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Journal Innovative Design

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The works must be unpublished and refer to topics of Design, Mechanical design, Electrical, Economic engineering, Technological innovation, Operations research, Solid waste management and treatments, Manufacturing, Planning, Industrial planning, Production, Programming and manufacturing, Industrial safety, Systems and other topics related to Engineering and Technology.

Presentation of the content

In the first article we present, *Proposal for structural testing of double root low capacity wind turbine blades based on the Iec 61400-2 Standard*, by SANTIBAÑEZ-MALDONADO, Adrian, LÓPEZ-GARZA, Víctor, SORIANO-PEÑA, Juan Felipe and MARIN-TELLEZ, Paulina, with adscription in the Universidad Michoacana de San Nicolas de Hidalgo, in the next article we present, *Prospective of the need for a heuristic model for the improvement of home electricity consumption in favor of an energy transition in Mexico*, by MONROY-CARREÑO, Roberto & DOMÍNGUEZ-PACHECO, Flavio Arturo, with adscription in the Instituto Politécnico Nacional, in the next article we present, *Construction of Kaplan turbine test bench for mini hydraulic power generation*, by FRANCO-MARTÍNEZ, David & ARBOLEYA-ORTIZ, José Raúl, with adscription in the Centro Tecnológico, Facultad de Estudios Superiores Aragón, UNAM, in the next article we present, *Design and implementation of an ecological cooler*, by MOLINA-GARCÍA, Moisés & MELCHOR-HERNÁNDEZ, Cesar L., with adscription in the Instituto Tecnológico Superior de Huatusco.

Content

Article **Journal Innovative Design**
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Proposal for structural testing of double root low capacity wind turbine blades based on the Iec 61400-2 Standard

Propuesta de ensayos estructurales de aspas de turbina de viento de baja capacidad de doble raíz con base a la Norma IEC 61400-2

SANTIBAÑEZ-MALDONADO, Adrian†*, LÓPEZ-GARZA, Víctor, SORIANO-PEÑA, Juan Felipe and MARIN-TELLEZ, Paulina

Universidad Michoacana de San Nicolas de Hidalgo, Facultad de Ingeniería Mecánica

ID 1st Author: *Adrian, Santibañez-Maldonado* / **ORC ID:** 0000-0003-2090-9556, **Researcher ID Thomson:** AAF-7625-2021, **CVU CONACYT ID:** 1009460

ID 1st Co-author: *Víctor, López-Garza* / **ORC ID:** 0000-0001-9090-9119, **Researcher ID Thomson:** H-6969-2018, **CVU CONACYT ID:** 554311

ID 2nd Co-author: *Juan Felipe, Soriano-Peña* / **ORC ID:** 0000-0003-1370-2274, **CVU CONACYT ID:** 233426

ID 3rd Co-author: *Paulina, Marin-Tellez* / **ORC ID:** 0000-0003-2966-3409, **Researcher ID Thomson:** G-2113-2019, **CVU CONACYT ID:** 928539

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Abstract

In this article, the results of the numerical simulation are shown, as well as the results of the structural tests using extensometry, for a low capacity double root wind turbine blade based on the IEC 61400-2 standard. A methodology was developed to carry out the experimental plan. The results obtained by means of numerical simulation were compared with those obtained by extensometry, concluding that the blade will work safely already in operation because the values obtained from microdeformations are far from the blade failure limit.

Blade, Tests, Simulation

Resumen

En el presente artículo, se muestran los resultados de la simulación numérica, así como también los resultados de los ensayos estructurales mediante extensometría, para un aspa de turbina de viento de doble raíz de baja capacidad en base a la norma IEC 61400-2. Se desarrolló una metodología para llevar a cabo el plan experimental. Se compararon los resultados obtenidos mediante la simulación numérica con los obtenidos mediante extensometría, concluyendo que el álabe trabajará seguro ya en funcionamiento debido a que los valores obtenidos de microdeformaciones están lejos del límite de fallo del álabe.

Álabe, Ensayos, Simulación

Citation: SANTIBAÑEZ-MALDONADO, Adrian, LÓPEZ-GARZA, Víctor, SORIANO-PEÑA, Juan Felipe and MARIN-TELLEZ, Paulina. Proposal for structural testing of double root low capacity wind turbine blades based on the Iec 61400-2 Standard. Journal Innovative Design. 2021, 5-12: 1-9

*Correspondence to the Author (e-mail: 1214743e@umich.mx)
† Researcher contributing as first author.

Introduction

The production of electrical energy is a very important factor in the industrial and technological development of a country. Increasingly, energy production processes seek to be cleaner and with fewer greenhouse gas emissions. Renewable energies arise from this need to generate energy with less adverse effects on the planet. Among renewable energies, hydroelectric, solar and wind power stand out for their production.

Wind energy is produced by harnessing wind currents to move a generator through the blades of wind turbines. The blades are the main components of wind turbines, hence their importance in design and manufacture.

The structural integrity of the blades is of paramount importance because, if any blade fails, the turbine will no longer function properly. As a result of this problem, quality standards have arisen which propose a methodology of static and fatigue tests to ensure the service life of the blades and all the turbine components.

IEC 61400-2 is the standard par excellence for low power turbines, which classifies them as turbines delivering less than 50 KW.

This paper shows the evaluation of a double root blade of a 2400 W wind turbine, according to the load hypotheses of the IEC 61400-2 standard. The results of the numerical simulation and also the results obtained by means of extensometry are shown.

Load hypotheses to be applied based on the IEC 61400-2 standard

The standard specifies the methodology of simplified loads, as well as the modelling of AP (Small Wind Turbines) blades, in order to guarantee their quality and good operation. The load hypotheses that were evaluated are: normal operation, maximum rotor speed and extreme wind load, which are shown in table 1. For each design state, the appropriate type of analysis by "F" and by "U" is given. F refers to the fatigue load analysis, to be used in the fatigue stress assessment.

U refers to the analysis of critical loads such as the analysis of the maximum excess strength of the material, the analysis of the extreme deformation and the analysis of the stability.

Design situation	Load assumptions	Type of analysis	Design situation
Energy production	**A**	Normal operation	F
	B	Orientation	U
	C	Orientation error	U
	D	Maximum thrust	U
Producción de energía de más ocurrencia de fallo	**E**	Velocidad de rotación máxima	U
	F	Cortocircuito en la conexión de carga	U
Parada	**G**	Desconexión (frenado)	U
Carga extrema de viento	**H**	Carga extrema del viento	U
Condiciones de inmovilización y de falta	**I**	Inmovilización con carga del viento y exposición máxima	U
Transporte, montaje, mantenimiento y reparación	**J**	Deberá estar indicado por el fabricante	U

Table 1 *Design load assumptions for the simplified load calculation method.*
Source: IEC 61400-2 (2015).

Calculation of the loads to be applied to the blade

Scenario A: normal operation

The design load for "normal operation" is a fatigue load. The loading assumption assumes a constant range fatigue load for the blade.

$$\Delta F_{zB} = 2m_B R_{cog} \Omega_{n,design}^2 \quad (1)$$

$$\Delta M_{xB} = \frac{Q_{design}}{B} + 2\mathrm{m_B g R_{cog}} \quad (2)$$

$$\Delta M_{yB} = \frac{\lambda_{design} Q_{design}}{B} \quad (3)$$

Scenario E: maximum rotor speed

The load due to centrifugal force at the blade root FzB is calculated as follows:

$$F_{zB} = m_B R_{cog} \Omega_{n,máx}^2 \quad (4)$$

Scenario H: extreme wind load

In this load scenario, the wind turbine operates as designed for extreme wind speeds. The loads are to be calculated by taking the maximum wind speed recorded over the last 50 years, V_{e50}:

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$$M_{yB} = \frac{C_D}{4}\rho V_{e50}^2 A_{projB} R \quad (5)$$

The values obtained are shown in table 2.

	Load assumptions	Value
A	Normal operation	ΔF_{zB}=12151.12 N
		ΔM_{xB}=1666.57 Nm
		ΔM_{yB}=378.67 Nm
E	Maximum rotational speed	F_{zB}=62125 N
H	Extreme wind load	M_{yB}=2970.34 Nm

Table 2 Values obtained for each load scenario
Source: Own Elaboration

Methodology

Figure 1 shows in detail the stages of the experimental plan. The first is to identify all the non-experimental factors or variables that may affect the experiment and determine how to control them; such as environmental factors, temperature, noise, etc. In order to carry out the structural tests on the blades, the static and fatigue load test bench (figure 2) designed by Erick Pérez Juárez will be used, which is made up of the following parts:

1. Base
2. Head - support
3. Head - clamp
4. Blade
5. Force system

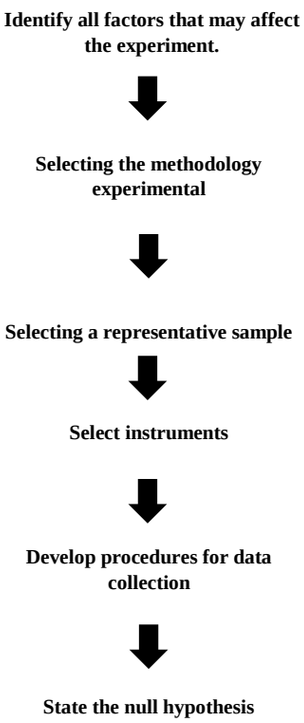

Figure 1 Methodology of the pilot scheme
Source: Monje, C. (2011). Metodología de la investigación cuantitativa y cualitativa guía didáctica, Neiva, Colombia: Universidad Surcolombiana

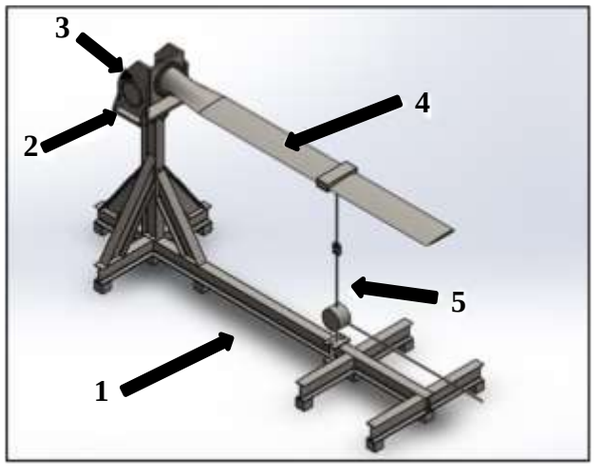

Figure 2 Static and fatigue test bench
Source: Erick Pérez Juárez. Construction of a fatigue testing machine for low-capacity wind turbine blades. UMSNH, 2019

Simulation of load assumptions on the double-root blade

The blade was modelled using CAD software and divided into 25 sections as shown in figure 3. A NACA 4412 profile was used for the modelling of the main root and the double root.

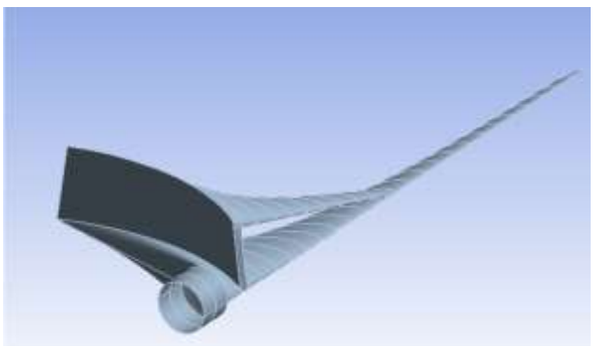

Figure 3 Blade modelling in CAD software
Source: Own Elaboration

The blade is made of several layers of composite material, glass fibre/epoxy, arranged at 45° and 90° as shown in figure 4.

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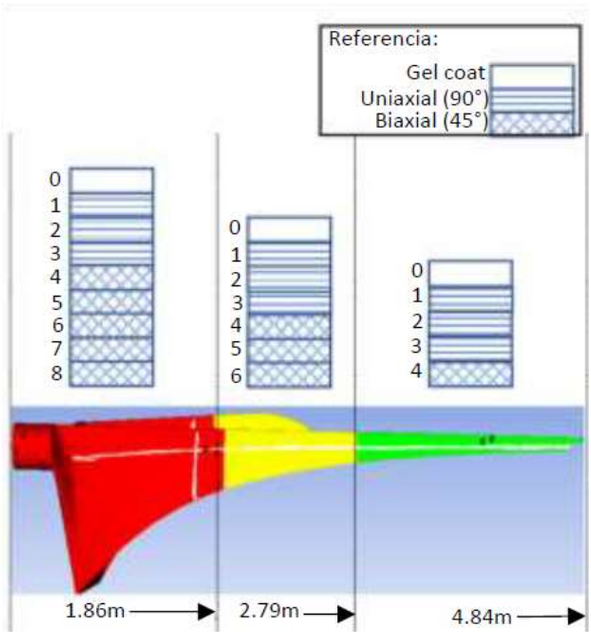

Figure 4 Distribution of fibreglass/epoxy sheets on double-rooted blades
Source: Own Elaboration

The root zone (in red) is defined by nine layers including the gel coat layer, the middle zone (in yellow) is defined by seven layers including the gel coat layer, and finally the tip zone (in green) is defined by five layers including the gel coat layer.

Meshing and boundary conditions

The meshing was done with the help of finite element software using triangular elements. The quality of the meshing is shown in table 3.

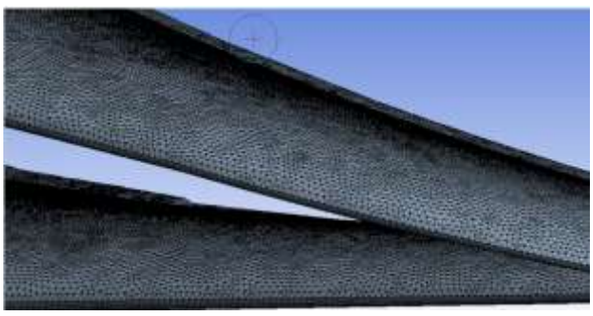

Figure 5 Blade grid, triangular elements
Source: Own Elaboration

Nodes	267276
Elements	534311
Mesh Metric	Promedio
Element Quality	0.967326688775866
Aspect ratio	1.1893
Skew	0.050672
Parallel skew	0

Table 3 Meshing metric
Source: Own Elaboration

The boundary conditions will consist of applying the load assumptions by adding an embedment condition at the root of the blade. For practical purposes, the loading assumptions involving moments on the blade will be transformed to forces on the same axis, using the distance to the root which in this case is 3.25 metres. A summary of the boundary conditions for the 3 load scenarios is presented in table 4.

Load assumptions	Moment at x (flapwise moment) N	Moment at y (edgewise moment) N	z-force (centrifugal) N
A	256	115	12151.12
E	Not applicable	Not applicable	62125
H	Not applicable	459.1	Not applicable

Table 4 Summary of loading conditions
Source: Own Elaboration

Next, the boundary conditions (figure 6) and the results in maximum Von Mises stress (figure 7), due to the stress concentrator at the root junction point, and total displacement (figure 8) are shown for load hypothesis A: Flapwise. According to Castillo, it is acceptable to apply the Von Mises failure theory to composite materials as long as the material behaves more or less linear in the elastic zone in the stress-strain diagram. The glass fibre/Epoxy composite material has this kind of linear behaviour.

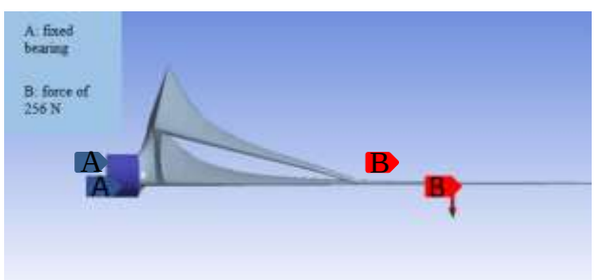

Figure 6 Blade boundary conditions
Source: Own Elaboration

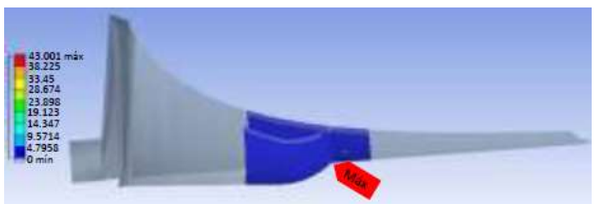

Figure 7 Von Mises maximum stress, on the top of the middle zone [MPa]
Source: Own Elaboration

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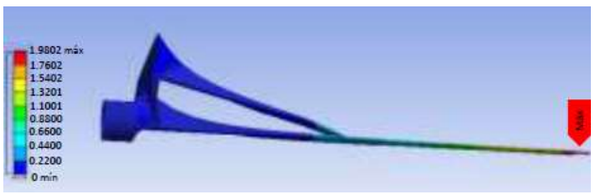


Figure 8 Total blade deflection [cm]
Source: Own Elaboration

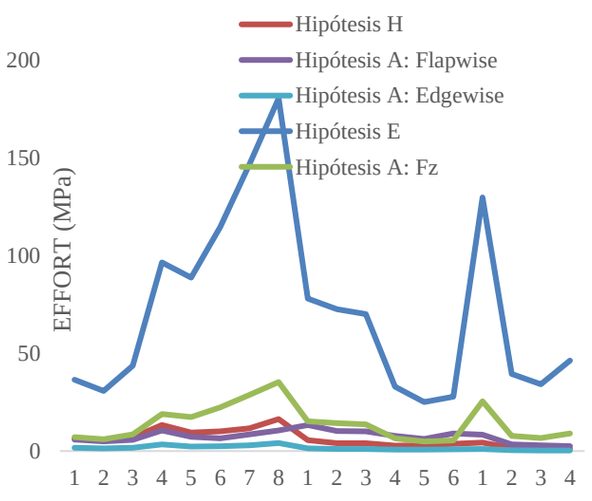
Figure 9 Directional blade deflection [με]
Source: Own Elaboration

Table 5 summarises the results obtained for total displacement, maximum Von Mises stress and directional displacement..

