

ISSN 2410-3950

Volume 9, Issue 26 — January — June - 2022

# Journal of Experimental Systems

**ECORFAN<sup>®</sup>**

## **ECORFAN-Bolivia**

### **Chief Editor**

BARRERO-ROSALES, José Luis. PhD

### **Executive Director**

RAMOS-ESCAMILLA, María. PhD

### **Editorial Director**

PERALTA-CASTRO, Enrique. MsC

### **Web Designer**

ESCAMILLA-BOUCHAN, Imelda. PhD

### **Web Diagrammer**

LUNA-SOTO, Vladimir. PhD

### **Editorial Assistant**

SORIANO-VELASCO, Jesús. BsC

### **Philologist**

RAMOS-ARANCIBIA, Alejandra. BsC

**Journal of Experimental Systems**, Volume 9, Issue 26, January – June 2022, is a journal edited sixmonthly by ECORFAN-Bolivia. Loa 1179, Cd. Sucre. Chuquisaca, Bolivia. WEB: [www.ecorfan.org/bolivia](http://www.ecorfan.org/bolivia), [journal@ecorfan.org](mailto:journal@ecorfan.org). Editor in Chief: VALDIVIA - BARRERO-ROSALES, José Luis. PhD. ISSN On line: 2410-3950. Responsible for the latest update of this number ECORFAN Computer Unit. ESCAMILLA-BOUCHÁN, Imelda. PhD, LUNA-SOTO, Vladimir. PhD, last updated June 30, 2022.

The opinions expressed by the authors do not necessarily reflect the views of the editor of the publication.

It is strictly forbidden to reproduce any part of the contents and images of the publication without permission of the National Institute of Copyright

# **Journal of Experimental Systems**

## **Definition of Research Journal**

### **Scientific Objectives**

Support the international scientific community in its written production Science, Technology and Innovation in the Field of Biology and Chemistry, in Subdisciplines Logical Methods, Research methods, Hypothetical-deductive method, Scientific observation method, Measuring method, Scientific experimentation, Climatology, Geology, Geochemistry, Acoustics.

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

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

### **Scope, Coverage and Audience**

Journal of Experimental Systems is a Research Journal edited by ECORFAN-Mexico S.C in its Holding with repository in Bolivia, is a scientific publication arbitrated and indexed with semester periods. It supports a wide range of contents that are evaluated by academic peers by the Double-Blind method, around subjects related to the theory and practice Logical Methods, Research methods, Hypothetical-deductive method, Scientific observation method, Measuring method, Scientific experimentation, Climatology, Geology, Geochemistry, Acoustics with diverse approaches and perspectives , That contribute to the diffusion of the development of Science Technology and Innovation that allow the arguments related to the decision making and influence in the formulation of international policies in the Field of Biology and Chemistry. The editorial horizon of ECORFAN-Mexico® extends beyond the academy and integrates other segments of research and analysis outside the scope, as long as they meet the requirements of rigorous argumentative and scientific, as well as addressing issues of general and current interest of the International Scientific Society.

## **Editorial Board**

CARVAJAL - MILLAN, Elizabeth. PhD  
École Nationale Supérieure Agronomique de Montpellier

CÓRDOVA - GUERRERO, Iván. PhD  
Universidad de la Laguna

ARMADO - MATUTE, Arnaldo José. PhD  
Universidad de los Andes

RIVERA - BECERRIL, Facundo. PhD  
Institut National de la Recherche Agronomique

CRUZ - REYES, Juan. PhD  
Instituto de Catálisis y Petroleoquímica

LOPEZ - ZAMORA, Leticia. PhD  
Universidad Politécnica de Valencia

STILIANOVA - STOYTCHEVA, Margarita. PhD  
Universidad de Tecnología Química y Metalurgia de Sofia

CORNEJO - BRAVO, José Manuel. PhD  
University of California

SOTERO - SOLIS, Victor Erasmo. PhD  
Universidade de São Paulo

OROPEZA - GUZMÁN, Mercedes Teresita. PhD  
National Polytechnique de Toulouse

## **Arbitration Committee**

**ALVARADO - FLORES, Jesús. PhD**  
Universidad Autónoma de Aguascalientes

**DE LEON - FLORES, Aneel. PhD**  
Universidad Nacional Autónoma de México

**MARTÍNEZ - QUIROZ, Marisela. PhD**  
Centro de Investigación y Desarrollo Tecnológico en Electroquímica

**MAGANA - BADILLA, Héctor Alfonso. PhD**  
Universidad Autónoma de Baja California

**VALDEZ - CASTRO, Ricardo. PhD**  
Universidad Nacional Autónoma de México

**QUIROZ - CASTILLO, Jesús Manuel. PhD**  
Universidad de Sonora

**SANTACRUZ - ORTEGA, Hisila del Carmen. PhD**  
Instituto Tecnológico de Tijuana

**MENDOZA - CASTILLO, Didilia Ileana. PhD**  
Instituto Tecnológico de Aguascalientes

**OCHOA - TERÁN, Adrián. PhD**  
Tecnológico Nacional de México

**FRONTANA - VAZQUEZ, Carlos Eduardo. PhD**  
Universidad Autónoma Metropolitana

**SALDARRIAGA, Hugo. PhD**  
Universidad Autónoma del Estado de México

## **Assignment of Rights**

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

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

## **Declaration of Authorship**

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

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

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

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

## **Plagiarism Detection**

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

## **Arbitration Process**

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

## **Instructions for Scientific, Technological and Innovation Publication**

### **Knowledge Area**

The works must be unpublished and refer to topics of Logical Methods, Research methods, Hypothetical-deductive method, Scientific observation method, Measuring method, Scientific experimentation, Climatology, Geology, Geochemistry, Acoustics and other topics related to Biology and Chemistry.

## **Presentation of Content**

In the first article we present, *Design of experiments to evaluate the equation to obtain the operating parameters in a 3-axis Numerical Control Machine* by MONDRAGÓN-MENDOZA, Ricardo, PAZ-CABRERA, Mauro and DELGADO-PRESA, Florencio, with adscription in the Universidad Politécnica de Juventino Rosas, as next article we present, *Trend analysis in the 1D solution of the inverse heat conduction problem by the sequential function specification technique* by TÉLLEZ-MARTÍNEZ Jorge Sergio, PÉREZ-QUIRÓZ José Trinidad, HORTELANO-CAPETILLO Juan Gregorio and PÉREZ-PÉREZ Arnulfo, with adscription in the Universidad Politécnica de Juventino Rosas and the Instituto Mexicano del Transporte, as next article we present, *Adaptation of Higher Education to the attacks of the pandemic* by GALLEGOS-GALINDO, Juan Heriberto, ALVARADO-LOPEZ, Oscar, CORNEJO-TRIGUEROS, Veronica and RAMIREZ-SANLUISEÑO, Juan, with adscription in the Universidad Politécnica de Juventino Rosas, as the last article we present, *Electrical system simulation of an aircraft through ANSYS Electronics Desktop* by REGALADO-RANGEL, Karina, GASTELLUM-MICHEL, Filiberto, TORRES-RIVERA, Moisés and TRASLOSHEROS-MICHEL, Alberto, with adscription in the Universidad Aeronáutica en Querétaro.

## Content

Article	Page
<b>Design of experiments to evaluate the equation to obtain the operating parameters in a 3-axis Numerical Control Machine</b> MONDRAGÓN-MENDOZA, Ricardo, PAZ-CABRERA, Mauro and DELGADO-PRESA, Florencio <i>Universidad Politécnica de Juventino Rosas</i>	1-9
<b>Trend analysis in the 1D solution of the inverse heat conduction problem by the sequential function specification technique</b> TÉLLEZ-MARTÍNEZ Jorge Sergio, PÉREZ-QUIRÓZ José Trinidad, HORTELANO-CAPETILLO Juan Gregorio and PÉREZ-PÉREZ Arnulfo <i>Universidad Politécnica de Juventino Rosas</i> <i>Instituto Mexicano del Transporte</i>	10-16
<b>Adaptation of Higher Education to the attacks of the pandemic</b> GALLEGOS-GALINDO, Juan Heriberto, ALVARADO-LOPEZ, Oscar, CORNEJO-TRIGUEROS, Veronica and RAMIREZ-SANLUISEÑO, Juan <i>Universidad Politécnica de Juventino Rosas</i>	17-25
<b>Electrical system simulation of an aircraft through ANSYS Electronics Desktop</b> REGALADO-RANGEL, Karina, GASTELLUM-MICHEL, Filiberto, TORRES-RIVERA, Moisés and TRASLOSHEROS-MICHEL, Alberto <i>Universidad Aeronáutica en Querétaro</i>	26-35



## Design of experiments to evaluate the equation to obtain the operating parameters in a 3-axis Numerical Control Machine

## Diseño de experimentos para evaluar la ecuación de obtención de los parámetros de operación en una Máquina de Control Numérico de 3 ejes

MONDRAGÓN-MENDOZA, Ricardo†\*, PAZ-CABRERA, Mauro<sup>1</sup> and DELGADO-PRESA, Florencio<sup>2</sup>

*Universidad Politécnica de Juventino Rosas, Departamento de Ingeniería en Sistemas Automotrices*

ID 1<sup>st</sup> Author: *Ricardo, Mondragón-Mendoza* / ORC ID: 0000-0002-0945-8515

ID 1<sup>st</sup> Co-author: *Mauro, Paz-Cabrera* / ORC ID: 0000-0003-0728-7377

ID 2<sup>nd</sup> Co-author: *Florencio, Delgado-Presa* / ORC ID: 0000-0002-4045-577

DOI: 10.35429/JOES.2022.26.9.1.9

Received March 29, 2022; Accepted June 30, 2022

### Abstract

This article aims to evaluate the efficiency of the application of equations with which the operating parameters of the manufacturing process are obtained in a three-axis numerical control machine, in order to determine through analysis tests which is the most appropriate option when planning production in machines of this type. The methodology applied to obtain the results is based on the collection and analysis of data generated on a test bench to submit it to a design of 2K experiments, whose response variable is based on the roughness of the surface; using a roughness meter to determine the difference in finishes on a piece of aluminum 6160 T6 and jointly in the machining time; comparing theoretical vs real times. To obtain the comparative analysis, the revolutions per minute and the progress of the cutting tool will be considered as variables, it is expected that this will contribute to identifying the adjustment values that provide better results and standardize the correct use of the equations involved in obtaining the parameters.

**Cutting Parameters, Roughness, Standardize**

### Resumen

El presente artículo tiene por objetivo evaluar la eficiencia de la aplicación de ecuaciones con las que se obtienen los parámetros de operación del proceso de manufactura en una máquina de control numérico de tres ejes, con la finalidad de determinar mediante pruebas de análisis cual es la opción más adecuada al planear la producción en máquinas de este tipo. La metodología aplicada para la obtención de los resultados se basa en la recolección y análisis de datos generados en un banco de pruebas para someterlo a un diseño de experimentos 2K, cuya variable de respuesta se basa en la rugosidad de la superficie; empleando para ello un rugosímetro a fin de determinar la diferencia en los acabados sobre una pieza de aluminio 6061 T6 y de manera conjunta en el tiempo de maquinado; comparando los tiempos teóricos vs los reales. Para obtener el análisis comparativo se procederá a considerar como variables las revoluciones por minuto y el avance de la herramienta de corte, se espera que con ello se logre contribuir a identificar los valores de ajuste que provean de mejores resultados y estandarizar el uso correcto de las ecuaciones implicadas en la obtención de los parámetros.

**Parámetros de Corte, Rugosidad, Estandarizar**

**Citación:** MONDRAGÓN-MENDOZA, Ricardo, PAZ-CABRERA, Mauro and DELGADO-PRESA, Florencio. Design of experiments to evaluate the equation to obtain the operating parameters in a 3-axis Numerical Control Machine. Journal of Experimental Systems. 2022. 9-26: 1-9

\* Author Correspondence (rmondragonmendoza@gmail.com)

† Researcher contributing as first author.

## Introduction

In the different machining processes there are variants that make the surface finishes denote the quality of machining, with the advent of numerical control machines these processes are more controlled because the parameters and conditions of the machine tool are programmed and thus human error is eliminated from the variation of the feed rate and depth of cut.

The metal removal process known as milling is one of the most widely used manufacturing processes in industry because the degree of understanding of the operation is not complex for the operators performing this task. Furthermore, due to the variety of shapes that can be created through displacements and/or trajectories, as well as the production speeds of mechanical components from scratch, milling is one of the most versatile and widely used processes in the manufacturing world. (Groover, 2007).

We can summarise that milling consists of passing a fixed workpiece in front of a tool with a cylindrical geometry that has a defined number of edges with a certain cutting edge and rotating it in order to remove the excess material from the part to be machined.

The rotation in this case takes place in the work tool which is mounted on the milling machine head and the movement is perpendicular to the direction of feed, i.e. the sharp edges hit the surface to be machined to rough and give the desired dimensions to the workpiece.

On a three-axis numerical control milling machine, it is sufficient to define the revolutions per minute at which the cutting tool is to rotate, the cutting feed rates in the different axes of the machine (X, Y, Z...) and the depth of cut, so that the workpiece goes from being a raw material to a finished product.

Once any machining process has been carried out we will notice that the surface of the workpiece has an attribute called, "roughness". Roughness is the deviations that occur on the surface of the part and in other words, irregularities that are a consequence of the parameters set when a specific manufacturing process is carried out. Apud Kalpakjian & Schmid, 2008.

This does not mean that the part is defective, but rather that the properties of the material cause it to respond in a certain way to the mechanical wear generated by the process itself.

The surface roughness causes the physical properties of a final part to be immersed in variations such as: dimensional accuracy; how precise the geometric tolerances are for assembly with other components, the coefficients of friction and wear; the contact of the surface with another part will suffer more or less wear due to roughness, among others, the fatigue limit, corrosion resistance, thermal and electrical resistance will also be affected in an indirect way.

It is worth mentioning that whether a part requires a certain level of finish will also influence the production cost of the part; the more precise the level of finish, the more manufacturing processes will have to be adapted to achieve the desired result.

## Problem Statement

Given the complexity of the geometry and assembly precision of today's mechanical components, it is important to consider roughness as an essential factor that allows these components to meet the desired characteristics in order to comply with the standards considered in their design so that they are functional.

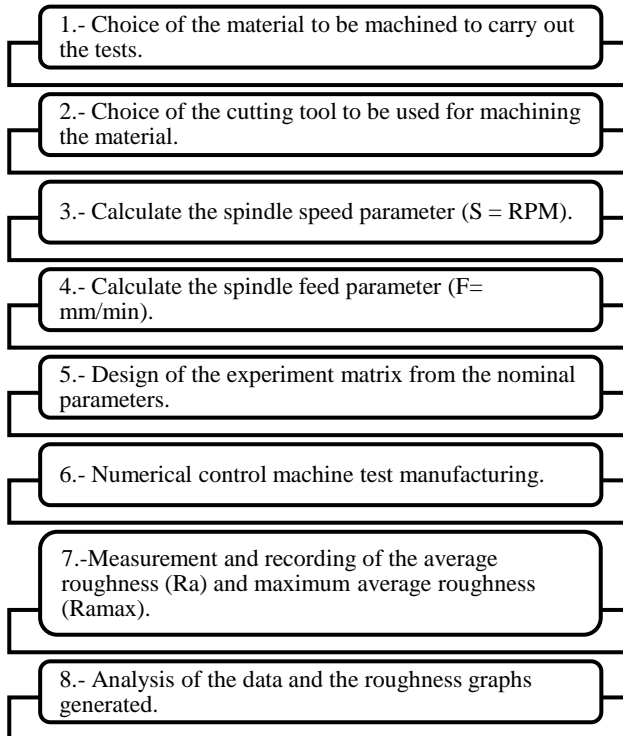
In this sense, it is important to establish the operating parameters of the numerical control machine with which these components are to be manufactured, in order to have a notion of which formulas give us a better surface finish, so that the variation in the different edges and/or faces of the final part are the required ones.

Starting from the formulas for obtaining the revolutions per minute of the spindle and the machine feed rate, we can define a design of experiments that allows us to apply an adjustment to these formulas to obtain an average roughness (Ra) closer to 1.6  $\mu\text{m}$ , this value is recommended for narrow assembly fits that are subject to stress, as well as for surfaces that have little movement and do not need to withstand too much load. (Xometry, 2022). Based on the fact that we want to know the roughness on a surface to start developing aluminium moulds, this average roughness value is adequate.

MONDRAGÓN-MENDOZA, Ricardo, PAZ-CABRERA, Mauro and DELGADO-PRESA, Florencio. Design of experiments to evaluate the equation to obtain the operating parameters in a 3-axis Numerical Control Machine. *Journal of Experimental Systems*. 2022

## Methodology

Considering the above, the methodology proposed for the development of the design of experiments is shown below.



**Figure 1** Methodology for the design of experiments to evaluate the equation to obtain the parameters.

Source: Own Authorship

This methodology seeks to evaluate the effectiveness of the application of the formulas for CNC machining parts, taking as the main attribute the surface roughness with which the part ends up at the end of the process. It is worth mentioning that this methodology also seeks to standardise how this experiment can be carried out on other ferrous and even non-ferrous materials.

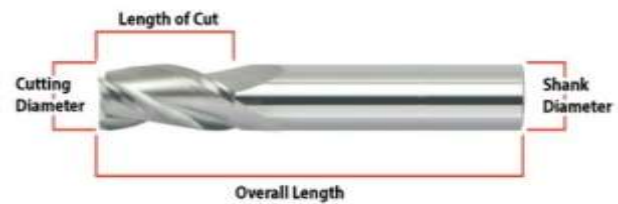
## Development of the methodology

### Choice of material

For this experiment we will take as reference the aluminium 6061 T6 since it is a type of material used in the industry dedicated to the manufacture of moulds, this is due to its mechanical properties such as: mechanical strength, corrosion resistance, good ability to be deformed, has a medium machinability and a hardness of around 100-120 HB. (GGD Metals, 2015).

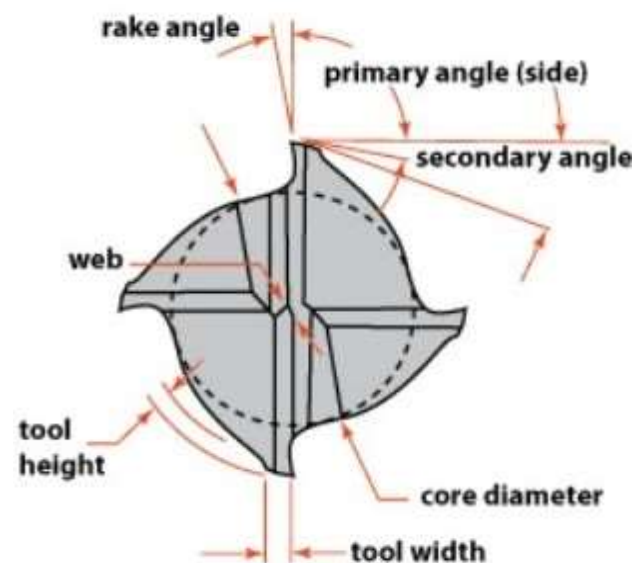
### Choice of cutting tool

It was decided to use a ½" inch diameter helical high speed steel cutter with 4 cutting edges similar to the following design.



