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Presentation of content

In the first article we present, *MFCC feature extraction for COPD detection*, by VILLAFUERTE-LUCIO, Diego Ángel, YAÑEZ-VARGAS, Juan Israel, QUINTANILLA-DOMINGUEZ, Joel and TREJO-FRIAS, Alejandra, with adscription in the Universidad Politécnica de Juventino Rosas and Universidad Virtual del Estado de Guanajuato; in the next article we present, T*heoretical determination of histories and carbon concentration profiles in steel resulted from a thermochemical process at a frontier*, by TÉLLEZ-MARTÍNEZ, Jorge Sergio, VEGA-FLORES, María Yaneth, PÉREZ-QUIROZ, José Trinidad and HERNÁNDEZ-MEDRANO, Verónica, with adscription in the Tecnológico Nacional de México / Instituto Tecnológico de Morelia, Instituto Mexicano del Transporte and Universidad Politécnica de Juventino Rosas; in the next article we present, *Sustainable design and manufacturing strategies, review in an appliance company*, by FÉLIX-JÁCQUEZ, Rosa Hilda, CRUZ-RENTERÍA, María Merced and DELGADO-CELIS, Ma. Dolores, with adscription in the Tecnológico Nacional de México - Instituto Tecnológico de San Luis Potosí; in the final article we present, *Energy analysis of lighting in high-impact buildings with transparent envelopes*, by GARCÍA-SERVÍN, Marco Antonio, HERNÁNDEZ-LÓPEZ, María Isabel, DEMESA-LÓPEZ, Francisco Noé and SERRANO-ARELLANO, Juan, with adscription in the Tecnológico Nacional de México / I. T. de Pachuca.

Content

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MFCC feature extraction for COPD detection

Extracción de características MFCC para la detección de la EPOC

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Abstract

Mel Frequency Cepstral Coefficients (MFCC) are acoustic features, which are based on human auditory perception, focus on spectral properties and capture relevant features of the audio signal related to vocal tract shape and energy in different frequency bands. The methodology for feature extraction involves several stages. First, the audio signals go through a preprocessing stage in which they are initially normalized, then background noise is reduced, and finally, they pass through a median filter. In the next block of MFCC feature extraction, the first task was to split the audio signal into small frames. Then, a hamming window is applied to smooth the edges of each frame and the short time Fourier transform of each frame is calculated. Next, Mel filters are applied, which adjusts the representation of the frequency spectrum to human auditory perception. Finally, cepstral coefficients are calculated from the frequency spectrum. The MFCC coefficients are then used as input features for classifiers and machine learning algorithms.

COPD Detection, Features extraction, coefficients MFCC

Resumen

Los coeficientes Mel Frequency Cepstral Coefficients (MFCC) son características acústicas, que se basan en la percepción auditiva humana, se centran en las propiedades del espectro y capturan características relevantes de la señal de audio relacionadas con la forma del tracto vocal y la energía en diferentes bandas de frecuencia. La metodología para la extracción de características implica varias etapas. Primeramente, las señales de audio pasan por una etapa de preprocesamiento en la cual inicialmente se normalizan, después se disminuye el ruido de fondo, por último, pasan a través de un filtro de medianas. En el siguiente bloque de extracción de las características MFCC la primera tarea que se realizo fue dividir la señal de audio en pequeñas tramas. Luego, se aplica una ventana hamming para suavizar los bordes de cada trama y se calcula la transformada de Fourier de tiempo corto de cada trama. Enseguida, se aplican los filtros de Mel, que ajusta la representación del espectro de frecuencia a la percepción auditiva humana. Finalmente, se calculan los coeficientes cepstrales a partir del espectro de frecuencia. Los coeficientes MFCC se utilizan luego como características de entrada para clasificadores y algoritmos de aprendizaje automático.

Detección EPOC, Extracción de características, MFCC coeficientes

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Introduction

Studies have shown that lung diseases are one of the leading causes of death in the world. Of the various lung diseases, Chronic Obstructive Pulmonary Disease (COPD) stands out.

According to the World Health Organization (WHO), it is estimated that around 384 million people worldwide are affected by COPD, it is the third leading cause of death worldwide, causing 3.23 million deaths in 2019, almost 90% of COPD deaths in people under 70 years of age occur in low- and middle-income countries (WHO, 2023). Over time, different techniques have been developed for the diagnosis of lung diseases, some of which include thoracic imaging examination, thoracic bronchoscopy, pulmonary auscultation, among others. Lung auscultation is a method used to examine and diagnose the behaviour of the respiratory system by listening to the sounds of breathing in and out (WHO, 2023).

Lung auscultation is usually performed on the posterior walls of the thorax and trachea, as shown in Figure 1. This provides useful information about the lungs, commonly when a respiratory condition is present, the first thing that is performed is a lung auscultation (Bohadana, 2014).

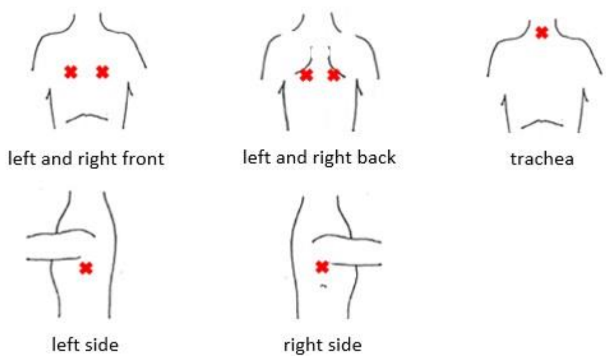

Figure 1 Key points for lung auscultation
Source: Own source

Dataset

The dataset used was the Int. Conf. on Biomedical Health Informatics (ICBHI) of breath sounds, this dataset contains audio samples collected from two research teams in two different countries over several years. The dataset includes 920 recordings of varying lengths (from 10 to 90 seconds).