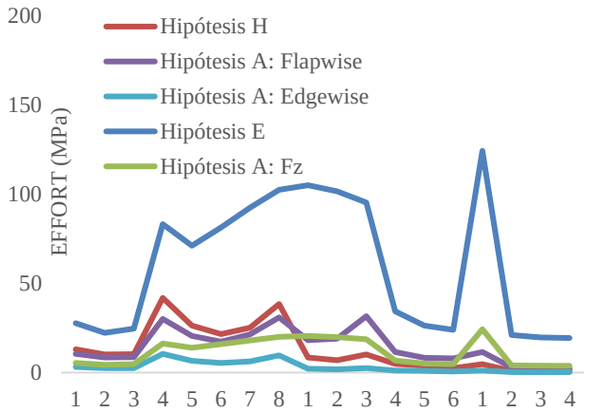
Load assumptions		Total displacement (mm)	Von Mises maximum stress (Mpa)	Maximum directional offset (μm)
A	Normal operation	F_{zB}: 24.93	35.27	424.52 (eje z)
		M_{xB}: 43.00	86.13	977.58 (eje z)
		M_{yB}=2.59	12.07	4.7282 (eje x)
E	Maximum rotational speed	F_{zB}: 127.48	180.35	2170.5 (eje z)
H	Extreme wind load	M_{yB}: 20.35	94.69	18.876 (eje x)

Table 5 Summary of the results obtained for the simulated load modes
Source: Own Elaboration

The results of the maximum Von Mises stresses for each layer and blade region are shown below



Graph 1 Stress distribution according to Von Mises failure theory, per blade for each loading scenario, blade socket [MPa]
Source: Own Elaboration



Graph 2 Stress distribution according to the Von-Misses failure theory, per blade for each of the loading hypotheses, blade top surface [MPa]
Source: Own Elaboration

As expected, the maximum stress values occur in the hypothesis of maximum rotational speed, close to the load application zone.

Laboratory tests

The methodology for carrying out the laboratory tests is as follows:

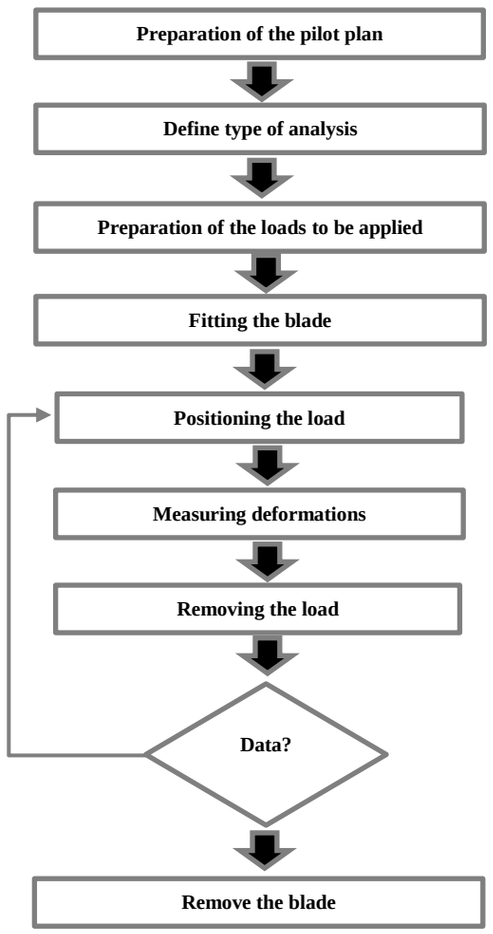


Figure 10 Methodology of laboratory tests
Source: Own Elaboration

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Strain gauges, which are basically a variable resistor, are attached to the surface of the blade for strain measurements.

The principle of operation of strain gauges is based on the piezoresistive effect of metals and semiconductors, whereby their resistivity varies according to the strain to which they are subjected, the material from which they are made and the design adopted. Thus, the change in electrical resistance will indicate a change in strain, which in turn is related to the forces acting on the instrumented element.

Figure 11 Calibre instalado en la hoja
Source: Own Elaboration

For data collection, the gauges of the CEA-06-240UZ-120 model and a strain gauge and recorder of the P3 model were used.

The location of the gauges was chosen according to the results obtained in the numerical simulation. It should be noted that 2 of the 5 loading modes cannot be reproduced in the laboratory due to their complexity, so it is limited to 3 loading modes. The following table summarises the loading modes and their magnitudes, both in Newtons and in kilograms:

Hypothesis	Charge (N)	Charge to be applied (kg)
A: Flapwise	256	26.1
A:Edgewise	115	11.8
H: Edgewise	459.1	46.8

Table 6 Summary of loads to be applied in the laboratory
Source: Own Elaboration

For the Flapwise tests, 4 gauges were installed, one on the root socket (A), 10 cm from the embedment, another on the socket of the double root (B), at 1.85 m, gauge C was installed on the socket of the double root at 1.85 m and finally gauge D was installed on the socket of the main vane at 2.62 m.

Figure 12 Flapwise testing gauges installed on blades
Source: Own Elaboration

Thirty measurements were carried out for each loading mode, sensing each gauge, its temperature, humidity and ambient temperature. To avoid blade fatigue, it was decided to carry out the measurements over two days. The results obtained are shown below for the Flapwise mode:

Load scenario A: Flapwise				
Measures of central tendency central tendency and dispersion	Gauge			
	A	B	C	D
Media (με)	54.76	20.76	-177.47	-191.11
Fashion (με)	54	20	-183	-194
Standard deviation (με)	2.75	2.04	5.14	4.44
Coefficient of variation	5.02	9.85	2.90	2.32

Table 7 Results for day 1, 17 measurements were performed
Source: Own Elaboration

Load scenario A: Flapwise				
Measures of central tendency central tendency and dispersion	Gauge			
	A	B	C	D
Media (με)	57.07	22.38	-185.46	-197.15
Fashion (με)	57	24	-186	-198
Standard deviation (με)	0.64	1.15	1.45	2.93
Coefficient of variation	1.12	6.71	0.78	1.49

Table 8 Results for day 2, 13 measurements were performed
Source: Own Elaboration

For the Edgewise tests, 4 gauges were installed, gauge A in the socket of the main root, 1.70 m from the embedment, gauge B at the same distance, 1.70 m in the socket of the main root, gauge C was installed in the socket of the main root at 2.40 m and finally gauge D was installed in the soffit of the double root at 2.40 m.

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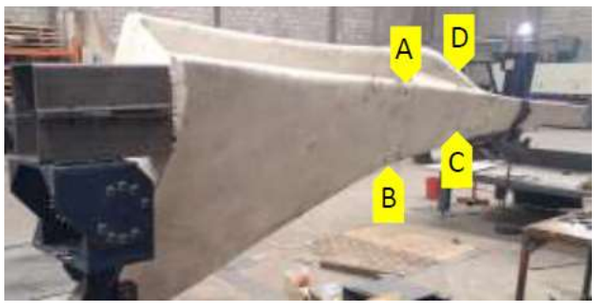


Figure 13 Blade mounted gauges for Edgewise tests
Source: Own Elaboration

The results for the Edgewise loading mode for scenario A are shown below:

Load scenario A: Edgewise				
Measures of central tendency central tendency and dispersion	Gauge			
	A	B	C	D
Media (με)	-2.73	20.93	12.13	2.86
Fashion (με)	-3	21	12	3
Standard deviation (με)	0.59	0.45	0.51	0.74
Coefficient of variation	21.71	2.18	4.25	25.92

Table 9 Results for day 1, 15 measurements were performed
Source: Own Elaboration

Load scenario A: Edgewise				
Measures of central tendency central tendency and dispersion	Gauge			
	A	B	C	D
Media (με)	-2.93	21.06	12.13	2.8
Fashion (με)	-3	21	12	3
Standard deviation (με)	0.59	0.45	0.35	0.67
Coefficient of variation	20.23	2.17	2.89	24.14

Table 10 Results for day 2, 15 measurements were performed
Source: Own Elaboration

Finally, results are shown for the hypothesis H:

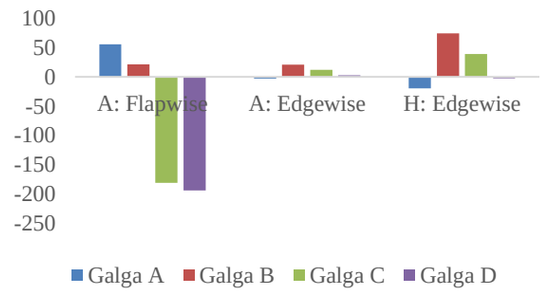
Load scenario H				
Measures of central tendency central tendency and dispersion	Gauge			
	A	B	C	D
Media (με)	-20.06	76.66	38.93	-2.8
Fashion (με)	-20	74	39	-2
Standard deviation (με)	0.79	1.17	0.88	0.77
Coefficient of variation	3.98	1.59	2.26	27.66

Table 11 Results for day 1, 15 measurements were performed
Source: Own Elaboration

Load scenario H				
Measures of central tendency central tendency and dispersion	Gauge			
	A	B	C	D
Media (με)	-19.33	72.73	38.86	-2.53
Fashion (με)	-19	74	39	-2
Standard deviation (με)	1.34	1.53	0.74	1.18
Coefficient of variation	6.95	2.10	1.91	46.86

Table 12 Results for day 2, 15 measurements were performed
Source: Own Elaboration

Below is a comparison of the averages for each gage for each resgitrated loading mode:



Graph 3 Recorded values for each load mode in micro deformations
Source: Own Elaboration

Results

For the loading mode of Hypothesis A: Flapwise, gauges A and B, recorded tension measurements, as expected according to the numerical simulation, gauges C and D recorded compression measurements, according to the numerical simulation, gauge C should record tension measurements, which did not happen, gauge D is behaving as expected (in compression), both gauges showed the highest values due to the proximity to the load application point.

For the Edgewise modes of analysis, gauges A, B and C had the same behaviour, both for hypothesis A and H, gauge D was the only one that behaved differently, in tension in hypothesis A and in compression in hypothesis H.

The coefficient of variation is low in general (except for a couple of occasions) which indicates that the tests were carried out homogeneously and that there is repeatability in the experiment. The highest standard deviation values were found for Hypothesis A: Flapwise, where the highest strain values were found, indicating that the higher the strain values, the greater the dispersion of the data and vice versa. Finally, the following graph shows an inversely proportional relationship between the values recorded by the gauge and the humidity in the environment, humidity being an important factor to consider when making the measurements.

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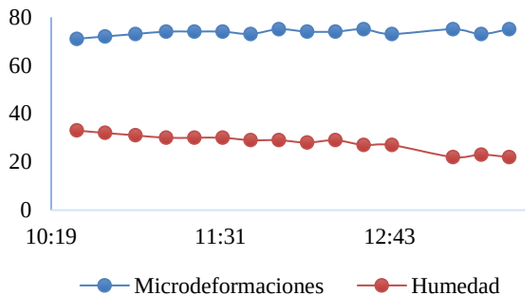

Gráfico 4 Correlation between ambient humidity and the value recorded in microdeformations for the B gauge of the H: Edgewise scenario
Source: Own Elaboration

Acknowledgements

To the Universidad Michoacana de San Nicolás de Hidalgo, to the Faculty of Mechanical Engineering and especially to the company NESTING CNC S.A. de C.V. and its staff for the facilities granted to develop this work. As well as to the National Council of Science and Technology for the scholarships granted to the postgraduate students.

Conclusions

As can be seen in this work, numerical simulation is a fundamental step prior to the design of turbine blades, as the results obtained are key to be able to carry out structural tests in the laboratory.

The highest deformation results measured in the laboratory by means of extensometry were obtained in Hypothesis A: Flapwise, as expected.

The values obtained in the laboratory indicate that the blade will work safely in operation, as the values obtained are far from the failure values. Therefore, we can conclude that the IEC 61400-2 standard can be perfectly applied to this type of double root blades following the methodology proposed for their structural analysis.

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Annexes

Glossary

$A_{proj,B}$ = Projected blade area
B= number of blades
C_d= drag coefficient
F_{ZB} = force on the blade at the root in the direction of the wingspan
g = acceleration of gravity
m_B = mass of the shovel
M_{xB} = bending moment at the blade root in direction x
M_{yB} = bending moment at the blade root in direction y
Q_{design} = design axis torque
R = rotor radius
R_{cog} = radial distance between the centre of gravity of the blade and the centre of the rotor.
V_{e50} = extreme value of speed in 50 years
ρ = air density
λ_{design} = blade tip speed ratio
$\Omega_{n,design}$= rotor rotation speed
$\Omega_{n,máx}$= maximum rotor rotational speed

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Prospective of the need for a heuristic model for the improvement of home electricity consumption in favor of an energy transition in Mexico

Prospectiva de la necesidad de un modelo heurístico para el mejoramiento del consumo eléctrico domiciliario en pro a una transición energética en México

MONROY-CARREÑO, Roberto†*& DOMÍNGUEZ-PACHECO, Flavio Arturo

Instituto Politécnico Nacional, SEPI ESIME-Zacatenco

ID 1st Author: *Roberto, Monroy-Carreño* / **ORC ID**: 0000-0002-2556-1723, **CVU CONACYT ID**: 856509

ID 1st Co-author: *Flavio Arturo, Domínguez-Pacheco* / **ORC ID**: 0000-0003-3561-7257, **CVU CONACYT ID**: 231069

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Abstract

Environmental problems have shown that as the days go by, the estimated negative scenarios are closer to being achieved. Despite this, in Mexico there are few programs that are directed or implemented in response to this need, and those that do exist do not have a systemic vision that ensures sustainability for the different factors that have a correlation with the system. On this premise, the research was carried out from a descriptive theoretical study method that allowed to visualize the background of this sector in a global way and its subsequent territorial delimitation, which when encompassed from the approach of the Transdisciplinary Cyber Cyber System, the different types of the knowledge. All with the purpose of seeking the transition towards beings more aware of their environment and the impact of their actions, for which, using the Cyber-Systemic Planning-Action Process, the different tools available to solve the need under study and with this, the creation of the adaptive methodology to the context and the model for environmental awareness based on contextualization, with the aim that the student population reaches more significant knowledge in relation to their surrounding environment.

Energy, Awareness, Education

Resumen

Los problemas ambientales han demostrado que con el paso de los días se está más cerca de alcanzar los panoramas negativos estimados. A pesar de ello en México son escasos los programas que van dirigidos o que se implementen ante esta necesidad, y los que existen no tienen una visión sistémica que asevere la sostenibilidad para los diferentes factores que tienen correlación con el sistema. Sobre esta premisa la investigación se llevó a cabo desde un método de estudio teórico descriptivo que permitiera visualizar el trasfondo de este sector de manera global y su posterior delimitación territorial, que al abarcarlo desde el enfoque de la Ciber Sistema Transdisciplinar admitió conjuntar los diferentes tipos del conocimiento. Todo con el propósito de buscar la transición hacia seres más conscientes de su entorno y el impacto de sus acciones, para lo cual empleando el Proceso Ciber-Sistémico de Planeación-Acción se contrapusieron las diferentes herramientas que se disponen para solucionar la necesidad en estudio y con ello la creación de la metodología adaptativa al contexto y el modelo para la concientización ambiental basado en la contextualización, con el objetivo de que la población estudiantil alcance saberes más significativos en relación a su medio circundante.

Energía, Concientización, Educación

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*Correspondence to the Author (e-mail: roberto.monroy@cch.unam.mx)
† Researcher contributing as first author.

1. Introduction

Among the main causes that have been studied to improve the correlation between the human being and the environment, is the search to minimize the ecological footprint; translated into treaties for the reduction of Greenhouse Gases (GHG). The drawback with this type of pollutant lies in the fact that it is caused by the increase of comfort in daily life, which means an increase in energy consumption per capita.

With this scenario in mind makes environmental experts wonder why Mexico being a country rich in favorable conditions for clean energy has not taken advantage of them. The first answer that usually accompanies this type of technology is the high cost of investment and the years of recovery, which enters a contrast between the different economist's approaches, since from a traditional point of view they are not profitable, but from an environmental vision it is shown that more is lost if this change is not sought, since everyone will be affected by the alteration of the natural conditions of ecosystems.

Paulette Dieterlen Struck, researcher at the Institute of Philosophical Research of the UNAM, sees as one of the main factors to achieve a real solution in the decrease of the ecological footprint, the change of socio-environmental awareness. Since; for some time humanity has been exercising an irrational consumption, where 75% of the products sold are not necessary (Gutiérrez, 2020), which requires the development of less selfish, fairer and more caring societies, which will have the task of decreasing by 7.6% global carbon emissions by 2020 and continue at that same rate each year for the next decade to keep global warming below 1.5° by the end of the century, according to the United Nations Environment Programme's 2019 Emissions Gap Report (Organización de las Naciones Unidas [ONU], 2020b).

It must be understood that for any of the energy alternatives to be a feasible option, a restructuring of the final consumer is first required, since he will stipulate how much should be produced and thus which solution is viable for both sectors; the economic and the environmental.

In this way it is reflected that the environmental system and its effects are intimately or connaturally related to cultural profiles of communities and societies. There is a lack of awareness and education programs on issues related to climate change (Vergara, 2015); since millions of people use electricity, but only a minimum of these know how it works, how much is spent by each appliance, how to reduce consumption, what is the impact it causes on the environment and what energy sources or alternatives are available (Olivares, 2018, p. 302).

The importance of considering this problem from the proposed approach is that even when given cheaper technological alternatives that have a lower environmental impact these will not have a real impact if the target audience is not aware of why it is important to opt for these solutions, since the energy sector is relatively strong, the average end consumer is only interested in supplying their consumption and that is competitive monetarily.

In view of this fact, the new generations are being targeted because it is to a certain degree normal for them to have a general understanding of global warming, since they were born when it was already present, so they have seen firsthand the changes in ecosystems, which has made them a little more sensitive and aware of this problem. Because of this, it is essential to teach people from an early age to understand what their role is if they want to change the unfavorable scenarios of this situation.