**Figure 2** Endmill Design Basics 1

Source: <https://mastercuttool.com/endmill-design-basics/>



**Figure 3** Endmill Design Basics 2

Source: <https://mastercuttool.com/endmill-design-basics/>

### Calculation of RPM

To calculate the revolutions per minute of the spindle, the formula was applied:

$$S = \frac{1000 \times V_c}{\pi \times D_c} \text{ (rpm)} \quad (1)$$

Where:

$V_c$  = Cutting speed of the material.

$D_c$  = Cutting diameter of the cutter.

$S$  = Spindle revolutions per minute.

Now some of the values applied to the variables are:

$$V_c = 100 \text{ mts/min}$$

$$D_c = 12.7 \text{ mm}$$

Substituting is:

$$S = \frac{1000 \times 100 \frac{\text{mts}}{\text{min}}}{\pi \times 12.7 \text{ mm}} = 2506.37 \cong 2506$$

This means that 2506 revolutions per minute will be taken as the nominal value for the design of the die to program the spindle speed of the machine.

#### Calculation of the feed rate

To calculate the feed rate of the spindle on the material to be machined, the formula was applied:

$$F = S \times f_z \times z_n \left( \frac{\text{mm}}{\text{min}} \right) \quad (2)$$

Where:

S=Spindle revolutions per minute.

F=Feed speed of the tool with respect to the material.

Fz=Chip size at the moment of cutting for each cutting edge of the tool.

Zn=Number of cutting edges of the tool.

Now some of the values applied to the variables are:

S= 2506.37 RPM

fz= 0.079 mm/edge

Zn= 4 cutting edges

Substituting is:

$$F = 2506.37 \text{ RPM} \times 0.079 \frac{\text{mm}}{\text{edge}} \times 4 \text{ edges}$$

$$F = 792.01 \cong 792$$

This means that as a nominal value for the die design, 792 millimetres per minute will be used to program the feed rate of the machine spindle.

#### Die design

		Spindle speed (S = rpm)		
		Under (-30%)	Nominal	High (+30%)
Advance (F =mm/min)		1754	2506	3258
Under (-30%)	554	1	3	5
		2	4	6
Nominal	792	7	9	11
		8	10	12
High (+30%)	1030	13	15	17
		14	16	18

**Table 1** Matrix to be used to evaluate the machining parameters

Source: Own Authorship

Once the nominal values of the RPM and spindle feed rate parameters were obtained for machining tests on the 3-axis machining centre, it was considered that it was congruent to lower and increase them by 30%, because they cannot be varied too much as it would not make sense to calculate the nominal values as a reference.

As can be seen in the table, for each test, two replicates will be made in order to evaluate that the machined surface under certain parameters, really has the value given by the roughness test and looking for repeatability under certain operation scenarios.

#### Test manufacturing

The machining process was carried out on a Sunmill® 3-axis vertical numerical control machine, model JHV-1300, equipped with a Fanuc® Series Oi-MD controller model A02B-0309-B522.

At the foot of the machine and with the programming of a code that allows a lateral cut to be made on the 6061 T6 aluminium blocks, the number of tests obtained in the matrix is carried out, varying the RPM and advance parameters in every two tests.



**Figure 4** Test manufacturing

Source: Own Authorship

The following equation was used to determine the lateral depth of cut:

$$5\% \text{ of stepover} = D_c \times 5\% \quad (3)$$

Where:

D<sub>c</sub>=Cutter cutting diameter.

So the value of the variable is:

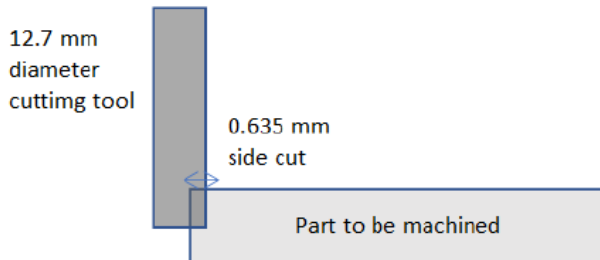
$$D_c = 12.7 \text{ mm}$$

Substituting it is:

$$5\% \text{ of stepover} = 12.7\text{mm} \times 5\%$$

$$5\% \text{ of stepover} = 0.635 \text{ mm}$$

This means that the side cut will be carried out giving a depth of cut of 0.635 mm on the test pieces, as can be seen in the following figure.



**Figure 5** Machining at 5% stepover  
*Source: Own Authorship*

**Measurement and recording of roughness**

Once the 18 tests were completed on the numerical control machine, the Ra (average roughness) and Ramax (maximum average roughness) were evaluated in pairs.

A Mitutoyo® surface roughness meter, model SURFTEST SV-2000, was used to carry out the measurement.



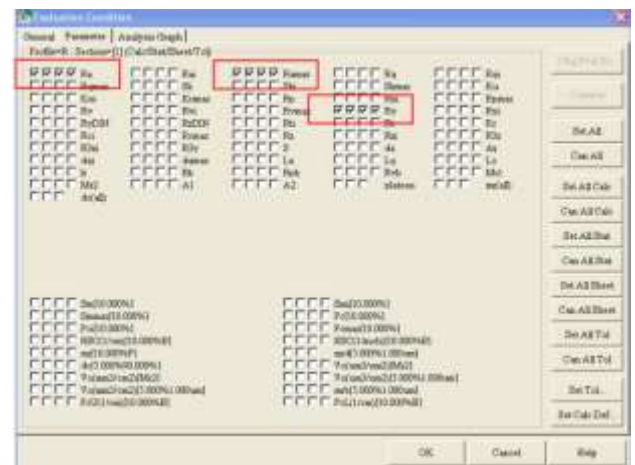
**Figure 6** Mitutoyo SURFTEST SV-2000 roughness tester  
*Source: Own Authorship*

Firstly, the device was calibrated by carrying out the measurement on a standard block whose Ra and Ramax should be 3.0 µm.



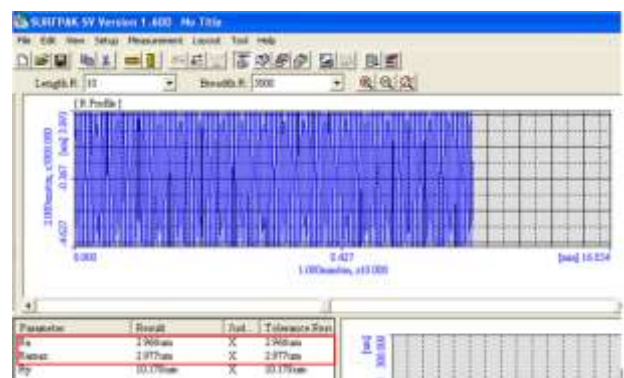
**Figure 7** Standard block test  
*Source: Own Authorship*

In the computer interface screen we can indicate the para-metres that we wish to obtain through the interpretation of the measurement in it we must select Ra, Ramax and Ry.



**Figure 8** Selection of the measurement to be assessed  
*Source: Own Authorship*

Once the test had been carried out on the standard block, the results obtained were as follows:

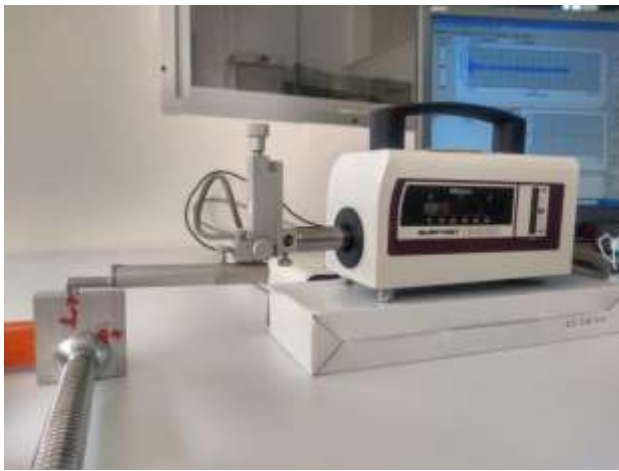


**Figure 9** Results of the master block  
*Source: Own Authorship*



The blue graph indicates the variation in the surface of the part on which the measurement was taken (in this case the pattern block), up and down oscillations were detected continuously on the surface, the Ra is 2.966  $\mu\text{m}$  and the Ramax is 2.977  $\mu\text{m}$ .

Once the roughness tester was calibrated, a "C" type press was used to hold each of the machined parts so that they would not move when the test was carried out.



**Figure 10** Test performed on each of the machined parts.  
Source: Own Authorship

The 18 tests performed were recorded in the matrix now putting the value of Ra (Table 2.) and Ramax (Table 3.).

		Spindle speed (S = rpm)		
		Under (-30%)	Nominal	High (+30%)
Advance (F =mm/min)		1754	2506	3258
Under (-30%)	554	1.094	1.501	1.569
		1.261	1.566	1.496
Nominal	792	1.690	1.406	1.235
		1.600	1.326	1.281
Alto (+30%)	1030	2.003	1.527	1.406
		1.955	1.403	1.281

**Table 2** Ra Register  
Source: Own Authorship

		Spindle speed (S = rpm)		
		Under (-30%)	Nominal	High (+30%)
Advance (F =mm/min)		1754	2506	3258
Under (-30%)	554	1.146	1.688	1.840
		1.495	1.738	1.727
Nominal	792	1.756	1.582	1.394
		1.763	1.400	1.394
High (+30%)	1030	2.120	1.604	1.777
		2.061	1.461	1.393

**Table 3** Ramax Register  
Source: Own Authorship

## Results

### Analysis of data and graphs

From the recording of the Ra and Ramax data, it is possible to identify the values that comply with the roughness characteristic closest to 1.6  $\mu\text{m}$  and that are below this value, which is suitable for CNC machining, as mentioned in the problem statement of this article.

		Spindle speed (S = rpm)		
		Under (-30%)	Nominal	High (+30%)
Advance (F =mm/min)		1754	2506	3258
Bajo (-30%)	554	1.094	1.501	1.569
		1.261	1.566	1.496
Nominal	792	1.690	1.406	1.235
		1.600	1.326	1.281
High (+30%)	1030	2.003	1.527	1.406
		1.955	1.403	1.281

**Table 4** Ra analysis  
Source: Own Authorship

		Spindle speed (S = rpm)		
		Under (-30%)	Nominal	Alto (+30%)
Advance (F =mm/min)		1754	2506	3258
Under (-30%)	554	1.146	1.688	1.840
		1.495	1.738	1.727
Nominal	792	1.756	1.582	1.394
		1.763	1.400	1.394
High (+30%)	1030	2.120	1.604	1.777
		2.061	1.461	1.393

**Table 5** Ramax analysis  
Source: Own Authorship

In "Table 4" and "Table 5" we can see values in bold, these are below the desired value (1.6  $\mu\text{m}$ ) so we can take into account the parameters with which they were obtained for the programming of our machining, since this indicates a good surface finish.

The data that are shaded orange indicate that the machining parameters are the least effective decision to obtain the roughness that is common on a numerical control machine.

The data that is shaded in grey is the data that has the lowest average roughness measurement, which means that it is the option that leaves the best surface finish, theoretically speaking.

The data shaded in green are the best option in theory and practice, given that the parameters used at the time of machining show an increase in the revolutions per minute used on the machine spindle and as this data correlates with the machine feed rate, we can infer that the machining time is reduced, also note that the average roughness values are very similar to those obtained in grey.

In addition to this, if we analyse the graphs of the tests that are shaded in grey, green and orange, we can visually obtain what is shown below.

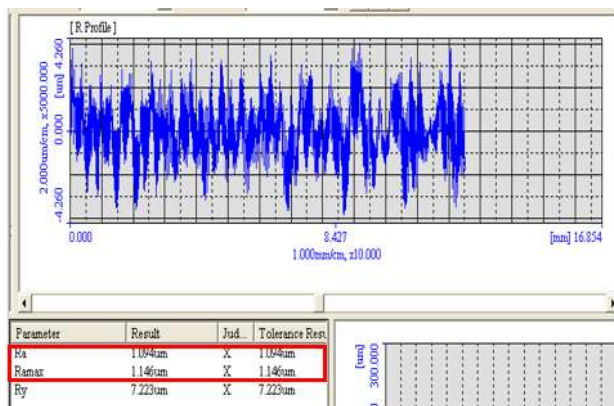


Figure 11 Exhibit 1  
Source: Own Authorship

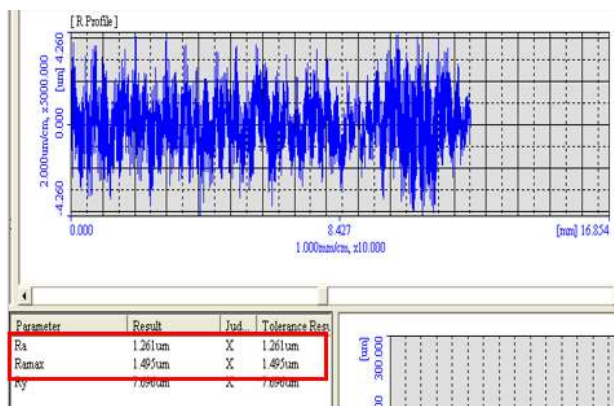


Figure 12 Test number 2  
Source: Own Authorship

These graphs (Figure 11 and Figure 12) show a particular irregularity with little deviation in the surface roughness of test 1 and test 2 (data in grey) correspondingly.

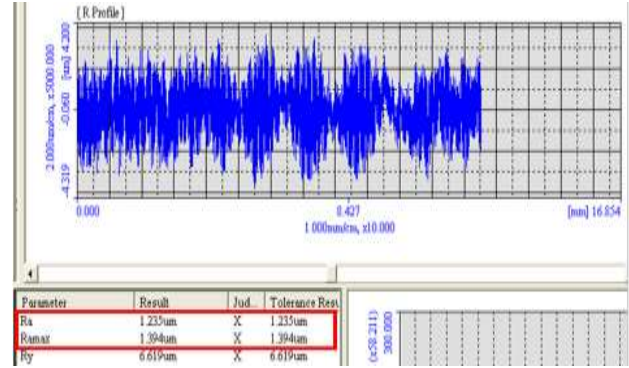


Figure 13 Test number 11  
Source: Own Authorship

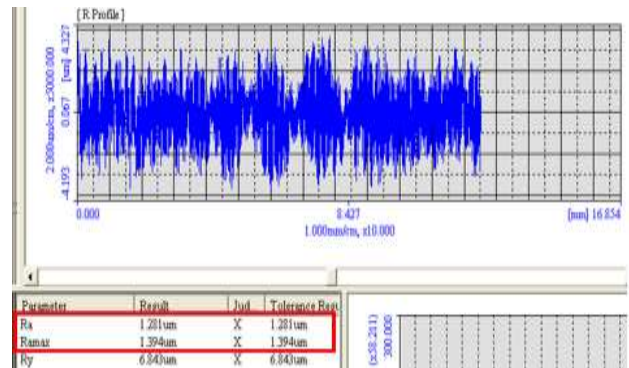


Figure 14 Test number 12  
Source: Own Authorship

These graphs (Figure 13 and Figure 14) show homogeneity in the surface roughness deviation of test 11 and test 12 (data in green) correspondingly, it can be said that the surface has a symmetrical finish and is the most normalised in terms of roughness.

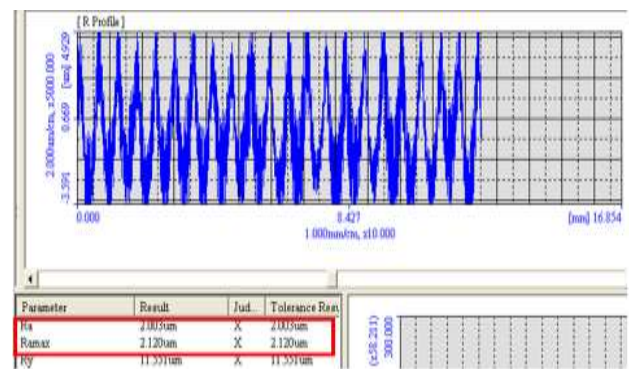
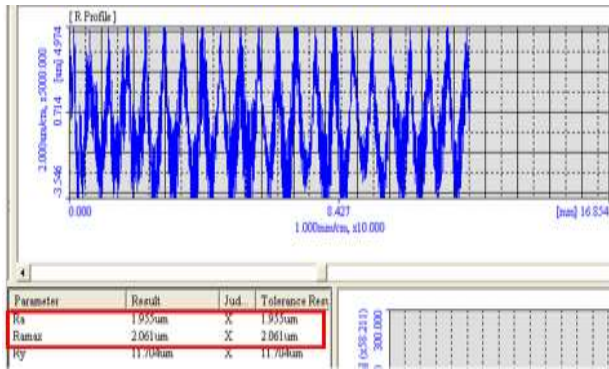


Figure 15 Exhibit 13  
Source: Own Authorship



**Figure 16** Test number 14  
Source: Own Authorship

These graphs (Figure 15 and Figure 16) show too much variation in the surface roughness deviation of test 13 and test 14 (data in orange) correspondingly, it can be said that this is the least viable option given that translated into practice the surface has a more irregular finish.

## Conclusion

From the analysis of the data and the graphs obtained by means of the software with which the roughness tester is coupled, it has been reached the conclusion that it is convenient to apply an adjustment to the machining parameters from the previously established formulas as suggested below.

Obtain by means of the formulas the nominal values for both:

Spindle revolutions per minute.

$$S_0 = \frac{1000 \times V_c}{\pi \times D_c} \text{ (rpm)} \quad (4)$$

Where:

$V_c$ =Cutting speed of the material.

$D_c$ =Cutting diameter of the cutter.

$S_0$ =Nominal revolutions per minute of the spindle.

As well as, for the feed speed of the tool with respect to the material.

$$F_0 = S \times f_z \times z_n \left( \frac{\text{mm}}{\text{min}} \right) \quad (5)$$

Where:

$S_0$ =Nominal spindle speed per minute.

$F_0$ =Nominal feed speed of the tool with respect to the material.

$f_z$ =Chip size at the moment of cutting for each cutting edge of the tool.

$z_n$ =Number of cutting edges of the tool.

Then, an increase of 30% must be applied to the nominal value of the revolutions per minute, i.e. the new formula would be as follows:

$$S_1 = 1.3 S_0 \quad (6)$$

Where:

$S_0$ =Nominal revolutions per minute of the spindle.

$S_1$ =Revolutions per minute of the spindle to be used in machining.

