as well as terrain slope, all of which define the areas of deposition of the material (Eslava *et al*, 2006)

3. Channel design and construction

The process of calculating the main channel parameters and dimensions is based on well-known existing equations seeking to carry out a proper design. Among the parameters to be determined are the following: general geometry of the channel, the occurring water specific energy and the channel depths for each regime conditions.

3.1 Geometry of the channel

Based on the present conditions of the Laboratory of Hydraulics of the Polytechnic University of the Metropolitan Zone of Guadalajara and the specific characteristics of the existing hydraulic bank, the construction of a rectangular channel was chosen.

The equations to be used in order to obtain the eigenvalues of the channel are taken from literature provided by several authors (Chow, 2004, Rodríguez, 2008. Morales Nava *et al*, 2013), initial dimensions proposed for design of the channel are: channel width b = 0.11 m and channel height HT= 0.09 m.

4. Methodology

Freeboard height (FB) is obtained by a simple Rule of Three calculation, taking into account that it would approximately be 30% of the height of the channel.

$$FB = \frac{30\% * 0.09\ m}{100\%} = 0.027\ m \quad (1)$$

The hydraulic or flow depth (y) is:

$$HT = BL + y\ \therefore$$
$$y = HT - BL = 0.090 - 0.0275 = 0.0625\ m \quad (2)$$

Geometric Calculations

The area (A) of the channel is:

$$A = b * y = 0.11\ m * 0.037\ m = 0.0041\ m^2 \quad (3)$$

Wetted perimeter (P)

$$P = b + 2y = 0.11 + (2 * 0.037) = 0.184\ m \quad (4)$$

Hydraulic radius (R)

$$R = \frac{A}{P} = \frac{0.0041}{0.184} = 0.022\ m \quad (5)$$

Section factor (Z)

$$Z = b * y^{1.5} = 0.11 * 0.037^{1.5} = 0.00078\ m \quad (6)$$

From Manning´s equation we have that:

$$V = \frac{R^{3/4}\, S^{1/2}}{n} \quad (7)$$

Where
R = hydraulic radius (m),
S = slope of the channel (dimensionless factor)
n= roughness coefficient (s/m^3).

The flow rate (m^3/s) is defined as:

$$Q = V * A \quad (8)$$

Where
V = is the velocity of water inside the channel (m/s)
A = cross-sectional area of the channel (m^2)

By replacing equation (7) in (8), we obtain another expression for the flow rate, which will be used later on

$$Q = A * \frac{R^{3/4}\, S^{1/2}}{n} \quad (9)$$

Now, the section factor (Z) can also be calculated by the following expression:

$$Z = \frac{Q}{\sqrt{g}} \quad (10)$$

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Finally, by equating the equations and replacing the value of the channel width (b) and the gravity force at sea level g = 9.81 m/s², we arrive at equation (11), which will be used together with equation (9), in order to determine the critical slope of the channel Sc, a dimensionless factor.

$$Q = 0.344 * y^{1.5} = 0.344 * 0.037^{1.5} = 0.00245\ m^3/seg \quad (11)$$

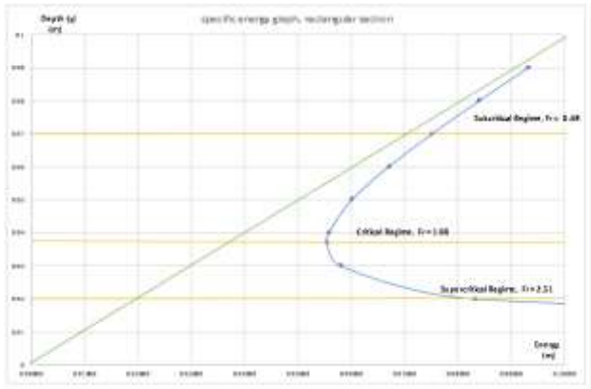
4.1 Graph of the curve of depth vs specific energy

In order to determine the depth vs specific energy curve graph, the critical depth range yc (m) and subsequently the operation flow, it is necessary to perform iterations using equations (9) and (11), in order to obtain the value of the critical point directly from the specific energy curve, as show in Graph 1.

The performed iterations are shown in table 1, where flow depth values are given from a range of 0.01 to 0.09 m, with a roughness coefficient n = 0.010, which is the roughness value corresponding to plastic. These data will be used to obtain the graph of the specific energy in addition to obtaining the operating point of the equipment (Chow, 1994).

Depth (m)	Area (m^2)	Wetter perimeter (m)	Hydraulic radius (m)	Energy (m)	Froude
0.010	0.0011	0.13	0.0846	0.2684	7.11
0.020	0.0022	0.15	0.0146	0.0831	2.51
0.030	0.0033	0.17	0.0194	0.058	1.36
0.037	0.0040	0.184	0.0217	0.0554	0.99
0.040	0.0044	0.19	0.0231	0.0558	0.88
0.050	0.0055	0.21	0.0261	0.0601	0.63
0.060	0.0066	0.23	0.0286	0.067	0.48
0.070	0.0077	0.25	0.0308	0.0751	0.38
0.080	0.0088	0.27	0.0325	0.0839	0.31
0.090	0.0099	0.29	0.0341	0.0931	0.26

Table 1 Maximum and minimum depths, to obtain the critical conditions or each regime
Source: Caro Becerra et al., 2022



Graph 1 Graph of the specific energy, to obtain the Froude number, speed and energy available in each regime
Source: Caro Becerra, et al, 2022

When constructing the graph of the specific energy, it is evident that the graph is an asymptotic curve, and precisely in the point where the change of slopes occurs we can locate the operating flow rate, as can be seen in graph 1, yc = 0.037 m, Qc = 0.00245 m³/s.

Therefore, the operating flow rate will be given by the following equation:

$$Qop = \frac{Qc*ymax}{yc} = \frac{0.00245 * 0.09}{0.0375} = 0.00588\ m^3/s \quad (12)$$

Finally, we determine the operating speed of the channel.

$$Vop = \frac{Qop}{A} = \frac{0.0058}{0.0099} = 0.593\ m/s \quad (13)$$

Depth correction – operating flow rate – critical velocity

$$ycc = \sqrt[3]{\frac{Qop^2}{g* b^2}} = \sqrt[3]{\frac{0.0058^2}{9.81*0.11^2}} = 0.065\ m \quad (14)$$

$$Vcc = \sqrt[3]{\frac{Qop *g}{b}} = \sqrt[3]{\frac{0.0058*9.81}{0.11}} = 0.802\ m/s \quad (15)$$

$$Qcc = Acc * Vcc = 0.065 * 0.11 * 0.802 = 0.00573\ m^3/s \quad (16)$$

4.2 Normal depth calculation

For the calculation of the normal depth, the iteration method is used again, making use of the equations proposed by (Streeter et al, 2000), which are shown below:

$$A = C * P^{\frac{2}{5}} = b * yn \quad (17)$$

$$P = b + 2y \quad (18)$$

$$C = \left(\frac{Qop*n}{S^{0.5}}\right)^{\frac{3}{5}} \quad (19)$$

$$C = \left(\frac{0.00585 * 0.010}{0.0057^{0.5}}\right)^{3/5} = 0.0136$$

S represent the slope of the channel template and the value used in our case is 0.0057 (dimensionless).