Due to the seriousness of the problem and that it is not so recent, numerous studies have been made for its solution from different perspectives; almost always very positive or negative, without contemplating what happens in that range of possibilities that have been left when opting for one or another approach. In virtue of this, an integral vision that contemplates the following objectives is proposed:

– Descriptive and critical research on energy consumption and its conscious use.

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– Design of a methodology for the improvement of household energy consumption in consideration of the ecological footprint.

– Proposal of a flexible, dynamic and user- friendly system for the study of household energy consumption.

Its orientation to the domestic sector is aimed at a long-term solution to climate change, since this unresolved need demands that the population takes a more active role in this situation and is not a temporary change but becomes a lifestyle that improves their coexistence with the environment.

In addition, its viability is observed if the numbers related to the chosen sector are reviewed, since its demand represents 40% of the global primary energy and about 70% of the electrical energy consumed. Therefore, it is required to reduce its consumption and the formation of infrastructure of almost zero energy consumption. All for the formation of a base towards the transition of an energetically sustainable city where its value lies in the set of new processes and new human relations of how energy consumption is understood (Soto, 2019; Del Valle, 2017, p.51).

2. System context

By using a descriptive theoretical study method, the background of the energy sector was visualized in a global way and later segmented towards the market of the United Mexican States; with which the currents of the system and its connatural relation with the trident that establishes the human activities and that has an impact in its surroundings; the economy, the environment and the society were contemplated diametrically.

In the global energy market four major changes are considered, the rapid development and decreasing costs of clean technologies to generate electricity, the increasing use of this approaching the consumption of fuels associated with oil, the shift to a cleaner mix in the economy, and the resilience of gas and oil technologies (Correa, 2018 p.152).Certainly the problems of hydrocarbon scarcity and climate change have imposed the need to make a transition to renewable energies in the treaties postulated by the countries.

In order to build a new energy system that limits the worst consequences of climate change, however it has been slowed down by a lack of political capital due partially to the blockade of the United States of America, Saudi Arabia, Russia and Kuwait; which do not agree that if the Earth's temperature increases more than 1.5ºC there may be an irreversible impact on the world (Lara, 2019, p.4).

Thus, finding a dilemma between changing the comfort of the current life or improve the quality of existence of not only living beings, but all those who interact with him. Proposing this way technological innovations that allow to diminish the environmental impact but that have a disadvantage, the high cost of investment and the years of recovery.

Generating an alarming panorama, since the curve of the Earth's temperature (figure 1) from the era of the industrial revolution (1760-1840) to the present tends to continue increasing, since, as the Jevons paradox expresses, the more efficient the equipment, the more use it will have, since steam engines not only allowed work to be done in less time and at a lower cost, but also allowed a greater number of products to be obtained which would cause another extra energy consumption, which is still contemplated in the current conditions of life, and which translates into generating a large percentage of pollutants and which, together with the accumulated damage caused by greenhouse gases, makes this problem more aggravating.

Note that the curves have a dispersion between 1920 and 1980 where the history of humanity suffered different geopolitical changes and was centralized in war activities, which again emphasizes the importance of humanity in this phenomenon and how only by exceptional situations and far from this area have caused the ecological footprint to be minimized.

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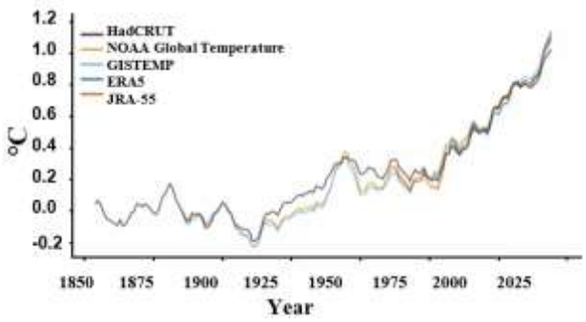

Figure 1 Increase in the Earth's average temperature from 1850 to 2025
Source. Adapted from World Meteorological Organization [WMO] (2019)

In subsequent years the most relevant organizations in the study of the problem of global warming (NASA's GISTEMP, the JRA-55 project of Japan, the National Oceanic and Atmospheric Administration NOAA of the United States, the Copernicus ERA5 program of the European Commission and the monthly HadCrut data of the University of East Anglia in conjunction with the Hadley Centre of the United Kingdom); have shown that the changes on the planet are almost the same, with no great influence of the method and areas of study, so that by 2025 it can be predicted that the temperature will continue to increase by up to 1. 6° compared to the period 1900-1925.

While it is known that the search for a transition from the current forms of energy generation to clean sources is necessary, there are many personal, economic, and social factors that do not allow it. Mexico has been characterized as an oil country, a pillar in its economy, however, the prospect of a shortage and changing prices have been shaping the need to restructure this sector. This does not mean that it can be done from one day to the next, since the necessary technologies to carry out this transformation are not usually produced in the country, besides, they do not currently guarantee energy security. For which and postulating the Mexican population as the main actor of the actions that allow decreasing the ecological impact, National Programs such as Green Mortgage, Sustainable Integrated Urban Developments (DUIS), and programs of international character that were adopted in Mexico, coordinated by Mexican institutions, which function as lines of financing to develop and acquire housing that use technology focused on saving and use of natural resources (Vallejo, 2016, p.102) were proposed.

The drawback is that, in the case of Mexico, there is no proven model or methodology to develop environmental infrastructure (Hernández, Hernández y Alcaraz, 2019, p.51).

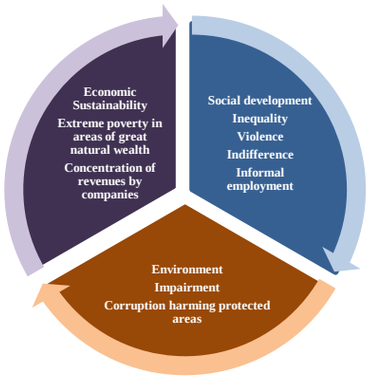

Figure 2 Problem of the most relevant aspects for Sustainable Development in Mexico
Source. Adapted from Hernández, Haro, Medina, Gutiérrez y Espinosa (2018)

Due to the unresolved needs of the GHG problem and the lack of programs proposed for its solution, activities oriented to satisfy the electricity requirements in Mexico were structured in a holistic way; having as first instance an administrative and logistic stage; for its later transportation, commercialization, and operation; however, this does not include the new energy efficiency models.

In conception to the previous disjunctive, the energy sector of the country should be directed towards a sustainable development approach, where the relationship between economic, social, and environmental systems is studied (figure 2); which in turn serve as the most relevant factors when thinking about raising awareness of the population in the efficient use of resources. Taking care that when trying to modify the current conditions, it is not deprotecting another sector or just producing a rebound effect, where the conflict is transferred to another area or another time.

This makes it essential to understand that it is not only the fact of the acceptance of the use of clean energy in the market; but to understand what this change will bring about, since modifying a system does not always mean that only benefits will be obtained. For the sector under study, one of the consequences will be that the separation of activities may cause underinvestment problems.

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A producer who must make large investments in very specific assets, which cannot be easily reconverted for use in other activities, runs the risk that, once they have been made, consumers will not be willing to pay a price that allows the expected profitability to be obtained. At the same time, self-consumption does not include any taxes, these being those currently borne by essential areas of each country's economy (Molina, 2017, p.75; Alba, Aragones, Barquín y Moreda,2017, p.41) Forcing to think about the preservation of security in sectors interrelated to energy, i.e. sustainable development must be sought to meet the requirements of electricity generation without unprotecting other needs, which makes foresee the integral and heuristic contemplation of the principles that underpin this position; which show that for a proposal to be valid from an ecological perspective, it is essential to visualize an equitable use of resources ratifying that the next generation have the same possibility to make use of these; where in an individual and participative way each individual has to ensure this fact and whoever does not comply must be responsible for the damage caused to the environment.

The conceptualization of sustainable development evokes different approaches that have been modified over time due to the evolution of the problem; falling into two perspectives one that tries to understand the three most important systems (economic, environmental, and social) in relation to the ecological footprint of human activities and a regulatory framework to solve the problems in a holistic manner where ethics and equity in the use of natural resources are preserved.

Requiring that actions are taken from a principle of responsibility, which avoids making the same mistakes by contemplating only the temporary benefits of human activities. Working with the cultural conditions of a society makes that connaturally it is studied from an ideological background; having to understand their actions and what is required to be modified. What makes us think about the principle of responsibility of Jonas (table 1) for the change that is being sought in the energy sector (which can be described by the will of sense of life of Frankl).

That even when it shows that both are directed to the search for decent living conditions, the first seeks to overcome hedonism and utilitarianism to adopt a style of consumption more moderate, ethical and moral, without falling into the radical ecological anthropocentrism, since the needs of the other sectors must be reviewed. For his part Frankl, recalls the current conditions with which the processes are managed and the irresponsible narcissism of the waste of resources without contemplating their present and future fellows.

Jonas Principle of Responsibility	Frankl's Meaning of Life
The imperative for the permanence of humanity is justified in dignified conditions.	Meaning of life: life is potentially meaningful, striving for a life worth "living".
Freedom is guaranteed by uncertainty, it moves away from totalitarianism and the dictatorship of the market.	It advocates freedom of will that allows you to overcome various conditioning. It is irresponsible choices to imitate what others do.
The responsibility of human life on Earth, without falling into contemplative environmentalism and radical anthropocentrism.	Will of meaning; capacity to be responsible, recognition of the other, sacrifices, seeking the good for the other.
Hedonism and utilitarianism must be overcome, a moderate lifestyle must be adopted.	The will to pleasure and power is insufficient; it leads to hedonistic narcissism and ignorance of the "other", whose actions have no present and future consequences.

Table 1 Convergence factors between the Principle of Responsibility and the Will to Meaning
Source. Adapted from Diaz (2017)

3. Territorial delimitation in conception of the relevance of education and economy

Usually, education is a sector that relegates the study of climate change, since in the first instance it is not seen as a natural relationship. However, as the problem of climate change is an old one, the new generations have become more aware of this issue, and it is visible both in their daily context and in the literature, they study from lower to higher grades. Therefore, it is a segment of the population that should continue to be directed to have a reflective thinking and act against the ecological footprint caused by human activities.

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In Mexico for the year 2015, the country reported an educational level higher than 9.1 grades of schooling on average, which means a little more than high school completed (Instituto Nacional de Estadística y Geografia [INEGI], 2015). For 2019 the enrollment data increased reaching a demand of 36,635,816 students where 69.6% is in basic education, 14.3% at higher secondary level and 10.8% at the higher level (Dirección General de planeación, Programación y Estadística Educativa [DGPPyEE] ,2019), having the lowest number of young people in the southeast region, while in Baja California Sur, Sinaloa, Nuevo León, San Luis Potosí, Yucatán, and the central zone has a population (in the educational age) of about 97% in school (PrepaUP,2020).

For its part contemplating the national economic level for the year 2014 the United Nations Children's Fund (UNICEF) (2014), postulated that 1 in 2 children and adolescents in Mexico live in poverty; of these, 20% are in extreme poverty, such data comes from the study of poverty measurement that considers how many people live with lower incomes to ensure their welfare and that their social rights are not respected. More recently the National Council for the Evaluation of Social Development Policy (CONEVAL) in 2019 shows how last year the percentage of poverty decreased, the downside is that the number of people has increased considerably, as 48.8% of the population have incomes below the poverty line and 16.8% are in extreme poverty, which translates into 61.1 million and 21 million people, respectively. While it is true that the southeast region of the country suffers the most backwardness, the entity with the largest number of individuals in poverty is the State of Mexico, with 7.5 million in this condition and the fifth with extreme poverty with 865,748 inhabitants (Lopez, 2019).

One might think that due to the above the choice of study would move away from the State of Mexico because of its economic lack, but from an integral approach makes it an area with great potential to carry out a pragmatic change in the efficient use of energy, since its educational level is one of the highest in the country and lacking resources a reduction in electricity consumption will mean an economic saving in the home which is one of the objectives set by the proposal in this research.

A motivator. At the same time the infrastructure of the RTN ensures that the service will be available to most of its population. Now, if we start from the perspective of shared ecological responsibility, the neighboring states will potentiate the State of Mexico; since by maintaining similar or superior conditions and a continuous interrelation, they can, in a particular and joint way, look for alternatives to increase the benefits obtained. Therefore, there will be local and network publicity, which will be an incentive to increase the participation of the proposed system; gradually implementing actions that go from the simple to the complex to achieve long-term objectives; in favor of a more harmonious life with the environment.

Due to the facts mentioned above and the factors that influence the problem under study, the area proposed for the present work is the Metropolitan Zone of the Valley of Mexico (figure 3).

Figure 3 Territorial delimitation of the Metropolitan Zone of the Valley of Mexico
Source. Prepared by the authors

4. Approach to the problem under study

To prevent proposals for an unresolved need of the system under study from bringing more disadvantages than solutions in the long term, it is necessary to establish limits and approaches with which it will be necessary to contemplate it to avoid subjectivity in its approach as much as possible.

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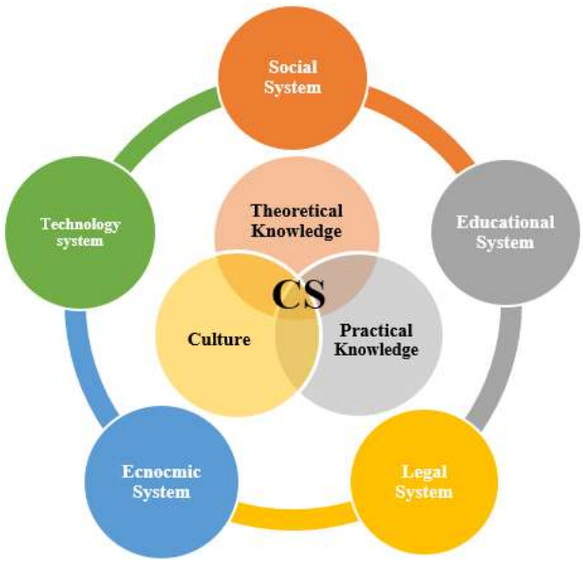

Figure 4 Systemic theoretical framework
Source. Prepared by the authors

Therefore, the research was structured based on the systems (figure 4) that are related to the problem and the approach of the Transdisciplinary Cyber-Systemic (CST), allowing the integration of thought, action, and tools for the development of a systemic theoretical framework, which in turn served to diagnose the most appropriate methodology to address the situation and to improve the current situation.

Social system

As is well known, the abnormal increase in the average temperature of the planet is due to the concentration of greenhouse gases in the atmosphere, which are produced by anthropogenic action (Intergovernmental Panel on Climate Change, 2008), which causes a negative impact on the lives of people, ecosystems, and the economy. In recent years, this has resulted in the detonation of diseases that threaten human beings because of their own actions, as it is recorded that man has modified approximately 80% of the earth's surface (Santana, 2020). Within this perspective it is undoubtedly the fact that today's society is more directed towards an anthropocentric interaction through a hedonistic consumption of resources for their own welfare and only a small amount is aware that this excessive spending generates not only individual impacts, but there is an interwoven relationship in subsystems and systems that interact with society, and which are the main actors for a possible solution in the medium and long term.

Demanding the generation of a society that is more aware of its actions and the impact they will have on its environment. This change is not immediate, since it requires contemplating both intrinsic and extrinsic factors of the person, for which phases are proposed through which the individual must pass to achieve this environmental awareness and that also lasts over time. Figure 5 shows a cyclical model that starts from the affective dimension with the sensitization and motivation of the individual so that he/she is interested in continuing with the following stages, then the cognitive dimension that will give him/her the necessary tools to formulate his/her own beliefs and solutions to the problem;

This will be joined to the active dimension by experiencing and interacting first hand with this problem; in this way a reflective feedback of the capacities that have been obtained throughout the process is obtained and that at the end a disposition is formed to want to participate in these activities and contribute improvements to the situation under study (conative dimension).

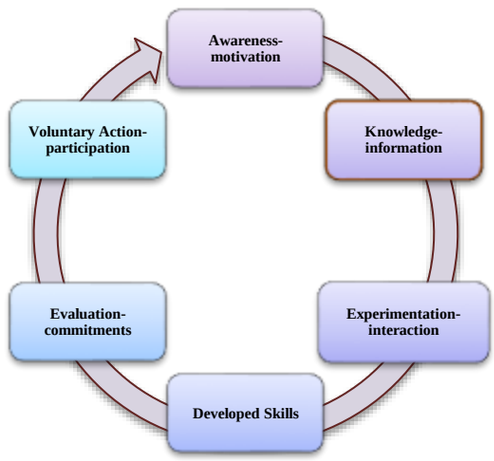

Figure 5 Phases of Environmental Awareness through which a person passes
Source. Adapted from Laso, Ruiz y Marbán (2019)

Educational system

Education serves as an instrument of social transformation, which is a viable way to generate favorable changes in the face of environmental conflicts, not only creating awareness, but also facilitating the training space for people intrinsically aware of environmental damage and the possibilities of solving problems in this regard (Fuentealba y Soto, 2016, p. 449).

It is an indispensable task, aimed at both young generations and adults, to widen the bases of a well-informed public opinion and of an individual and collective conduct inspired by the sense of their responsibility regarding the protection and improvement of the environment in all its human dimension (Román y Cuesta, 2016, p.26).