It is necessary to clarify that the nominal calculations of the parameters must be made first, given that as the revolutions per minute are correlated with the calculation of the spindle feed rate, the 30% increase in the value of the nominal revolutions cannot be applied directly, as this would affect the value obtained for the calculation of the nominal feed rate.

The aim of the present study was to lay the foundations for the development of experiments of this type, so this same methodology can be applied to any other type of ferrous or non-ferrous material.

It should be noted that in the tables as well as the graphs, values of Ra and Ramax were obtained, so it is up to the person in charge of replicating the experiment to decide which value to take as a critical factor to implement the parameters in the machining.

The main difference is that Ra is the average of the absolute values on the surface to be measured taking as reference the midline while Ramax is the measurement of the highest roughness in the partial measurements of the surface. (GTM, 2022).

It is expected that with the application of the adjustment in the formulas of the operating parameters in the numerical control machine, the mechanical components, as well as the parts manufactured in the same, will be of better quality in terms of mechanical characteristics and properties.



Let's remember that roughness directly influences how the different components of a final part are assembled and the mechanical properties such as: friction and wear coefficients, fatigue limit, corrosion resistance, thermal and electrical resistance.

Finally, it is only necessary to add that thanks to the work carried out, we now have new knowledge about the efficiency of the nominal values of the equations for the calculation of the operating parameters in a numerical control machine, which will help us to obtain better results in the parts machined on this equipment.

### References

GGD Metals. (2015). *6061-T6*. Recuperado el 20 de julio de 2022, de Home/Produtos/Aluminios/6061-T6: <https://www.ggdmetals.com.br/es/produto/6061-t6/>

Groover, M. (2007). *Fundamentos de Manufactura Moderna* (Tercera ed.). México, D. F.: Mc Graw Hill.

GTM. (2022). *Rugosidad Superficial*. Recuperado el 20 de julio de 2022, de GRUPO TECNOLOGÍA MECÁNICA – PROCESOS DE FABRICACIÓN: <http://www3.fi.mdp.edu.ar/tecnologia/archivos/TecFab/10.pdf>

Kalpakjian, S., & Schmid, S. (2008). *Manufactura, ingeniería y tecnología* (Quinta ed.). Naucalpan de Juárez, Edo. de México: Pearson.

Xometry. (9 de junio de 2022). *Selección de la rugosidad superficial adecuada para el mecanizado CNC*. Recuperado el 20 de julio de 2022, de Mecanizado CNC: <https://xometry.eu/es/seleccion-de-la-rugosidad-superficial-adecuada-para-el-mecanizado-cnc/>

## Trend analysis in the 1D solution of the inverse heat conduction problem by the sequential function specification technique

### Análisis de tendencia en la solución 1D de un problema inverso de conducción de calor por la técnica secuencial de especificación de la función

TÉLLEZ-MARTÍNEZ Jorge Sergio<sup>1†\*</sup>, PÉREZ-QUIRÓZ José Trinidad<sup>2</sup>, HORTELANO-CAPETILLO Juan Gregorio<sup>1</sup> and PÉREZ-PÉREZ Arnulfo<sup>3</sup>

<sup>1</sup>Universidad Politécnica de Juventino Rosas. Academia de Ingeniería en Metalúrgica. Hidalgo 102, Comunidad de Valencia, Santa Cruz de Juventino Rosas, Gto.; México.

<sup>2</sup>Instituto Mexicano del Transporte, Parque Tecnológico Sanfandila, Pedro Escobedo, Querétaro C.P. 76703, México.

<sup>3</sup>Universidad Politécnica de Juventino Rosas. Academia de Ingeniería en Sistemas Automotrices. Hidalgo 102, Comunidad de Valencia, Santa Cruz de Juventino Rosas, Gto.; México.

ID 1<sup>st</sup> Author: *Jorge Sergio, Téllez-Martínez* / ORC ID: 0000-0003-0587-0059, CVU CONACYT ID: 40084

ID 1<sup>st</sup> Co-author: *José Trinidad, Pérez-Quiróz* / ORC ID: 0000-0002-7230-9715, CVU CONACYT ID: 91805

ID 2<sup>nd</sup> Co-author: *Juan Gregorio, Hortelano-Capetillo* / ORC ID: 0000-0002-3702-4853, CVU CONACYT ID: 347496

ID 3<sup>rd</sup> Co-author: *Arnulfo, Pérez-Pérez* / ORC ID: 0000-0001-6354-8899, CVU CONACYT ID: 176434

DOI: 10.35429/JOES.2022.26.9.10.16

Received: March 30, 2022; Accepted June 30, 2022

#### Abstract

Inverse heat conduction problems are categorized by the solution technique or algorithm (Function Specification, Regularization, Laplace Transform, Conjugate Gradient, Mollification), by the solution method (Duhamel's Theorem, Difference Method Finite, Finite Element Method), and by the time domain (Stoltz Method, Sequential Method, and Complete Domain). In the direct approach, the unique solution of an effect due to a cause is obtained. From the cause-effect view, inverse problems are characterized by not meeting the existing criteria and the uniqueness of determining the cause when analyzing an effect. However, this has promoted the implementation of robust methods to optimize the stability of a solution. In this work, the study system consists of a long solid cylinder at an elevated temperature that is cooled. The implemented methodology allowed the creation of data trends through linear extrapolation to improve estimation accuracy for abrupt changes in the function (boundary condition). The results show an acceptable increase in punctual precision in the estimation, and it is a consequence of the solution that the calculated thermal histories already contain an implicit degree of error.

**Inverse problems, Heat transfer, Sequential function specification**

#### Resumen

Los problemas inversos de conducción de calor se categorizan por la técnica o algoritmo de solución (Especificación de la Función, Regularización, Transformada de Laplace, Gradiente Conjugado, Mollificación), por el método de solución (Teorema de Duhamel, Método de Diferencias Finitas, Método de Elemento Finito) y por el dominio de tiempo (Método de Stoltz, Método Secuencial y de Dominio completo). De la visión causa-efecto, a diferencia de un planteamiento directo en el que se obtiene la solución única de un efecto debido a una causa, los problemas inversos se caracterizan por no cumplir los criterios de existencia y unicidad de determinación de la causa cuando se analiza un efecto. Esto ha promovido la implementación de métodos para optimizar la estabilidad de una solución. En este trabajo el sistema de estudio consiste de un cilindro sólido largo a temperatura elevada que se enfría. La metodología implementada permitió crear tendencias de datos mediante extrapolación lineal para mejorar la precisión de estimación para los cambios abruptos de la función (condición de frontera). Los resultados obtenidos muestran un incremento aceptable de precisión puntual en la estimación, pero se induce por solución que las historias térmicas ya contienen implícito un grado de error.

**Problemas inversos, Transferencia de calor, Especificación secuencial de la función**

**Citation:** TÉLLEZ-MARTÍNEZ Jorge Sergio, PÉREZ-QUIRÓZ José Trinidad, HORTELANO-CAPETILLO Juan Gregorio and PÉREZ-PÉREZ Arnulfo. Trend analysis in the 1D solution of the inverse heat conduction problem by the sequential function specification technique. Journal of Experimental Systems. 2022. 9-26: 10-16

\* Author Correspondence (jtellez\_ptc@upjr.edu.mx)

† Researcher contributing as first author.

## Introduction

The interest in the theory and application of inverse mathematical problems has maintained constant work since its growing use in the last century. The inverse problem statement is found in diverse applications of science and engineering, contributing to creating new paradigms in the field of research due to its unique characteristic of not having a single solution. This condition mathematically defines them as poorly conditioned problems; therefore, they generally require applying specific mathematical techniques to ensure the solution method's stability (Beck, Litkouhi, & St. Clair, 1982) (Krzysztof, 2011) (Meekisho, Hernandez-Morales, Tellez-Martinez, & Chen, 2005) (Beck, Blackwell, & Haji-Sheikh, 1996) (Blanc, Raynaud, & Chau, 1998). Therefore, since there is high-capacity computing technology, the possibility of implementing additional analyzes or modifications to the techniques that contribute to its optimization arises. In metallurgical processes that occur in transitory states of heat transfer, knowledge of the conditions that modify the thermal field of a system is vital to obtain better control.

In particular, heat conduction problems are a reference for the frequent application of the inverse formulation. Some examples are the nuclear, aerospace, mechanical, and metallurgical fields (Hernández-Morales, Cruces-Reséndez, & Téllez-Martínez, 2018) (Kumar, 2004). In metallurgical processes that occur in transitory states of heat transfer, knowledge of the conditions that modify the thermal field of a system is vital to obtain better control. Therefore, the formulation and solution of an inverse heat conduction problem (IHCP) will consider a viable method to achieve this.

This work shows the analysis of the behavior of the temperature change rate at a point near the border of a system. It can use to define critical points of the variation of the thermal boundary condition before estimating it by the sequential function specification (SFS) technique. This analysis was carried out to implement improvements in estimating thermal boundary conditions through trend analysis, and to define key points of extrapolation techniques from thermal history data obtained by direct measurement.

The results obtained help to propose the modification of the data trend in the thermal history to avoid losing precision in the characteristic biases of the estimated function; the subsequent calculation of the thermal field would introduce differences concerning the reference temperatures.

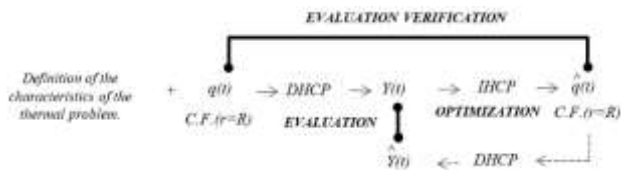
## Development

Precisely, the development of this work consists of proposing the mathematical model that governs heat transfer by conduction in a solid cylinder considered to be of infinite length (on its axial axis) and performing the following procedure:

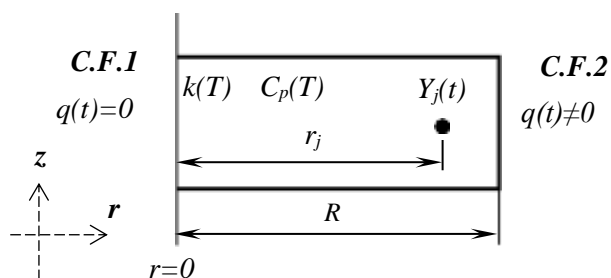
- a) Define the characteristics of the problem considering the interaction of the solid with a medium at different temperatures.
- b) Solve the forward heat conduction problem (DHCP) in a transient state by setting a known thermal boundary condition  $q(t)$ .
- c) Process at least one thermal history  $Y_j(t)$  calculated in the vicinity of the surface of the solid in contact with the medium.
- d) Solve the inverse heat conduction problem (IHCP) using the thermal history(s) from the previous step to estimate the thermal boundary condition  $\hat{q}(t)$ .
- e) Validate the mathematical model using the results obtained in the previous step by evaluating the differences (error) between the proposed and estimated thermal boundary conditions and the thermal histories. In particular, the thermal history  $\hat{Y}_j(t)$  is equivalent to the one processed in step (c).
- f) Carry out the steps from (a) to (e) introducing the optimization method.

Fig. 1 schematically summarizes the previous procedure, and Fig. 2 outlines the characteristics of the thermal problem considering a representative element of the system under study.  $Y(t)$  represents the known thermal history,  $r$  and  $z$  represent the geometric variables, radius, and length, respectively, as well as  $k(t)$  and  $C_p(t)$ , the thermal conductivity and thermal capacity of the material, respectively.

The maximum dimension of the element radius will specify with the magnitude  $R$ , and  $r_j$  represents the position concerning the cylinder center of the thermal history(s) used for the analysis of the IHCP as a function of the value of indicator  $j$ . The material's properties depend on the temperature  $T$  for the approach in this work.



**Figure 1** Schematic procedure for the development of data generation and its analysis. Source: Self-Made [MS Word LTSC Pro Plus 2021]



**Figure 2** Schematic representation of the axisymmetric element of the system under study and the characteristics of the thermal problem

Source: Self-Made [MS Word LTSC Pro Plus 2021]

The mathematical formulation of DHCP that governs the transfer is:

$$\frac{1}{r} \frac{\partial}{\partial r} \left( kr \frac{\partial T}{\partial r} \right) = \rho C_p \frac{\partial T}{\partial t}, \quad 0 \leq r \leq R, \quad t > 0 \quad (1)$$

$$\frac{\partial T}{\partial r} \Big|_{r=0} = 0, \quad -kr \frac{\partial T}{\partial r} \Big|_{r=R} = q(t) \quad (2)$$

$$T(r, T) = T_0, \quad 0 \leq r \leq R, \quad t > 0 \quad (3)$$

Where  $\rho$  represents the density of the material as a constant property. On the other hand, the IHCP approach is formulated similarly to DHCP with changes in equations (2) and (3), such that:

$$\frac{\partial T}{\partial r} \Big|_{r=0} = 0, \quad -kr \frac{\partial T}{\partial r} \Big|_{r=R} = q(t) = i? \quad (4)$$

$$T_j = (r_j, t_i) = \hat{Y}_j, \quad j = 1, 2, \dots, n, \quad i = 1, 2, \dots, M \quad (5)$$

Where  $i$  represents the number of elapsed time steps or time index until the current calculation step  $M$  in the temporal analysis interval of the thermal phenomenon.

It was to use the SFS technique to solve the IHCP. In the technique, the sum of the squares of the difference between the measured temperatures  $Y_j$  and the estimated temperatures  $\hat{Y}_j(t)$  is minimized in a calculation time interval  $(M + l - 1)$  to estimate at the same time the thermal boundary condition as a function of known thermal histories ( $j = 1, 2, \dots, n$ ). The objective function defines as:

$$\frac{\partial S}{\partial q} = \frac{\partial}{\partial q} \left[ \sum_{l=1}^L \sum_{j=1}^n (Y_{j, M+l-1} - \hat{Y}_{j, M+l-1})^2 \right] = 0 \quad (6)$$

Where  $l$  is the index that defines the number of discrete temperature data at time instants after calculating instant  $M$ . This index is called the future time step index. It establishes that the solution is "stabilized" for estimating the thermal boundary condition that satisfies the energy balance in the mathematical heat conduction model. Therefore, when developing equation (6), it is established that the sequential estimation of the boundary condition can obtain it through the following equation:

$$q_M = q_{M-1} + \frac{1}{\Delta M} \left[ \sum_{l=1}^L \sum_{j=1}^n (Y_{j, M+l-1} - \hat{Y}'_{j, M+l-1; q})^2 \right] (\hat{Y}'_{j, M+l-1; q}) \quad (7)$$

The apostrophe means the calculation of the field variable considering the properties that prevail in the conditions of the calculation step  $(M - 1)$ . That is, at the instant prior to estimating the boundary condition value. In this way,  $\hat{Y}'_{j, M+l-1; q}$  represents corresponding values of the field variable called sensitivity coefficient, defined by the differentiation of equations (1) to (3) concerning the estimated variable  $q$ .

$$\Delta M = \sum_{l=1}^L \sum_{j=1}^n (\hat{Y}'_{j, M+l-1; q})^2, \quad \hat{Y}'_{j, M+l-1; q} = \frac{\hat{Y}_{j, M+l-1}}{\frac{\partial q_M}{\partial q_M}} \quad (8)$$

As part of the thermal problem analysis procedure, a computer program written in Visual C# language was generated to solve both DHCP and IHCP.

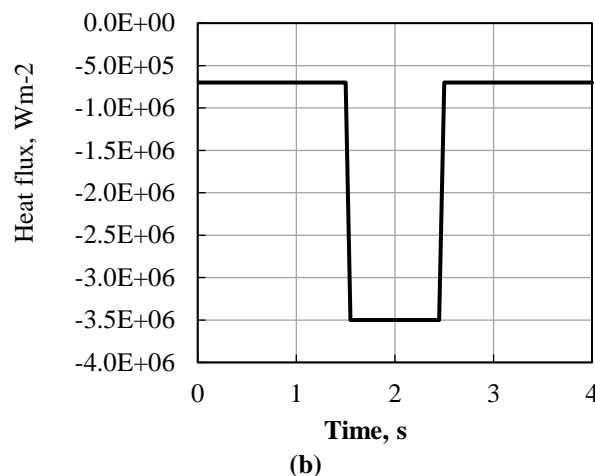
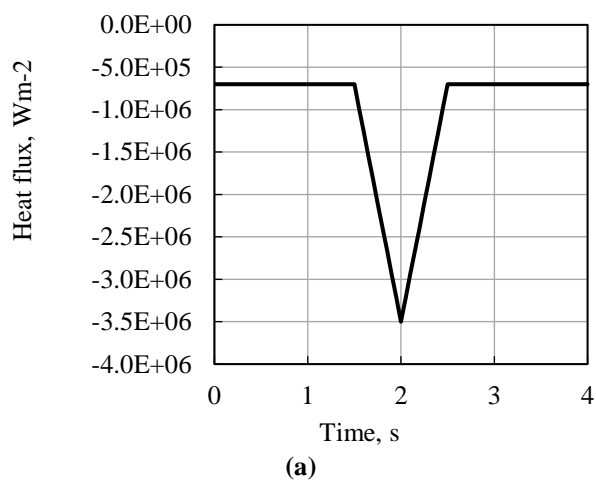
The DHCP solution was verified with results obtained from generating various models in the Ansys® commercial program, which establishes a high degree of confidence in the results of the IHCP solution.

In particular, the methodology adopted for the analysis considers the cooling of the cylinder element from an initial temperature of 911°C. The thermal properties used were obtained from the literature and correspond to AISI 304 stainless steel. The traces of the thermal boundary conditions used are shown in the graphs of Graphic. 1(a) and 1(b).

## Results and Discussion

According to the procedure described at the beginning of the preceding section and outlined in Fig. 1, the thermal boundary conditions  $q(t)$  was used to solve the DHCP using the Ansys computer program. In the analysis, an axisymmetric model with a radius  $R=0.635$  mm defined, creating a partition of the section drawn at 1 mm from the surface. First-order quadrilateral finite elements were used in the structured mesh type, defining 10 and 20 elements in the sections 1 mm and 0.535 mm.

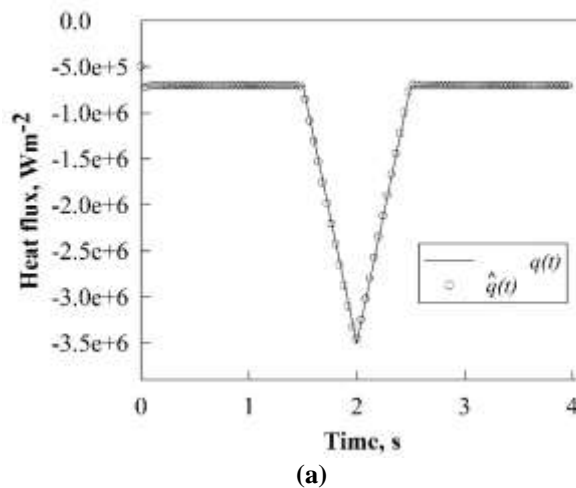
Thermal history calculations with a step of 0.01 at the partition position were used to solve the IHCP using the computer program developed for this work. The algorithm proposed the finite difference technique through the Crank-Nicolson solution method and the Thomas method for the inversion of the matrix of the system of equations. The program was subjected to a mesh sensitivity analysis, determining that ten control volumes in both sections, considering the same system partition, are adequate to obtain results without discretization effects.