These recordings were taken from 126 patients for a total of 5.5 hours. The dataset is made up as shown in Figure 2 of different lung diseases such as: COPD, pneumonia, bronchiolitis, bronchiectasis, URTI, LRTI, asthma, and healthy (Rocha BM, 2019).

Diseases															
URTI		Healthy		Asthma		COPD		LRTI		Bronchiectasis		Pneumonia		Bronchiolitis	
M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W
6	8	13	13	0	1	48	15	2	0	2	5	4	2	4	2
14		26		1		64		2		7		6		6	

Figure 2 Number of patients for each disease
Source: Own source

Each of the audio signals has the following attributes, as shown in Figure 3:

Sample rate	Number of channels	Duration	Format
44100 Hz	1	20 seg	WAV

Figure 3 Attributes of the audios
Source: Own source

Methodology

Figure 4 presents the proposed methodology for MFCC feature extraction consisting of data acquisition, preprocessing and feature extraction blocks. Each of the presented blocks plays an important role in the effective processing of the audio signal to obtain MFCC features that will later be used for sound classification..

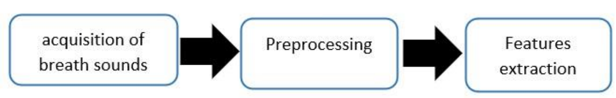

Figure 4 oposed methodology for MFCC feature extraction
Source: Own source

Data acquisition

For the acquisition of the data, a segmentation was performed by taking only the EPOC and Sanos audios of the male gender. Ten patients were selected for each type of audio, taking one audio for each patient as shown in Figure 5.

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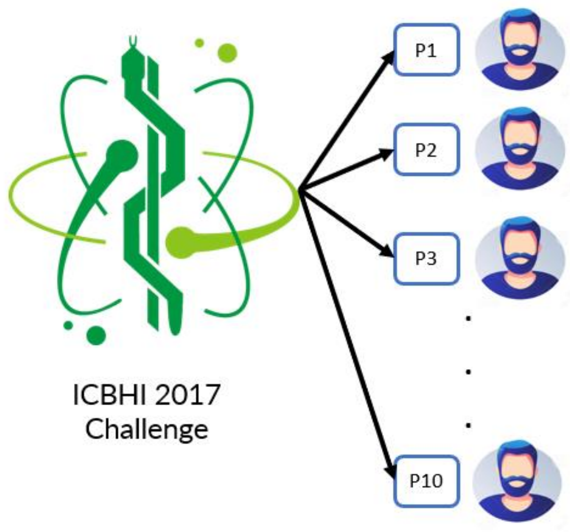

Figure 5 Data acquisition
Source: Own source

Preprocessing

In the pre-processing stage, operations are performed with the intention of improving the audio signal and eliminating unwanted noise. The operations performed in this stage are represented in Figure 6 and are the stages of normalisation 0-1, Wiener Filter and Median Filter.

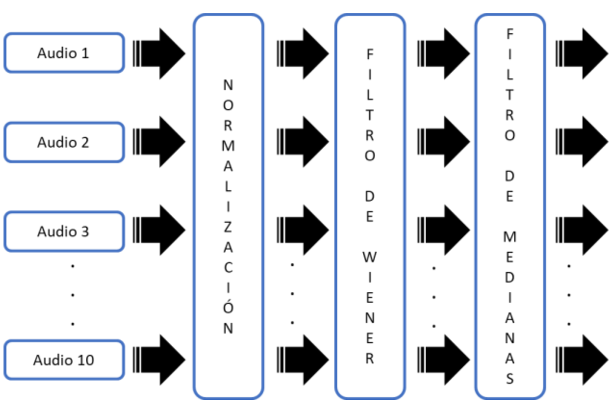

Figure 6 Pre-processing stage
Source: Own source

Normalisation

Normalisation is quite useful when seeking to equalise amplitudes or to adapt values to specific ranges. In this stage, the aim is to scale the values of the audio signal so that they are in the range 0 to 1, this is done by means of the formula 1:

$$x\_out = \frac{(x - min\,(x))}{(max(x) - min\,(x))} \quad (1)$$

Where:

x is the input value to be normalised.

min(x) is the minimum value in the input matrix or vector x.

max(x) is the maximum value in the input matrix or vector x.

x_out is the normalised value that will be in the range [0 1].

Wiener filter

The Wiener filter is used to perform background noise filtering of the audio signal, providing an estimate of the signal of interest as used in (Pascal). This process is depicted in Figure 7.

Where:

w [n] = is the input signal.

x [n] = is the output of the filter.

s [n] = is the reference signal.

e [n] = is the filter error.

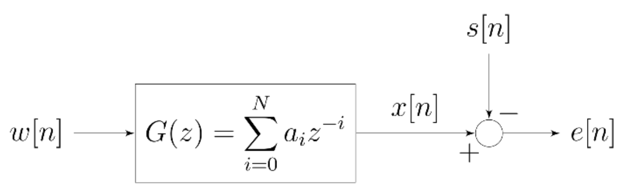

Figure 7 Schematic of the Wiener filter
Source: Own source

Median filter

The median filter is quite useful for removing noise in audio signals, such as clicks, pops or sudden interference. This type of noise is usually more noticeable compared to background noise. By applying the median filter, the amplitude of the noise is reduced without smoothing the audio signal of interest too much, which helps to improve the quality of the audio signal by eliminating or significantly reducing the noise.

MFCC Feature Extraction

MFCC feature extraction is a process used in audio signal processing, audio classification and speech recognition. MFCC is based on human auditory perception and is used to represent the acoustic features of an audio signal more efficiently this process can be seen reflected in (Winursito, A) and (Alodia Yusuf).

The feature extraction process performed is represented by Figure 8.