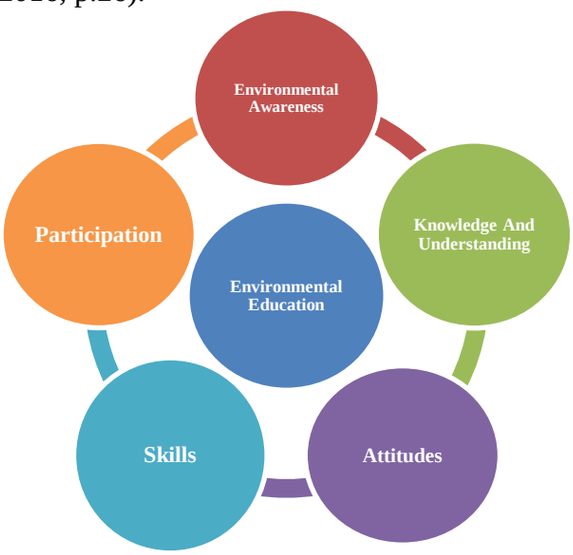

Figure 6 Components of Environmental Education
Source. Adapted from U.S. Environmental Protection Agency [EPA] (2019)

This connotes that environmental education has a higher level of complexity than environmental knowledge, since this teaching-learning process is based on a constructivist vision aimed at the integration of five fundamental components (figure 6) among them present knowledge and understanding; together with awareness and sensitization, and attributes that characterize the human (habits, attitudes and participation) with the objective that the individual learns to learn, learns to be, learns to do and learns to live together.

Therefore, a total change is needed in the perspective of the different systems that aim to find solutions to the problem of climate change, given that, as has been repeatedly mentioned, the human being, individually and socially, is the key to changing the alarming scenarios of global warming, since it must be remembered that he himself is the generator of this ecological footprint. Being imminent the incorporation of the population to the plans and governmental programs to generate individuals with better knowledge on the subject and that can participate proactively.

Legal system

Mexico is in an exceptionally privileged country in biological terms, where destructive environmental public policies are applied, which have serious repercussions on the health of Mexicans and the environment, this reality is caused by the weak national legislation, exemplified by (Santana, 2020):

- The alarming reduction of the environmental budget. Such as the 75% cut in the operating expenses of the Natural Protected Areas Commission (CONANP), which makes it impossible for the government to fulfill its function of protecting nature, controlling pollution, and operating sustainable rural development projects.
- The Federal Government's refusal to update Mexico's Climate Change Strategy and Regulations, and the withdrawal of support, incentives, and budget to achieve the transition to renewable energy production.
- Lack of a long-term vision to meet the needs of present and future generations by implementing projects that may undermine the protection of forests and ecosystems.

This demonstrates the need for a more proactive society in the face of environmental problems, since even when their representatives do not support the application of programs and plans that on paper are ideal, the same population can force a change in the way they are directed, since they are the final actors of these projections.

Economic system

The ecological economy considered as the science of sustainability management, is born by the importance of making organizations aware of the impact on the environment, nature and climate effects, which would generate higher costs in the way of marketing (Delgado y Mariela, 2017, p.15-18), thus promoting and seeking the transformation of production, distribution and consumption systems, considering the finiteness of the resources that are exploited and the urgency of turning around the economy-environment relationship (Cuadra, Véliz, Sandoval y Castro, 2017).

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Due to the approach that was given to the economic ecology was classified in the circular or cyclical models where the process continues to maintain the trend that the company acquires and transforms the primary materials to provide a service or good and that is directed towards the final consumer, however, intermediate stages were included as the incorporation of recycling and the power to use the waste by another energy market in the company of renewable sources admits that the same organization that produced the market chain acquires this product.

This alternative ensures the minimization of the environmental impact of the activities carried out by human beings to obtain a monetary remuneration without having a considerable impact on the systems that are related to it, since it is based on the characteristics and conditions of this ecological approach, based on limits set by nature and therefore give a different value to the service or product in terms of the environmental impact it will generate, with the aim of maintaining a closed cycle so that waste is minimal and there is a constant investment in cleaner technologies, all in order to search for a low-carbon business.

That once again it is remarked that to opt for this option, the education and environmental awareness of the individual must be promoted, since he will be responsible for carrying out this task that completely changes the monetary meaning given to goods and services, since he will consider how much it will affect the environment and consequently the future conditions of the market.

Technological system

It is necessary to be clear with the point of why this investigation did not consider the benefits that renewable energies bring with them, since that is an undoubted fact if it is contrasted with the decrease in the environmental impact that it will generate if it is compared with the one caused by fossil fuels. However, it is not yet aimed at a market such as the national one, because it requires a considerable investment that, despite the fact that political proposals give support for its incorporation, this is still unfeasible for most of the population, requiring a social system of a defined size so that this cost can be cushioned;

Besides demanding that society itself has technical knowledge and basic planning for its self-management; which requires first of all a change in how citizens conceive the environmental issue so that they can be aware of the need to generate a more balanced lifestyle with their environment and impose a different value to goods and services in relation to the ecological footprint that will cause.

For this reason, it was decided to consider only that technology that most of society can acquire and/or manage at home, because it is a key sector for the reduction of GHG caused by human activity itself.

Within this approach has the advantage that homes are currently more energy efficient and coupled with the pandemic by Covid, now many people work in their homes, making the perfect time to monitor every action, every gesture, that can make a difference, a before and after (Yáñez, 2020a). Remembering that energy efficiency does not seek to reduce or stop performing certain activities to avoid energy consumption (Lizárraga, 2020), but seeks to optimize the use of energy resources without diminishing in any case the quality of life of whoever adopts measures of good energy use (Emol, 2017). In a timely manner this progress is complicated to analyze since it is an intangible consumption that represents the absence of energy consumption and that can only be estimated (SEGOB, 2020a), so it is essential to visualize all the agents that influence this activity and that allow giving feedback to modify or restructure the proposed actions, such as, for example, the decrease in the receipt of the service.

A clear example of this is that even when most of the current technological products have a better energy efficiency they still have consumption that can be minimized or avoided, for example, when analyzing graphic 1 it is noted that the expenditure generated by equipment on stand-by is a value of 6% which can be reduced by simply informing the population about what generates it and how to solve it, this being the easiest way, since it is enough to turn off and / or disconnect the devices; This may seem an insignificant contribution on an individual basis but it becomes relevant when considering society in general.

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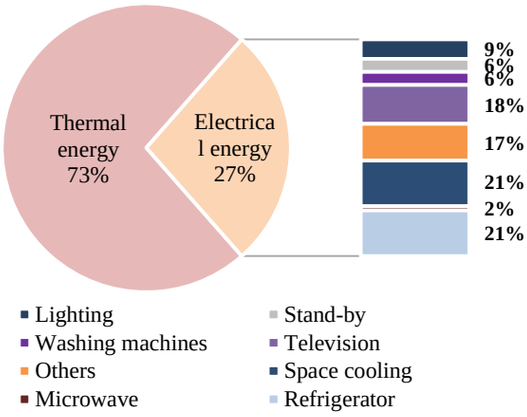

Graphic 1 Mexico's National Energy Efficiency Monitoring Report 2018
Source: Adapted from SEGOB (2020a)

Undeniably the mere existence of human beings demands energy consumption, and as a result of their current lifestyle there are actions that cannot be minimized or eradicated, so we must take advantage of all available openings with which to support the reduction of the effects caused by global warming, actions that individually will be banal if combined with a larger number of individuals will make it closer to achieving a future benefit for humans and everything around him.

5. Methodology

Consequently, from the above diagnosis regarding the main components to generate a conscious energy consumption by the population arises the need to contemplate a methodology that is appropriate to the research in correspondence to the integration of the most relevant factors of the problem.

Therefore, for this purpose it is decided to use the Cyber-Systemic Action-Planning Process (PAP method) with reflective feedback, to diagnose the structure of the methodologies, to observe if they comply with the condition of linking or cybernetically feeding back the ontological and epistemological knowledge. Since linking theory and practice requires a participatory and iterative circular interaction that serves to obtain continuous learning by comparing the models of the systems with the concrete results under the dynamic conditions of the real world (Peón, 2015).

In conception of the above, the sections of the comparative table of methodologies (table 2) were filled in according to the steps and/or sub- steps that are related to the objectives of the PAP method, which are listed below: defining the boundaries of the system (D1), specifying the problem (D2), proposing the theoretical solution of the problem (D3), documenting the decisions of the planning process (A1), implementing the planned theoretical model (A2) and, operating the constructed system during its life cycle and improvement (A3); alluding to planning (D1,D2 and D3) and action (A1,A2 and A3) stages, respectively.

Pap Method (D3-A3)						
Methodology		**Jenkins**	**Checkland**	**Hall**	**MIO**	**Transdisciplinary**
Planning	***D1***	1.2, 1.3, 1.4, 1.8	2,3	1,2	P1, P2, P4, P5	1.4, 2.1, 2.2, 3.2
	D2	1.1	1	4	P3, P6	1.1, 1.3, 3.1, 4.1
	D3	1.5, 1.6, 1.7, 2	4, 6	3,5	Phase 2	1.2, 1.5, 2.3, 2.4, 2.5, 2.6, 3.3, 3.4
Action	*A1*	3.1	5	6	S1, S2, S3	1.6, 3.5
	A2	3.2	7		S4, S5, S6, S7, S8 Phase IV y V	4.2
	A3	4			Phase VI	3.6,4.3,4.4,4.5,4.6

Table 2 Comparative table of methodologies using the PAP method
Source. Prepared by the authors

The cybernetic method of Participative Action- Planning D3-A3, hides a potential masked by its graphic simplicity, since it allows the analysis of the methodologies from a systemic vision admitting diagnosing which of them can be adjusted in a better way to the project.

Construction of the methodology

The advantage of carrying out the previous activity is that it makes it possible to create a flexible and dynamic methodology that allows the researcher to correlate his or her needs and interests in the study and modify it according to the scenarios that arise. The organization of the steps and sub-steps that are suggested to be followed in the face of the problem are shown below in a global manner.

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Methodology adaptive to the context

1. Context and state of the art (Cx)
   C1) Definition and justification of the project. C2) Context and state of the art research.
   C3) Bibliographic research of practical and/or theoretical solutions.
   C4) Compilation of the most relevant factors of the system.
2. Problem (P)
   P1) Define unmet needs.
   P2) Problem formulation.
   P3) Comprehensive hierarchical diagnosis of the situation of the relevant problems.
3. Modeling (M)
   M1) System objectives.
   M2) Definition of feasible desirable changes. M3) Document the rejected alternatives.
   M4) Construction of the model.
   M5) List the functions of the model.
   M6) Compare the model theoretically with the objectives.
4. Documentation (D)
   D1) Elaboration of the plan.
   D2) Program development.
5. Implementation (I)
   I1) Action to solve the problem or improve the situation.
   I2) Diagnose the alternatives that can be adjusted from the implementation process.
6. Operation and Improvement (O)
   O1) Evaluate and diagnose the impact of the proposal.
   O2) Retrospective appreciation
   O3) Improved operation
   O4) Development of a growth and upgradingprogram.

Figure 7 shows the recommended relationships between the different stages of the methodology created. Starting with the justification, the delimitation of the boundary and the collection of information (context and state of the art) that will cement a deep knowledge of the system and its most relevant factors. Based on this, we proceed to the definition of the problem and the unresolved needs, to diagnose systemically and integrally the most relevant situations in conflict and prioritize them according to their importance (Problematic).

These two steps maintain constant feedback since the previous research will establish the limits and scope of the problem situation, but if this second stage finds factors that were not initially contemplated, it will require a new evaluation of the information obtained. This is essential since we have a dynamic system where its different actors maintain a broad relationship with their context.

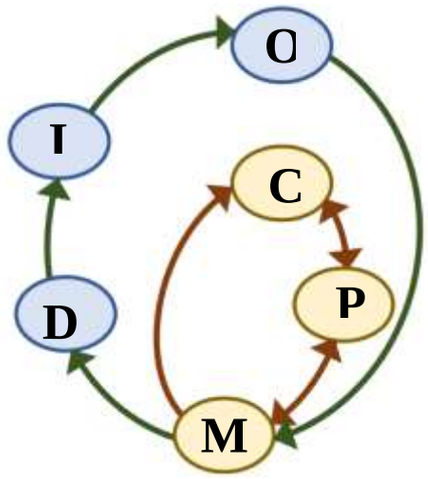

Figure 7 Context-adaptive methodology
Source. Prepared by the authors

When the previous condition is fulfilled, the actions to be taken are specified, for this purpose the objectives pursued by the system are outlined and the facts, alternatives and criteria that validate the satisfaction of what is proposed are established (modelling). Having a premature stage of documentation that establishes the rejected alternatives but that by its nature allows to think about its later implementation and a phase of continuous appreciation that allows not to lose sight of what is pursued theoretically; and that in turn shows if there is missing information or factors that have a considerable impact on the system. Because of this, this step maintains constant communication with the first and second step to update these aspects.

On the other hand, the steps corresponding to the action stage maintain a linear sequence to avoid the vices that are usually stigmatized to the systemic, since usually he wants to cover everything and does not proceed to carry it out in a practical way. Certainly, the sub-steps corresponding to this phase are designed to provide feedback on everything that was planned.

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To do this, first the stipulated agreements that support the implementation of actions that improve the current situation are documented and alternatives that facilitate this process in future applications are foreseen. The final step is the operation and improvement of the system, which corresponds to the prospective of the system and the evaluation of the fulfillment of what was planned.

This last step is linked to the third one (modeling) so that it allows to evaluate if the model covers the objectives and the unresolved needs raised; or if what is not being fulfilled was discarded in the first instance or was not contemplated and the current proposal must be restructured.

Application

As it can be noticed, the purpose of this research is to seek environmental awareness in the population, starting with the educational sector since they are in a process of integral development and have tools and knowledge that help them to correlate their actions and their impact on their environment in a more plausible way. In addition, it must be remembered that the problem is not temporary, so it is required that the new generations begin to be more sensitive about the issue if it is really required to reduce the expected situation.

Thus, in the search for the transition to a more environmentalist population, the need to make society aware of its impact on its environment becomes evident, in order to think about a real modification of the current energy sector in the country; which demands that the following changes be considered: gradual replacement of inefficient products, new consumption habits, education, information and advertising that influence the decision to purchase appliances and their use, transmission of information among a population more and better informed about environmental issues, and lasting lifestyles in search of sustainability.

The proposed change is not immediate, since it requires contemplating both intrinsic and extrinsic factors of the person, for which phases are proposed through which the individual must pass to achieve this environmental awareness and that also lasts over time.

Starting from the affective dimension with the sensitization and motivation of the individual so that he/she has an interest in continuing with the following stages; subsequently the cognitive dimension is approached which gives him/her the necessary tools to formulate his/her own beliefs and solutions to the problem, in this way a reflective feedback of the capacities that have been obtained throughout the process is obtained and that at the end a disposition is formed for wanting to participate in these activities and to contribute improvements to the situation under study (conative dimension).

For the above, it is proposed to approach the problem under study from a model based on the phases of environmental awareness that a person goes through (awareness-motivation, knowledge-information, experimentation, interaction, developed capacities, valuation-commitment, voluntary action-participation), the components of environmental education (awareness and sensitization, knowledge and understanding, attitudes, skills, and participation), the ERCA model (Experience, Reflection, Conceptualization, and Application), and the six levels to be able to form the necessary skills to build critical thinking (reflective thinking, reflection, conceptualization, and application), knowledge and understanding, attitudes, skills, and participation).

Originating the model for environmental awareness based on contextualization (figure 8) which consists of 6 moments:

– Conceptualization
– Reflection - information / knowledge
– Skills-attitudes
– Active participation
– Applications-voluntary action
– Lifestyle.

Maintaining a circular base structure but including different stages of feedback focused on a heuristic process.

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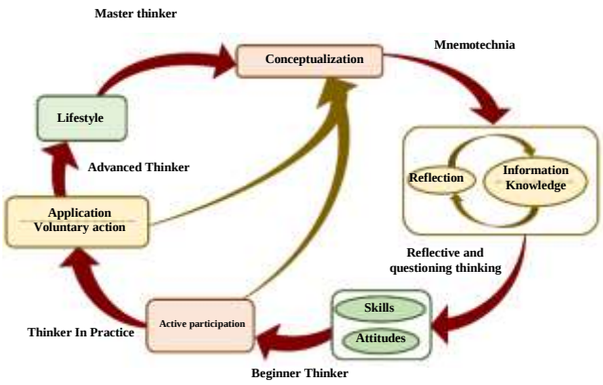

Figure 8 Model for environmental awareness based on contextualization
Source. Prepared by the authors

The model is based on the conceptualization that considers the need for the basic foundations required for the student to have tools with which to contrast the knowledge acquired and their experiences, to reach a higher cognitive level. Although mnemonics are often stigmatized in the teaching process, memorizing also serves to think, to make decisions and thus to solve problems. This means that it is a systemic triad that leads to understanding the need to study not only isolated parts and processes, but also to solve problems (Equihua, 2017).

Therefore, an educational action oriented to transmit contents with the support of this technique must take into account: the pedagogical action has to respond with successful alternatives that facilitate the approach to the complicated reality, propose didactic alternatives to obtain knowledge, turn the classroom into a center of discussion and debate, and overcome the schemes that reproduce information by initiatives that stimulate creativity, criticality and innovation (Santiago, 2005, p.58). But only having tools and concepts is not enough since this only supposes the repetition on the part of the student, so it requires now to integrate it for the acquisition of information and to find the interrelation between the different types of knowledge that he has; always with the intention of maintaining a reflective vision. Subsequently, skills and attitudes must be founded so that the young person can present his conjectures and debate them, always supporting them logically and with values that maintain an environment in accordance with this process.

This can be seen as a stage where theoretical knowledge is developed and all the bases for making quality decisions that are pertinent to the present need. This leads to the proposition of questions where the young person continues to be guided to correlate their knowledge, but now in relation to practical aspects, leaving their passive role and taking an active one.

Evidently, to totally dominate an area of knowledge is impossible because day by day more information continues to emerge that is added to the great accumulation that we already have, so in the action stage there is a bifurcation in each of the subsequent moments; well, to improve in a subject it requires practice as every skill that the human being learns. In this way first it is understood that the level reached is that of a beginner thinker where he begins to shape his understanding of the problem in an environment controlled by a third party, for its subsequent application, but from a specific problem that the same thinker has shaped and voluntarily wishes to solve or improve the current scenario. At the end of this long and complex process

it is expected that the actor manages a high level of awareness and understands how their actions will have a negative or positive effect on the environment and take a stance on it; it is their lifestyle. As mentioned at the beginning, no matter how many years of study there will always be something new to learn, which will allow the process to be holistic and heuristic to the present needs and that will result in the need to take on the role of student, but now with a set of new knowledge and tools to address this scenario.