Having done enough iterations, a normal depth was obtained yn = 0.06 m.

The results obtained show that yn < ycc, which indicates that the slope of the channel is moderate and it is in zone 1. It sholuld also be noted that the profile can change with the value of the flow rate used, which indicates that three types of regimes can be obtained in the same channel: critical, subcritical and supercritical.

Figure 1 Design and construction of a rectangular channel-prototype for the elaboration of uniform flow practice and obtaining these results, by students of the University Polytechnic of the Metropolitan Zone of Guadalajara and University of Guadalajara
Source: Caro, J. L. 2022

Figure 2 Appreciation of the critical, subcritical and supercritical flow in the rectangular section channel with the dimensions and results obtained in the practice
Source: Caro, J. L. 2022

4.3 Final prototype of the channel and its dimensions

Figure 1 shows the final prototype of the channel once it is in operation for different flow rates; Figure 2 and table 2 shows the general dimensions of the channel and data base.

Length	L = 5 m
Width	b = 0.11 m
Maximum height of the channel	H = 0.09 m
Operating range of the channel	Q = 0 – 0.00585 m³/s
Channel speed variation	V = 0 – 0.802 m/s
Water level variation	h = 0 – 0.0725 m
Channel slope variation	S = 0 – 0.0057

Table 2 Range of data base obtained with the prototype-channel
Source: Caro, J. L. 2022

From graph 2, the experiment values of yc and Emin were obtained for each of the runs carried out with a constant flow rate (Chow, 2004; Mejía, 2008) are given at the inflection point of the curve of the specific energy graph and are detailed in the following table 3.

Experiment 1	Q1 = 0,0050 m³/sec	yc1exp = 0.06 m	E1exp = 0.10 m
Experiment 2	Q2= 0,0025 m³/sec	yc2exp = 0,038 m	E2exp = 0.057 m
Experiment 3	Q3 = 0.0011 m³/sec	yc3exp = 0,022 m	E3exp = 0.030 m

Table 3 Experimental data obtained from the specific energy graph for different design flow rates
Source: Caro, et al., 2022

5. Results and discussion

To validate the operation of the prototype channel already built, an experiment was carried out to determine the relationship between the specific energy and the hydraulic load above and below a triangle-shaped block submerged in the channel to determine the specific energy before and after the block. Sudden changes in the flow are not taken into account because there are no changes in the geometry of the section, in order to obtain multiple critical stresses.

According to (Mejía, 2008; Marbello, 2005), it is important to remember that the specific energy is defined as the sum of the potential energy (depth of flow) plus kinetic energy.

$$E = y + \frac{V^2}{2g} \quad (21)$$

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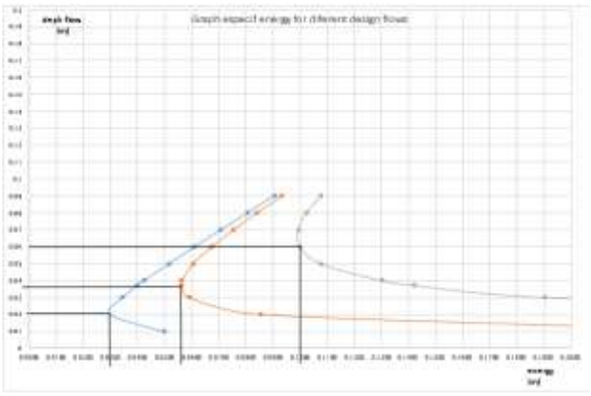
$$E = y + \frac{Q^2}{2g\,y^2} \quad (22)$$

Where
E = specific energy (m)
y = depth of flow (m)
Q = flow rate (m^3/s)
g = gravitational force (m^2/s)

Three flow rates were used with the rectangular channel prototype, which are as follows: Q1 = 0.0050 m^3/s, Q2 = 0.0025 m^3/s, Q3 = 0.0011 m^3/s, for each of the experiments performed, were obtained directly from the flow sensor, for each value of Q depths were taken before and after the values were reported with the use of the Vernier which offers an accuracy of $\mp 0.05\ mm$.



Graph 2 Graph of specific energy for different types of regimen and flow
Source: González, G. K. 2022

6. Conclusions

From the results obtained, the following can be concluded: the design and construction of the rectangular channel with variable a slope represents a low-cost investment compared to those existing in the market. The construction of the channel has also increased the free development of laboratory practices in the areas of hydraulic and fluid mechanics at the Polytechnic University of the Metropolitan Zone of Guadalajara. The results obtained as validation of the prototype, show that the channel effectively meets the necessary conditions to study and validate the different physical phenomena that can be represented at low scale and thus can be used as a modeling for real studies.

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Contingency Access Control COVID-19

Control de Acceso por Contingencia COVID-19

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Abstract

The main goal of this work is to show results obtained from a software called "Access Control by Contingency COVID-19" which allows the institution control the access to facilities after returning from COVID pandemic in order to avoid crowds of people, this software will help avoid COVID-19 infections .The methodology used for this project was Scrum ,since the development of the project required mainly a constant testing and delivery follow-up, prioritizing activities and adapting changes for greater flexibility to modifications to achieve the main objective in a established time. Currently web applications are being used as a resource in order to put together different projects, in this case health control and University access, applying a survey to generate a QR code with which people will be able to enter the university facilities, this code is read by a mobile application that sends data via wifi to a desktop application that is in charge for validating and recording student`s data, employees and external personnel accessing the institution facilities.

Contingency, Pandemic, Contagions

Resumen

El presente trabajo tiene como objetivo mostrar los resultados obtenidos del software “Control de Acceso por Contingencia COVID-19” que permite a la institución el acceso y control de personal en la reanudación de actividades, para evitar aglomeraciones de personas, buscando como resultado evitar los contagios de COVID-19. La metodología utilizada para este proyecto fue Scrum dado que el desarrollo del proyecto requirió principalmente un seguimiento de prueba y entrega constante, priorizando actividades y adaptando los cambios para mayor flexibilidad a las modificaciones para lograr el objetivo en el tiempo establecido. Las aplicaciones web se están utilizando como recurso frecuente para acoplar diferentes proyectos, en este caso el control de salud y de acceso a la Universidad, aplicando una encuesta para generar un código QR con el cual las personas ingresan a las instalaciones, este código es leído por una aplicación móvil que envía los datos por wifi a una aplicación de escritorio que se encarga de validar y registrar los datos de los alumnos, empleados y personal externo que ingresa a la institución.