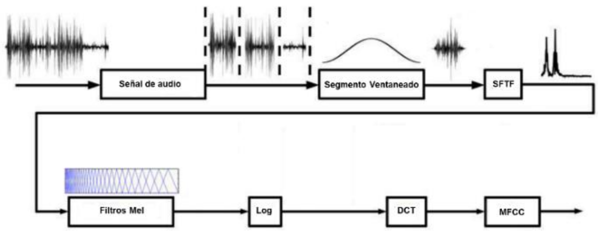

Figure 8 Stages of feature extraction
Source: Own source

Frames

For a better analysis of the lung sounds, 500 ms frames will be extracted, as this is where a better spectral analysis is possible.

First, the time of each of the frames is defined, as in Equation 2.

$$Tt = 0.5\, seg \tag{2}$$

Where:

Tt = is the time of the frame.

Once the time of the frames is known, the number of samples that will make up the frames is obtained, according to equation 3.

$$Nm = Tt\, x\, f \tag{3}$$

Where:

Nm = es the number of samples of each frame.

f = is the sampling frequency.

To avoid loss of information at the ends, we will overlap half the number of samples in each of the frames, as described in equation 4.

$$Op = \frac{Nm}{2} \tag{4}$$

Where:

Op = is the number of samples to be overlapped

Windowing

By dividing the signal into 500 ms frames, discontinuities occur at the beginning and end of each frame. This leads to errors in the spectral analysis.

To reduce discontinuities and minimise the introduction of spurious frequency components, a windowing technique, such as the Hamming window, is used.

This mathematical function described in equation 5 is multiplied point-by-point with the raster, which smooths the raster edges.

$$w(n) = 0.54 - 0.46\cos(2\pi \frac{n}{N}) \tag{5}$$

Short-Time Fourier Transform (STFT)

The short time Fourier transform of each frame is represented by the following equation 6.

$$X_m(f) = \sum_{n=-\infty}^{\infty} x(n) g(n - mR) e^{-j2\pi fn} \tag{6}$$

Where:

g(n) = window length.

Xm(f) = DFT of the data centred at time *mR.*

R = Jump size between successive DFTs. The skip size is the difference between the window length M and the overlap length L.

Mel filters

A set of Mel filters is used to map the linear scale of frequencies to a Mel scale, which better approximates human auditory perception. The Mel filters are superimposed and placed on the frequency scale, covering the whole range of frequencies relevant to human speech, as described in equation 7.

$$mel = 2595\, log_{10}(1 + \frac{f}{700}) \tag{7}$$

Log

The logarithm of the spectral power is calculated for each of Mel's filters. This is done to account for the non-linear response of the human ear to differences in sound intensity.

Discrete Cosine Transform (DCT)

Finally, the discrete cosine transform is applied to the logarithmic power spectral coefficients to reduce their dimensionality and obtain the cepstral coefficients, which represent the acoustic characteristics of the audio signal.

Feature selection

Feature selection using variance is a technique used to reduce the dimensionality of a set of features by selecting those features that have a high variance and discarding those features with a low variance.

Using variance it can be determined that if the variance value is small the content of that feature is very likely to be the same or very similar, so it will contribute little to the classifier.

Results

The results obtained by performing each of the processes are shown in Figure 9 and 10:

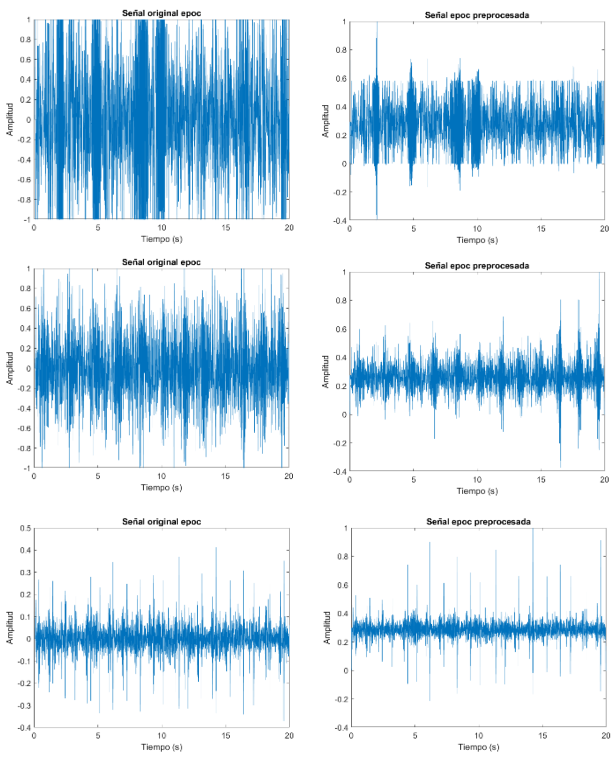

Figure 9 Graphical representation of the audios before and after pre-processing
Source: Own source

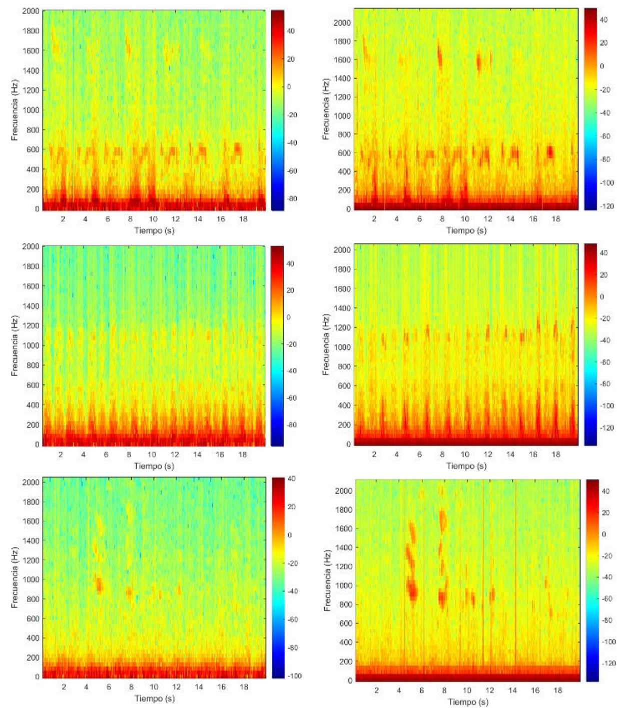

Figure 10 Graphical representation of the spectrograms before and after pre-processing
Source: Own source

After the MFCC feature extraction process, the result is 13 coefficients, described in Table 1 and 2, per audio type to be used as input data for an audio signal classification system.