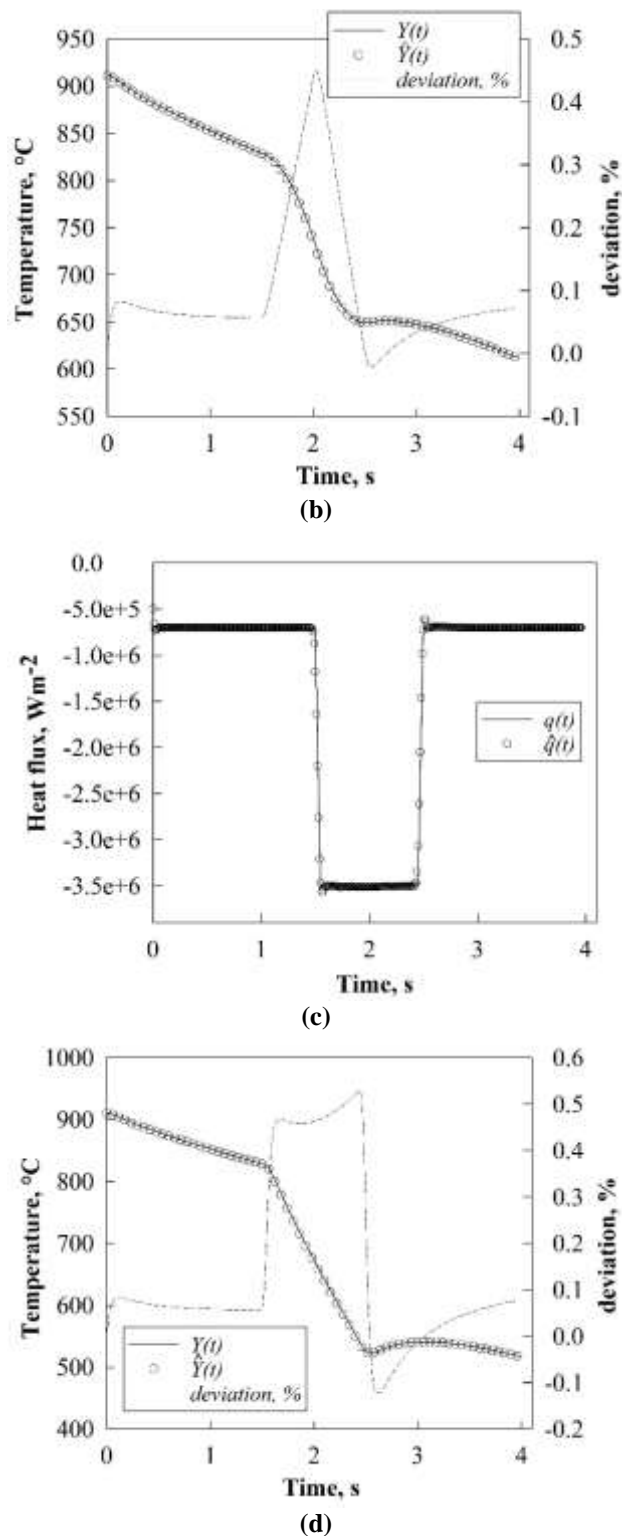


**Graphic 1** Graphical representation of the functions  $q(t)$  (thermal boundary conditions) proposed for the cases of thermal analysis

Source: Self-Media [MS Excel LTSC Pro Plus 2021]

The results of the estimation of the thermal boundary conditions product of the IHCP solution using several future time steps  $L=4$ , as well as the thermal histories calculated after solving the DHCP, with the respective ones, are shown. Graphic 2. The curves drawn with solid lines represent the reference data, and those drawn with symbols represent the estimates (specifying the comparison step associated with virtual validation). Additionally, graphs (b) and (d) show curves with segmented lines that indicate the temperature data's deviation percentage. The deviation is less than 1%, indicating that even with the abrupt changes and magnitudes of the boundary conditions in each case, the IHCP solution generates excellent results. Analyzing the deviation percentage curves (segmented line of graphs (b) and (d) of graphic 2), it can be deduced that the temperature variations resemble in segments the functional form of the heat flux density curve.



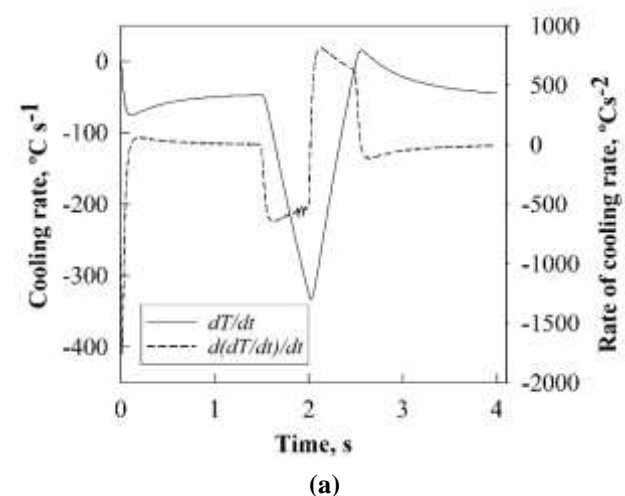


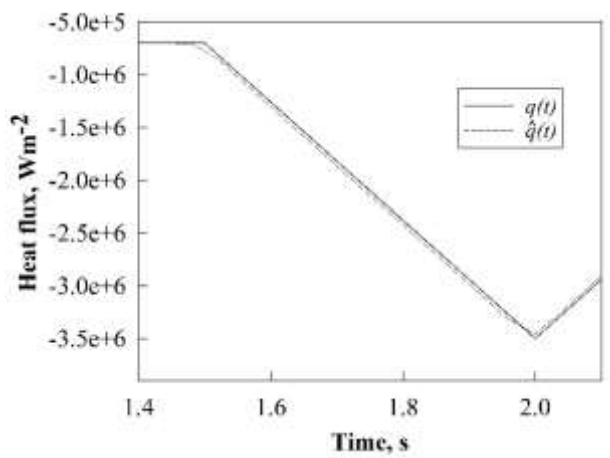
**Graphic 2** Graphs (a) and (c): curves of the proposed thermal boundary conditions  $q(t)$  (continuous line) and estimated  $\hat{q}(t)$  solving the IHCP (open symbols). The curves of graphs (b) and (d) show the excellent validation of the calculated thermal histories  $\hat{Y}(t)$  (open symbols) and the reference  $Y(t)$  (continuous line) in each case of the proposal. The dashed line shows the % deviation. Source: Self-Made [SigmaPlot V12.0]

Thus, if in the transient heat transfer state, the thermal field is affected by the rate of change of the thermal boundary condition, then the rate of temperature must reflect the same critical values of the differences between the reference and calculated thermal history.

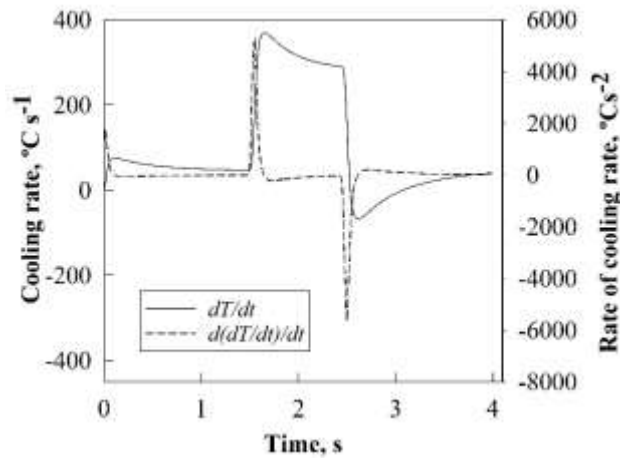
Graphic 3 shows the cooling rate curves' calculation, and the rate of change thereof in graphs (a) and (c) for each case analyzed. The results make evident the similarity of the behavior of the cooling rate and the percentage deviation curve, while the curves of the rate of change of the cooling rate precisely define the points of critical changes in the thermal boundary condition. That is, in small changes in cooling rate, the rate of change is close to zero. While being significant, they deviate towards negative or positive values depending on the increase or decrease in cooling rate, respectively. On the other hand, manipulating the scale in graphs (b) and (d) allows us to note the deviations from the estimated boundary condition.

Defining the critical points to implement a possible correction in the calculation process is essential. The deviation in the estimate starts at the first critical point of the cooling rate due to the SFS technique. The greater the number of temperatures considered, the more significant the deviation, which depends on the number of future temperatures that are considered to solve the objective function at each time step (refer to Eq. 6). In an attempt to correct the deviation in the first abrupt change for the proposed functions, the analysis of the trend of the data, both of the boundary conditions and the reference thermal histories, was carried out to accurately determine the point critical variation of the rate of cooling. The point in question was found at a time of 1.47 s. According to this reference, it is observed that to estimate the function data; it is necessary to modify the trend of the thermal history, adopting a linear behavior from 1.46 s, that is, keeping the cooling rate before the critical deviation. The extrapolation curve and usual trend are shown in Graphic 4, considering that four data are used for the SFS technique in the IHCP solution.

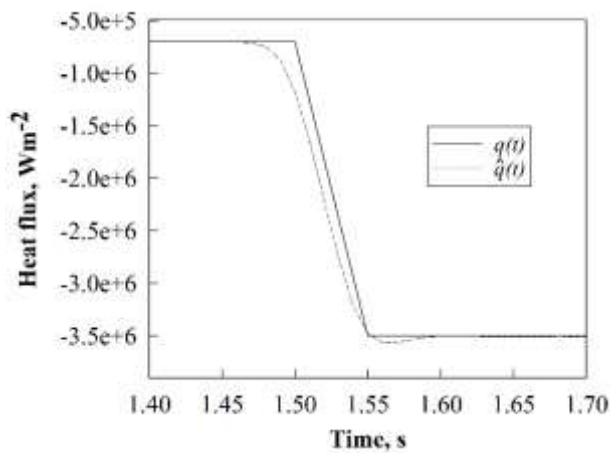




(b)



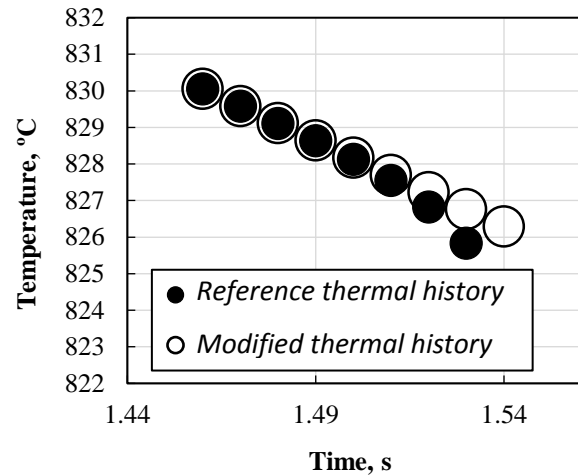
(c)



(d)

**Graphic 3** Graphs (a) and (c) show the cooling rate curves (continuous line) and their rate of change (dotted line) concerning the reference thermal history  $Y(t)$  for each case studied. The deviations of the estimated boundary condition  $\hat{q}(t)$  concerning those proposed  $q(t)$  are exemplified by plotting the curves at a modified scale in graphs (b) and (d)

Source: Self-Made [SigmaPlot V12.0]



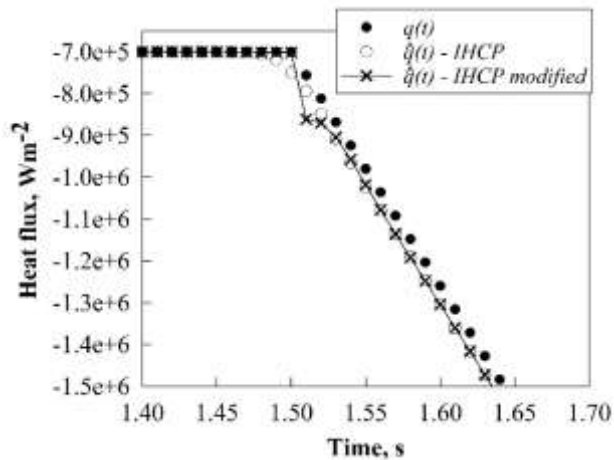
**Graphic 4** Reference thermal history (closed symbols) and modified thermal history (open symbols) curves, respectively. The second is created by extrapolation to force the temperature field calculation at the critical point of the thermal boundary condition

Source: Self-Made [MS Excel LTSC Pro Plus 2021]

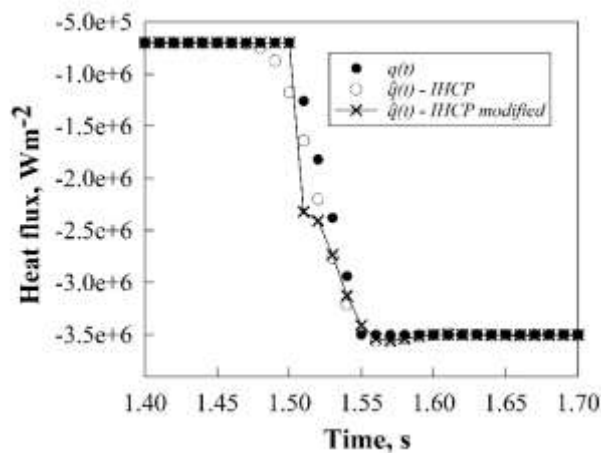
Additionally, graphs (a) and (b) of Graphic 5 also show the curves of the functions proposed (closed symbols) and estimated with and without the implementation of the modification by extrapolation (open symbols and line with symbols in x). It can be seen in both cases that the modified solution adjusts excellently to the point of change of direction at 1.5 s. Notwithstanding, the stability of the solution is lost when calculating the value of the functions in 1.51 s. For this point, the modification with extrapolation is no longer used, and although the function recovers its original trend, continuity on the curve of the proposed function is not achieved.

Through the analysis of the obtained information set, it can be deduced that starting from virtually constructed information, the modification of the estimated function will not depend on the optimization of the objective function (refer to Eq. 6).

The angular form of the proposed boundary condition function has not been strictly applied in the DHCP solution. Although there is an error in the IHCP solution, as indicated by the temperature differences (refer to graphs (b) and (d) of graphic 2), the reference thermal histories already introduce a certain degree of deviation from the numerical solution of the direct model.



(a)



(b)

**Graphic 5** Plots (a) and (b) show, at a fraction of a scale, the curve comparison of the proposed (closed symbols), modified estimated (line and symbols), and estimated (open symbols) heat flux density functions by solving the IHCP

Source: Self-Made [SigmaPlot V12.0]

## Thanks

To the Posgrado en Ciencias en Metalurgia of the Tecnológico Nacional de México campus Morelia, for facilitating the use of the Ansys program.

## Conclusions

Considering that temperature-dependent thermal properties were used for the thermal analysis, the validation results of the IHCP have a low degree of uncertainty. The approach of the case studies free of systematic errors allows us to determine that the SFS technique can be optimized through a trend analysis coupled with the stability introduced by the number of future time steps.

On the other hand, the defined analysis procedure will support the study of analytical systems to have better control of the reference information and those influenced by systematic errors (noise) with more than one active thermal boundary condition.

## Referencias

Beck, J. V., Blackwell, B., & Haji-Sheikh, A. (1996). Comparison of some Inverse Heat Conduction Methods Using Experimental Data. *International Journal of Heat and Mass Transfer*, 39(17), 3649-3657. doi:10.1016/0017-9310(96)00034-8

Beck, J. V., Litkouhi, B., & St. Clair, C. R. (1982). Efficient Solution of the Nonlinear Inverse Heat Conduction Problem. *Numerical Heat Transfer*, 5(3), 275-286. doi:10.1080/10407788208913448

Blanc, G., Raynaud, M., & Chau, T. H. (1998). A Guide for the Use of the Function Specification Method for 2D Inverse Heat Conduction Problems. *Revue Générale de Thermique*, 37(1), 17-30. doi:10.1016/S0035-3159(97)82463-4

Hernández-Morales, B., Cruces-Reséndez, R., & Téllez-Martínez, J. S. (2018). Revisiting the Temperature Gradient Method. *Materials Performance and Characterization*, 8(2), 170-187. doi:10.1520/MPC20180031

Krzysztof, G. (2011). *Inverse Heat Conduction Problems* (Vols. In Heat Conduction - Basic Research). London, United Kingdom: IntechOpen [Online]. doi:10.5772/26575

Kumar, T. S. (2004). A Serial Solution for the 2-D Inverse Heat Conduction Problems for Estimating Multiple Heat Flux Components. *Numerical Heat Transfer, Part B: Fundamentals*, 45(6), 541-563. doi:10.1080/10407790490277940

Meekisho, L., Hernandez-Morales, B., Tellez-Martinez, J. S., & Chen, X. (2005). Computer-aided cooling curve analysis using WinProbe. *International Journal of Materials and Product Technology*, 24(1-4), 155-169. doi:10.1504/IJMPT.2005.007946



## Adaptation of Higher Education to the attacks of the pandemic

### Adaptación de la Educación Superior ante los ataques de la pandemia

GALLEGOS-GALINDO, Juan Heriberto†\*, ALVARADO-LOPEZ, Oscar, CORNEJO-TRIGUEROS, Veronica and RAMIREZ-SANLUISEÑO, Juan

*Universidad Politécnica de Juventino Rosas, México*

ID 1<sup>st</sup> Author: *Juan Heriberto, Gallegos-Galindos* / ORC ID: 0000-0002-5199-731

ID 1<sup>st</sup> Co-author: *Oscar, Alvarado-Lopez* / ORC ID: 0000-0001-9714-8543

ID 2<sup>nd</sup> Co-author: *Veronica, Cornejo Trigueros* / ORC ID: 0000-0001 8996-2377

ID 3<sup>rd</sup> Co-author: *Juan, Ramírez-Sanluiséño* / ORC ID: 0000-0001-5073-6962

DOI: 10.35429/JOES.2022.26.9.17.25

Received 09 March, 2022; Accepted 28 June, 2022

#### Abstract

The objective of this study is to understand the impact of the Covid-19 pandemic on the mental health of students and teachers, as well as the challenges that have arisen over the years in rural and urban population. The situation was different in both cases. We know that in urban areas the proximity to technology is something of daily life, fast and simple, while in rural areas it is more difficult to have access to technology and media. An investigation was made consulting different sources, including INEGI data to determine an analysis of the desertion of students in the last years 2019-2020 and 2020-2021, in the same way a survey was made considering a sample of student population from the Polytechnic University of Juventino Rosas through which data was collected on their experience during the pandemic. The conclusions show an impact on the mental health of the participants. It indicates that most of them had emotional conditions, causing problems such as stress, anxiety, frustration, among other symptoms.