Contingencia, Pandemia, Contagios

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Introduction

The main goal of this work is to show results obtained from a software called "Access Control by Contingency COVID-19" which allows the institution control the access to facilities after returning from COVID pandemic in order to avoid crowds of people, this software will help avoid COVID-19 infections. Web applications have been used since browsers got greater capabilities other than displaying text and images. Software industry relays on a new generation of modern applications that take advantage of new web technologies (HTML, CSS and JavaScript) to create interfaces for Internet services. Web applications have become indispensable because of their usefulness. Basically, it is a web page that has been optimized in order to be used from a cell phone. It is also called a web app. The objective is no more than increasing the adaptability of the web to any device. (Ayoze Castillo, 2015)

The QR code technology was created in 1994 by the Japanese company Denso Wave, a subsidiary of Toyota, to speed up the process of registering the necessary parts during the car production process. The goal of its creators was always to develop a system that could allow a certain content to be displayed very quickly. In 1999 the company released the patent for widespread use. QRs are very common in Japan, where they are the most popular two-dimensional code. (Gascón, 2021). There are multiple uses of QR codes. Some of the most important ones are mentioned below:

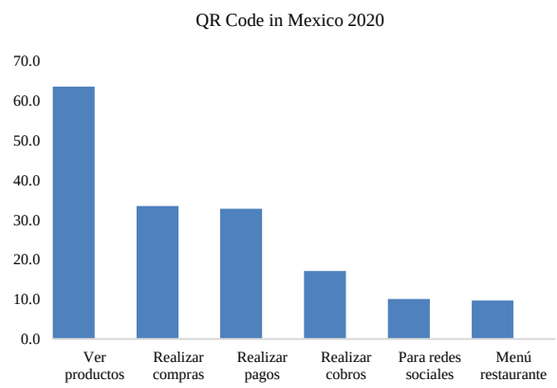
1. Storage and dissemination:

As it replaces the traditional bar code, its use is very similar to the previous one, although taken to the digital terrain in which we move. In summary , it is used to store information and spread it instantaneously , simply and creatively.

2. Creation of company-consumer relationships

They are being used for marketing campaigns and, even, to contact your audience and create closer ties with them, but, be careful , not all companies know how to integrate them or where to place them. (Regrag, 2018).

A study conducted in 2020 identified the most frequent applications of QR (Quick Response) codes in Mexico. The majority of mobile internet users who participated in the survey, about 64%, mentioned that they used QR codes to see the features of a product. Other frequent uses were for shopping and making payments, with 33.5% and 32.8%, respectively. Lack of interest is one of the main reason for not using QR codes according to Mexican consumers. (Kohl, 2021)



Graphic 1 Percentage of people who have used a QR code in Mexico in 2020, by type of use
Source: Statista

Java with SQLite

One of the advantages that SQLite has over common database engines, is that it does not need to be installed to run it, you simply need the binary execution file, add it to the system variables, so that later we can use it wherever we want, now well, query commands, insertion, and creation are exactly identical to those of SQL, however, commands such as show databases and show tables of MySQL do not exist, for this we use .tables, even so as in every good engine, we can consult the help section with .help to see all possible commands. (Diaz, 2014)

SQLite stores data in a single cross-platform file. Since there is no dedicated server or specialized file system, "deploying" SQLite is as simple as linking your library and creating a new regular file. This simplicity has resulted in the mass adoption of SQLite as the database system of choice for embedded applications and devices.

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Just to mention, the total count of SQLite implementations overpasses that of all other database engines combined, as it is included with all major operating systems, most programming languages, an extensive list of embedded hardware, and many major software products. Java and JavaScript. (Olg, 2021)

JavaScript was designed to add effects and animations to websites, but it has evolved over the years, becoming a multipurpose language. It is from 2005, with the arrival of GMail and its use of AJAX, Asynchronous JavaScript And XML technology (thanks to the XMLHttpRequest object created by Microsoft for Internet Explorer 5.0), that launched its popularity.

Currently JavaScript is used in many places, Frontend, Backend, isomorphic applications, microcontrollers, Internet of Things, wearables, etc.... Making it one of the most important programming languages of the present. Recently (March 22, 2016), the website Stackoverflow published a report from a survey of developers using its platform this reports shows that JavaScript is in fact the most used language in the world, not only by Frontend developers but also by Backend developers. (Azaustre, 2016)

Java is a general purpose programming language, especially for internet and web; it is currently found in numerous applications, devices, communication networks, etc. (Joyanes Aguilar & Zahonero Martínez, 2011)

C++ allows programming in high-level language, and if needed, it can even be downgraded to assembly language. That is, it is a language that allows both high, as well as low level programming, to optimize our program. (Bustos, 2018)

Problem

During the pandemic, regular activities that are part of the curriculum and work at the Universidad Tecnológica de San Juan del Río were affected, and students, employees and external personnel interested in accessing the university facilities were not allowed to access the institution due to their unknown health status, as well as the access control all facilities

Justification

The Technical Board of Health requests as a requirement to report on the health status and symptoms of COVID-19 of the people who need to enter the facilities of the institution, that is why a survey is the most convenient thing to do.

Methodology

A project involves a collaborative effort to create a new product, service, or other outcome. Projects are affected by constraints of time, cost, scope, quality, resources, organizational capabilities, and other limitations that make them difficult to plan, execute, manage, and ultimately succeed. (Satpathy, 2013)

A Scrum methodology was chosen because it has the advantage of adapting to the constant change of projects, in which there are three main roles: product owner, scrum master and development team.

Product owner role is the only profile that constantly talks to the customer, which requires him to have a lot of knowledge about the business.

He is responsible for maximizing the value of the development team's work. Maximizing the value of the work goes hand in hand with good product backlog management. The scrum master role is responsible for ensuring that scrum techniques are understood and applied in an organization. It is the scrum manager, a leader who is responsible to remove impediments or drawbacks that the team has within a sprint. Applying the best techniques to strengthen the digital marketing team. (Jeff Sutherland, 2016)

The development team is in charge of carrying out the tasks prioritized by the product owner. It is a multifunctional and self-organized team. They are the only ones who estimate the product backlog tasks, without being influenced by anyone. (Abellán, 2020)

This process consists of the following phases: sprint planning, development stage, sprint review and feedback.