	1	2	3	4
1	0.2488	-1.8851	-0.6121	-3.3223
2	1.4328	2.8509	2.1186	3.1375
3	0.4041	1.0396	-0.2124	-0.0243
4	0.6045	0.8364	1.9249	-0.1647
5	0.5093	0.5619	0.1245	0.3481
6	-0.5724	-0.0789	0.0635	1.0783
7	-0.0588	0.1585	0.0745	0.8590
8	0.7250	0.5187	0.2915	0.1677
9	0.2026	-0.0608	0.4754	-0.3561
10	0.7426	0.2865	0.3625	-0.1885
11	0.3227	0.1910	-0.0001	0.4146
12	-0.0980	0.0370	0.2977	0.4764
13	0.1760	0.2003	0.2746	0.0629

Table 1 MFCC coefficients of COPD patients
Source: Own source

	1	2	3	4
1	-10.9472	-5.8302	-4.0880	-9.3527
2	3.6684	3.0756	3.0943	5.1568
3	1.2175	0.8550	0.8539	1.3832
4	1.2603	1.0096	0.9853	0.9061
5	0.6564	0.6493	0.6354	0.4463
6	0.7117	0.6419	0.6213	0.4045
7	0.4813	0.4771	0.4561	0.2069
8	0.3474	0.4380	0.4435	0.1608
9	0.3499	0.3367	0.3569	0.2208
10	0.2725	0.3162	0.3516	0.2336
11	0.2770	0.2526	0.3002	0.1741
12	0.4101	0.2578	0.2899	0.2863
13	0.3601	0.2048	0.2398	0.2615

Table 2 MFCC coefficients of HEALTHY patients
Source: Own source

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The results obtained from the selection of characteristics are shown in Table 3, where it is determined to take the first five coefficients from the variance study carried out on all the data as input for the classifier and to find their degree of dispersion.

	Variaance	
Coefficient	EPOC	Healthy
1	3.4455	9.0377
2	0.9791	0.8834
3	0.3008	0.7591
4	0.1665	0.1894
5	0.0953	0.1885
6	0.1406	0.0580
7	0.0561	0.0598
8	0.0478	0.0572
9	0.0724	0.0380
10	0.0418	0.0245
11	0.0318	0.0265
12	0.0318	0.0220
13	0.0233	0.0208

Table 3 Values resulting from the selection of characteristics
Source: Own source

Next, the normal distribution of the selected characteristics is shown by variance, through the Gaussian bell, quantile plot and box and whiskers diagram, this is done in order to analyse and model the distribution of values, it is worth mentioning that not all characteristics must necessarily follow a normal distribution, the data are represented in Figures 11, 12, 13, 14 and 15.

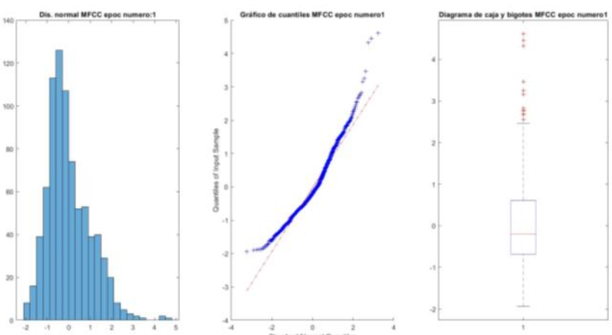

Figure 11 Normal distribution of coefficient 1 EPOC Gaussian Bell, Quantile Plot, Box and Whisker Plots
Source: Own source

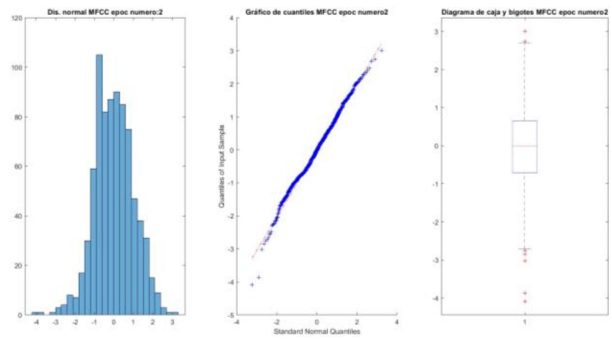

Figure 12 Normal distribution of coefficient 2 EPOC Gaussian Bell, Quantile Plot, Box and Whisker Plot
Source: Own source

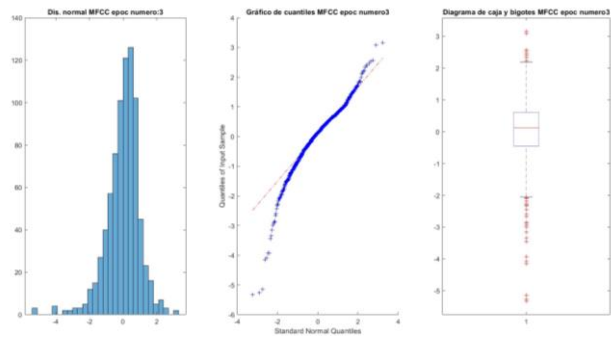

Figure 13 Normal distribution of coefficient 3 EPOC Gaussian Bell, Quantile Plot, Box and Whisker Plots
Source: Own source