**Pandemic, Education, Mental health**

#### Resumen

El objetivo del presente estudio es el entendimiento del impacto que tuvo la pandemia de Covid-19 en la salud mental, de estudiantes y profesores, así como también los desafíos que se presentaron a lo largo de estos años tanto en la población rural como urbana. En las zonas rurales y urbanas se vivió diferente, sabemos que en las zonas urbanas la cercanía a la tecnología es de manera diaria, rápida y sencilla, mientras que en zonas rurales es más difícil tener acceso a la tecnología y medios de comunicación. Se realizó una investigación en diferentes fuentes incluyendo el INEGI para determinar un análisis sobre la deserción de alumnos en los últimos años 2019-2020 y 2020-2021, de igual manera se realizó un análisis cuantitativo, para esto se llevó a cabo una encuesta sobre una muestra de población estudiantil de la Universidad Politécnica de Juventino Rosas mediante la cual se recopilaban datos sobre su experiencia durante la pandemia. Las conclusiones muestran un impacto en la salud mental de los participantes e indica que la mayoría tuvo afecciones emocionales, causando problemas como estrés, angustia, frustración, entre otros síntomas.

**Pandemia, Educación, Salud mental**

**Citation:** GALLEGOS-GALINDO, Juan Heriberto, ALVARADO-LOPEZ, Oscar, CORNEJO-TRIGUEROS, Veronica and RAMIREZ-SANLUISEÑO, Juan. Adaptation of Higher Education to the attacks of the pandemic. Journal of Experimental Systems. 2022. 9-26: 17-25

\* Correspondence to Author (e-mail: jgallegos\_ptc@upjr.edu.mx).

†Researcher contributing as first Author.

## Introduction

In the year 2019 the World Health Organization (WHO) spoke for the first time about a new virus for the year 2020 was declared as a pandemic. Many areas were severely affected, and due to the confinement, all school activities were suspended from one day to the next without prior notice to anyone, possible strategies were planned as quickly as possible, taking all solutions off the table. Schools opted to continue and close the school cycle that year and continue virtually.

Because of this, roles began to change, not only at school, but also in our homes. Some of the parents also became teachers, supporting, above all, the children at home. In the middle of the 2021 school year, many schools opted to run pilot schemes, starting in classrooms at 70% or 80% of their capacity or some returning to 100% face-to-face teaching.

Due to the fact that teaching was in decline and there was beginning to be more student desertion (Geography, n. d.), it was decided that students would return to the classroom, preserving all the safety and hygiene measures that were taught worldwide, re-adopting the old roles, but with new habits. The current paper presents a general approach to the crisis generated by the pandemic.

It will show the challenges of what education in times of pandemic has been like, how it has impacted on teachers and students, mental health issues, and how it has impacted on both rural and urban populations.

The study was based on an analysis of different sources of information, including the National Institute of Statistics and Geography (INEGI), and will make clear how the pandemic has affected education and how it has been adapting to it.

Similarly, a qualitative approach was used in which data was collected from surveys of a selected from surveys of a certain population at the Polytechnic University of Juventino Rosas, to identify how the pandemic has affected them.

## Background

In October 2020, at the Universidad Iberoamericana in Mexico City, Sylvia Schmelkes described the likely short- and long-term impact of the pandemic on higher education by analysing economic, technological and pedagogical-organisational factors, analysing the situation of higher education in Mexico and data from the Ministry of Public Education (SEP) and INEGI. As well as in September of the same year at the Autonomous University of the State of Hidalgo, he conducted a quantitative approach using a sample of 168 indigenous students in Mexico, with the aim of identifying the impact of indigenous students on their learning. On 25 October 2020, at the Autonomous University of Chiapas, Mexico, Lilia González Velázquez proposed to demonstrate the increase of academic stress associated with the pandemic and some mental health problems, through the analysis and questionnaires of perception of academic stress in students.

Similarly, on 31 May 2021 at the Universidad Anahuac Mexico (Mexico), Carlos Gabriel Colín Flores wrote an article to understand the impact of the pandemic on the mental health of students and teachers through a study of 834 participants (161 teachers and 673 students).

In October 2020 at the Instituto Tecnológico de Sonora, Samuel Alejandro Prtillo Puñuelas, Oscar Ulises Reynoso González, Lidia Isabel Castellanos Pierra conducted research on teachers in different states of the country with the aim of identifying the rural areas that have greater complexity in teaching and making a comparison between rural and urban contexts.

## COVID-19 pandemic

COVID-19 was first reported in China by the Center for Disease Control and Prevention (CDC). It had a negative impact on multiple aspects of human life, physically, psychologically, economically, socially and culturally.

Our daily lives were suddenly changed, worst of all by the confinement, which caused society to feel frustrated as important aspects of their daily lives were limited.

A pandemic is the spread of an infectious disease of humans over a geographically large area, i.e. extending to many countries or attacking almost all individuals in a locality or region. The word comes from the Greek πανδημία, from παν (pan, all) and δῆμος (demos, people), an expression meaning a gathering of a whole people.

**COVID-19:** A highly contagious respiratory disease caused by the SARS-CoV-2 virus. This virus is transmitted from one person to another in droplets that are dispersed when the infected person coughs, sneezes or speaks.

**Confinement:** Confinement is the action and effect of confining. This verb refers to confining someone within boundaries or banishing them to a mandatory residence.

**Roles:** The role is the part or function that someone or something represents or performs, either willingly or by imposition. The word, as such, comes from the English role, which means 'role of an actor', and this in turn comes from the French rôle.

**Strategies:** Strategy is a procedure for decision-making and/or action in a given scenario. The aim is to achieve one or more previously defined objectives.

**Families:** A family is a group of people who have a degree of kinship and live together as such. The word family comes from the Latin famulus which means 'servant' or 'slave'. In fact, in ancient times the expression included the relatives and servants of the master's household.

**Teaching:** Example, action or event that serves as experience, teaching or warning how to act in similar cases.

### **Development of Sections and Paragraphs of the Article with subsequent numbering**

#### **Challenges generated by the pandemic**

The pandemic not only affected the country economically, but also socially and above all the basis of any society.

The family was affected in a direct and catastrophic way, but this is not all bad, it also brought with it many advantages for the understanding between parents and children, the roles that are lived in the day to day normality were modified taking other roles within the home, in the same way it brought with it advantages of good knowledge, due to the fact that many parents do not live much with their children, this helped to increase communication and to learn from each other.

In summary, it can be said that the advantages of this family-school alliance are:

1. Increased parenting skills. By constantly interacting in the educational process, parents have a better understanding of their children's development and therefore improve family dynamics.
2. More effective teaching. By involving parents, school administrators and teachers can carry out activities that lead to better quality education, this is mentioned in the article "Out-of-school education in times of pandemic by Covid 19. Experiences of students and parents".

On the other hand, we have what are the disadvantages that occurred within the home with the arrival of the pandemic some of these are:

1. The affectation of the parent-teacher relationship, leading to a certain degree of authority to teach, but not to exceed this power so as not to lead to opposition with the pupil.
2. The adaptation of parents not only to learn ICT as quickly as possible, but also the relationship of learning with their children. Before the pandemic, only teacher and student interacted, but in the situation of confinement, parents have had to take action if they want to support the educational process of their children.
3. Emotions such as control, self-awareness and self-regulation are some of the emotions which pupils and parents, under constant stress at home due to work, school, homework, etc., have not been able to manage in the right way.

Categories in which the family had changes in several areas, which are set out in the following points:

1. Responsible for upbringing. Where parents are in charge of the care and protection of children, also promoting the necessary conditions for their children to attend school.
2. Guardians or teachers. This category refers to the continuation and reinforcement of education at home. They play the role of supervisor and facilitator to complete homework, as well as the development of projects that help to more effectively implement knowledge.
3. School support agents. In this case, we are talking about the contributions made by parents to improve the conditions of the learning process, both financially and in terms of time, as well as the contribution of ideas and materials.

In conclusion, the greatest challenges presented by the pandemic were adapting to this new school modality and to the new changes presented at home. Adaptation is something that human beings do every day of their lives, but when we suffer adaptations to such sudden situations it generates a certain type of stress, fear and sometimes denial of the new changes, bringing with it difficulties in carrying out our daily activities and relating to our families as well as to other people.

**Impact on teachers and students**

The impact caused by the pandemic since 2019 has not only been socio-economic, but has also left damage to mental health, which has been compromised differently in each phase of the pandemic and it is therefore important to identify how it is affected at different stages of the pandemic process (WHO, 2020).

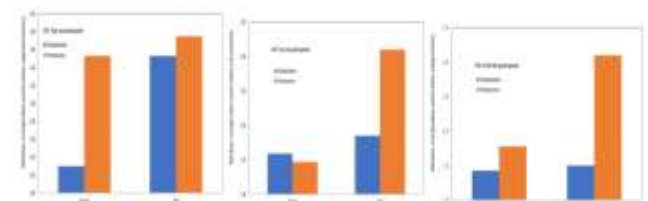
At the Ibero-American University in Mexico, ENCOVID19(2020) surveys were carried out and the results were as follows: 27% of respondents over the age of 18 reported depressive and severe anxiety symptoms. This allowed us to assume that the Covid-19 pandemic will affect the mental health of the population in Mexico in general. (Flores, 2021).

According to the article El impacto de la pandemia Covid-19 sobre profesores y estudiantes en escuelas de negocios en México (The impact of the Covid-19 pandemic on teachers and students in business schools in Mexico), a study was conducted in which the mental health of teachers and students was analysed due to the change from face-to-face classes to virtual classes. The variables and results obtained are presented in table 1, where the level of affectation is observed.

Inicio del curso (febrero 2020)							
Level of impairment	Total	%	Estudiantes	%	Profesores	%	p Value
Depression (PHQ-9)							
Normal	517	62.0	441	65.5	76	47.5	0.01<
Mild	246	29.5	190	28.2	57	35.1	
Moderate	44	5.2	28	4.1	16	10.0	
Severe	27	3.2	15	2.2	12	7.4	
Anxiety (GAD-7)							
Normal	452	54.3	376	55.8	77	47.8	0.01<
Mild	297	35.6	235	34.9	62	38.7	
Moderate	65	7.7	48	7.2	16	10.0	
Severe	20	2.4	14	2.1	6	3.5	
Insomnia (SIS)							
Normal	616	73.9	505	75.1	111	68.7	0.01<
Mild	139	16.6	104	15.4	35	21.8	
Moderate	64	7.6	51	7.6	13	7.8	
Severe	16	1.9	13	1.9	3	1.7	
Impact of the event (IES-R)							
Normal	731	87.7	589	87.5	142	88.5	0.05<
Mild	71	8.5	59	8.7	13	7.8	
Moderate	25	3.0	21	3.1	4	2.4	
Severe	7	0.8	5	0.7	2	1.3	
Burnout							
Normal	535	64.1	445	66.1	90	55.8	0.01<
Mild	194	23.2	151	22.4	43	26.8	
Moderate	87	10.4	68	10.1	19	11.6	
Severe	19	2.2	9	1.4	9	5.8	

**Table 1** Level of impairment in mental health variables by type of participant at the beginning of the course (n=834) (Flores, 2021)

With these results of the level of affectation, more precise results have also been obtained, such as the variables with the highest level, which can be seen in graph 1.



**Graph 1** Main variables with the highest level of affectation

The results of the study show that before the pandemic was declared, at the beginning of the academic year, in February 2020, the indicators of the variables associated with health were at normal levels, but once the pandemic was declared, these levels increased (Flores, 2021).

However, once the pandemic was declared, these levels increased (Flores, 2021). Furthermore, the article states that the group most resistant to mental health problems caused by the pandemic are students and the most affected are teachers.

Given this, the levels of cases with mental health problems are currently increasing, given that the confinement has not yet completely ended. Even today, the majority of schools in Mexico have returned to face-to-face classes, but, although they have returned, the levels of mental health problems are still present, given that there are students who have not yet become accustomed to the face-to-face modality, while for those who are still in the online modality, these problems can be presented at a higher level.

### **Impact on the rural and urban population**

The reality of COVID in rural and urban areas was different, we know that in urban areas the proximity to technology is daily, fast and simple, many of us are used to live with such devices in our homes as televisions, telephones, computers, among others; so the adaptation to the classes and the delivery of these were simple and not so complicated.

We know that a percentage of students living in rural areas do not have access to this type of technology, so the government looked for some alternatives to provide them with a means to continue their classes. Many areas of the country presented certain problems at the time of adaptation, especially because many of the students did not have at least a mobile phone, let alone a computer, to be able to carry out their school activities.

Adaptability in urban areas was also affected by the roles they played at home, as many parents worked practically all day and having to adapt and support their children generated certain conflicts and problems at home.

Teachers were obliged to dedicate more time and effort to teach their students, some of them risked their health in order to be able to continue teaching in person and to work longer hours.

One of the most popular strategies was teaching through television, where different subjects were taught at certain times, "in this sense, efforts were directed in different directions, highlighting the inequalities and inequity of educational conditions for both teachers and students" (Portillo, Samuel, Reynoso, Oscar, & Castellanos, Lidia 2020) as mentioned in the article EL INICIO DE UN NUEVO CICLO ESCOLAR EN MÉXICO ANTE EL COVID-19. COMPARATIVE BETWEEN RURAL AND URBAN CONTEXTS, this teaching option was not the best planned, closing activities unexpectedly and postponing the holiday period to reorganise the whole panorama for the next school cycle, thinking about all possible ways to teach all students and above all to think about all the conditions of each one of them. A big complaint in the first few months was the lack of accessibility of these means for many students to keep up with their studies.

This also affected the support from their families and the increase of problems at home, and because of this, it began to affect the school performance of each of the students, noticing that self-teaching was not the strongest, the decline of learning and the lack of interest of students to continue studying began to be noticed especially in the return to classes in person, many students have deficiencies in the different subjects to be treated within the school, leading to a much lower educational level than normal.

### **INEGI analysis**

As a result of the pandemic since March 2020, the National Education System has faced an unprecedented challenge, implementing distance learning classes in the face of temporary school closures, impacting school cycles in recent years.

INEGI provides information of interest to various sectors of society and through the Survey for the Measurement of the Impact of COVID-19 on Education (ECOVIED-ED), the impact of the temporary cancellation of face-to-face classes in the country's educational institutions is made known.

According to the Survey for Measuring the Impact of COVID-19 on Education (ECOVID-ED), schooling in different grades has been as follows in the 2019-2020 school year, graph 2.



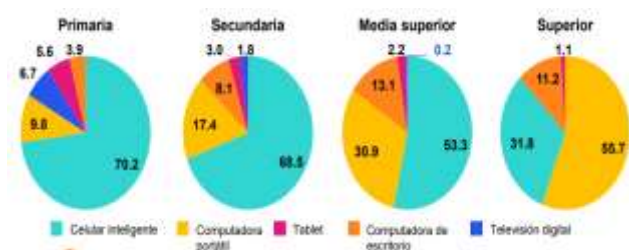
**Graph 2** Percentage of schooling 2019-2020

For the following cycle 2020-2021 the percentages of students decreased mainly due to lack of resources, work, among other problems, etc., as shown in graph 3.



**Graph 3** Percentage of students enrolled and not enrolled in the 2020-2021 cycle

Given this, the students who were enrolled in the different school grades used different means to do their homework and receive classes virtually, the devices they had are shown in graph 4.



**Graph 4** percentage of devices in place in the 2020-2021 school year

In spite of having the appropriate devices, education brought with it advantages and disadvantages of which the population gave their opinion and which are shown in the following graph 5 (Geografía, n. d.).



**Graphic 5** Advantages and disadvantages of e-learning

**The pandemic has affected or benefited the population differently**

Education as such has been affected as shown in the graphs above and the question is, will this continue, will there continue to be more school dropouts, the answer is yes, school dropouts will continue not only because of the pandemic but also for different reasons as mentioned above, to which we conclude that the pandemic is not the only cause of the problems in education.

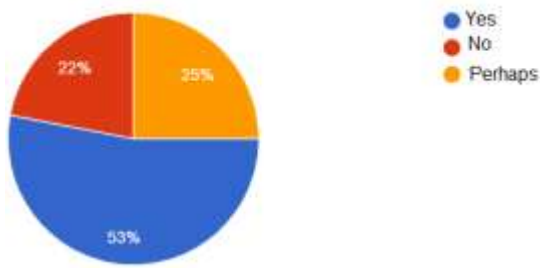
**Analysis of a certain population at the Universidad Politécnica de Juventino Rosas**

The quantitative analysis was carried out on a certain population of the Universidad Politécnica de Juventino Rosas, the samples collected were a total of 100 data of which are students from different careers of the university (Engineering in Networks and Telecommunications, Engineering in Plastics, Bachelor in Business Administration and Management and Engineering in Metallurgy).

The study that was carried out was a survey of 19 questions through which we asked about how the online classes have been, how their school performance has been and how they have kept in touch among other topics.

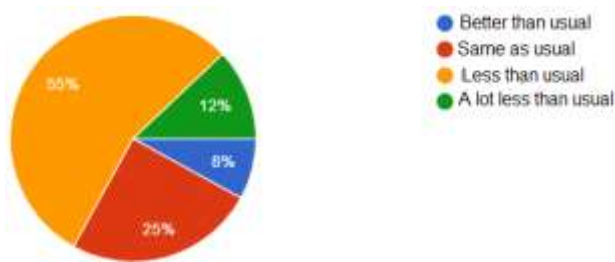
The first most important part of our questionnaire was to find out if the academic performance of the students has decreased. 53% of the students mentioned that their performance had decreased during the confinement, which is shown in graph 6.





**Graph 6** Percentage of students with poor academic performance

Concentrating in virtual classes was not easy for most of the students, even before the pandemic it was difficult to concentrate, so we also decided to ask whether it was possible for students to concentrate in the classes. We obtained 55% less than usual and 12% much less than usual to be able to concentrate as shown in graph 7.

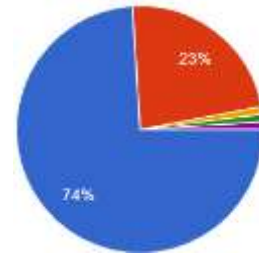


**Graph 7** Percentage of students' concentration in virtual classes

However, we also found that 25% of students have found it equally difficult to concentrate and 8% have found it easier to concentrate using this method.

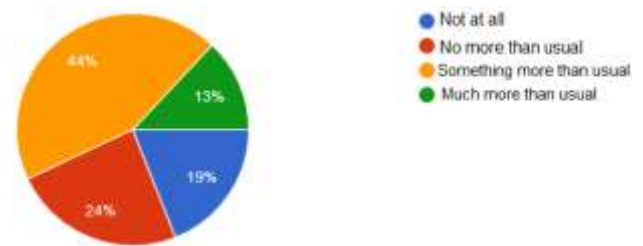
The students have not only decreased their performance and concentration, but it has also affected their mental health, with problems such as stress, anxiety, frustration, tension, etc. This is caused by constant homework, work, problems at home, difficulty in accessing classes or the media, being able to go out with friends or visit family, etc.