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In sprint planning, the goal is to define what can be delivered in the sprint and how that work will be accomplished. Sprint planning is done in collaboration with the entire scrum team. (West, 2022)

A list of activities were made based on the project requirements, considering the estimated days of development, the status of each activity, the conditions and the approval of the result.

In the development stage, when the sprint is in progress, we must ensure that:

– No changes are made that affect the objective of the Sprint;
– Quality objectives are not lowered

Scope may be clarified and renegotiated between the product owner and the development team as it is learned. (Perez, 2021).

In the sptrint review, a review is made to check the progress of the project, short meetings are held and with this rhythm irregularities in the performance and vision of the project are identified.

The project is tracked and built to obtain the final result of the first sprint, at the same time planning the next review for product improvements.

At the end of the process, the results are delivered to the customers who could use the software and in response to which they could have opinions as feedback and which allow for correction and testing each time a sprint is completed.

The empirical process control is retrospective and not predictive (as in traditional management) It implies that decisions are made based on evidence and knowledge is enhanced by experience. (Duarte, 2019).

The product backlog contains all the work that is necessary for the development or construction of our system or product and is the responsibility of the product owner. In fact, it is the result of the product owner's work with the different stakeholders (customer/s, user/s). (Tamarit, 2019).

Development

Once user stories were analyzed, tasks were prioritized in the product backlog, It then allows the approval and estimation of times and degree of difficulty of the list of tasks.

The following tables describe each of the the tasks prioritized according to the institution's development needs, with three products to be developed.

Task ID	Tasks	Estimate (days)	Priority	State	Condition of approval	Approved
1	As a student, employee or external staff, I want to obtain my QR code to enter the university facilities.			100%	The Qr code saves the data and the answers made.	Ok
2	As a student, employee or external personnel, I would like to complete a survey to verify my health status with the university.	5		100%	Have a yes and no option to answer concise questions.	Ok
3	As a student or employee, I require medical attention for my checkup in case I have any symptoms.			100%	The physician can visualize the patient's symptoms and receive the staff.	Ok
4	As a student, employee or external personnel I want to record my time and date of entry for attendance control.			100%	The time and date of entry for the validity of the Qr code is recorded.	Ok
5	As a student, employee or external staff, I want to record my answers every 24 hours for my follow-up in case I have any symptoms.			100%	That the Qr code has an expiration date so that the survey can be answered each day of admission to the university.	Ok
6	As a student, employee or external staff, I want to select the type of person to enter the university facilities.			100%	Have the option to select the type of user, employee, students and external and generate forms according to the type of user.	Ok
7	As a student, employee or external staff, I want to download my qr code to print it and present it physically.			100%	That the Qr code is generated in a pdf file that allows it to be downloaded and subsequently printed.	Ok

Table 1 Product Backlog of the QR generator
Source: Own Elaboration

Task ID	Tasks	Estimate (days)	Priority	State	Condition of approval	Approved
1	As administrator I want two options for connecting and disconnecting from the server			100%	Automatic disconnection if the server is not started	Ok
2	As administrator I want it to show the number of detected when reading Qr.	5		100%	Display the number of Qr detections read.	Ok
3	As an administrator I want to display the data saved in the qr code when reading.			100%	The personal data of the student, employee or external personnel, as well as the survey responses, are displayed.	Ok

Table 2 Product Backlog of the server
Source: Own Elaboration

Task ID	Tasks	Estimate (days)	Priority	State	Condition of approval	Approved
1	As administrator I want to connect to the server to use the reader.			100%	The server validates the client connection to be able to use it	Ok
2	As an administrator I want to check the server status to verify my connection.	5		100%	Display a server status message	Ok
3	As administrator I want to have the option to connect and disconnect to start and close the server.			100%	The interface has two buttons to connect and disconnect.	Ok
4	As an administrator I want to see the number of users connected to have a control			100%	When generating connection status, show the number of connected clients.	Ok

Table 3 Product Backlog of the QR reader
Source: Own Elaboration

A meeting is held with the team to define the deliverables and objectives of a sprint, then the team asks itself some questions for a better definition: What is going to be done in the sprint? and How are we going to achieve it?

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The team develops and defines the necessary tasks based on the needs of the project. This definition commits the team to the delivery of value that would be made in each final milestone with the client. As a result of the meeting a sprint is created with the defined tasks.

The tasks that were proposed in the start of the product backlog, to carry out the follow-up of the project.

Product backlog		Start		End
To do		Doing	Review	Done
Question Form	Home page design			
Question Form	User type option			
Multiple choice of questions	QR download button			
Page generates QR	Information panels			
SQLite database design	Page that lists users with symptoms			
Database connection	Database connection tests			
Customer connection and disconnection	Server status			
QR reader interface	Server interface			
Test with generated QR	Connection to the server			

Table 4 Set of general project tasks
Source: Own Elaboration

Three sprints were created, one for each part of the project.

The first sprint of the project corresponds to the creation of the web application that aims to present the survey of health status of the person and the generation of a QR code with such data, also within this sprint is the creation of the database and finally the testing.

Sprint	Start		End
To do	Doing	Review	Done
QR download button	Page that lists users with symptoms	Question Form	Information panels
Home page design		User type option	Question Form
Multiple choice of questions			SQLite database design
Database connection			Page generates QR
			Database connection tests

Table 5 Sprint May 2021 QR Generator
Source: Own Elaboration

The second sprint is executed for the creation of the desktop application, a server that is responsible for maintaining connections with mobile devices for the registration and updating of the database of people entering the University.

Sprint	Start		End
To do	Doing	Review	Done
			Server interface
			Customer connection and disconnection
			Server status

Table 6 Sprint June 2021 Server
Source: Own Elaboration

At the end, the sprint was carried out where the tasks prioritized for the generation of the mobile application, responsible for reading the QR code, sending information to the server for registration and showing the person responsible for admission if an individual has any respiratory symptoms, She or He must be addressed to the medical department or if he/she can be admitted to access the facilities.

Sprint	Start		End
To do	Doing	Review	Done
			QR reader interface
			Connection to the server
			Test with generated QR

Table 7 Sprint July 2021 Lector
Source: Own Elaboration

One of the activities of the scrum methodology is the sprint review, which consists of demonstrating the hard work of an entire team: scrum master, product owner and development team. According to the methodology, it is desirable to keep sprint reviews informal. Team members gather around a desk for informal demonstrations and describe the work they are doing for that iteration. (Radigan, 2020).