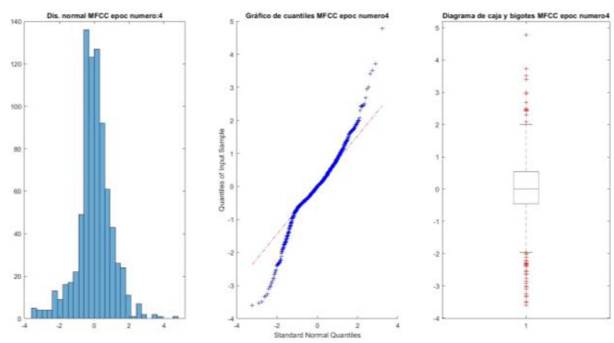

Figure 14 Normal distribution of coefficient 4 EPOC Gaussian Bell, Quantile Plot, Box and Whisker Plot
Source: Own source

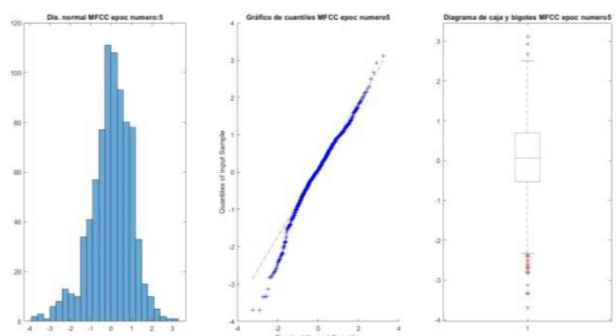

Figure 15 Normal distribution of coefficient 5 EPOC Gaussian bell, quantile plot, box and whisker plot
Source: Own source

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Conclusion

MFCC feature extraction is a very efficient technique in audio signal processing. It provides an effective representation of the acoustic characteristics of an audio signal, allowing for more accurate analysis and classification.

MFCC provides several advantages, one of which is the ability to compact spectral information into a small number of coefficients, which reduces the dimensionality of the data and improves computational efficiency. In addition, MFCCs are relatively robust to noise and changes in acoustic conditions, which makes them suitable for applications in speech recognition, speech synthesis, sound classification and other audio signal processing tasks.

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Article

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Theoretical determination of histories and carbon concentration profiles in steel resulted from a thermochemical process at a frontier

Determinación teórica de historias y perfiles de concentración de carbono en acero como resultado de un proceso termoquímico desarrollándose en una frontera

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Abstract

Steel is used to manufacture auto parts due to its properties and the ability to modify them through solid-state thermal processing. In some cases, the treated alloy itself does not satisfy the requirements of combined properties in the integrity of a single part. In these cases, thermochemical treatments do apply, with which the chemical composition does alter in a localized way. The mechanism of atomic diffusion in the solid is the mean by which atoms of a chemical element can mobilize in the lattice of the crystalline structure and concentrate, depending on the distance penetrated. The mass transport equation adequately describes concentration gradients if the diffusivity property is precisely known. The applicability to the analysis of the carburization method of steel can do a micrometric scale in one dimension. The results obtained on a computer application calculating the carbon concentration profile in iron can be shown. The strategy consists of qualitatively evaluating the distribution of equilibrium phases by optical microscopy and associating it with the carbon concentration profile.

Mass Transport, Atomic Diffusion, Carburization

Resumen

En la manufactura de autopartes se utiliza acero debido a sus propiedades y a la capacidad de modificarlas mediante procesamiento térmico en estado sólido. En algunos casos la propia aleación tratada no satisface los requerimientos de combinación de propiedades en la integridad de una parte única. Es estos casos, se recurre a los tratamientos termoquímicos con los cuales se altera la composición química de la aleación de forma localizada. El mecanismo de difusión atómica en el sólido es el medio por el cual átomos de algún elemento químico puede movilizarse en la red de la estructura cristalina y concentrarse en función de la distancia penetrada. La ecuación de transporte de masa describe adecuadamente los gradientes de concentración si se conoce con precisión la propiedad de difusividad. La aplicabilidad al análisis del método denominada carburización de aceros, puede minimizarse a sistemas en escala micrométrica en una dimensión. Como puede mostrarse, una aplicación informática que describa el perfil de concentración de carbono en hierro puede utilizarse para asociar los cálculos con el análisis metalográfico. La estrategia consistió en evaluar cualitativamente la distribución de fases de equilibrio mediante microscopia óptica y asociarla al perfil de concentración de carbono.

Transporte de Masa, Difusión Atómica, Carburización

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Introduction

The carburizing process dates back to the initially unknown technique of handcrafting swords through forging. In the evolutionary process of understanding the phenomenon, an extensive review of the theoretical foundations and industrialized processes was presented by (Edenhofer, Joritz, Rink, & Voges, 2015). His work explains that one way of executing a practice emulating ancient processes consists of imbibing a piece in a box full of powder of substances rich in carbon (pulverized charcoal, anthracite coal, or coke). The box is sealed and placed inside an oven at temperatures above 850°C for a set time. After the middle of the 20th century, salt baths and ovens with controlled gas atmospheres were used as carbon donor media.

For the processes with the carbon sources mentioned, theories of the kinetics of carbon transfer in iron and steel have been presented, the works of (Goldstein, 1978), (Grabke & Wolf, 1987), (Rahmel, Grabke, & Steinkusch, 1998), and (Grabke H. J., 2002), even address some additional topics such as the degradation effects of the substrates and the susceptibility of formation of intermetallic compounds with the alloying elements. Some approaches to mathematical models support developing computer programs for analysis (Lee, Matlock, & Van Tyne, 2013).

Modeling phenomenology

Phenomenologically, the estimation of the processing time at the carburization temperature is approximated by solving the transport equation of the carbon species (solute) in a matrix of a crystalline solid (solvent) in a transient state (Crank, 1975). Except for some cases in which assumptions about the system simplify the equation, the approach of a numerical technique is required to obtain the solution of the total field of the affected region. Therefore, when developing algorithms from specific mathematical approaches and coding them, there is the freedom to modify or implement add-ons that optimize the modeling of the system under study.