We decided to ask if the students had any of these types of health problems, to which 74% responded yes, as can be seen in graph 8.



**Graph 8** Percentage of students who present some kind of mental health problem

23% said that they did not have these problems, while the other 3% said that they had these problems depending on the situation. They were also asked if they felt tired or under stress, to which we obtained the following answers in graph 9.



**Graph 9** Percentages of students with tension and stress

We obtained high percentages of those who tell us that there are also mental health problems, personal or other types of problems, causing these ailments.

We asked what types of media they used and how they adapted to the new communication model, to which we obtained answers that all the students used and use their mobile phones to communicate, using social networks (Facebook, Instagram, Messenger, WhatsApp) and what made them feel better and helped them to overcome the confinement was spending time with their friends, going out to the parks, doing some activity that they enjoyed.

They also told us that it was difficult for their families to adapt in the same way to this new modality at the beginning of the pandemic, but today they are completely adapted and communication is better established.

Finally, the students told us what they miss about the online classes, to which we obtained responses such as:

- They were comfortable, as I avoided travel time and felt more comfortable at home.

- I had everything at hand, I didn't miss anything.
- I enjoyed my free time more without complications.

We also surveyed some of the university's lecturers about what online classes were like for them, to which they commented:

- They were a drastic change:
  - a. They were a drastic change, however they were not as efficient as face-to-face classes.
  - b. They were limited
  - c. They were enjoyable, with difficulties when students did not want to participate or attend the activities.

In the same way, some of them also had problems such as stress and tension, although they also told us that there were good things such as the economic savings, doing sport, the ease of travel to meetings, among others.

We have come to the conclusion that the pandemic and the virtual classes brought with them new challenges and problems, but also taught us to adapt and to know how to overcome each of them.

## Results

As results, we found that the educational level has been affected in different ways, not only because of the pandemic, but also because of school dropout due to different reasons such as; economic resources, personal problems, lack of interest, lack of support, etc.

Given this, we decided to carry out a quantitative analysis, in which 100 people from our school participated in the survey with the aim of analysing how virtual education has affected them and how they have adapted. By conducting the surveys, we obtained information and gave us a wide scope to obtain varied responses, with which we have realised that being in confinement has not only affected school performance, but also their concentration and affected their mental health, because most of the people who took the survey, say they have symptoms such as stress, frustration, overwhelm, among others.

We also understood that the way in which the students adapted to the confinement was to talk to their friends through social networks or to carry out some activity of interest.

## Conclusions

The pandemic that surprised us with covid-19 caused the way of life to change, bringing us to a sudden confinement, making our whole way of life take a radical change.

All this surprised us by adapting new roles at home, social roles were modified and social-motor skills began to diminish, especially for the youngest members of the household. The new adaptation of teaching made learning and understanding more expensive, many of the students, especially in rural areas, had very little access, as due to the fact that the classes were online they could not access many of their classes due to lack of resources (computers, mobile phones or televisions, etc.). Teachers were also affected by this situation, many of them doubled their hours of work and effort in order to teach all their students.

Another problem caused by the pandemic was mental health problems, as mentioned above, which have had a great impact on pupils and even led to them dropping out of school. The return to face-to-face classes has been slow and they have realised that the teaching in the previous cycle, which was virtual, did not produce many results.

With their classmates and teachers. One of the main properties of this pandemic disease, unlike other pandemics that occurred in previous years, is the monumental communication network available to us, which was undoubtedly key at several points and, in addition to social networks, allowed us to be informed almost in real time.

The challenge facing teachers in Mexico is very great, to reinforce learning and continue to make progress with respect to the year they are studying will be a problem to which they will have to find an optimal solution in order to continue making progress with the students on a daily basis.



**References**

Flores, C. G. C. (2021, 31 marzo). Impacto de la pandemia Covid-19 sobre profesores y estudiantes en escuelas de negocios en México | Revista del Centro de Investigación de la Universidad la Salle. Recuperado 2 de octubre de 2022, de <https://revistasinvestigacion.lasalle.mx/index.php/recein/article/view/2773>

Geografía, E. D. N. I. Y. (s. f.). Encuesta para la Medición del Impacto COVID-19 en la Educación (ECOVID-ED) 2020. Recuperado 2 de octubre de 2022, de <https://www.inegi.org.mx/investigacion/ecovided/2020/>

Moo, D. L. B. D. (2020, 1 septiembre). Plataformas de medios sociales y uso dado por estudiantes indígenas durante el confinamiento por la pandemia COVID-19 | Dzib Moo | Revista Metropolitana de Ciencias Aplicadas. Recuperado 2 de octubre de 2022, de <http://remca.umet.edu.ec/index.php/REMCA/article/view/336/358>

Portillo Peñuelas, Samuel Alejandro, Reynoso González, Oscar Ulises, & Castellanos Pierra, Lidia Isabel. (2020). El inicio de un nuevo ciclo escolar en México ante el Covid-19. Comparativo entre contextos rural y urbano. *Conrado*, 16(77), 218-228. Epub 02 de diciembre de 2020. Recuperado en 02 de octubre de 2022, de [http://scielo.sld.cu/scielo.php?script=sci\\_arttext&pid=S1990-86442020000600218&lng=es&tlng=es](http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1990-86442020000600218&lng=es&tlng=es)

Schmelkes, S. (2020b, noviembre 13). La educación superior ante la pandemia de la Covid-19: el caso de México | Universidades. Recuperado 2 de octubre de 2022, de <http://udualerreu.org/index.php/universidades/article/view/407>

## Electrical system simulation of an aircraft through ANSYS Electronics Desktop

### Simulación del sistema eléctrico de una aeronave a través de ANSYS Electronics Desktop

REGALADO-RANGEL, Karina†\*, GASTELLUM-MICHEL, Filiberto, TORRES-RIVERA, Moisés and TRASLOSHEROS-MICHEL, Alberto

*Universidad Aeronáutica en Querétaro*

ID 1<sup>st</sup> Author: *Karina, Regalado-Rangel* / ORC ID: 0000-0002-4497-665X

ID 1<sup>st</sup> Co-author: *Filiberto, Gastellum-Michel* / ORC ID: 0000-0001-7578-0257

ID 2<sup>nd</sup> Co-author: *Moisés, Torres-Rivera* / ORC ID: 0000-0001-6668-2903, CVU CONACYT ID: 634138

ID 3<sup>rd</sup> Co-author: *Alberto, Traslosheros-Michel* / ORC ID: 0000-0002-9857-7777, CVU CONACYT ID: 103311

DOI: 10.35429/JOES.2022.26.9.26.35

Received 09 March, 2022; Accepted 28 June, 2022

#### Abstract

More Electric Aircraft is a new technology that allows the aeronautical sector to innovate in the electrical part when it comes to implementing it, that is, it consists of replacing part of the current pneumatic, hydraulic and mechanical systems that make up an aircraft, with electrical systems, for this reason, the main purpose is to design and develop a simulation model in ANSYS Electronics Desktop of the Boeing 777 architecture to analyze all the parameters such as: the voltage, current and power of each subsystem, so for the development, they are simulated one by one and later, they are joined based on the electrical diagram of the aircraft in order to be able to test them in normal and abnormal conditions, and make the comparison of when they are simulated individually, in this way, it creates an impact when rebuilding the electrical system, generating advantages that benefit those companies in this sector for the contribution of their innovations.

**Power Electronics, Aircraft, Simulation**

#### Resumen

More Electric Aircraft es una nueva tecnología que permite al sector aeronáutico innovar la parte eléctrica cuando esta se implementa, es decir, esta consiste en reemplazar parte de los sistemas neumáticos, hidráulicos y mecánicos actuales que conforman una aeronave, por sistemas eléctricos, por ello es que el propósito principal es diseñar y desarrollar un modelo de simulación en ANSYS Electronics Desktop de la arquitectura del Boeing 777 para analizar todos los parámetros como: el voltaje, corriente y potencia de cada subsistema, por lo que para el desarrollo, se simula uno por uno y posteriormente, se unen con base en el diagrama eléctrico de la aeronave con el fin de poder probarlos en condiciones normales y anormales, y realizar la comparación de cuando se simulan de manera individual, por lo que crea un impacto al reconstruir el sistema eléctrico, generando ventajas que beneficia a aquellas empresas de este sector para la contribución de sus innovaciones.

**Electrónica De Potencia, Aeronaves, Simulación**

**Citation:** REGALADO-RANGEL, Karina, GASTELLUM-MICHEL, Filiberto, TORRES-RIVERA, Moisés and TRASLOSHEROS-MICHEL, Alberto. Electrical system simulation of an aircraft through ANSYS Electronics Desktop. Journal of Experimental Systems. 2022. 9-26: 26-35

\*Correspondence to Author (e-mail: 5689@soyunaq.mx)

†Researcher contributing as first Author.

## Introduction

The aeronautical industry and the development of simulations have been evolving over time, because those platforms that serve as a tool to perform simulations, help to have a better overview of specific tests which benefits a large number of users, as this allows them to modify the simulation as many times as necessary and at the same time check results to achieve the desired goal, and avoid costs when it is done in a physical way.

On the other hand, since the beginning of aircraft development, general problems have been solved and the electrical system has been innovated: in question of the generators, at the beginning there were direct current generators, and provided on average 250 W at 6 V or 500 W at 12 V by the year 1936, and later, in the year 1950, this was able to provide 1 kW at 28 V and soon after it was possible to obtain a power of 18 kW, however, this power level had limitations at significant heights so that several generators of this type had to be connected in parallel causing converters and bulky batteries, and the properties of the insulators were not sufficient, which is why they began to implement alternating current generators in order to solve those drawbacks of direct current generators.

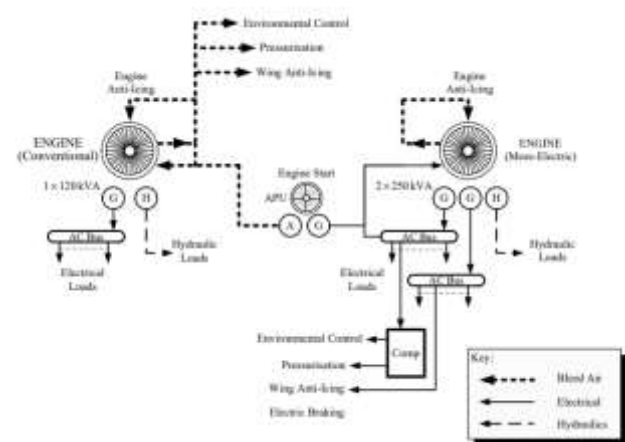
This type of generators have advantages such as being able to provide higher power levels and are lightweight by reducing the number of cables by having a voltage of 120 VAC, and the voltage change can be done more easily thanks to the use of transformers, despite this, it has disadvantages such as its frequency instability so additional units are needed to control it as is the Constant Speed Driver or hydromechanical systems that have evolved over time, and this is where More Electric Aircraft (MEA) enters (Arabul, *et al.*, 2021).

MEA is a technology focused on power generation, i.e., its conversion and distribution. MEA does this by eliminating part of the pneumatic, hydraulic and mechanical systems by electrical systems, i.e., when part of the pneumatic system is eliminated, it has an engine without bleeding.

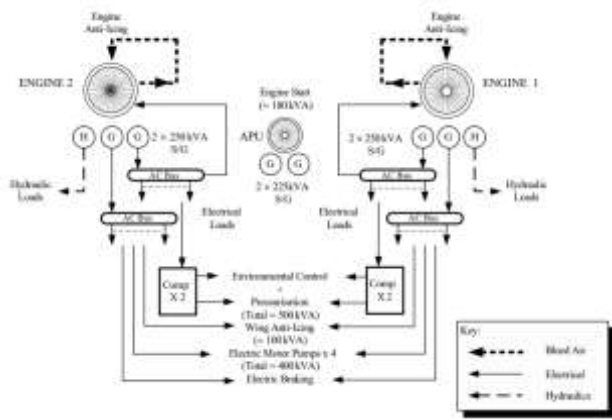
So that in this way fuel consumption is reduced, when talking about the other two mechanical and hydraulic systems, they reduce installation and operating costs as they are less complex systems, so that in general, there are advantages such as: having a simple monitoring of the components and less time for maintenance, prediction of the useful life of the aircraft, advanced prognostics and diagnostics, as well as an important feature which is the reduction of air pollution.

Now, making relevance to one of the main features is that, in this, the use of relays or contactors are replaced by MOSFET or IGBT type transistors for load control, either in DC or AC which impacts on power generation, which is why the electrical system of the Boeing 777 is simulated which compared to the Boeing 787, This is done with the purpose of being able to analyze its parameters and from this, begin to make modifications for the innovation of this aircraft, and in turn, this simulation serves as a basis for any other type of commercial aircraft.

Next, an example of the difference between a conventional aircraft and an aircraft with MEA is presented, in Figure 1, it can be seen that several functions are carried out thanks to the air bleed, compared to Figure 2, these functions are replaced to do it electrically, leaving only the anti-icing system that performs the pneumatic system with the air bleed.



**Figure 1** Electrical system of a conventional aircraft (Moir & Seabridge, 2011)



**Figure 2** Boeing 787 aircraft electrical system with MEA (Moir & Seabridge, 2011)

Through this pair of examples, it can be seen that thanks to MEA technology, it is possible to replace part of the pneumatic systems that generate the air bleed, and hydraulic systems, by electrical form, in order to modify the architecture of the complete system of the aircraft and obtain benefits such as having more power thanks to the generators (Wheeler & Bozhko, 2014).

All the changes observed were achieved with an extensive study, simulation and testing of the same, and this is where the importance of the simulation of the aircraft systems comes in (Faruque, 2015) (Zhangang, Junchao, Yingchuan, & Xudong, 2015), since in this way, allows you to perform different types of tests according to the needs you have, and in this case, by doing it through ANSYS Electronics Desktop, all its results are validated by the Federal Aviation Administration (FAA), therefore, those tests that are performed, may be implemented in real applications.

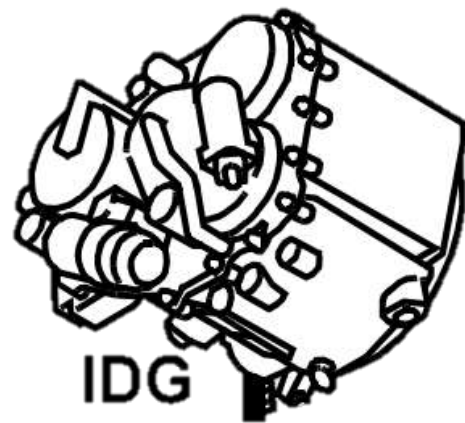
The following sections are presented in this article, in which, first is a brief theory about each of the subsystems that are simulated, then, the simulation of them, and finally, the simulation of the complete electrical system and its results respectively.

## Aircraft electrical subsystems

### Integrated Drive Generator

It is one of the main sources that make up the electrical system of the aircraft, they work under normal conditions and there is one on each side, that is, on the left side and on the right side.

The architecture of this consists of four main parts, which are: *the turbine*, which generates mechanical power and this is extracted through a shaft which is then distributed in a gearbox, which is responsible for converting this mechanical power into variable speed, so that it then enters the *Constant Speed Driver* and converts this variable speed by constant speed to generate the rpm necessary to obtain the 400 Hz and thus the *generator* with the help of the *General Control Unit* can turn on and feed the corresponding subsystems.



**Figure 3** Integrated Drive Generator

### Transformer Rectifier Unit

It is considered as the main converter of the electrical system, since it converts from alternating current (AC) to direct current (DC), that is, this unit consists of a three-phase transformer with star-delta arrangement, which receives 115 VAC and after the transformer acting as a step-down type, enters a three-phase bridge rectifier to obtain at the output a voltage of 28 VDC with the help of capacitors and resistors that act as a filter and current control.

### Main Battery

As is known, a battery is one that is capable of converting chemical energy into electrical energy, and in an electrical system, it is one of the secondary sources. In general, within the aeronautical sector there are three types of batteries: nickel-cadmium, lithium-ion and lead-acid, each with different characteristics, however, in the Boeing 777 the nickel-cadmium type is used, due to the advantages it has over the others, for example, that it maintains a constant voltage when discharged at high current levels, and also has a balanced ratio between capacity and weight.

They are usually found near the busbars in special trays to avoid the use of long cables and if at any time there is a leakage of any chemical, they remain in the trays and do not affect other components. Regarding its functions, the battery helps to supply power in the short term when the IDG or the Auxiliary Power Unit are not available, likewise, in emergency conditions, it supplies power to the flight instruments essential for maneuvering the aircraft, radio communication equipment, etc.



Figure 4 Representation of an aircraft battery

### Main Battery Charger

Due to the limited capacity of the battery, there is a charger designed for it, so that, depending on the battery conditions used, the charger will be able to control the battery contactors for connecting and disconnecting the busbars during charging and discharging. This charger is 24 V, 15 kVA and has a power factor of 0.95.

### Flight Control Direct Current

It refers to the flight instruments that are responsible for maneuvering the aircraft, so it is a subsystem that needs redundancy in its power supply, so it can be fed from the CD transfer bar, the battery or the output of the Permanent Magnet Generator.

### Subsystem Simulations in ANSYS Electronics Desktop

#### Integrated Drive Generator

The simulation is presented below, where the output is 115 VAC and a current of approximately 900 A.

This simulation consists of the 4 stages previously mentioned, the turbine, where after it is the gearbox that enters directly to the Constant Speed Driver, and then the generator, which as seen, is connected to a unit (GCU), which is essential, since it serves as voltage, frequency and current control, as well as protection for the generator, and finally, there are three electrical resistors, for the three-phase output of this generator.

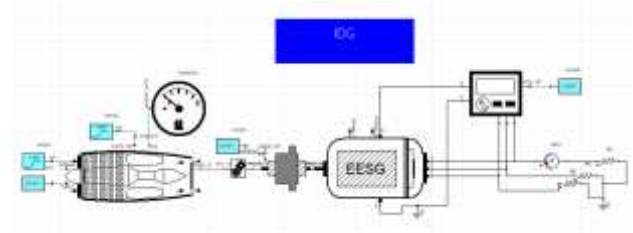


Figure 5 GDI simulation

#### Transformer Rectifier Unit

For this part, at the input we receive 115 VAC three-phase through the transformer, which as mentioned above, will act as a step-down with star-delta arrangement and as can be seen, then we have the bridge rectifier to obtain direct current of approximately between 250 and 300 A with 28 V.