Finally Scrum methodology asks us to do a sprint retrospective, which is a type of meeting within the agile framework, where teams reflect on what went well and what could be improved in the next sprint. These are essential to continuously improve the development process and ensure that key learnings are incorporated for the next sprint. (MacNeil, 2022)

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Results

The web application for the execution of a survey with the health elements related to COVID-19 for all persons interested in entering the facilities of the Technological University of San Juan del Río and the generation of the QR code with the data of the person and the survey.

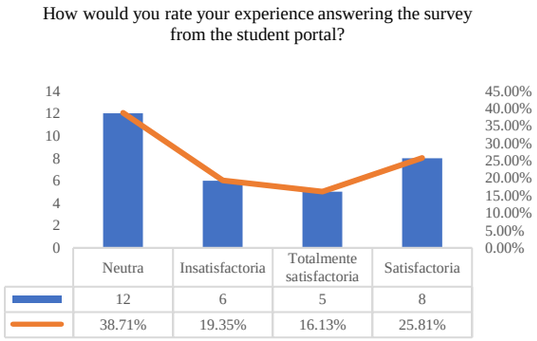
This web application contains a welcome section with a form where time and day of a visit is selected, as well as the type of user entering the university and depending on whether a user is a student, employee or external staff, a different window in the application is displayed to select where to go, after that the survey is displayed with the same selection elements, for all persons. With this data the QR code is generated and can be downloaded in PDF format.

The desktop application was also developed, which serves as a server that allows connecting with the mobile application. The server reads the data sent by the client and stores it in the database. It was developed C++ .

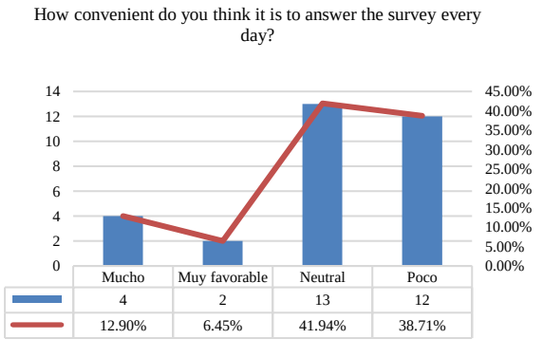
Finally, a mobile application was developed to read the QR code generated with the web application, this information is sent to the server for registration. As the server was developed with C++, the QZXing library was used for the generation and reading of QR codes.

QZxing is a library that has been used for years in all kinds of applications, from personal to professional. This library allows us in a very simple way to read a large number of codes, but we focus on the QR code. (Kotlin Course, 2021)

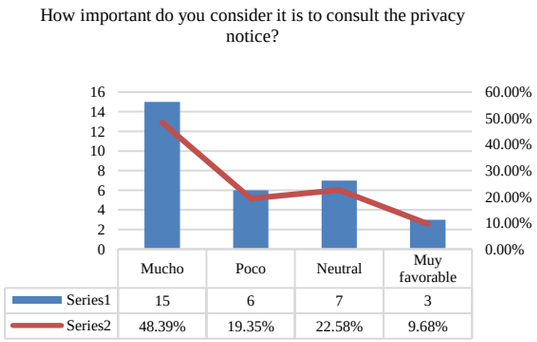
We applied a survey to the students, to reflect their opinion when using the applications developed in the present project. The following figures show the results obtained from the questions asked.



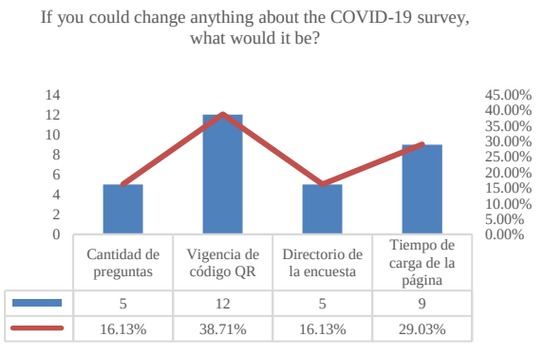
Graphic 2 Satisfaction survey
Source: Own Elaboration



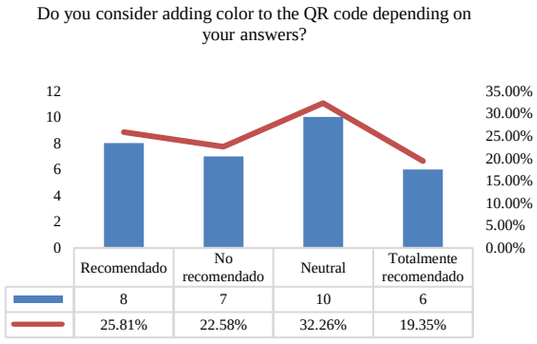
Graphic 3 Satisfaction survey
Source: Own Elaboration



Graphic 4 Satisfaction survey
Source: Own Elaboration



Graphic 5 Satisfaction survey
Source: Own Elaboration



Graphic 6. Satisfaction survey
Source: Own Elaboration

We show a comparative table showing the differences between projects similar to those of other universities in Mexico.

Comparative characteristics:

1. Students
2. Employees
3. Interest offer
4. E-mail address
5. External
6. Date/time
7. Privacy Notice
8. File number
9. Family member data
10. Questionnaire COVID-19
11. COVID-19 test data
12. Color QR code
13. Generate document with QR
14. Legend with QR

	Institution	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	San Juan del Río Technological University	X	X			X	X	X	X		X			X	
	Anahuac University Mexico	X	X			X		X	X		X		X		
	Mexicali National Technological Center	X							X		X		X	X	
	Monterrey Institute of Technology	X	X												
5	Millennium University	X	X	X	X	X		X	X		X			X	
	Tecnológico Nacional de México	X	X				X		X	X	X	X		X	X

Table 8 Similar projects of universities in Mexico
Sources: Anáhuac Qro, Tecnológico Nacional de Méxicali, Tecnológico de Monterrey, UniverMilenium, Tecnológico Nacional de México

The process for registration with Indautor began with the necessary requirements.

The National Copyright Institute (Indautor) is a decentralized entity in charge of promoting creativity, cultural development and the administration of the public registry of copyright by promoting international cooperation among institutions in charge of the registration and protection of copyright and related rights. (López, 2015)

Conclusions

A pandemic is a situation that we were not prepared to face it , during the first days of confinement we were obligated to adapt as soon as possible to the changes generated like online work and occasional attendance at work facilities , one of the challenges was to control the entrance and attendance in order not to exceed the number of persons allowed within the facilities. Technology is a tool that has made our work much easier, web applications, desktop applications and mobile applications have helped in the control of the capacity to avoid possible infections and thus cut the chains of infection, to try to achieve as far as possible the health safety of the community at the University.