Starting from the definition that the transfer balances of chemical species in solids in terms of flow through surfaces (physical boundaries), these are developed by the law of mass transfer by diffusion or Fick's law represented by **Equation 1** (Porter, 2021).

$$J = -DA_{\perp}\frac{\partial C}{\partial \lambda} \tag{1}$$

Where J defines the flow of an amount of the chemical species (mass), D represents the concept of diffusivity of the species in the matrix or medium; $A_{\perp}$ represents the surface perpendicular to the flow direction of the species, C is the concentration which corresponds to the dependent variable or of interest of the transfer problem in quantities of mass per unit of volume and, λ can be any dimensional variable concerning a coordinate system. In such a way, the amount of flow is directly proportional to the difference in concentration of the species concerning two positions interconnected by the continuous medium of the matrix, whose homogeneity depends on the capacity factor or mechanism of mobility accounted for through a surface.

In general, the flow balance equation (see **Equation 2**) defined for the domain of a differential volume of the matrix, establishes that the subtraction of the mass flow that enters J_E and leaves J_s through their boundaries or dimensional limits and the mass per unit of volume in which chemical reactions experience transformations, J_T is equivalent to the mass that accumulates of the species in a unit of time J_A.

$$[J_E - J_s] + J_T = J_A \tag{2}$$

Equation 3 results by writing **Equation 2** in differential form, considering three dimensions in a cylindrical coordinate system.

$$-\left[\frac{1}{r}\frac{\partial}{\partial r}\left(-Dr\frac{\partial C}{\partial r}\right) + \frac{1}{r}\frac{\partial}{\partial \theta}\left(-D\frac{1}{r}\frac{\partial C}{\partial \theta}\right) + \frac{\partial}{\partial z}\left(-D\frac{\partial C}{\partial z}\right)\right] + \dot{r} = \frac{\partial C}{\partial t} \tag{3}$$

The nonlinearity characteristic of **Equation 3** and its boundary conditions do not allow mathematical treatment to obtain analytical solutions. Cases in which D cannot be considered constant increase the complexity even further.

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Alternatively, the systems are discretized, and numerical solution techniques, such as the finite difference or finite elements, are implemented. In this process, the systems under analysis are subdivided into many subsystems (discrete systems). Differential analysis is transformed into a series of algebraic equations with approximations that depend on the magnitude of the spatial parameters to evaluate the concentration variable (field variable).

In the new discrete scale, the concentration difference in a space interval or gradient is governed by **Equation 4**.

$$\frac{dC}{dx} \cong \frac{\Delta C}{\Delta x} = \frac{C_{x+\Delta x} - C_x}{(x+\Delta x) - x} = \frac{C_{x+\Delta x} - C_x}{\Delta x} \qquad (4)$$

Similarly, **Equation 5** specifies the rate of change concerning time.

$$\frac{dC}{dt} \cong \frac{\Delta C}{\Delta t} = \frac{C^{t+\Delta t} - C^t}{(t+\Delta t) - t} = \frac{C^{t+\Delta t} - C^t}{\Delta t} \qquad (5)$$

By deduction from **Equations 4 and 5**, the smaller the magnitudes of the corresponding intervals, the greater the approximation to the solution of the differential equation. In this sense, the precision of the solution of the numerical analysis by finite differences depends strongly on a correct discretization.

Case study

In the thermochemical carburizing treatment, the objective is to increase the carbon concentration in a region adjacent to the surface of a part (layer), just as swords were in ancient times, and currently, a wide variety of components used for the formation of vehicles, as well as other applications. Typically, the metallographic preparation technique can detect the carburized layer and correlate with processing parameters. Similarly, the results of calculations of carbon transport in steel structures can also be validated with at least two decimal places of precision.

This work presents a methodological structure for developing the fundamental analysis of carburization by solving the transportation problem and its association with a low-cost, reproducible experimental procedure.

The validation method will be limited to assessing the quantification of the ferrite and cementite phases and the pearlite microconstituent (which implies a carbon content) using optical microscopy of samples of an SAE 1018 steel bar.

Methodology

The development of the following methodology was proposed:

1) Formulate the partial differential equation governing the problem of diffusion of the chemical species carbon in iron.

2) Pose the discrete solution problem using the finite difference technique and solve the resulting matrix of the system of algebraic equations using the Thomas algorithm.

3) Use the Microsoft Visual Studio Express platform to code the solution algorithm of the system of equations in the Visual C# language.

4) Carburize 1-inch Ø steel bar samples using pulverized charcoal ($C_{16}H_{10}O_2$) as a carbon “donor”. In the procedure, a chamber made of steel plate sealed with refractory mortar was used to prevent excess oxygen from flowing inside. The box was heated to 950°C inside a muffle furnace and held for nine hours before being slowly cooled inside the furnace out of operation.

5) Perform the analysis of the treated samples using optical microscopy, quantifying the percentage of carbon that causes the distribution of the ferrite phase and the pearlite microconstituent identified, and then compare against the results calculated with the algorithm.

Due to the geometric characteristics of the steel sample, the mathematical formulation of the carburization problem, **Equation 3**, was simplified to one dimension in the radial direction. Also, the chemical reaction of Fe3C formation does not participate in the analysis because it is a component of the pearlite microconstituent. Therefore, by eliminating terms from **Equation 3**, **Equation 6** is formulated.

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$$\frac{1}{r}\frac{\partial}{\partial r}\left(Dr\frac{\partial C}{\partial r}\right) = \frac{\partial C}{\partial t} \quad (6)$$

The diagram in **Figure 1** represents a transverse plane of the discretized bar, specifically with three control volumes, where the circle with a solid line defines the edge of the sample. Therefore, the circles with a segmented line define the virtual borders of the subdomains and the points or nodes, their dimensional reference centers.

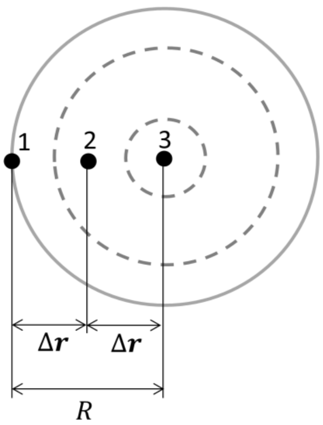

Figure 1 Scheme of the discretization of the geometric model of the cylinder
Source: Own creation in Microsoft PowerPoint 2016

As **Figure 1** dictates, points 1 and 3 define the two physical boundaries for the solution of **Equation 6**. In addition, an initial condition is needed to obtain a particular solution.