6. Implementation of the project "My impact on the environment"

In conception of what was shown, it was decided to implement a pilot test in the Escuela Nacional Colegio de Ciencias y Humanidades (ENCCH) Plante Vallejo; located in Av. 100 Metros corner Fortuna, Magdalena de las Salinas, Gustavo A. Madero, Mexico City. Which complies with its student population is between the territorial delimitation.

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In addition, it seeks to potentiate the essence of its educational model which is based on four main axes: basic culture, academic organization by areas, the student as the subject of culture and main actor in their training, and the teacher as a guide in learning (Gaceta CCH, 2001), where innately by its constructivist approach aims to train the student integrally generating a critical thinking based on ethical and contextualized values (CCH, 1996).

This test was applied to a non-probabilistic sample with a total population of 240 students, corresponding to six fourth semester groups enrolled in Physics. Initially, in the period 2021- 1, the teaching process was implemented in the traditional way, from the perspective of the study program, except for the laboratory practices due to the SARS-CoV-2 pandemic. In the first instance so that the students could adapt to the new normality and to a subject that requires the incorporation of a more technical language for the understanding of the topics.

Therefore, addressing these issues from a traditional approach apart from generating the necessary tools to achieve the objectives proposed by the project will also serve to reflect on what impact it will have on the performance and learning achieved by students when implementing the proposed model.

At the end of the semester, with the most relevant factors in mind, the construction of the methodology and method, we began the creation of different digital environments aimed at informing and generating debates on topics of the mathematical physics area and its contextual application. These technological spaces were chosen because they were easy to access, free of charge and required few technological and network resources.

Thus, on February 15, 2021, access to the YouTube channel titled Fiscch was opened, aimed at addressing step by step the topics of the CCH Physics II program from a practical perspective based on previous learning and experiences. Simultaneously, to maintain communication and generate a repository of printed materials, different teams were created in Teams to maintain a more personal relationship and a continuous discussion of the elements reviewed in the course.

For the development of the necessary materials to meet the proposed objectives in search of environmental awareness, a form was made on the Microsoft Forms platform due to its compatibility with Teams, which allows only the desired student population to answer it. This previous activity has the purpose of visualizing the level of understanding that young people have of environmental problems and the importance of what they learned in Physics. It should be clarified that the questions proposed in this activity follow the essence of the project, that from a friendly language young people can define and explain the physical phenomena and ecological needs.

This form was applied to students who had already completed a semester of the subject from the approach proposed by the study program with adaptations to online teaching, the most relevant results obtained are the following:

- 40% of students do not consider that the subject of physics has any impact on their life.
- 52% mentioned that they do not know how to interpret an electricity bill and 60% indicated that they do not know the factors that are considered to charge them for this service.
- 26% do not recognize energy-saving equipment, a percentage that is repeated with the implementation of incandescent lamps in their homes.
- 82% mention that they try to save electricity, but 77% don't know what phantom consumption is.
- 72% know how electricity is generated, indicating 66% that this activity pollutes the environment, while only 3% do not believe it does, and the remaining 3% mention that they cannot decide on any of the answers.
- 55% know what renewable energies are, 42% indicate that they have heard of them, but do not know what they are and 3% have never heard of them.
- 45% consider that Mexico does implement renewable energies in its matrix, but only 26% believe that the country does support this type of projects.

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– 98% and 96% indicate that they know or have heard of global warming and the greenhouse effect, respectively. But 32% do not know how to differentiate between these terms.
– 63% know someone who is interested in environmental issues, showing that for 70% it is essential to understand this type of problem, 15% believe that it is relevant but only from time to time and the rest mention that they are interested when they see, read, or hear about it in the media.
– 76% have seen the causes of the greenhouse effect in school mainly in biology and chemistry subjects. 21% have done it on their own and 3% mentioned that they had never heard of it.

This brought about the verification of the initial premise of the project; the current generations are more aware of the existence of environmental problems and are more sensitive to them because they were born when they were already present and have experienced them firsthand. However, most of the population are in the basic levels since they are still unable to explain it in a clear way, they confuse the concepts, they do not find the relationships between factors, they try to take care of their consumption, but they do not know how to do it in a correct way.

Reflecting that their intentions are good, but they lack tools and actions that support them in their perspective of the world. In this way it was noted that a foundation of concepts that allow young people to understand the phenomena present in their daily lives is required, as they showed that they had that practical experience but could not consciously capture it. Based on the above, we proceeded to create the necessary material to be able to approach the course from a contextualized vision. Zoom was used to record the videos by means of the electronic whiteboard (figure 9) and their subsequent processing and editing using the VEGAS Pro software.

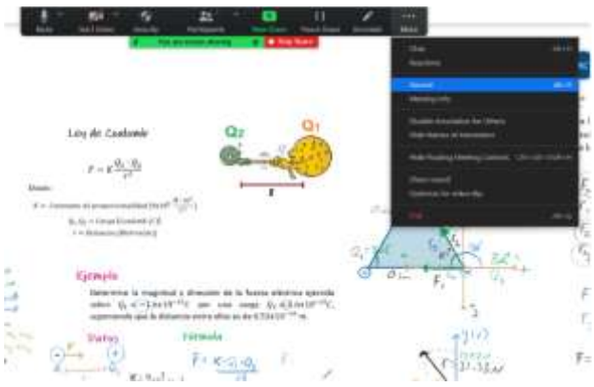

Figure 9 Creation of materials
Source. Prepared by the authors

Thus, generating more than 40 videos with durations ranging from 30 to 80 min, hosted on the YouTube channel mentioned above (figure 10) and that to date totals more than 8000 views from both the study population and the general population, since at the request of the students their privacy was changed to public so that they could share it with their friends and acquaintances.

Figure 10 Replenishment of the videos on the Fiscch YouTube channel
Source. Prepared by the authors

In addition to the above, the students were invited to an extra course-workshop called "My impact on the environment", to study climate change in greater detail, its elements, correlations, effects, alternatives to improve the situation and what their role is in the face of this problem. The meetings began on March 4th and were held eight to fifteen days apart so that the young people did not have any setbacks with their academic activities.

We counted with the participation of 102 students who were encouraged to participate in scientific and outreach events that the National Autonomous University of Mexico (UNAM) opens each year; also, through a discussion group created on the Facebook page with the same name as the YouTube channel students proposed their conjectures to the concerns, they had about the issues seen and needs they noticed in their environment.

During this period, they were invited to create two materials as a team to publish in this social network and open it to the general public to share what they learned during this period; Therefore, on June 1, 2021, the population is given access to the activities developed by the students, where they explain in short videos global warming and its consequences from their perspective, and through infographics propose simple solutions that do not greatly affect the lifestyle of the person but that allow to improve the current situation of the environment; to turn it into an action that lasts for its simplicity.

7. Results

The following results were obtained when applying the themes of the Physics syllabus from the perspective of the model proposed in the project:

- Students were more active during class, reflecting and creating questions about everyday phenomena.
- Decreased the failure rate by 20% with respect to semester 2021-1.
- The acceptance form indicated that 94% found the subject of Physics to be interesting or useful in their daily lives.
- 94% of the students can correctly exemplify a practical application in relation to the career they want to study or an aspect they are interested in.
- An online repository of audiovisual materials that exemplifies the subject of Physics in a contextualized way, hosted on the YouTube channel named "Fiscch".
- Students can explain both colloquially and with physics concepts what global warming is, they can differentiate it from the greenhouse effect, but at the same time they understand its relationship and impact.
- Public Facebook group called "Fiscch" aimed at discussion and feedback of acquired knowledge. It currently hosts materials created by students explaining global warming and alternatives to improve it.
- A public diffusion considerably higher than initially expected by raising private environments, counting more than 8000 reproductions on YouTube and close to 1000 reactions on Facebook. Highlighting the fact that by making them public many aspects of the platform's history were reset.
- The continuity and acceptance of more than 100 students for the implementation of the Course-Workshop My Impact on the Environment.
- Incorporation of teachers from the experimental area to the course-workshop.
- Interest on the part of young people in science outreach events promoted by UNAM.
- Assessment of the projects that the young people proposed and registered for the different UNAM events and that mainly addressed environmental problems.
- Participation of students in the 10th meeting of the High School Meteorological Stations Program (PEMBU) and obtaining the first place.
- Participation in the XXIX University Contest Science Fair, obtaining the first, second and third place in different categories with the works entitled: "The temperature and the hot air balloon", "Everything you should know about vampires" and "Proposition of systems to improve environmental coexistence", advised by different teachers belonging to the course-workshop.
- Finalist in the Youth Program towards research in Natural Sciences and Mathematics of the Secretary of Learning Support Services, which made the young people were worthy to present their project "Environmental Coexistence in the CCH" in the 3rd Student Meeting of initiation to research.

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– The evaluating jury of the 3rd Student Meeting of Initiation to Research encouraged the young people to present this proposal to the authorities of the CCH Vallejo and the corresponding town hall so that they can jointly seek a greater good and the conscious use of the resources they have.

8. Conclusions

On an international level, various literary sources have emerged that from different visions address the unresolved needs that are present in the increase of the planet's temperature and that are intertwined in agreements to rectify the alarming panoramas due to the irreversible modifications of the ecosystems. But they remain as idealistic qualitative alternatives since they have no repercussion and do not play a relevant role in the solution of the problem.

The shared but differentiated responsibility is one of these alternatives to achieve that the human being looks for a better coexistence with the environment, since the one who damages, his environment will have to pay for these actions and support the one who does not do it, nevertheless, it continues being an idea directed to the conscience of each individual and for the hedonistic consumerism it is far from being a valid form to solve this conflict.

Particularly Latin American countries lack plans focused on providing their population with a solid environmental education, since they state in their programs that the most relevant element to combat climate change is the transition of their current power plants to renewable energies. Without foreseeing the negative consequences that this will have on their neighboring sectors; A clear example of this is what happened in Spain that when implementing large-scale solar collection technology did not foresee that this sector is the basis of the main activities of a nation either by creating products and services, or by charging for their use, which consider a tax charge that people to self-supply not pay and that caused havoc in different areas, bringing with it that the government had to take out a proposal to cushion this loss, around the world was known as "sun tax".

Which without background seems an idea that leads to authoritarianism and imposition of an owner to natural resources; But it is nothing more than an unforeseen consequence of a solution that imposes a rebound effect in the short term.

Unfortunately, sustainable development in Mexico is a distant prospect, since it is not a global priority, first, the ideas of its leaders must be consolidated and cemented, and the benefits they seek must be eradicated, since even when the population has good intentions, there is a lack of knowledge of this nature. Therefore, in order to reduce the risks in this aspect, a dynamic strategy is required since, as it has been shown, it is essential to make the population aware of these issues, which ideally should arise governmental environmental programs that have a continuous monitoring aimed at all sectors in relation to their contextual needs; but since this is not possible, the most appropriate idea is to take advantage of the knowledge acquired by the students of the country; since they already have the bases, they only need to be guided so that they have the tools to take action to mitigate this problem and transmit their perspective to their third parties. As it can be noticed, this option does not require a drastic modification in the current style of the educational sector since it would be a way for young people to develop their learning integrally by relating theory, practice, and culture; of course, requesting for it to train teachers.

In conception to the above it was required to identify and diagnose the main factors and systems in relation to the energy sector from systemic methods, which admit determining a long-term solution of the connatural problems that climate change brings with it. Thus, avoiding the dilemma between economic, social, and environmental processes that impact their environment due to human activities. Thus, allowing the design of a methodology for the improvement of household energy consumption in consideration of the ecological footprint, which was based on the approach of the Transdisciplinary Cyber Systemic, which brings together different types of knowledge; ontological, epistemological, and cultural.

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Directing in this way the activities towards the environmental education of the population and mainly to those who are already in this training process; since it was found that the application of efficient technologies is necessary, but not urgent, since as suggested by the paradox of Jevons "more efficiency more use", which will bring a decrease in energy expenditure in a period expected but that will contribute equal or more to the one that currently has. Making imminent the need for a society more aware of its actions in favor of a more friendly relationship with the environment, which by leading to a change of thinking brings with it a complex system in relation to all the elements that establish the way of being of the individual.

Taking into account the above, the model for awareness raising based on contextualization considers a holistic, heuristic and flexible process; so as not to affect the person's current lifestyle to a great extent, but rather that with simple actions he will understand the importance of his actions in the present environmental problems; and also that he obtains a more egocentric benefit and motivates him to continue with these actions until he establishes the necessary skills and attitudes to overcome this individualistic feeling and move on to a more systemic one that leads him to understand his role in the system, to have an active participation and a more eco-environmental way of life.

The implementation of this proposal in the Colegio de Ciencias y Humanidad Plantel Vallejo, brought with it a great reflection since in addition to obtaining good results by implementing it in a particular area of knowledge from contextualized problems, showed that young people already had cemented this thought for wanting to contribute something to their environment although they did not know how or do not carry it in the best way; making it plausible that guiding these activities will generate better results in their comprehensive training and will support a deep foundation of cognitive skills necessary to properly establish critical thinking.

A favorable consequence of the project is that it was achieved that young people willingly enrolled in scientific outreach events to present their understanding of the reality of environmental problems and proposals for their possible minimization. Their conjectures were transmitted and were also well seen by the evaluators and the student population, so that they wanted to continue in this area, to learn more and better about this problem and to continue making proposals in their environment to solve the current needs.

On the other hand, the participating teachers understood the level that the students have of the problems of their environment, what is the acceptance of their subject and what significant knowledge was achieved; but at the same time they learned new aspects because depending on the conditions of each individual they had a different understanding of how to solve the problem and they found from browsers that every time they use them they plant a tree (Ecosia), to video games that through fables try to make young people understand the consequences of their actions on the environment.

As has been alluded to, environmental awareness is complex and its foundation will not be laid from one moment to the next; it will require the acquisition of knowledge and its maturation; Therefore, in order to improve the proposal, it is foreseen that this vision be included in a transdisciplinary way, incorporating experts in different areas who contribute their understanding, for the formation of plans and programs to be applied in the educational field, to be restructured and optimized in the search for the continued growth of the system by means of word-of-mouth publicity of the different actors and the benefits obtained in the short, medium and long term; always foreseeing in the first instance the context to which it will be applied.

Certainly, at some point it will be mandatory the acquisition and implementation of renewable sources and more efficient equipment in each of the nations because the current excessive lifestyle is not possible to maintain it; but it will require a society that understands why this transition was necessary and is measured in its consumption subjecting it to the ecological footprint that will generate in the present and future environment.

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Remembering that there is no technology that is one hundred percent friendly to the planet and that the best way to reduce energy consumption is not using it; but not being able to comply with it will require the population to take prudent measures to ensure a future for future generations.

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Construction of Kaplan turbine test bench for mini hydraulic power generation

Construcción de un banco de pruebas de turbinas Kaplan para la generación de energía minihidráulica

FRANCO-MARTÍNEZ, David†* & ARBOLEYA-ORTIZ, José Raúl

Centro Tecnológico, Facultad de Estudios Superiores Aragón, UNAM

ID 1er Author: *David, Franco-Martínez* / **ORC ID**: 0000-0002-0464-8504, **CVU CONACYT ID**: 69978

ID 1er Co-author: *José Raúl, Arboleya-Ortiz* / **ORC ID**: 0000-0002-7779-801X

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Abstract

The general objective of the work was the design, development, and construction of a Test Bench for Kaplan type turbines suitable to be installed in a rural environment, through which we can check if the characteristics of the turbines are ideal to meet the generation goals of electrical power required. To carry out this purpose, a Kaplan-type turbine prototype was designed and built-in order to install it in our Test Bench and verify that this Bench is adequate to check the operation of the turbine subjected to different input conditions and for Therefore, this will help us to arrive at an ideal turbine design to take advantage of the mechanical energy of water and therefore the generation of electrical energy. This is a project that was developed with the design objectives from scratch to the physical creation of a test bench for turbines, specifically for a Kaplan type turbine where tests can be carried out in a controlled environment where new designs are put into practice. of turbines to know their operation in a scaled manner and then be able to take them to production and installation in different regions.

Kaplan, Mini hydraulic, Testing bench, Electricity

Resumen

El objetivo general del trabajo fue el diseño, desarrollo y construcción de un Banco de Pruebas para turbinas tipo Kaplan adecuadas para instalarse en un medio rural, mediante el cual podamos comprobar si las características de las turbinas son las ideales para cumplir con las metas de generación de potencia eléctrica requerida. Para llevar a cabo este fin, se diseñó y construyó un prototipo de turbina tipo Kaplan con el objetivo de instalarla en nuestro Banco de Pruebas y verificar que este Banco es el adecuado para comprobar el funcionamiento de la turbina sometida a diferentes condiciones de entrada y por lo tanto, esto nos a va servir para llegar a un diseño de turbina ideal para aprovechar la energía mecánica del agua y por consiguiente, la generación de energía eléctrica Este es un proyecto que se desarrolló con los objetivos del diseño desde cero hasta la creación física de un banco de pruebas para turbinas, en específico para turbina tipo Kaplan donde se puedan llevar a cabo pruebas en un ambiente controlado donde se pongan en práctica nuevos diseños de turbinas para conocer su funcionamiento de manera escalada para luego poder llevarlas a la producción e instalación en diferentes regiones.

Kaplan, Minihidráulica, Banco de pruebas, Electricidad

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*Correspondence to the Author (e-mail: davidfrancomartinez@comunidad.unam.mx)
† Researcher contributing as first author.