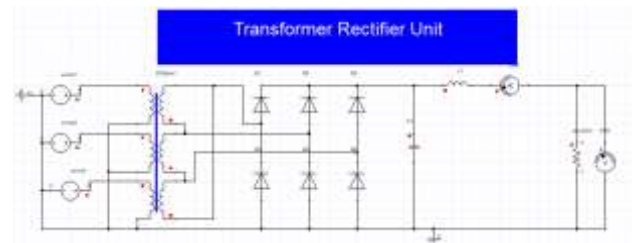


Figure 6 TRU simulation

#### Main Battery/ Main Battery Charger

The main battery and its charger are simulated as follows, i.e., with the help of a switch, it can be decided whether the battery is powered or charged through the switch. For the battery part, it consists of two parts, which is the battery with a current source that the battery will be able to supply, and for the charger part it consists of two parts, the three-phase step-down transformer and the three-phase bridge rectifier, in order to obtain direct current and thus can charge the battery.

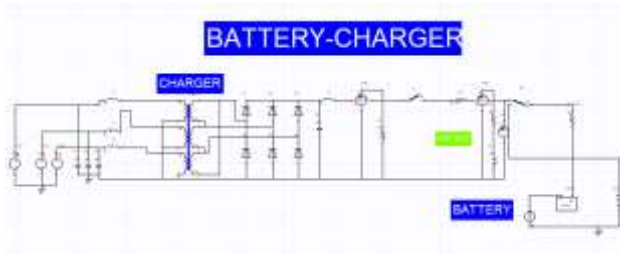


Figure 7 Simulación de Main Battery/ Main Battery Charger

**Flight Control Direct Current**

Being the representative subsystem for the flight controls, i.e. those that manage the control surfaces, this is simulated by means of resistors, however, as mentioned before, it is a subsystem that needs redundancy, so it will have three possible power supplies available.

**Simulations of the complete electrical system**

**Power flow diagram**

In order to make the connection between each subsystem, it was based on the following diagram obtained from Boeing 777 Electrical System: *Wings of America Training Center Training Manual*, in which you can see the power flow on both sides, in order to identify in which part is the AC power and DC, and thus, the analysis can be performed under normal conditions, ie, when the system is operating normally.

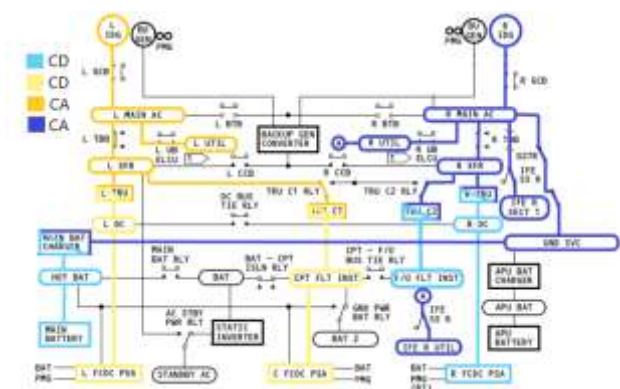


Figure 8 Power flow diagram of the Boeing 777 electrical system

From the above, we proceed to join each subsystem in order to subsequently obtain the results and compare them when the subsystem works individually.

**Left Side**

Based on the previous diagram, the subsystems corresponding to the left side are joined and the corresponding connections are made to the busbars shown in the diagram.

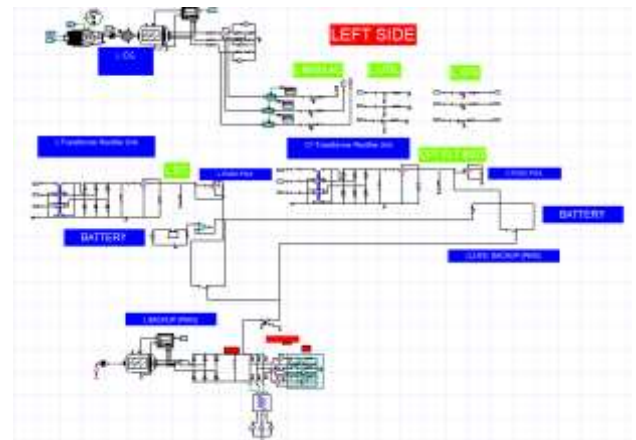


Figure 9 Simulation corresponding to the left side of the electrical system

It starts from its main source, which is the IDG, and from there, the left AC main bus is connected so that, from it, power can be supplied to the other buses and to both TRUs so that they can perform their function properly.

**Right Side**

For the case of the right side, the same thing happens, in which the subsystems are joined and the busbars are added along with switches to be able to control the current flow in them, again starting from the IDG power supply that goes to the right AC main busbar and thus, through labels, connections can be made between each bus and each subsystem to be able to feed them.

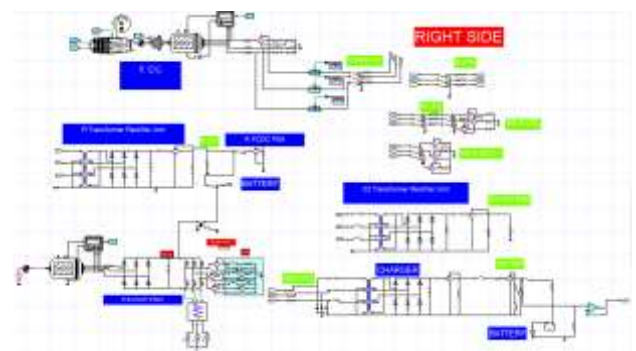


Figure 10 Simulation corresponding to the right side of the electrical system

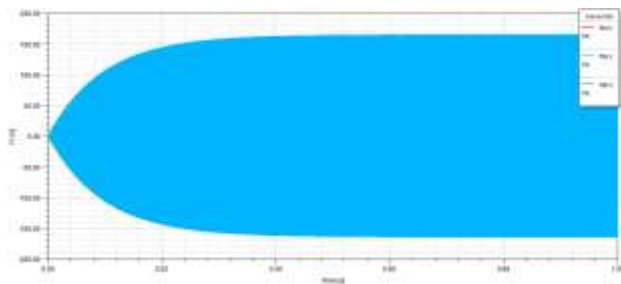


**Simulation results by subsystems**

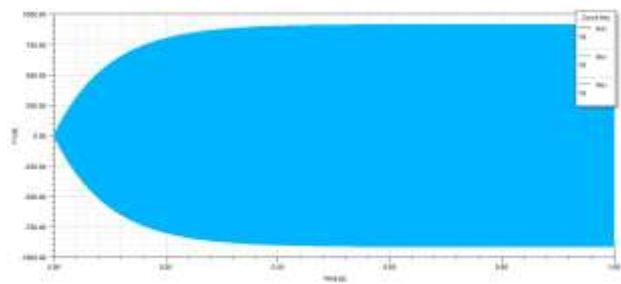
For this section, the most representative graphs of each subsystem are presented with the purpose of verifying that the parameters mentioned in the Subsystems section correspond with the output of each one of them already in simulation, that is to say that they have the same behavior both individually and as a whole.

**Integrated Drive Generator**

For this subsystem, in the following Figures, it can be seen that the voltage is 162.63 V which corresponds to 115 VRMS with a current of approximately 900 A.



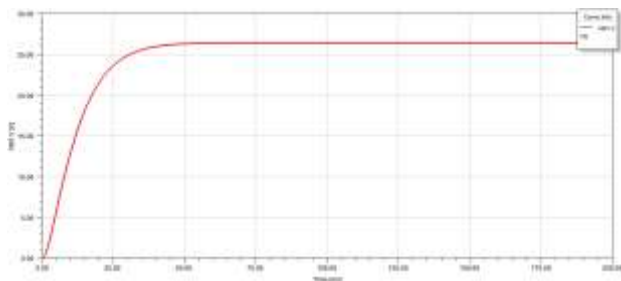
**Figure 11** IDG voltage output during a simulation period of 1 second



**Figure 12** IDG current output during a simulation period of 1 second

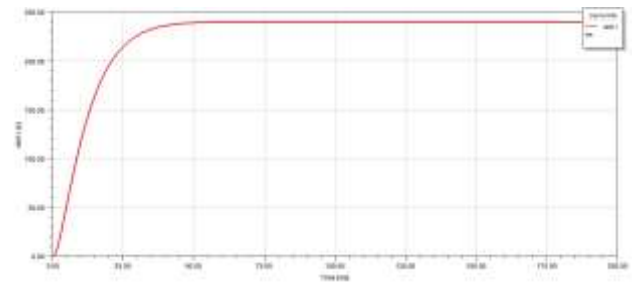
**Transformer Rectifier Unit**

The voltage output of this subsystem is 28 V as can be seen and remains constant.



**Figure 13** TRU voltage output

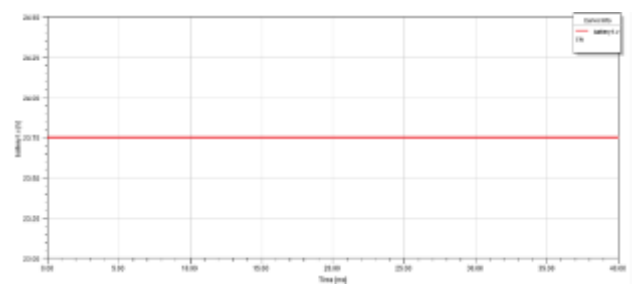
For the current case, it is very close to 250 A, so it falls within the current range mentioned above.



**Figure 14** Current output of the TRU

**Main Battery**

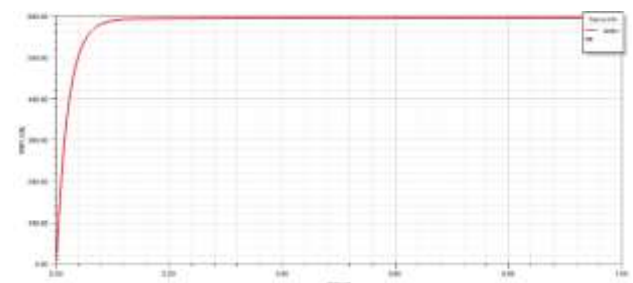
For the battery case, it is 23.75 V with 25 A current.



**Figure 15** Battery voltage output

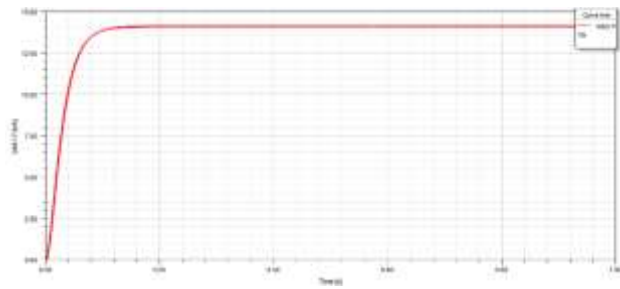
**Main Battery Charger**

In this section we have 24 V output with a current of 600 A as shown in the following result.



**Figure 16** Battery charger current output

Having a voltage of 24 V and a current as mentioned, the power is approximately 14.25 kW considering the power factor of 0.95.



**Figure 17** Resulting power output from the battery charger

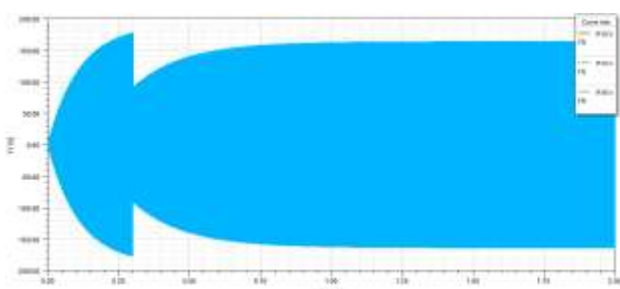
**Simulation results of the complete electrical system**

After the above, the results are divided into two sides, and each side is presented below.

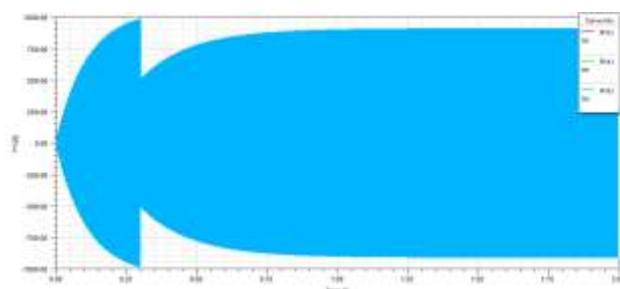
**Left Side**

**Integrated Drive Generator**

As can be seen, the voltage is the same as when simulated by itself, however, in the complete simulation, a block is used to control the time in which the breaker closes, that is why in both voltage and current graphs can be seen that after 300 ms, the breaker closes, and creates that drop, and from that, it begins to stabilize after feeding the corresponding subsystems on this side. It is worth mentioning that the same thing happens for the right side. The voltage is 162.63 V and the current is 900 A.



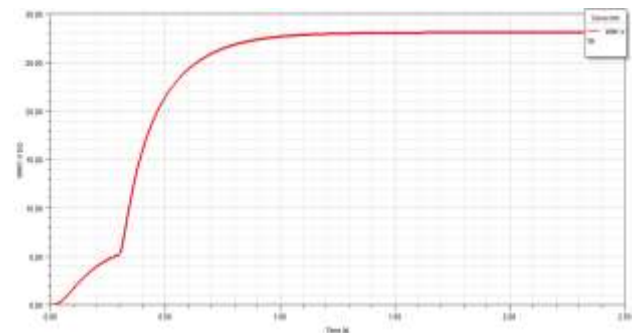
**Figure 18** IDG voltage output during a simulation period of 2 seconds



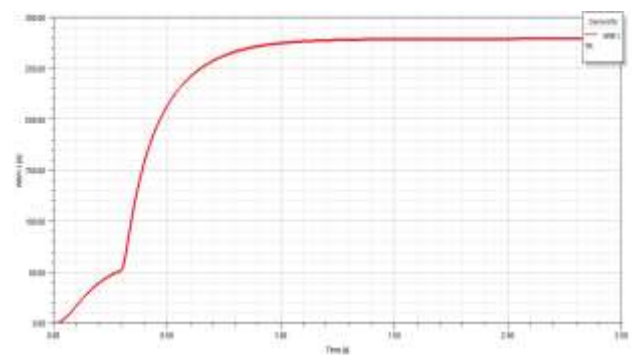
**Figure 19** IDG current output during a simulation period of 2 seconds

**Transformer Rectifier Unit**

Because its main source starts feeding after 0.3 seconds, the TRU outputs are affected by this and as can be seen, after that time, it starts to simulate until it stabilizes after the second, the voltage is still 28 V and a current of approximately 280 A.



**Figure 20** Left side TRU voltage output

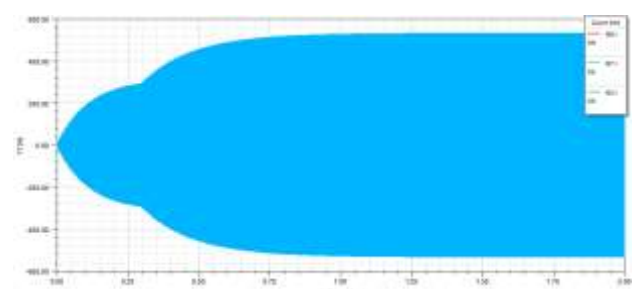


**Figure 21** Left side TRU current output

**Bars**

As seen in the simulation development section, the bars are represented by electrical resistors, and the resulting values will depend on the value of these resistors. For this side, we have: the main AC busbar, the utility busbar, the DC busbar and the Capitan Flight Instrument busbar.

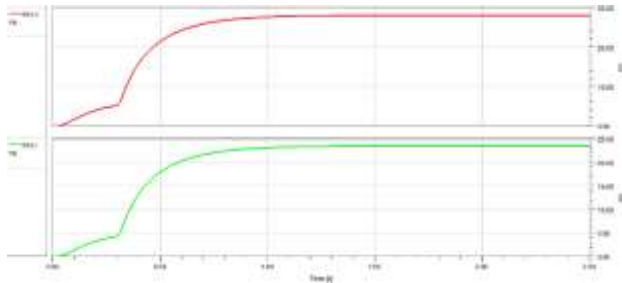
The main AC bus and the utility bus are three-phase AC bus, where their voltage goes into the range of 160 VAC with a current of 520 A.



**Figure 22** Utility bus current output



The DC bar and the Capitan Flight Instrument bar, are direct current, each will have a voltage of 28 V with current of 28 A when given a unit value to the resistor.



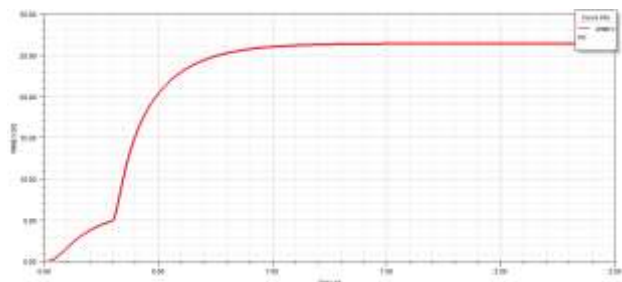
**Figure 23** DC bus voltage and current

**Flight Control Direct Current (FCDC)**

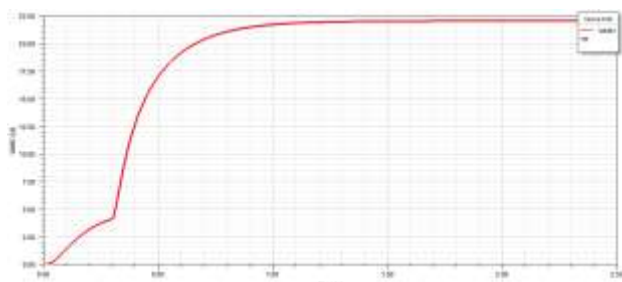
In this section, the output of the electrical resistor representing this subsystem with the three power supplies is going to be presented.

**DC Bus**

First, we have the corresponding output when the DC bus is feeding this subsystem.



**Figure 24** Resulting voltage of FCDC when the DC bus supplies it

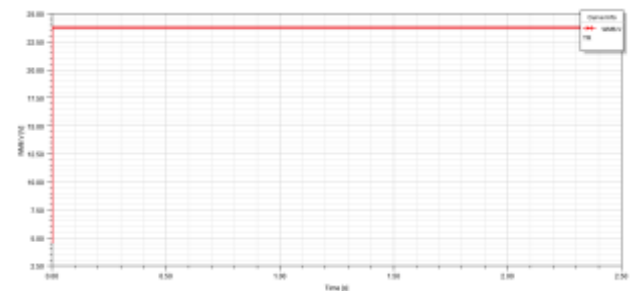


**Figure 25** Resulting current of FCDC when the DC bus is feeding it

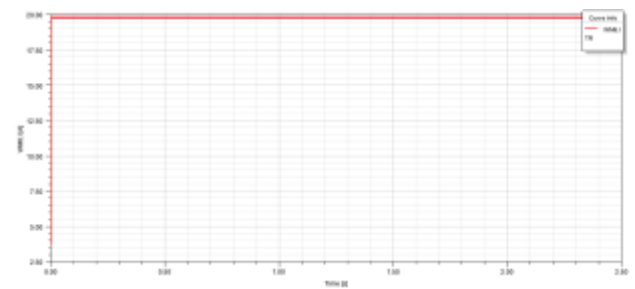
As can be seen, the voltage is approximately 26.5V with a current of 22.5A.