In addition, the development of the project was carried out with great haste because the situation warranted it, there are many opportunities for improvement in the presentation of the user interfaces, possibly more graphics can be used for a better experience, it is necessary to evaluate the client-server technology through sockets to see if it is the most efficient way to solve the problem or if some technological alternative can improve the speed, the distance of the clients with the server since wifi is used and has well known limits in the scope.

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Optimal active yaw control for a wind turbine

Control de guiñada activo óptimo para un aerogenerador

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Abstract

In this work a control strategy based on the mathematical model of an active yaw system for a 20 KW horizontal axis wind turbine is proposed. It allows to increase its efficiency in the presence of changes in the intensity and direction of the wind. The inverse optimal control strategy is implemented based on the mathematical model using the equations of state that represent the dynamics of the yaw system, whose model was obtained with the FAST program, specialized software for modeling wind turbines, which allows obtaining the mathematical model of the orientation system in a more precise way. The results are presented via simulation, where the control strategy is validated in the presence of disturbances. The contribution of this work lies in the application of the optimal control strategy and the tuning parameter search strategy of the control law.

Inverse optimal control, Parameter search strategy, Yaw control

Resumen

En este trabajo se propone desarrollar una estrategia de control avanzada para el modelo matemático que representa un sistema de orientación activa de un aerogenerador de eje horizontal de 20 KW, que le permita incrementar su eficiencia en presencia de cambios en la intensidad y dirección del viento. Se implementará la estrategia de control óptimo inverso basado en el modelo matemático usando las ecuaciones de estado que representan las dinámicas del sistema de orientación, cuyo modelo fue obtenido con el programa FAST, programa especializado para el modelado de aerogeneradores, que permite obtener el modelo matemático del sistema de orientación de forma más precisa. Los resultados se presentan vía simulación, donde se valida la estrategia de control en presencia de perturbaciones. La contribución de este trabajo radica en la aplicación de la estrategia de control óptimo y la aplicación de la estrategia de búsqueda de parámetros de sintonización de la ley de control.

Control óptimo inverso, Estrategia de búsqueda de parámetros, Control de orientación

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Introduction

Due to the great environmental pollution caused by gasoline motor vehicles, nuclear plants, hydroelectric plants that use turbines activated by fossil fuels and the high costs for the installation of electrical networks in the communities, it is necessary to use clean energy obtained from the air, water, sun, as well as their optimization to make the most of the energy obtained from different sources at cheaper costs. The electrical energy generated by wind turbines has advantages to satisfy the demand for energy worldwide, for example: a)- it is energy that does not produce toxic gases such as CO_2 that increase global warming, b)- the energy source is constantly renewed.

To reduce the cost of energy produced by wind turbines and make them competitive for conventional power plants, power generation can be optimized (Farag, W. et al, 2017). In the last two decades many investigations have discussed how to maximize the wind energy extracted from wind turbines. Local control systems in wind turbines are responsible for controlling each element of the wind turbine individually, such as: attack angle control system, yaw control, and generator torque control.

The control of the attack angle and the torque of the generator has been of greater interest on the part of the researchers, since it has a notable effect on the extraction of energy; on the other hand, yaw control of the nacelle is of lower interest due to its lesser effect on small and medium size turbines (few hundred KW). However, the trend in the industry is to use turbines with megawatt capacities and sophisticated control systems for the nacelle, which are necessary for energy extraction and protection of internal components (Farag, W. et al, 2017).

The kind of orientation system for low power wind turbines with the greatest application is the passive type, which has a vane at the rear of the wind turbine, which positions the rotor in the direction of the wind, the active orientation system is made up of mechanical, electrical, and hydraulic elements.

The disadvantage of this kind of passive orientation system is that the wind rotor always remains oriented in the predominant direction of the wind, consequently, it is not possible to regulate the output power of the electric generator in the face of different magnitudes of wind speed (Rodríguez-Solano A. et al, 2018). The normal function of the active guidance system is to follow the direction of the wind. Also, in extreme conditions like a storm, the rotor is positioned 90° out of the wind (De Zutter, S. et al, 2017). In this work, it is proposed to develop an advanced control strategy for the mathematical model that represents an active orientation system of a 20 KW horizontal axis wind turbine, which allows it to increase its efficiency in the presence of changes in the intensity and direction of the wind.

Justification

This project originated from the need to increase the efficiency of horizontal axis wind turbines, implementing an advanced control technique, making the most of the force of the wind to generate energy. The contribution of this project lies in developing a control strategy to optimize the energy produced by adjusting the orientation angle of the wind turbine nacelle. The content of the article is presented as follows: section 1, a brief description of the wind turbine, section 2 presents the mathematical model of the orientation system, section 3 describes the control strategy, section 4 presents the method of searching for parameters of the control law, section 5 the results, and finally the conclusions.

1. Description of the wind turbine

The wind turbine system considered in this article is a three-blade horizontal axis type. A typical wind turbine consists of 3 main components: a)- The nacelle, which contains the main components of the turbine, including the gearbox and the electric generator, b)- The tower, where the nacelle is supported, c)- Rotor and its blades which capture the energy of the wind and transfer it to the rotor shaft and then to the electric generator.

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2. Mathematical model of the active yaw system

The active orientation system consists of a planetary gear coupled with one or more DC or AC motors depending on the torque required to move the wind turbine nacelle, the control system is responsible for activating the motor coupled with the gear to rotate the nacelle towards the direction of the wind. In the literature, different expressions have been used for the turbine power in case the orientation angle γ is different from zero. Fig. 1 illustrates the definition of the orientation angle γ. It is the angle between the direction of the approaching wind speed and the rotor axis (De Zutter, S. et al, 2017).

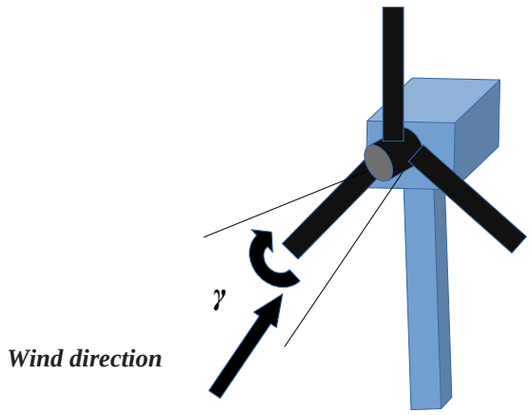

Figure 1 Definition of the orientation angle
Source of Own Elaboration

The power is multiplied by the cosine of the orientation angle:

$$Pt=1/2\,\rho\pi\,R^2V^3Cp\,\cos\gamma \qquad (1)$$

This equation is based on the fact that the wind mass flux across the rotor surface decreases by cos γ when the rotor surface normal has an angle γ with the wind direction. The energy extracted from the wind is proportional to the mass flux of the wind, and consequently the power also decreases by cos γ. However, this reasoning does not take into account the fact that blade efficiency decreases under oriented inflow conditions. When the orientation angle γ is different from zero, the wind does not hit the blade leading edge orthogonally (De Zutter, S. et al, 2017). Therefore, the blade does not generate the same lift forces as it would with an orthogonal inlet flow, that is the lift forces decrease.