Introduction

The general objective of the work was the design, development, and construction of a Test Bench for Kaplan type turbines suitable for installation in a rural environment, through which we can check if the characteristics of the turbines are ideal to meet the goals of generating required electrical power. To carry out this purpose, a prototype of a Kaplan type turbine was designed and built with the aim of installing it in our Test Bench and verifying that this Bench is suitable to check the operation of the turbine subjected to different input conditions and, therefore, this helped us to arrive at an ideal turbine design to take advantage of the mechanical energy of water and therefore, the generation of electrical energy.

Hence, a Kaplan-type turbine was first printed using an ABS filament through a 3D printer; subsequently, the Test Bench was designed and built taking advantage of an existing structure in the Technology Center and providing it with all the necessary components to make some first basic measurements and thereby verify the proper functioning of our Test Bench and therefore the behavior of the turbine previously installed and with it will have the necessary elements to analyze the feasibility of building it in aluminum or another material for a greater duration of use in rural areas.

1. Test Bench

This section is dedicated to the assembly of the Test Bench from scratch, using to verify its operation the installation of the prototype of a Kaplan type turbine, includes the development of the corresponding plans, as well as the calculations involved for the test of the turbine.

What is a test bed?

A test bed can be defined as a space designed with the characteristics of a given environment to provide a form of rigorous, transparent, and repeatable verification of scientific theories, computational elements, new technologies, etc. These banks can be found in many industries, which install their parts.

For example, to know the resistance of the materials that are used, testing the various efforts that can be achieved depending on the work to which it is going to be subjected; know if the new designs of parts comply as they were designed or if some changes must be made to improve or perfect the design, or in such a case to eliminate it in case it is not profitable. About our test bench, you will have the function of experimenting if our prototype Kaplan turbine or any other turbine that you want to install, will have the appropriate design to be able to be used on a larger scale with respect to a river.

1. Some of the characteristics that our test bench has is that you can experience different types of flow that our flow (laminar or turbulent) can have to which the turbine can be subjected, the height of the waterfall modifying the height of the pipes, the position of the turbine depending on the base that is designed.
2. It can be moved in a relatively simple way.

Next, we will present the development that had its assembly along with its justification, the errors that were had at the beginning, the way we corrected the problems, in addition to the plans for the design of the pieces.

1.1. Construction of the Test Bench

For the construction of our test bench, we occupy materials that do not suffer any type of damage or wear to be in constant contact with water. They also came to consider the cost of the products, the way to be able to obtain them, which will cover the needs during the testing, installation, and measurement periods.

Storage tank – Rotoplas

At the beginning it was proposed that the equipment be connected to an outlet of the Technology Center to provide water to the test bench for its operation, but for reasons of time and optimization of the development of this project, the decision was made to install a water storage tank with return of the same to the tank to use it continuously in the project, that is, we made the test bench a closed cycle, this means that there should be no significant losses of the amount of water stored by our tank.
But why choose a Rotoplas tank?

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A. Dimensions: you have the right size with which you can hold most of your body on the top base of our test bench.
B. Capacity: its storage becomes sufficient to be able to have the necessary water to perform the tests and the movement of the turbine.
C. Stamina: thanks to the low-density linear polyethylene material with which the tank is manufactured, it is resistant to various conditions, in addition to which it does not oxidize or corrode. As an extra fact some suppliers mention that they get to have a lifetime warranty.
D. Easy Maintenance: suppliers mention that it must be kept always closed to avoid the development of bacteria and contaminants, in addition to recommending that it be washed every 6 months.

Characteristics:

– black Rotoplas
– Stores up to 250 liters of some fluid
– Nose valve
– Hose connection
– Connection for a 4-inch Cople
– Cost of 1,200.00 pesos.
– Height of 75 cm
– Diameter of 60 cm
– Weight of 1 kg

Figure 1 Rotoplas Water Storage Tank
Own Elaboration

Base structure

The function of this structure is to be able to load all the components that our test bench needs to be able to perform the simulation of the water of a flowing river and that gives movement to the Kaplan turbine.

We took advantage of a structure belonging to the technological center, which allowed us to use it as the base. We used the features we already had to be able to couple all our components and build the river simulation.

Figure 2 Test bench base
Own Elaboration

Characteristics:

1. The total length of the test bench is 147.5 cm
2. Its width is: 47.4 cm
3. It has three sections on one side, where in the upper part the Rotoplas will be placed, in the middle part a part of the step valve will be placed and in the lower part will be an empty space to place equipment that is needed (Tools, accessories, etc.)
4. It has 4 wheels to make your transfer to another place is easier.
5. Here we will only have a cost of 50 pesos for the purchase of the tables in the upper section and in the middle.

PVC pipes

These pipes are the ones that will help the water to reach its destination, pvc was selected for the following reasons:

1. It is an easy material to find and suitable for water management, plus it was easy to acquire (pipes, fittings, etc.)
2. Its low cost, easy installation, and low maintenance.
3. Durability, this type of materials does not need to be changed frequently.
4. Light Elements, with what was investigated it was found that the pipes of these materials are the lightest on the market, this helps that at the time of their installation and transfer there is too low a risk for there to be any possibility of being damaged.
5. Resistant to corrosion and erosion, since PVC is a material that is not affected by corrosion both underground and outdoors or indoors and this is a very important factor because as we mentioned above the contact with water will be constant since in addition to working with it, it is located to the environment in the State of Mexico, where there is constant rain.
6. Long Shelf Life, PVC suppliers mention that they have recorded more than 50 years of useful life in this type of pipes and scientists from Australia made a study in 2014 in which they mentioned that they can last more than 100 years.

During the test bench, 2 types of PVC pipes, sanitary PVC and hydraulic PVC were occupied.

Figure 3 Sanitary PVC Pipe
Own Elaboration

Figure 4 Hydraulic PVC
Own Elaboration

Characteristics:

1. The two PVC pipes are 4 inches in diameter
2. The existing difference from one to the other is that the thickness of the wall is larger in the Hydraulic than in the sanitary, so it resists better the high temperatures.
3. Sanitary PVC pipe 76 cm long
4. Hydraulic PVC pipe 50 cm long
5. Cost: PVC Sanitary 40.00 pesos
6. PVC Hydraulic 0 pesos, the reason why the store gave it to us.

Note: Our system is not going to be exposed to high temperatures which is one of the reasons why hydraulic PVC is used, but the only valve that met the measures we needed was this type of PVC.

Step or ball valve

This is one of the valves that are most used when a constant opening and closing is required in a piping system. The main reason why we came to install this valve was because we could control in a more precise way the passage of water to modify the necessary amount that passes and be able to determine the ideal flow to have the best performance of our turbine.

Also, for its size and the way in which it is constituted, it is one of the most resistant valves that could be obtained, in addition to comparing it in price with other valves that were for sanitary PVC, this was the best option if we see it in the cost-benefit way.

Figure 5 Ball Valve
Own Elaboration

Characteristics:

1. 4-inch Ball Valve.
2. Valve for hydraulic PVC making it stronger than a normal valve
3. PN10 150 PSI 10K
4. Cost of $1,050.00 pesos

90° elbow

Accessory that was acquired to be able to connect with the correct direction the Rotoplas tank to the balloon valve, using of course the PVC pipes, in this part of the project a 90° elbow was used because there was the need to place the PVC pipe where the water passes in the first section parallel to the tub.

Characteristics:

1. Cost 167.00 pesos
2. 90° elbow for Hydraulic PVC

Figure 6 45° elbow
Own Elaboration

Accessory used to define the output of the water to the tub that contains the Kaplan turbine, with this elbow we could define the angle of attack of the water towards the turbine so that it was the ideal since this would serve to give a greater power to the turbine, this in the way that the water would enter with the flow that would be leaving the pipe without having losses somewhere in the tray, in addition, its displacement to enter the turbine was not complicated. (see its placement in Figure 34, the final assembly)

Figure 7 45° elbow
Own Elaboration

1. Cost: 21.00 pesos
   PVC sheet

Polyvinyl chloride sheet provided by Professor Franco David to help the test bench in two ways:

1. To be able to define a curve in the tray and that there would be no water losses on our test bench.
2. It also helped us to adjust the sanitary PVC pipe to our valve since there was a separation in the thicknesses of these that made our pipe not completely impregnate with the risk that it would decouple from the valve (Observe in the final assembly)

Figure 8 PVC sheet
Own Elaboration

Aluminum Disc

As we can see in the figure below our aluminum disc occupies the function of holding the Kaplan turbine while it performs its movement and is supported with a complement which has a built-in bearing. In addition, it also has the task of holding the power generator so that the process of transformation from mechanical to electrical energy is carried out in a corresponding manner.

Figure 9 Aluminum Disc
Own Elaboration

This aluminum disc was already in the Technology Center, but it was necessary to make the modification to adapt it and comply with the conditions.

Characteristics:

1. Aluminum Composition
2. Weight 3 kg
3. Diameter 356 mm = 35.6 cm

Sealed ball bearing

This bearing is one of the most common on the market, being able to withstand axial and radial loads. One of its main characteristics is the speed of rotation that these counts since it is higher than that of other types of bearings.

This was one of the main characteristics that we considered to select this bearing, since it was going to be coupled to the Kaplan turbine, which will have the work of turning to transform the mechanical energy into electrical, therefore, it was important that the rotation was not limited in some way.

Figure 10 Ball Bearing
Own Elaboration

Characteristics:

1. Outside Diameter of 16 mm
2. Interior diameter of 8 mm
3. Width 5 mm
4. Material: High carbon steel
5. Cost: 20 pesos

Asparagus 1/2''

The asparagus has the function of holding and giving the necessary height to the turbine to be in the ideal area at the entrance of the water, these bars would be placed in the supports responsible for keeping the aluminum disc static.

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At the beginning they chose to place some construction rods of 1/4 "to support the turbine, but they began to find some small inconveniences at the time of the first assembly of the test bench, so it was recommended to change the rods for asparagus.

Figure 11 Asparagus
Own Elaboration

Characteristics:

1. 1/2" threaded rod or sprat
2. Length of 91 cm
3. Quantity 2
4. Material: Metal
5. Cost 50 pesos each, total: 100 pesos

Base/Bra/Disc Holder

One problem was the way in which the disk would have to be held so that there was no movement in the turbine (only its rotation) and in the generator when the flow of water met our turbine. So the following design was made in the Solidworks software:

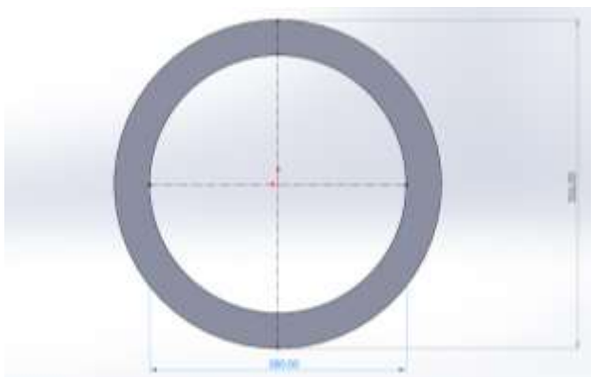

Figure 12 Top View of the Media Design
Own Elaboration

The diameter of the aluminum disc was replicated in the design so that the entire circumference was the same and there were no problems where the curves did not fit into the disc and its support. While the inner diameter was designed of 280 mm so that the area it held was spacious enough to keep the disc without fear of it coming out and that it was not too large so that at the time of being printed a lot of material and hours were used, since it was prototype.

Figure 13 Side View of the Media Design
Own Elaboration

With respect to the separation distance between the upper and lower face so that the disc entered adjusted and did not get to move was 7 millimeters. Then we proceeded to cut the support at an angle of 45 ° to cover a wide distance from the disc and not get to occupy a large amount of material in these first pieces.

Figure 14 Top View of Clipped Bracket
Own Elaboration

After the cutout, what was seen was the thickness of the face of the top and bottom, where the bottom would have priority with respect to its thickness since it would be the one that carried the weight of the aluminum disc so based on trial and error it was determined that it had a thickness of 4.7 millimeters while the upper face was 2.7 millimeters.

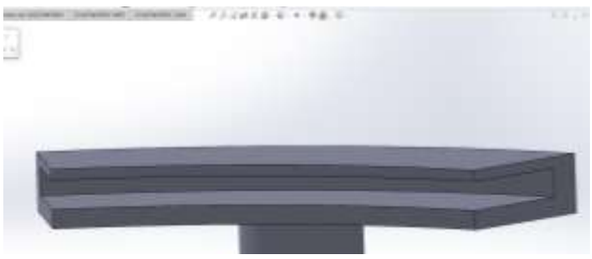

Figure 15 Media Faces
Own Elaboration

Then the next process was the design of a Coupler which met the following requirements:

1. Have the diameter corresponding to the 1/2" rod
2. Cover a relatively wide space for efforts
3. Have a thickness in such a way that it does not break.

And this was the result.

Figure 16 Test couple
Own Elaboration

The final design of the piece was as follows:

Figure 17 Aluminum Disc Support
Own Elaboration

In the end we occupied the 3D printer to be able to have three prototypes in physical and begin to perform the tests with these supports and realize the defects that could come out and the improvements that they could have.

Figure 18 Printed Media, Front View
Own Elaboration

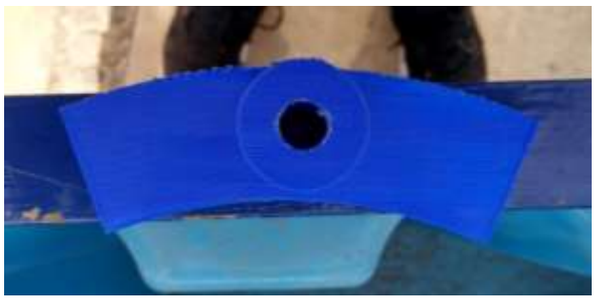

Figure 19 Printed Media, Bottom View
Own Elaboration

Bearing and its compartment

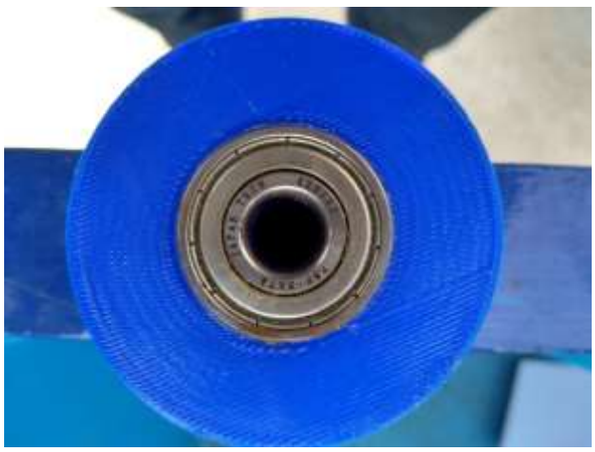

Figure 20 Bearing
Own Elaboration

For this design we based ourselves on the bearing and the compartment that was originally in the aluminum disc but adjusting it to the necessary measures for our new bearing, in addition to the fact that the previous compartment was already in oxidation condition and the bearing was broken.

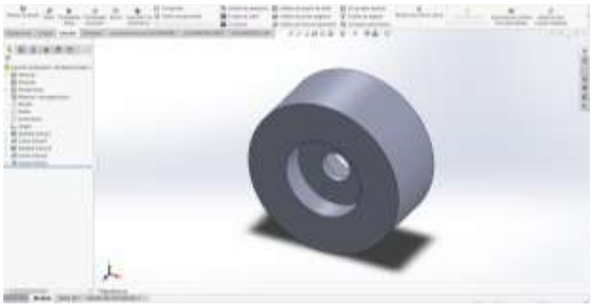

Figure 21 Bearing Compartment Design
Own Elaboration

Characteristics of the part:

1. Outside diameter of 64 mm (Original size)
2. Inside diameter of 32.05 mm (Adjusted to bearing diameter)
3. Auger diameter of 12.10 mm (Made with respect to turbine shaft diameter)
4. Volume 28.75 mm (Original size)
5. 9.96 mm cut on the front face with respect to bearing volume
6. Material: PLA (Also known as Polylactic Acid)

Bearing couple

This part was based on the design of the original couple which was responsible for pressing the bearing compartment and as a result remained static while the turbine was rotating by the impulse of the water.

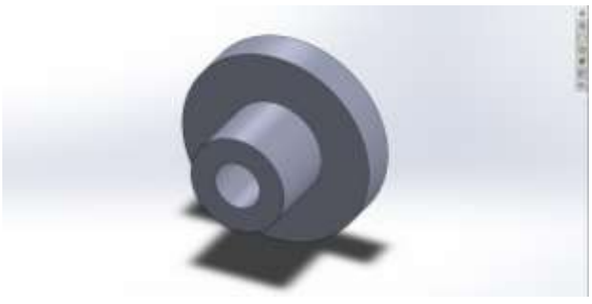

Figure 22 Compartment couple
Own Elaboration

As well as the bearing compartment, some adjustments had to be made to be able to be used with respect to the needs of our test bench.

Characteristics:

1. Auger 12.50 mm in diameter
2. Outside core diameter 51.65 mm
3. Outside body diameter 25.80 mm
4. Inside body diameter 25.80 mm
5. Core height 10 mm
6. Body height 20 mm
7. Total height 30 mm
8. Material: PLA

Asparagus stands

Other problems that came to be had were the way in which the asparagus would be held to always stay straight while there was movement and the weight of the disc, the generator and the turbine were constant. What was devised was the design of some supports which could cover a certain length of the base of the asparagus to keep it fixed while working so the first design was as follows:

Figure 23 Asparagus Support
Own Elaboration

This support was designed with a base of 30 millimeters in diameter with the aim that for some effect the support did not get to pass to the other side of the tray and with a thickness of 5 millimeters.

Then that the body had an outside diameter of 15 millimeters so that it entered the tray under pressure and that at the time of receiving the load weight it was not pushed easily and as a result it went out of the tray.

And finally, with an interior diameter of 12.40 millimeters that would be the size of the auger. At first it was thought that the supports were designed in such a way that a rod crossed them with relative ease but then with the advice of Mr. Franco it was determined that it would be better to make inner rope.