Equations 7 to 8 define the two boundary conditions: 1) the condition of the interaction of the solid with its environment and 2) the condition at the central (axial) axis of the cylinder. While **Equation 9** defines the starting state or at time zero for the transient analysis.

$$-D\frac{\partial C}{\partial r} = f, \qquad f = C_b, \qquad r = R \quad (7)$$

$$-D\frac{\partial C}{\partial r} = 0, \qquad r = 0 \quad (8)$$

$$C(r) = C_0, \qquad t = 0 \quad (9)$$

The function f in **Equation 7** was limited to the definition of a constant concentration value. However, it can be more complex.

Fundamentally, for the numerical analysis, the three control volumes determined the representative equations of the entire domain (one for each border and the third according to the geometric pattern between them). In this way, **Equations 6 to 9** were transformed using **Equations 2, 4, and 5**. As a result, after a brief arithmetic development, **Equations 10, 11, and 12** were obtained.

$$C_1^t = C_1^{t+\Delta t} \quad (10)$$

$$\left(\frac{\overline{D_{1\to 2}}A_\perp \Delta t}{\Delta r}\right)C_1^t + \left(1 - \frac{\overline{D_{2\to 3}}A_\perp \Delta t}{\Delta r} - \frac{\overline{D_{1\to 2}}A_\perp \Delta t}{\Delta r}\right)C_2^t + \left(\frac{\overline{D_{2\to 3}}A_\perp \Delta t}{\Delta r}\right)C_3^t = C_2^{t+\Delta t} \quad (11)$$

$$\left(\frac{\overline{D_{2\to 3}}A_\perp \Delta t}{\Delta r}\right)C_2^t + \left(1 - \frac{\overline{D_{2\to 3}}A_\perp \Delta t}{\Delta r}\right)C_3^t = C_3^{t+\Delta t} \quad (12)$$

Equation 11 is multiplied based on the number of control volumes the user determines to achieve the highest precision in a calculation. Generally, all algebraic equations adopt the structure of **Equation 13**.

$$a_i C_{i-1}^t + b_i C_i^t + c_i C_{i+1}^t = C_i^{t+\Delta t} \quad (13)$$

$a, b, c,$ y, d, represent the respective factors or coefficients of **Equations 10, 11, and 12**. Thus, by proposing an open criterion for specifying the number of control volumes (n), the system of equations represented in matrix form in **Equation 14** was generated, whose explicit solution depends on the calculation time step Δt. The determination of this parameter, called stability criterion, was obtained considering each of **Equations 11 and 12** coefficients, having to satisfy the inequality of being greater – equal to zero, as determined by **Equations 15 and 16** for **Equation 11**, and subsequently detecting the magnitude of the slightest value, which is considered the maximum calculation step.

$$\begin{bmatrix} b_1 & c_1 & \cdots & 0 & 0 \\ a_2 & b_2 & c_2 & 0 & 0 \\ \vdots & \ddots & \ddots & \ddots & \vdots \\ 0 & 0 & a_{n-1} & b_{n-1} & c_{n-1} \\ 0 & 0 & \cdots & a_n & b_n \end{bmatrix} \begin{bmatrix} C_1^t \\ C_1^t \\ \vdots \\ C_{n-1}^t \\ C_n^t \end{bmatrix} = \begin{bmatrix} C_1^{t+\Delta t} \\ C_2^{t+\Delta t} \\ \vdots \\ C_{n-1}^{t+\Delta t} \\ C_n^{t+\Delta t} \end{bmatrix} \quad (14)$$

$$\Delta t \leq \frac{1}{\left(\frac{A_\perp \overline{D_{i-1\to i}}}{\Delta r}\right)}, \qquad \Delta t \leq \frac{1}{\left(\frac{A_\perp \overline{D_{i\to i+1}}}{\Delta r}\right)} \quad (15)$$

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$$\Delta t \leq \frac{1}{\left(\frac{A_{\perp}\overline{D_{\iota\to\iota+1}} + A_{\perp}\overline{D_{\iota-1\to\iota}}}{\Delta r}\right)} \qquad (16)$$

In turn, the diffusion coefficients were calculated with **Equation 17** and the data table in **Figure 2** and extracted from (Askeland, 2010).

$$D = D_0 exp\left(\frac{-Q}{RT}\right) \qquad (17)$$

TABLE 5-1 ■ *Diffusion data for selected materials*

Diffusion Couple	Q (cal/mol)	D_0 (cm²/s)
Interstitial diffusion:		
C in FCC iron	32,900	0.23
C in BCC iron	20,900	0.011
N in FCC iron	34,600	0.0034
N in BCC iron	18,300	0.0047
H in FCC iron	10,300	0.0063
H in BCC iron	3,600	0.0012
Self-diffusion (vacancy diffusion):		
Pb in FCC Pb	25,900	1.27
Al in FCC Al	32,200	0.10
Cu in FCC Cu	49,300	0.36
Fe in FCC Fe	66,700	0.65
Zn in HCP Zn	21,800	0.1
Mg in HCP Mg	32,200	1.0
Fe in BCC Fe	58,900	4.1
W in BCC W	143,300	1.88
Si in Si (covalent)	110,000	1800.0
C in C (covalent)	163,000	5.0
Heterogeneous diffusion (vacancy diffusion):		
Ni in Cu	57,900	2.3
Cu in Ni	61,500	0.65
Zn in Cu	43,900	0.78
Ni in FCC iron	64,000	4.1
Au in Ag	45,500	0.26
Ag in Au	40,200	0.072
Al in Cu	39,500	0.045
Al in Al_2O_3	114,000	28.0
O in Al_2O_3	152,000	1900.0
Mg in MgO	79,000	0.249
O in MgO	82,100	0.000043

Data from several sources, including Adda, Y. and Philibert, J., La Diffusion dans les Solides, Vol. 2, 1966.