Therefore, it is argued that only the orthogonal component of the wind should be used to compute the power. Therefore, the turbine power becomes:

$$Pt=1/2\,\rho\pi\,R^2V^3Cp\,\cos^3\gamma \qquad (2)$$

Wind tunnel tests were performed on a turbine rotor under oriented inlet conditions. Pressure distributions over the blade section were measured to calculate forces and power (De Zutter, S. et al, 2017). The measurements were shown to be close to the cos3 γ curve, ie equation (2). To accurately obtain the real power produced by the rotor, a detailed study using computational fluid dynamics (CFD) must be carried out, which is outside the scope of this work.

Fig. 2 shows the variation of the mechanical power produced from the orientation angle of the wind generator. It is observed that if the rotor faces the wind direction (yaw = 0°), the wind turbine will obtain the maximum efficiency in power generation. Otherwise, when there is a misalignment between the rotor axis and the wind direction (yaw ≠ 0 °), it implies a decrease in the capture of wind energy.

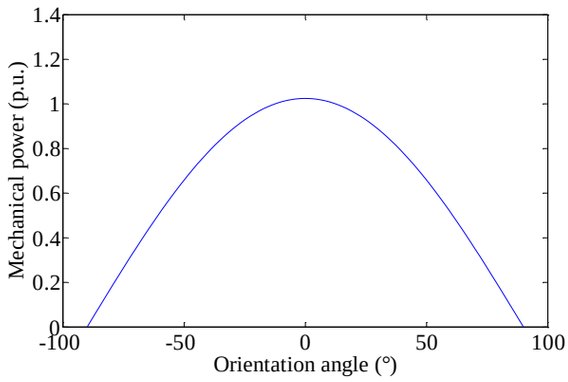

Figure 2 Mechanical power as a function of orientation angle
Source of own elaboration, Matlab 2013B.

Since the main objective of this work is the design of the controller, an existing mathematical model was taken, which was obtained with a specialized software for modeling wind turbines called FAST, since it allows obtaining a more precise model of the orientation system, the transfer function which represents the mathematical model of the wind turbine yaw system to control only the position is represented as (Jonkman, J. M., et al 2005):

$$G(s) = \frac{Yawsprint}{(YawIner(s^2)+YawDamp(s)+Yawsprint)} \quad (3)$$

where *Yawsprint* is the linear equivalent spring constant of the yaw actuator, *YawIner* is the inertia of the nacelle about the yaw axis, and *YawDamp* is the equivalent linear damping constant of the nacelle yaw actuator.

Parameter	Value
Nacelle mass	960 Kg
Yawsprint	75,392 N•m/rad
YawIner	7,532.9 kg•m²
YawDamp	55,336.7 N•m/(rad/s)
Rated speed of nacelle orientation	0.3 ° /s

Table 1 Nacelle features

To implement the optimal control strategy, the representation in the state space of the system is obtained:

$$\begin{aligned} \dot{x_1} &= x_2 \\ \dot{x_2} &= -10x_1 - 7.3x_2 + 10u \\ y &= x_1 \end{aligned} \quad (4)$$

where x_1 is the angular position of the nacelle, x_2 is the displacement speed, u is the input voltage to the system and y is the controlled variable of the system.

3. Optimal control strategy for the active yaw system

Consider a nonlinear system in discrete time:

$$x_{k+1} = f(x_k) + g(x_k)u_k \quad (5)$$

where $x_k \in R^n$ is the state of the system at time $k \in Z_+$, $u \in R_m$ is the control input, f: $R^n \rightarrow R^n$, g: $R^n \rightarrow R^{nxm}$ are smooth mapping functions. Assume f(0)= 0 and $g(x_k) \neq 0$, $\forall\ x_k$. The control law is inverse optimal in the sense that it minimizes the functional variety given as:

$$J(x_k) = \sum_{n=k}^{\infty}(l(x_n) + u_n^T R(x_n)u_n) \text{ , k=0, 1, 2, ...} \quad (6)$$

Using the optimal value function $J^*(x_k)$ for Equation (5) in terms of the Lyapunov function $V(x_k)$, Equation (6) can be rewritten as:

$$V(x_k) = l(x_k) + u_k^T R u_k + \sum_{n=k+1}^{\infty}(l(x_n) + u_n^T R u_n) \quad (7)$$

$$V(x_k) = l(x_k) + u_k^T R u_k + V(x_{(k+1)}) \quad (8)$$

where the boundary condition V(0)= 0 is required for $V(x_k)$ to become a Lyapunov function. We define the discrete-time Hamiltonian $H(x_k,u_k)$ as:

$$H(x_k, u_k) = l(x_k) + u_k^T R u_k + V(x_{(k+1)}) - V(x_k) \quad (9)$$

In (Ornelas-Tellez, F., et al, 2011), a Lyapunov function for discrete-time control is proposed to solve equation (9), in the form:

$$V_c(X_k) = 1/2\ x_k^T P_k x_k, P_k = P_k^T > 0 \quad (10)$$

Substituting (10) in (9) and solving, the optimal control law is obtained:

$$u_k^* = -1/2\left(R(x_k) + \cdots + 1/2\ g^T(x_k)P_k g(x_k)\right)^{-1} g^T(x_k)P_k f_d(x_k) \quad (11)$$

P_k and R are symmetric and positive definite matrices. Then the existence of the inverse in (11) is guaranteed. The control law (11) depends on the P_k matrix at each time step.

4. Searching method of tuning parameters

In (Villegas-Ruvalcaba, et al. 2021) a new method is given for adjusting parameters of the optimal control law. Equation (11) is replaced by:

$$u_k^* = -K\left(R(x_k) + \cdots + 1/2\ g^T(x_k)P_k g(x_k)\right)^{-1} g^T(x_k)P_k f_d(x_k) \quad (12)$$

The goal is to find the gain K that adjusts the control u^*_k, with control law parameters P_k and R fixed. To achieve this goal, we purpose the next methodology:

1. Select the values of *P* and *R* fixed heuristically.
2. Give values to the input variables and the system parameters to properly analyze which ranges of those variables generate an error ξ greater than the tolerance ε.
3. Find a *K* value for each desired reference variable in the ranges or values of the previous point that best fit.
4. Construct a function with the *K* gains found that depend on the input variable or parameter which destabilized the system.