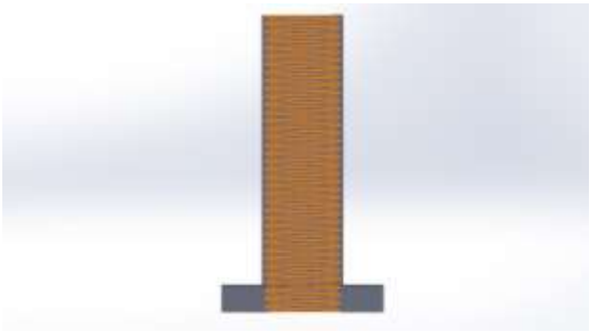

Figure 24 Inner Thread
Own Elaboration

By means of boards and with the threading that has the asparagus was chosen in the design a thread M20x1.5 since this measure is used for the female thread that has a diameter of 18 millimeters and as our asparagus is 17.8 millimeters was the closest value to the ideal.

Figure 25 Asparagus Support Prototype
Own Elaboration

The first design that was printed had the defects that the body of the support was a little thin so that in the first installations they came to break and came to separate from the base applying a not-so-great force. Then with these attempts, a redesign was made to the piece covering the errors that occurred and the piece was as follows:

Figure 26 Asparagus 2.0 Support
Own Elaboration

Now for this second piece the aspects that had failed in the first version were improved as follows:

1. The walls of the body thickened, so from having a 1-millimeter wall it thickened to a 3-millimeter wall.
2. The auger was made of the measure corresponding to asparagus.
3. A chamfer was made to make it difficult to separate the body from the base.
4. For the final piece the quality of the material was improved, and more material was added at the time of printing.

Tray

Figure 27 Tray
Own Elaboration

One of the main instruments where the stud supports are going to be placed and which has the job of holding the asparagus, the Kaplan turbine, the aluminum disc, and the power generator.

This idea was proposed because of the features we needed for a base that were as follows:

1. Have a size that covered 44 centimeters to be able to have the support of the base structure
2. That it did not suffer any damage when in contact with the water
3. A non-high cost
4. Preferably had a structure of circular shape or with some curvature to be able to define the water inlet in a simpler way
5. Walls high enough to prevent water from leaving the structure, even if the flow of water was large

Complying with the following characteristics we observed that this tray was the best option we had, so after this we proceeded to prepare it to start with the first assembly.

The modifications that were made were as follows:

1. The measurements were made to make 3 holes and that they were at an equal distance and to be able to introduce the first supports
2. Holes were also made to the sides to be able to attach to the base structure and with this avoid unwanted movement

Figura 28 Interior of the Tray with the brackets
Own Elaboration

After making the adaptations for the tray proceeded to perform the first assembly of the test bench.

1. Cost: 97.00 pesos

Water drain pump

For our project to be a closed cycle we require that there is a return of the water that falls in the tub to the Rotoplas, so we use a washing machine drain pump to be able to return the water that accumulates in the tub to the Rotoplas.

This pump had a cost of $ 199 pesos, although we had to make some small modifications to be able to have it submerged in our tub without there being the problem of a short circuit (but for any risk it can also be used outside the tub).

2. Kaplan turbine

Our main objective in our project is the realization of the design and construction of the test bench, but with regard to the construction of the Kaplan turbine it is also important here since it is the equipment, which would make the transformation from mechanical to electrical energy and which will say if our test bench is functional, so we made the decision to select the design of a Kaplan turbine awarded by Engineer David Franco that would fit the size of the test bench to begin printing it in 3D and abs plastic.

Kaplan Turbine Printing Time:

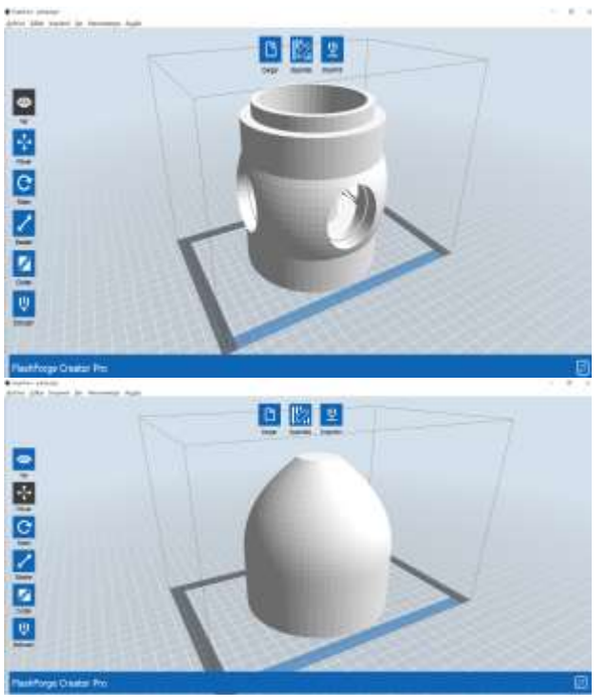

Figure 29 Turbine body: 10 hours and Turbine head: 8 hours
Own Elaboration

Figure 30 Kaplan Turbine
Own Elaboration

Although it is not the purpose of this thesis to carry out a cost analysis of the project, it includes as a reference the total cost of all the components we acquired for our test bench, which amounted to 3495 Mexican pesos, to which we will have to add the cost of the structure and the components that we were granted free of charge, labor, as well as the use of software and overheads.

After knowing the components, their characteristics and function, now it's time to join the whole test bench.

3. Arming the Test Bench 1

1. After the tub was painted, we proceeded to mount it inside the base structure and arrange it so that it was in the ideal position so that there would be no leak when the water came out of the channel.
2. The Rotoplas was drilled at the bottom and inserted (in addition to fixing) the couplet where the PVC pipe that would serve as a channel was to be placed.
3. It was mounted on top of the base structure of the Rotoplas, accommodating the couple with respect to the auger made in the wood of the upper part so that it was the best centered.
4. Then the first section of hydraulic PVC was mounted that would be the exit of the water from the Rotoplas to then the balloon wrench.

Figure 31 Section #1
Own Elaboration

5. The 90° elbow was connected to the first section, which would serve to orient the channel towards the tub and the turbine that would later be placed.
6. The tray was placed in the third section of the base structure, put on the tub and then tied to the ends to give it more stability in this first assembly.
7. At that time the rods were inserted into their supports and then placed on top the supports that were going to be attached to aluminum disc.
8. We place the aluminum disc in each of its supports.
9. When we finished seeing that there was not much movement until I developed the work, the turbine support, and the Kaplan turbine itself were placed on the aluminum disc.

Figure 32 Mounted Tray
Own Elaboration

1. After we finished assembling the turbine section, the second section corresponding to the step valve and the last section of the PVC that ends up running off in the turbine section was placed. In the following image you can see the final assembly.

(Note: During the first assembly of the test bench no modification had been made to the problems that were encountered and then changed.)

Figure 33 Test Bench 1
Own Elaboration

When the first assembly was finished, the first tests were made regarding the discharge of water into the canal and that all sections were properly connected so that there would not be a leak at some point.

Figure 34 Water flow test
Own Elaboration

After the first assembly was carried out, the first problems were discovered, which were:

1. Lack of stability with only 3 supports
2. The rods placed denoted a little volume that affected by holding the structures at the top
3. The supports of the rods were broken when they were removed.

For the resolution of these problems, I will make a summary and list of them:

1. Lack of stability and Rods

   About the lack of stability, the way it was solved was to first change the rods we used to asparagus that had a larger diameter, this would bring greater stamina to the efforts and.
   Modification: Change from 1/4" Rod to 1/2" Threaded Rod

2. Broken Supports
   For the broken supports, it was modified in design of them increasing the thickness of these, in addition to which a chamfer or bevel was made to reinforce the resistance to the load that the supports would have with respect to the asparagus.
   For each reprint with the improvement of the supports it took us a total of 51 minutes, for 4 pieces, then we took a total of 3 hours and 24 minutes to have all the pieces ready.

After the correction and printing of the new pieces proceeded to perform the second assembly of the test bench, but now if in order that this test bench was the end.

4. Arming the Test Bench 2

During the start of the second assembly of the test bench we began by adding a wire with peg to the drain pump and sealing the ducts through which the electricity comes to pass so that there is no short circuit, since our pump will be submerged to raise the water to a height of 1 meter and 60 cm.

Figure 35 Pump
Own Elaboration

After we took the height with which our pump could raise the water, we fixed a couple in the Rotoplas where the water would enter and then placed the hose, in addition to that to solve the problem that there was no garbage, leaves or sticks inside the tub we placed a metal mesh

Figure 36 Rotoplas and hose
Own Elaboration

We then placed the asparagus in the new tray with its new supports, which caused the stability problems and weak structures to be corrected and left in such a way that the stability was greatly improved without being completely aligned at first.

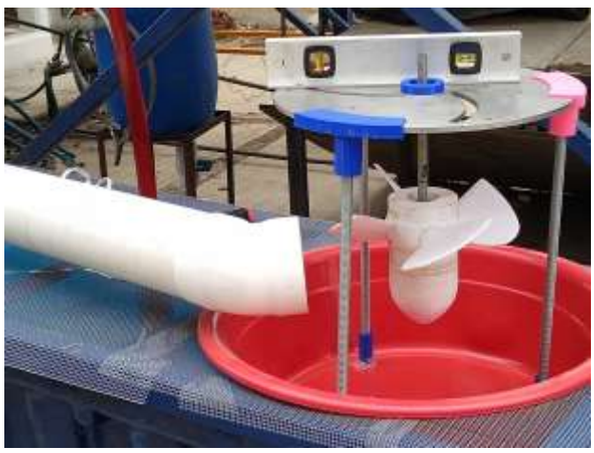

Figure 37 Disk Alignment
Own Elaboration

After these changes, we made sure that both the tank and the tub no longer had any kind of solid, be it a garbage, rock inside them so that they did not affect our system, especially the pump and the turbine, all this to start starting our test bench.

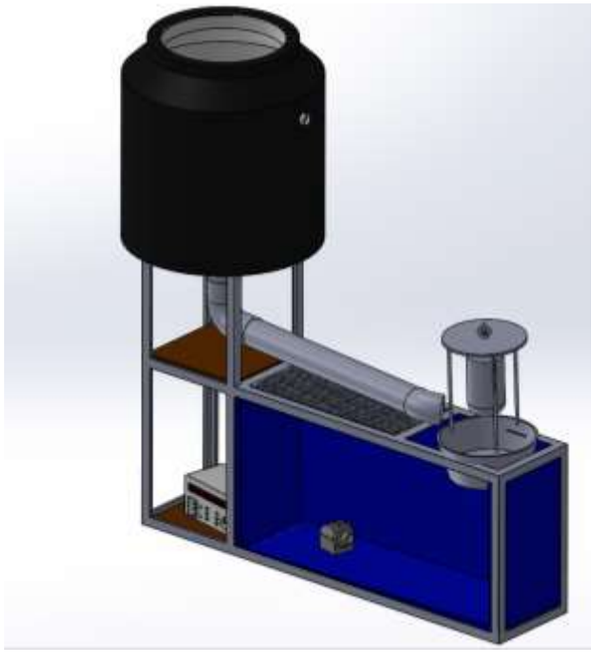

Figure 38 Bench Design in Solidworks
Own Elaboration

5. Calculations

In this section we develop the calculations of the main values that must be corroborated in the test bench, they will be calculated in a theoretical way at this time since the pandemic has not allowed us to start real tests.

Hydraulic diameter

For the hydraulic diameter when having a circular pipe its measurement will remain at 4" = .1016 m = 10.16 cm

Using the following formula:

$$Dh = \frac{4 \cdot \frac{\pi \cdot D^2}{4}}{\pi \cdot D} = \frac{4 \cdot \frac{\pi \cdot (.1016\ m)^2}{4}}{\pi \cdot (.1016\ m)} = .1016\ m \qquad (1)$$

Flow in the pipe

About the measurement of the flow what was done was that the Rotoplas of 120 Liters was filled, then we proceeded to open the key to passage to 3/4 where it was the ideal opening and took the time in which it was emptied, and it was obtained that in 2 minutes our tank was empty.

$$Q = \frac{120\ litros}{4\ minutos} = 30\ \frac{L}{m} = 500\ \frac{ml}{s} \qquad (2)$$

Average Speed

Occupying the formula 2, using the transverse area occupied in the hydraulic diameter and substituting the variables we have:

$$500\ \frac{ml}{s} = (8.10x10^{-1})\bar{v}$$

Changing positions, you have:

$$\bar{v} = \frac{.500\frac{m^3}{s}}{(8.10x10^{-1})m^2} = .6172\ \frac{m}{s}(\frac{3600s}{1h})(\frac{1km}{1000m}) = 2.2\ \frac{km}{h} \quad (3)$$

Yields

For the calculation of the yields in our test bench when having the turbine installed, we must consider the equation of the transformation of the energy that will exist from the top of the Rotoplas (point A) to the bottom of the tub (Point B).

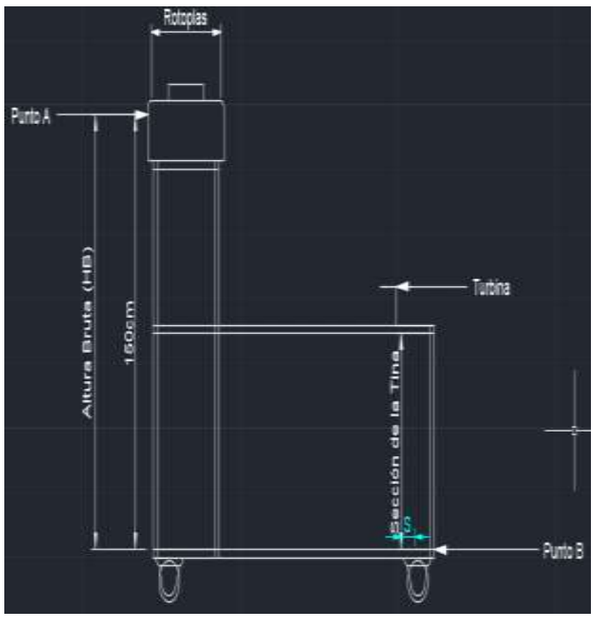

Figure 39 Benchmark Schematic
Own Elaboration

$$z_A + \frac{P_A}{\gamma} + \frac{V_S^2}{2g} = z_S + \frac{P_S}{\gamma} + \frac{V_S^2}{2g} + \sum h_{A-S} \quad (4)$$

$$\gamma = \rho * g = Densidad * gravedad$$
$$Z_{Punto} = Energía\ Potencial\ en\ el\ punto$$

This variation of energy will be established by Bernoulli's equation, where the energy of point A minus the energy extracted by the turbine will be equal to the energy in the output section (S) plus the sum of all load losses from point A to point S.

As our test bench is not an ideal system, there will be friction losses from point A to point E (from rotoplas to the turbine inlet). These load losses are due to friction losses and the loss due to accessories of our hydraulic system represented in the following equation.

$$H_B = H_E + \sum h_{a-s} \quad (5)$$

Then the next equation represents the height in the output or discharge chamber

$$H_s = Z_s + \frac{Ps}{\gamma} + \frac{v_2^2}{2g} \quad (6)$$

And its differential will give us the Net Height that exists in our system

$$H = H_E + H_s \quad (7)$$

Load losses

To know the yields that will exist in the turbines used in the test bench we first have to know the losses that will exist in the route using the Darcy-Weisbach equation:

$$hf_{A-S} = F\ \frac{L_T}{D}\ \frac{v_2^2}{2g} \quad (8)$$

Where we do not know the coefficient of friction, so we occupy the coefficient of friction Swaime-Jaine that gives us a result very similar to the ColeBrooke:

$$F = \frac{1.325}{\left\{\ln\left[\frac{\varepsilon_r}{3.7D} + \frac{5.74}{Re^{0.9}}\right]^2\right\}} \quad (9)$$

But before we need to know the reynolds number and the absolute roughness of our pipe (PVC), for the latter we are going to tables 1 and 2.

Material	Manning's Coefficient n	Hazen-William's Coefficient C_H	Absolute roughness Coefficient e (mm)
Asbestos (cement)	0.011	140	0.0015
Brass	0.011	135	0.0015
Partition Wall	0.015	100	0.6
Cast iron (new)	0.012	130	0.26
Concrete (metal formwork)	0.011	140	0.18
Concrete (wooden formwork)	0.015	120	0.6
Concrete	0.013	135	0.36
Plastic (PVC)	0.009	150	0.0015
Lead	0.011	135	0.0015
Copper	0.011	135	0.0015
Corrugated steel	0.022	---	45

Table 1 Absolute Roughness of Materials
Source: Computer Applications in Hydraulic Engineering, 5th Edition, Haested Methods

And for Reynolds number we occupy his formula:

$$Re = \frac{v*D*\rho}{\mu} = \frac{(Velocidad)(Diámetro)(Densidad)}{Viscocidad} \quad (10)$$

Where we know that our speed is .6125 m/s, the diameter of our pipe is .1016 m, the density of water is 1 kg/m^3 and the dynamic viscosity is obtained by tables.