**Battery**

For the case when the battery feeds it, if compared with the previous graph, the response to the power supply is direct, with a voltage of 23.75 V and a current of 20 A.



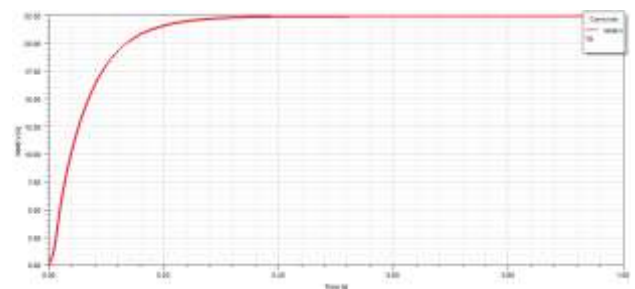
**Figure 26** Resulting voltage of FCDC when powered from the battery



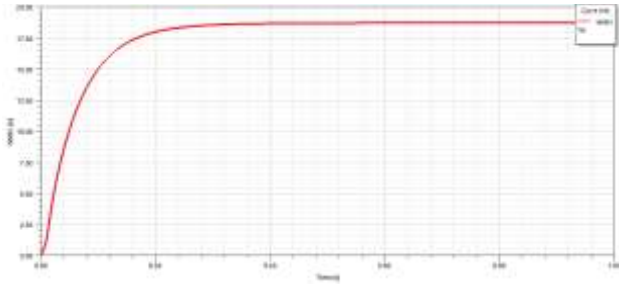
**Figure 27** Resulting FCDC current when supplied from the battery

**PMG**

And finally, when fed from the Permanent Magnet Generator, the voltage is 22.5 V and a current of 18.75 A, and the response also depends on the PMG obtained from the Backup Generator Converter, which is a subsystem that works under abnormal conditions such as emergency, which is capable of feeding either side, however, only the part of the TRU along with the transfer bar and the FCDC delivering a power of 25 kVA with a voltage of 115 VAC three-phase.



**Figure 28** Resulting FCDC voltage when fed through the PMG



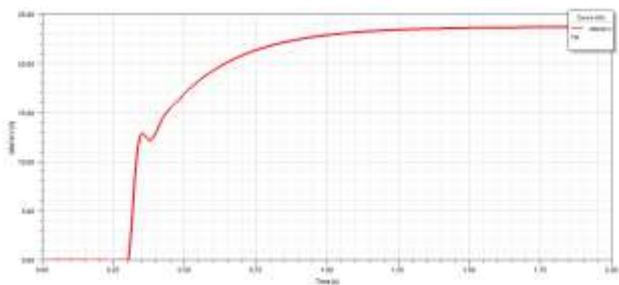
**Figure 29** Resulting FCDC current when fed through the PMG

**Right side**

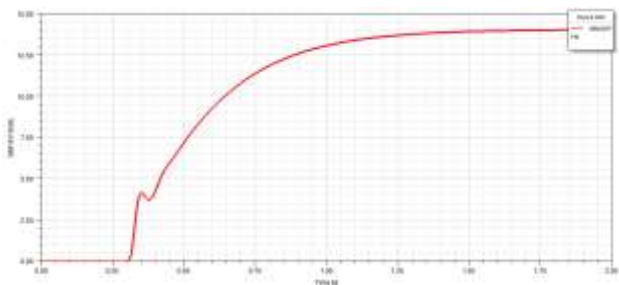
For this side, the results for the Transformer Rectifier Unit are exactly the same as mentioned above, as well as for the Integrated Drive Generator.

**Main Battery / Main Battery Charger**

The output of the battery is 23.75 V and the graphs corresponding to the charger are shown below, where, in the same way, after it starts feeding, it stabilizes with a voltage of 24 V and 14.25 kW of power.



**Figure 30** Resulting voltage of the charger

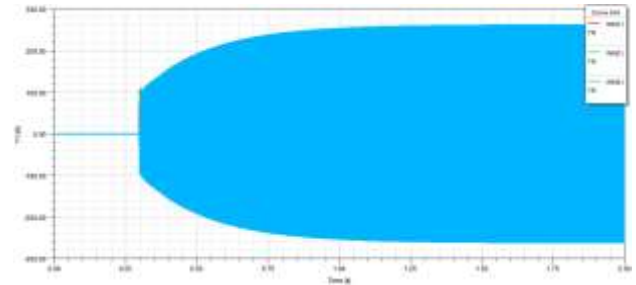


**Figure 31** Resulting power of the charger

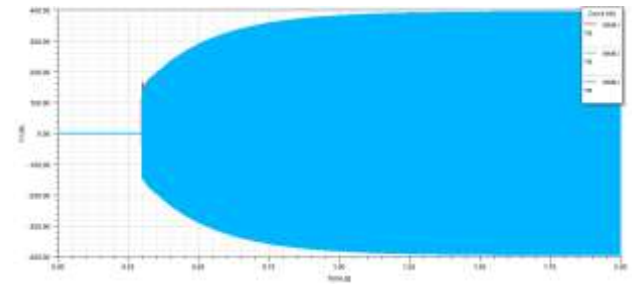
**Bars**

On this side, the following busbars are present: the right AC main bus, In Flight Entertainment utility bus and utility bus, IFE SECT 1 bus, as well as the GND SVC ground service bus, the First Official Flight Instrument bus and the right CD bus.

Both the main right AC bus, as well as the utility bus, IFE utility, IFE SECT 1 bus and GND SVC are three-phase alternating current, where the voltage is 162.63 V and the current depends on their values given to the electrical resistors, and ranges between 300 to 400 A.

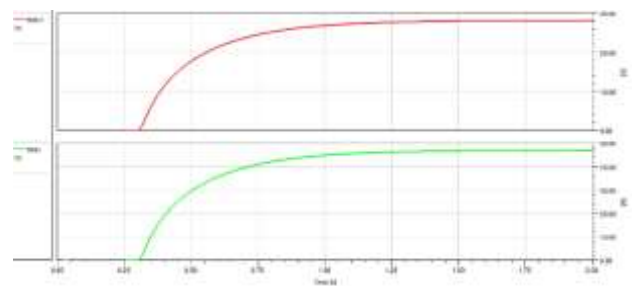


**Figure 32** Resulting current of the IFE utility bus



**Figure 33** Resulting current of the IFE SECT 1 bus

In the case of the right CD bar and First Official Flight Instrument, they are direct current, with a voltage of 28 V and 28 A.



**Figure 34** Voltage and current of the right CD busbar

**Flight Control Direct Current**

On this side, the same happens as on the left side, we have the three possible power supplies, so the results obtained during the simulation for this section are presented below.

Power supplies	Voltage	Corriente
CD Bar	26 V	52 A
Battery	23.75 V	47.5 A
PMG	20 V	40 A

**Table 1** FCDC output voltage and current results according to its power supply

**Acknowledgements**

The development of the present simulation was developed in ANSYS Electronics Desktop thanks to the license provided by ESSS Engineering Simulation and Scientific Software (ESSS) for the Aeronautical University in Queretaro.

**Conclusions**

As it could be observed in the results area, it was proved that the subsystems work properly when tested both individually and when joined according to the power flow diagram, and therefore, the results between them are very similar, so it is proved that the simulation works, as it was for the TRU case, and for the case of the IDG, each one, was able to feed its corresponding side, that is to say, contemplating the part of the loads and of what each one of the subsystems consumed, noticing that the right side consumes more than the left one, due to the part that has other busbars, as well as the charger and its corresponding battery.

On the other hand, the values of the busbars can be modified, and the more realistic their values are, the more accurate the results will be to a real aircraft. The present one has switches to control the power supply according to the diagram, and these could be implemented with control so that the change of open and closed is no longer manual and can be changed even when the simulation is running.

The results obtained, help to make a power analysis in each subsystem in order to later implement improvements in its power factor with appropriate circuits.

**References**

Arabul, A., Keskin Arabul, F., Kurt, E., Senol, İ., Schrötter, M., Bréda, R., & Megyesi, D. (2021). Perspectives and development of electrical systems in more electric aircraft. *International Journal of Aerospace Engineering*, 14. doi:10.1155/2021/5519842

Faruque, O. et al (2015). Real-Time Simulation Technologies for Power Systems Design, Testing, and Analysis. *IEEE Power and Energy Technology Systems Journal*, 2(2), 63-73. doi:10.1109/JPETS.2015.2427370

Moir, I., & Seabridge, A. (2011). *Aircraft Systems: Mechanical, electrical, and avionics subsystems integration*. John Wiley & Sons.

Wheeler, P., & Bozhko, S. (2014). The More Electric Aircraft: Technology and challenges. *IEEE Electrification Magazine*, 2(4), 6-12. doi:10.1109/MELE.2014.2360720

Zhangang, Y., Junchao, Q., Yingchuan, M., & Xudong, S. (2015). Modeling and Simulation of Power Distribution System in More Electric Aircraft. *Journal of Electrical and Computer Engineering*, 64. doi:10.1155/2015/847624

# Instructions for Scientific, Technological and Innovation Publication

---

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

Surname (IN UPPERCASE), Name 1<sup>st</sup> Author†\*, Surname (IN UPPERCASE), Name 1<sup>st</sup> Coauthor, Surname (IN UPPERCASE), Name 2<sup>nd</sup> Coauthor and Surname (IN UPPERCASE), Name 3<sup>rd</sup> Coauthor

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

International Identification of Science - Technology and Innovation

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

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

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

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

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

---

**Abstract (In English, 150-200 words)**

Objectives  
Methodology  
Contribution

**Keywords (In English)**

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

**Abstract (In Spanish, 150-200 words)**

Objectives  
Methodology  
Contribution

**Keywords (In Spanish)**

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

---

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

---

---

\* Correspondence to Author (example@example.org)

† Researcher contributing as first author.

## Introduction

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

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

What is your added value with respect to other techniques?

Clearly focus each of its features

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

Explanation of sections Article.

## Development of headings and subheadings of the article with subsequent numbers

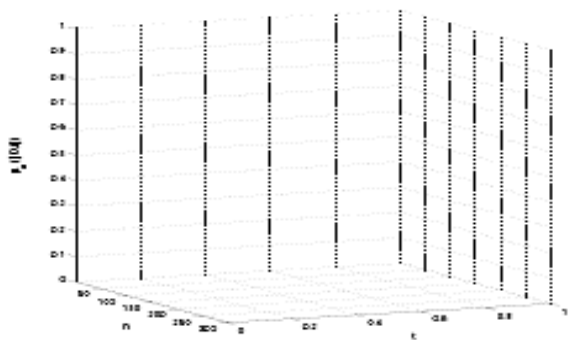
[Title No.12 in Times New Roman, single spaced and bold]

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

## Including graphs, figures and tables-Editable

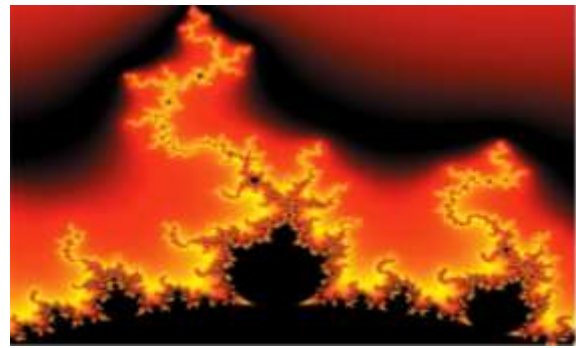
In the article content any graphic, table and figure should be editable formats that can change size, type and number of letter, for the purposes of edition, these must be high quality, not pixelated and should be noticeable even reducing image scale.

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



**Graphic 1** Title and *Source (in italics)*

Should not be images-everything must be editable.



**Figure 1** Title and *Source (in italics)*

Should not be images-everything must be editable.


**Table 1** Title and *Source (in italics)*

Should not be images-everything must be editable.

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

## For the use of equations, noted as follows:

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

Must be editable and number aligned on the right side.

## Methodology

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

## Results

The results shall be by section of the article.

## Annexes

Tables and adequate sources

## Thanks

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

## Conclusions

Explain clearly the results and possibilities of improvement.

# Instructions for Scientific, Technological and Innovation Publication

---

## References

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

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

## Technical Specifications

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

Journal Name

Article title

Abstract

Keywords

Article sections, for example:

*1. Introduction*

*2. Description of the method*

*3. Analysis from the regression demand curve*

*4. Results*

*5. Thanks*

*6. Conclusions*

*7. References*

Author Name (s)

Email Correspondence to Author

References

## Intellectual Property Requirements for editing:

-Authentic Signature in Color of Originality Format Author and Coauthors

-Authentic Signature in Color of the Acceptance Format of Author and Coauthors

-Authentic Signature in Color of the Conflict of Interest Format of Author and Co-authors.

## **Reservation to Editorial Policy**

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

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

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

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

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

Article title:

- The sending of an Article to Journal of Experimental Systems emanates the commitment of the author not to submit it simultaneously to the consideration of other series publications for it must complement the Format of Originality for its Article, unless it is rejected by the Arbitration Committee, it may be withdrawn.
- None of the data presented in this article has been plagiarized or invented. The original data are clearly distinguished from those already published. And it is known of the test in PLAGSCAN if a level of plagiarism is detected Positive will not proceed to arbitrate.
- References are cited on which the information contained in the Article is based, as well as theories and data from other previously published Articles.
- The authors sign the Format of Authorization for their Article to be disseminated by means that ECORFAN-Mexico, S.C. In its Holding Bolivia considers pertinent for disclosure and diffusion of its Article its Rights of Work.
- Consent has been obtained from those who have contributed unpublished data obtained through verbal or written communication, and such communication and Authorship are adequately identified.
- The Author and Co-Authors who sign this work have participated in its planning, design and execution, as well as in the interpretation of the results. They also critically reviewed the paper, approved its final version and agreed with its publication.
- No signature responsible for the work has been omitted and the criteria of Scientific Authorization are satisfied.
- The results of this Article have been interpreted objectively. Any results contrary to the point of view of those who sign are exposed and discussed in the Article.



## Copyright and Access

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

Article Title:

Name and Surnames of the Contact Author and the Coauthors	Signature
1.	
2.	
3.	
4.	

## Principles of Ethics and Declaration of Solution to Editorial Conflicts

### Editor Responsibilities

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

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

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

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

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

### Responsibilities of the Editorial Board

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

### Responsibilities of the Arbitration Committee

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

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

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

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

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

## **Responsibilities of the Authors**

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

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

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

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

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

## **Information services**

### **Indexation - Bases and Repositories**

RESEARCH GATE (Germany)

GOOGLE SCHOLAR (Citation indices-Google)

REDIB (Ibero-American Network of Innovation and Scientific Knowledge- CSIC)

MENDELEY (Bibliographic References Manager)

DULCINEA (Spanish scientific journals)

UNIVERSIA (University Library-Madrid)

SHERPA (University of Nottingham - England)

### **Publishing Services**

Citation and Index Identification H

Management of Originality Format and Authorization

Testing Article with PLAGSCAN

Article Evaluation

Certificate of Double-Blind Review

Article Edition

Web layout

Indexing and Repository

Article Translation

Article Publication

Certificate of Article

Service Billing

### **Editorial Policy and Management**

21 Santa Lucía, CP-5220. Libertadores -Sucre – Bolivia. Phones: +52 1 55 6159 2296, +52 1 55 1260 0355, +52 1 55 6034 9181; Email: [contact@ecorfan.org](mailto:contact@ecorfan.org) [www.ecorfan.org](http://www.ecorfan.org)

**ECORFAN®**

**Chief Editor**

BARRERO-ROSALES, José Luis. PhD

**Executive Director**

RAMOS-ESCAMILLA, María. PhD

**Editorial Director**

PERALTA-CASTRO, Enrique. MsC

**Web Designer**

ESCAMILLA-BOUCHAN, Imelda. PhD

**Web Diagrammer**

LUNA-SOTO, Vladimir. PhD

**Editorial Assistant**

SORIANO-VELASCO, Jesús. BsC

**Philologist**

RAMOS-ARANCIBIA, Alejandra. BsC

**Advertising & Sponsorship**

(ECORFAN® Bolivia), [sponsorships@ecorfan.org](mailto:sponsorships@ecorfan.org)

**Site Licences**

03-2010-032610094200-01-For printed material ,03-2010-031613323600-01-For Electronic material,03-2010-032610105200-01-For Photographic material,03-2010-032610115700-14-For the facts Compilation,04-2010-031613323600-01-For its Web page,19502-For the Iberoamerican and Caribbean Indexation,20-281 HB9-For its indexation in Latin-American in Social Sciences and Humanities,671-For its indexing in Electronic Scientific Journals Spanish and Latin-America,7045008-For its divulgation and edition in the Ministry of Education and Culture-Spain,25409-For its repository in the Biblioteca Universitaria-Madrid,16258-For its indexing in the Dialnet,20589-For its indexing in the edited Journals in the countries of Iberian-America and the Caribbean, 15048-For the international registration of Congress and Colloquiums. [financingprograms@ecorfan.org](mailto:financingprograms@ecorfan.org)

**Management Offices**

21 Santa Lucía, CP-5220. Libertadores -Sucre–Bolivia.

# Journal of Experimental Systems

“Design of experiments to evaluate the equation to obtain the operating parameters in a 3-axis Numerical Control Machine”

**MONDRAGÓN-MENDOZA, Ricardo, PAZ-CABRERA, Mauro and DELGADO-PRESA, Florencio**

*Universidad Politécnica de Juventino Rosas*

“Trend analysis in the 1D solution of the inverse heat conduction problem by the sequential function specification technique”

**TÉLLEZ-MARTÍNEZ Jorge Sergio, PÉREZ-QUIRÓZ José Trinidad, HORTELANO-CAPETILLO Juan Gregorio and PÉREZ-PÉREZ Arnulfo**

*Universidad Politécnica de Juventino Rosas*

*Instituto Mexicano del Transporte*

“Adaptation of Higher Education to the attacks of the pandemic”

**GALLEGOS-GALINDO, Juan Heriberto, ALVARADO-LOPEZ, Oscar, CORNEJO-TRIGUEROS, Veronica and RAMIREZ-SANLUISEÑO, Juan**

*Universidad Politécnica de Juventino Rosas*

“Electrical system simulation of an aircraft through ANSYS Electronics Desktop”

**REGALADO-RANGEL, Karina, GASTELLUM-MICHEL, Filiberto, TORRES-RIVERA, Moisés and TRASLOSHEROS-MICHEL, Alberto**

*Universidad Aeronáutica en Querétaro*