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5. In case an appropriate value of gain *K* is not found, adjust the parameters *P* and *R* to obtain a better convergence.

In this paper, ξ is taken as the percentage error when the system falls into a steady state error, that is, when this error converges to a point close to the desired reference. The error tolerance with respect to the desired reference is ε = 1%, consequently, there will be different gains K that satisfy ξ< ε.

5. Results

In order to evaluate the performance of the optimal control scheme, different operating points are proposed. The scheme is implemented in MATLAB/Simulink and the parameters for simulation are given in Table 1 and equations (13)-(15).

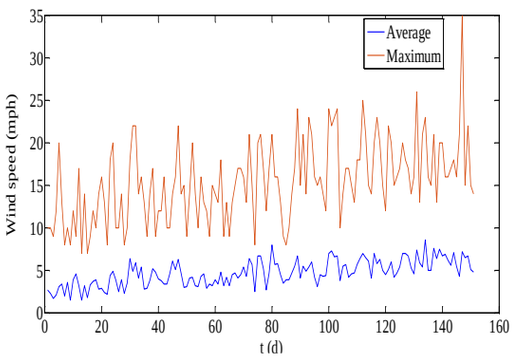

Figure 3 Wind speed.
Source of own elaboration, Matlab 2013B.

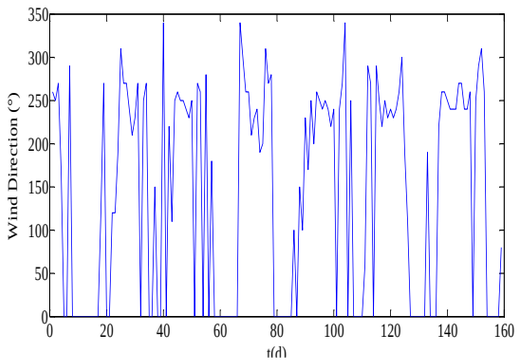

Figure 4 Wind direction
Source of own elaboration, Matlab 2013B

Figures 3 and 4 show the historical data of the wind speed and direction from January to May 2022 taken from the meteorological station of the international airport of Guadalajara, Jalisco (wunderground, 2022). The wind direction is in degrees respect north.

Fig. 5 describes the behavior of the wind turbine in the presence of different wind directions and at a constant speed. Different trajectory tracking tests were performed with different optimal control tunings, as a result the dynamic gain K for the control law parameter search is:

$$K = -(0.2)\text{Pref} + 2.12 \tag{13}$$

where P_{ref} is the reference of the wind di rection,the gains P and R were calculated heuris tically as:

$$P = \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix} \tag{14}$$

$$R = 0.8 \tag{15}$$

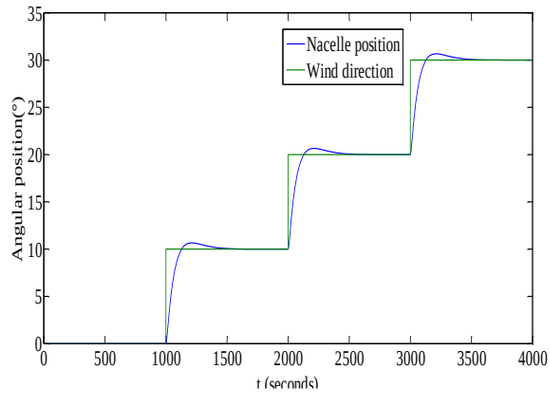

Figure 5 Wind direction tracking
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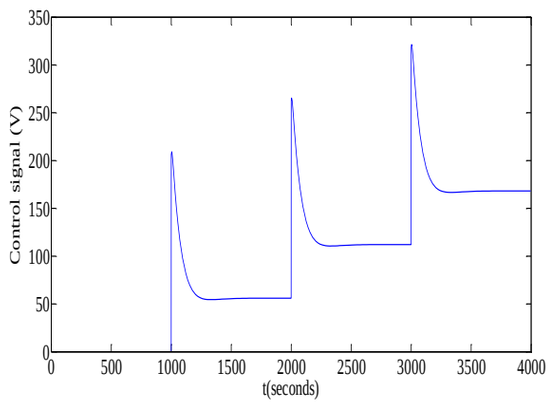

Figure 6 Actuator control signal

The optimal control strategy is subjected to three stepwise changes in wind direction: 0° to 10°, 10° to 20°, and 20° to 30°. The wind speed remains constant at 20 mph since at that value the wind turbine is capable of generating electricity at its nominal power (Haro *et al.*, 2021).

Fig. 5 shows the orientation tracking in the face of changes in wind direction, the optimal control keeps the wind turbine in the desired position in a stable manner, guaranteeing that the power generated by the system is maximum. Figure 6 shows the control signal of the actuator that drives the orientation of the wind turbine, dosing the necessary voltage in such a way that it represents energy savings.

Conclusions

This work presents an optimal orientation control strategy for a small-scale wind turbine (20kW). The control strategy is based on the system model and the tuning of its parameters is performed with a search method that depends on a function based on the desired references of the system. The proposed strategy allows regulating the power generated by the orientation of the wind turbine nacelle under different conditions of wind direction. The results obtained demonstrate the effectiveness of the proposed method to take advantage of the available wind potential in the event of unforeseen changes in the direction of the wind. Future work includes the validation of the control strategy in a scale wind turbine.

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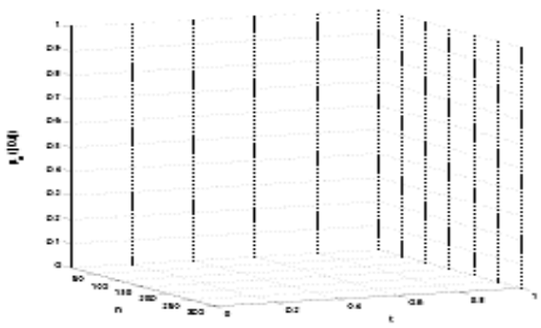

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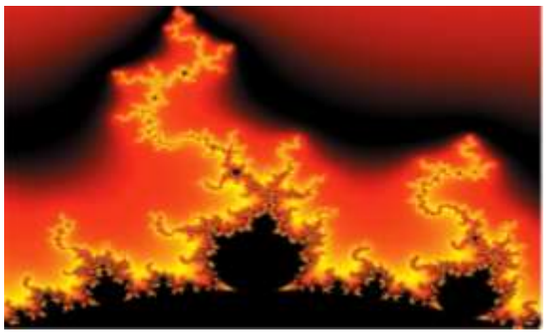

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