Tempeture °C	Dinamic viscocity Kg/(m*s)	Tempeture °C	Dinamic viscocity Kg/(m*s)	Tempeture °C	Dinamic viscocity Kg/(m*s)
0	0.001792	34	0,000734	68	0,000416
1	0.001731	35	0,000720	69	0,000410
2	0.001674	36	0,000705	70	0,000404
3	0.001620	37	0,000692	71	0,000399
4	0.001569	38	0,000678	72	0,000394
5	0.001520	39	0,000666	73	0,000388
6	0.001473	40	0,000653	74	0,000383
7	0.001429	41	0,000641	75	0,000378
8	0,001386	42	0,000629	76	0,000373
9	0,001346	43	0,000618	77	0,000369
10	0,001308	44	0,000607	78	0,000364

Table 2 Dynamic Viscosity of Water at various temperatures
Source: https://www.academia.edu/7129909/Viscosidad_din%C3%A1mica_del_agua_l%C3%ADquida_a_varias_temperaturas?auto=download

Using the viscosity of 0.0015 (pa/s) we have:

$$Re = \frac{\left(.6125\frac{m}{s}\right)(.1016\ m)\left(\frac{1kg}{m^3}\right)}{0.0015\frac{kg}{m*s}} = 41.4867 \ldots\ldots Flujo\ Laminar \quad (11)$$

Since we have the Reynolds number what we do is replace the unknowns in our Swaime-Jaine formula:

$$F = \frac{1.325}{\left\{\ln\left[\frac{0.0015\ kg/m*s}{3.7(.1016m)} + \frac{5.74}{41.4867^{0.9}}\right]^2\right\}} = 0.5269 \quad (12)$$

We now replace our Friction factor (F) in our loss calculation along the pipe:

$$hf_{A-S} = (0.5269)\left(\frac{1\ m}{0.1016\ m}\right)\left(\frac{\left(0.6125\frac{m}{s}\right)^2}{2\left(9.81\frac{m}{s^2}\right)}\right) = 0.0991\ m \quad (13)$$

We will have to have a loss of 0.0991 along our pipe, but by having a 90° elbow and a ball valve we must get their losses that exist. By tables we find the coefficient of friction of each accessory, considering that all the accessories are coupled and 4 ":

Nominal Diameter, in									
	Thread				Coupled				
	½	1	2	4	1	2	4	8	20
Valves									
Ballon	14	8.2	6.9	5.7	13	8.5	6.0	5.8	5.5
Gate	.30	0.24	0.16	0.11	0.80	0.35	0.16	0.07	0.03
Retention	5.1	2.9	2.1	2.0	2.0	2.0	2.0	2.0	2.0
Angle	9.0	4.7	2.0	1.0	4.5	2.4	2.0	2.0	2.0
Elbows									
45°	0.39	0.32	0.30	0.29					
90°	2.0	1.5	0.95	0.64	0.50	0.39	0.30	0.26	0.21
180°	2.0	1.5	0.95	0.64	0.41	0.35	0.30	0.25	0.20

Table 3 Coefficient of loss K, for open valves, elbows and te
Source: Fluid Mechanics, Frank M. White

Calculation of Load loss for the elbow of 90°:

$$h_{90} = k\frac{v^2}{2g} = (0.30)\left(\frac{\left(0.6125\frac{m}{s}\right)^2}{2\left(9.81\frac{m}{s^2}\right)}\right) = 0.0057\ m \quad (14)$$

Calculation of Load Loss for the balloon valve:

$$h_{va} = k\frac{v^2}{2g} = (6.0)\left(\frac{\left(0.6125\frac{m}{s}\right)^2}{2\left(9.81\frac{m}{s^2}\right)}\right) = 0.1147\ m \quad (15)$$

We add up all load losses:

$$\sum pc = hf_{A-S} + h_{90} + h_{va} = 0.0991m + 0.0057m + 0.1147m = 0.2195\ m$$

Pressure Drop

By having all the load losses, we can now calculate the pressure drop that exists:

$$\Delta P = \gamma * \sum pc = \left[\left(1\frac{kg}{m^3}\right)\left(9.81\frac{m}{s^2}\right)\right](0.2195\ m) = 2.1533\frac{kg}{m\ s^2} = 2.1533\ Pa \quad (16)$$

Our pressure drop is 2.1533 Pascals.

Now that we have the load losses, we can go back and find the yields that are going to exist in the occupied turbines on the test bench as follows:

We have that H_B is equal to 190 cm, our losses to 21.95 cm, so we clear the formulas

$$H_E = H_B - \sum h_{a-s} = 190cm - 21.95cm$$

$$H_E = 168.05\ cm = 1.68\ m$$

Now for Hs we replace the unknowns considering that our pressure at the outlet will be atmospheric as at the entrance, this will cause that being the same will give us 0 and our Zs will be given by the height of the water outlet in the turbine:

$$H_s = Z_s + \frac{Ps}{\gamma} + \frac{v_2^2}{2g} = .5700\,m + 0 + \frac{(0.6125\frac{m}{s})^2}{2(9.81\frac{m}{s^2})} = .5700m + +.0191m$$

$$H_{s=}.5891\,m = 58.91\,cm$$

By having our heights both at the entrance and at the exit we can now know our net height:

$$H = H_E + H_s = 1.68\,m + .5891\,m = 1.8691\,m = 186.91cm$$

Then these are all the data that are obtained in our test bench and that influence when making calculations in the turbines that are installed, for example:

If we want to know the power in a turbine what we do, we use the formula:

$$P = Q * \rho * H * g \qquad (17)$$

By substituting with our variables and converting our flow rate to (m^3/s)

$$P = 0.0005\left(\frac{m^3}{\mathrm{s}}\right) * \left(1\frac{kg}{m^3}\right) * (1.869\,m) * \left(9.81\frac{m}{s^2}\right)$$

The power absorbed from the turbine used is $9.1674x10^{-3}$ watts, power suitable for a small turbine. To know the manometric performance we can use the formula:

$$n_{man} = \frac{H_{u\infty}}{H} = \frac{175\,cm}{186.9\,cm} = 0.9363 \qquad (18)$$

Which falls into the range of gauge efficiency.

And we can complete all the necessary calculations that involve the turbines in our system, varying the factors of fluid entry, opening, and closing the valve, etc., until we find the ideal point that allows us to make the turbine design more efficient, using the facilities that our test bench gives us, which behaved as expected.

Conclusions

The generation of hydroelectric power in Mexico is a very important resource, since not only Mexico has been a precursor since the beginning as other countries to build hydroelectric plants using turbines of different types, also because in our country we have a geography which helps the creation of new hydroelectric plants. This has the advantage that it is currently being tried in various parts of the world, both in Europe and in South America, to make a change from the use of hydrocarbons to forms that pollute the environment less and these plants are a quite viable option because they have low pollution rates.

This is a project that was developed with the objectives of the design from scratch to the physical creation of a test bench for turbines, specifically for Kaplan type turbine where tests can be carried out in a controlled environment where new turbine designs are put into practice to know their operation in a scaled way and then be able to take them to production and installation in different regions.

While the second objective is linked to the academic field, referring to the possible development of test benches where students can learn in a practical way lessons such as the triangle of speeds, flow, calculation of losses, behavior of Kaplan turbines and their use in electric power generation, among other lessons of the subject of Hydraulic Machines since talking to friends of other engineering many of them present problems when they come to eat near to see these lessons and do not know how to interpret as the physical effect of all these variables.

This document has the realization of various plans with all the specifications to recreate the test bench for future users interested in its recreation and I leave the recommendation to make a turbine in aluminum or some alloy to improve its characteristics, in addition to that it could improve the base where the turbine is placed.

Acknowledgements

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Design and implementation of an ecological cooler

Diseño e implementación de un enfriador ecológico

MOLINA-GARCÍA, Moisés †*& MELCHOR-HERNÁNDEZ, Cesar L.

Tecnológico Nacional de México. Instituto Tecnológico Superior de Huatusco, Av. 25 Poniente No. 100, Col. Reserva Territorial Huatusco, Veracruz, México, C.P. 94100, División de Ingeniería Electromecánica.

ID 1st Author: *Moises, Molina-Garcia* / **ORC ID**: 0000-0002-4213-9591, **CVU CONACYT ID**: 311075.

ID 1st Co-author: *Cesar L, Melchor-Hernández* / **ORC ID**: 0000-0003-2154-6654, **Researcher Thomson ID**: AAU - 3494 – 2021, **CVU CONACYT ID**: 161766

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Abstract

This work shows the construction of an ecological cooler capable of fulfilling the functions of a conventional refrigerator, its operation is based on using Peltier cells which create cold on one side and heat on the other. It is about eliminating the use of refrigerant gases, which damage the ozone layer, in addition to oils and accessories that are harmful to the environment, electrical energy is also saved with the prototype. The construction of the prototype is based on the construction of a panel that has 2 Peltier cells, 3 fans and a radiator system, which is integrated into a cooling drawer, the system is connected to a direct current voltage source. The prototype is designed to be used as a cooling system to contain food mainly, in addition to completely eliminating the refrigerants and mechanical components that are used in conventional refrigeration, which cause contamination of the ozone layer and the environment.

Peltier cells, Savings, Environment

Resumen

El presente trabajo muestra la construcción un enfriador ecológico capaz de cumplir con las funciones de un refrigerador convencional, su funcionamiento se basa en utilizar celdas Peltier las cuales crean frio de un lado y calor del otro. Se trata de eliminar el uso de gases refrigerantes, los cuales dañan la capa de ozono, además de aceites y accesorios que son perjudiciales para el medio ambiente, también se ahorra energía eléctrica con el prototipo. La construcción del prototipo se basa en construcción de un panel que cuenta con 2 celdas Peltier, 3 ventiladores y un sistema de radiador, el cual va integrado a un cajón de enfriamiento, el sistema esta conectado a una fuente de voltaje de corriente directa. El prototipo esta diseñado para ser utilizado como un sistema de enfriamiento para contener alimentos principalmente, además de eliminar por completo los refrigerantes y componentes mecánicos que son utilizados en la refrigeración convencional, causantes de contaminar la capa de ozono y el medio ambiente.

Celdas Peltier, Ahorro, Medio ambiente

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*Correspondence to the Author (e-mail: mmolinag@huatusco.tecnm.mx)
† Researcher contributing as first author.

1. Introduction

Sustainable energy is providing energy that meets the needs of the present without compromising the needs of future generations. Sustainable energy sources include all renewable energies, including also technologies designed to improve energy efficiency. [III].

For the development of the cooler it must be known that it is a Peltier cell and its operation, knowing its properties allows us to know which is the most appropriate to put the cooler into operation since there is a wide range of cells on the market, but each one with a different application according to its cooling capacity, energy consumption, dimensions, voltages, heat capacity, among others.

The Peltier effect consists in that when a current is passed through a circuit composed of different materials whose junctions are at the same temperature, the inverse effect of the Seebeck effect occurs. [I] In this case, heat is absorbed in one joint and is released in the other, the part that cools is usually close to 25º C, while the part that absorbs heat can quickly reach 80º C, all according to the cooling system connections, it is a system that allows the temperature level to lower and cool.

In the transport of biological samples, containers with 3 cells have been used, which allows reaching a temperature of 0 ° C; Most materials can be obtained from automotive coolers, fridges, and water coolers. [IV].

For vaccine cooling, 2 cells are generally used, consuming approximately 25 Watts. [V].

With the prototype, the use of refrigerant gases that cause damage to the ozone layer is being eliminated, as well as the use of compressors and oils that damage the environment. The development of the prototype is presented, explaining the parts that comprise it, in materials and methods, the connections that must be made to have the complete system are explained and finally the tests that were made are shown, when connecting the prototype and observing its operation.

2. Developing

For the creation, implementation and development of the ecological cooler, it was decided to connect 2 Peltier cells that are the ones that provide us with the necessary cooling capacity, the dimensions are similar to that of a conventional minibar, the measurements are 50 cm long by 40 cm wide, leaving a space in the container of 200 cm^3, as the number of cells increases, its cooling capacity increases and consequently the size. Three axial fans, two external and one internal, are those that disperse the cold from the cells to which a heat sink is connected, which is an instrument used to lower the temperature of some electronic components. A voltage source of 12 Volts that provides us with a current of 20 Amps.

3. Methodology to be developed

The material inside is food grade 304 stainless steel sheet, once the cooler's shape is created, the 2 cells are installed, which are connected together with a cooling system as a whole, which It consists of 1 heat sink, 2 external radiators connected to a ½”copper tube, 3 fans, one of 3” and the other two of 5”. The Peltier cells are of the TECI-12715 model since they are the ones that reach the lowest temperatures according to the comparison with another cell model when performing the tests. The system must be connected to a source that generates 12 Volts with a current capacity of 20 Amps, so that the system can cool as quickly as possible.

Heat dissipator

The function of a heat sink is to keep the hot part of the cells on the outside as cold as possible, maintaining a heat transfer from the inside to the outside, while the other heat sink that goes through the inside together with the The fan is responsible for dispersing the temperature constantly.

Aluminum air heatsinks are an option to take into account since they are great heat sinks, it should be noted that these components are made up of a fan together with an aluminum heatsink that comes with copper tubes for being better heat conductors. . The operation is ultimately the same as the series, but these are characterized by having a greater power. [II]

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Su funcionamiento se basa en la ley cero de la termodinámica, transfiriendo el calor de la parte caliente que se desea disipar al aire. [VI]. The internal cooling system consists of 1 aluminum panel model 536343, measuring 3 ½ ”long by 3” wide and 1 ½ ”high, and the external part also consists of 1 aluminum panel model 536393 , with measures of 10 ½ ”long by 6 ½” wide and ½ ”high.

Figure 1 Heat sink installed on the outside

Drawer insulation

Polyurethane of the pressurized type in a can with a capacity of 300 ml was used. The polyurethane aerosol foam has a class B3 component according to DIN 4102, which serves to seal and fill large gaps, preventing the passage of heat from the interior to the exterior or vice versa. This was an insolation type finish that it takes care of in all cooling and temperature insulation processes. The density of the foam is 225 to 35 kg / m³, the temperature resistance ranges from -55 ºC to 100 ºC, the thermal conductivity is 0.63 W / m K (R value = 4-5 per inch) and the expansion Thermal of the can is from 300 ml to 18 lt.

Fans

The fans used correspond to the common ones of a normal desktop computer, these are responsible for ensuring that the heat sink does not overheat, but in turn will have the function of releasing or removing little of the heat generated by the cells. 3 axial fans were installed, 2 of 5 ”wide and 1 of 2 ½” wide, its model is AD0812MS-A70GL, they work with direct current at 12 Volts and their consumption is 0.5 A.

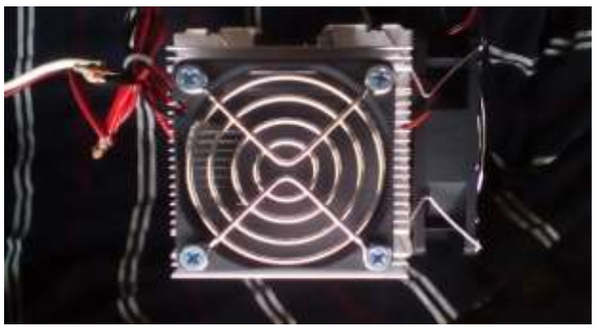

Figure 2 Axial fans

4. Results

When starting the tests, the external ambient temperature must be taken into account, preferably having the cooler at an ambient temperature no higher than 25 ° C. The voltage should be 12 Volts and the current should be as close to 20 A as possible, to have the highest possible performance. Once these conditions were met, the results were the following:

Weather	Temp.	Temp.	V	A	Consumption
0 min.	23ºC	20ºC	12 V.	20 A.	0.8 A.
15 min.	23ºC	18ºC	12 V.	20 A.	0.8 A.
30 min.	24ºC	17ºC	12 V.	20 A.	0.8 A.
1 hora	24ºC	15ºC	12 V.	20 A.	0.8 A.
2 horas	25ºC	15ºC	12 V.	20 A.	0.8 A.
3 horas	25ºC	15ºC	11.35 V.	20 A.	0.76 A.
4 horas	24ºC	14ºC	11.19 V.	20 A.	0.73 A.
5 horas	22ºC	14ºC	11.62 V.	20 A.	0.78 A.
6 horas	21ºC	12ºC	12 V.	20 A.	0.8 A.
7 horas	20ºC	10ºC	12 V.	20 A.	0.8 A.
8 horas	20ºC	9ºC	12 V.	20 A.	0.8 A.
9 horas	20ºC	9ºC	12 V.	20 A.	0.8 A.
10 horas	19ºC	9ºC	12 V.	20 A.	0.8 A.
11 horas	17ºC	9ºC	12 V.	20 A.	0.8 A.
12 horas	17ºC	9ºC	12 V.	20 A.	0.8 A.

Table 1 Results obtained

The internal temperature of the cooler continued to be read for up to 12 hours, it was recorded that the temperature no longer dropped more than 9 ° C and remained constant.

Figure 3 Final structure of the prototype

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5. Appreciation

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6. Conclusions

The energy consumption during the entire cooling process is 0.8 amps at its maximum working point, which is an excessively low consumption compared to the frigobars that are on the market, they have a consumption of 5 to 5.3 Amps at their point. maximum. Using this prototype of ecological cooler there is an energy saving of up to 6 times compared to the normal ones, this shows that to reach a consumption similar to the home refrigerator we would have to use 6 Peltier cells to be almost on par with normal consumption. Energy is saved by using the ecological cooler, in addition to taking care of the environment by not having an equipment that uses refrigerant gas, or oils and compressors.

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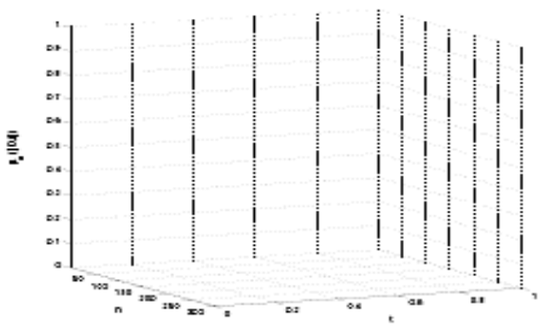

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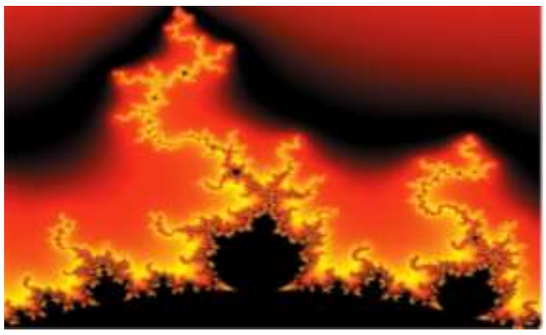

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