Figure 2 Table of thermodynamic data for determining the diffusion of a couple of chemical species
Source: Image obtained from (Askeland, 2010).

The temperature T corresponds to the conditions of the thermal index reached during carburization (950 °C), and R represents the universal gas constant.

Equations 18 and 19 define the sequence of the Thomas algorithm for the solution of the matrix system of **Equation 14**.

$$c'_i = \begin{cases} \frac{c_i}{b_i}; \ i = 1 \\ \frac{c_i}{b_i - c'_{i-1}a_i}; \ i = 2,3,\dots,n-1 \end{cases}$$

$$d'_i = \begin{cases} \frac{d_i}{b_i}; \ i = 1 \\ \frac{d_i - d'_{i-1}a_i}{b_i - c'_{i-1}a_i}; \ i = 2,3,\dots,n \end{cases} \qquad (18)$$

$$C_n = d'_n$$
$$C_i = d'_i - c'_i C_{i+1}; \ i = n-1, n-2, \dots, 1 \qquad (19)$$

Therefore, the pseudocode presented in **Figure 3** defines the general calculation algorithm.

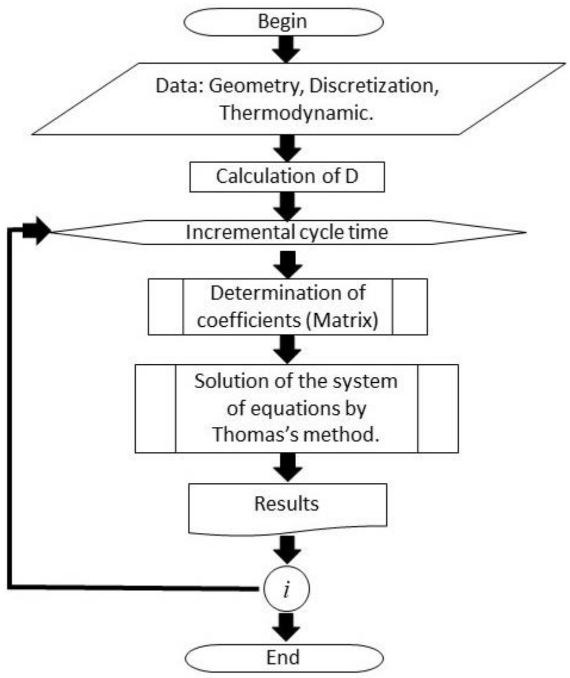

Figure 3 Flow chart for the development of computer programming
Source: Own creation in Microsoft PowerPoint 2016.

Figure 4 shows the graphical user interface developed in the Visual C# language for data entry and presentation. Calculations of carbon concentration histories and profiles will be tabulated in a table (middle) and plotted in a scatter plot when selecting some set for trend analysis (right).

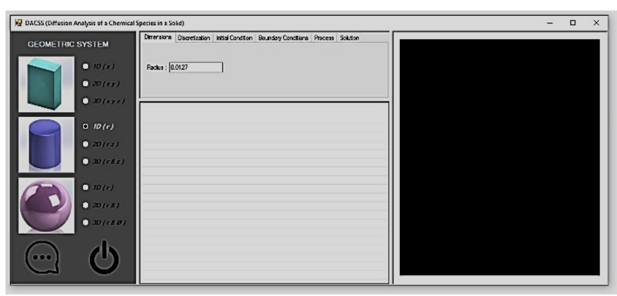

Figure 4 Graphical user interface developed for calculating carbon concentration histories and profiles in the carburization process
Source: Image by screenshot of the development in MS Visual Studio Express 2010.

The carburization process involves the calculation of carbon concentration histories and profiles. This includes the preparation of charcoal powder inside a metal box, which is then sealed and introduced into the muffle furnace (Nabertherm, 2023). The process is shown in **Figures 5(a) and 5(b)**.

(a)

(b)

Figure 5 Experimental procedure: a) metal box containing the charcoal powder and the test sample, b) sealed box introduced into the muffle furnace
Source: Own photographs. Metallurgy laboratory.

To analyze the phase distribution of untreated and treated samples, optical microscopy analysis is conducted at 10X. The surfaces are etched with 3% Nital for 5 seconds, as shown in the micrograph of **Figure 6**.

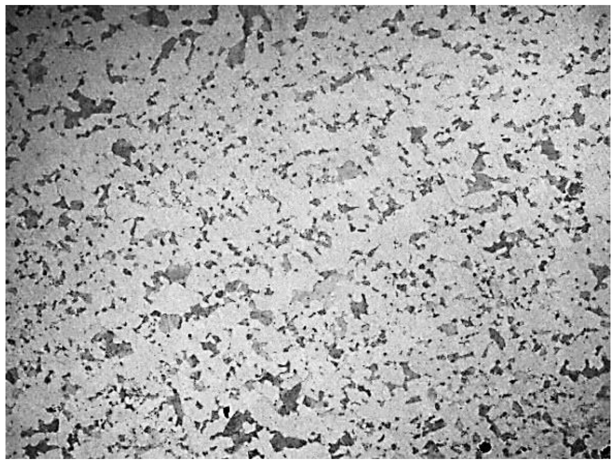

Figure 6 Micrograph obtained at 10X of the preparation of the original SAE 1018 steel specimen, etched with 3% Nital for 5 s
Source: Own image (PAX-it!, 2022).

Figure 7 is a diagram of the Fe-C predominance or metastable equilibrium, with the marking of the composition for the formation of one hundred percent pearlite (vertical line segmented at 0.77%), as well as the partition for the application of the lever rule (solid line and dot, red color). The dot indicates the average 0.20 weight percent C composition of SAE 1018 steel.

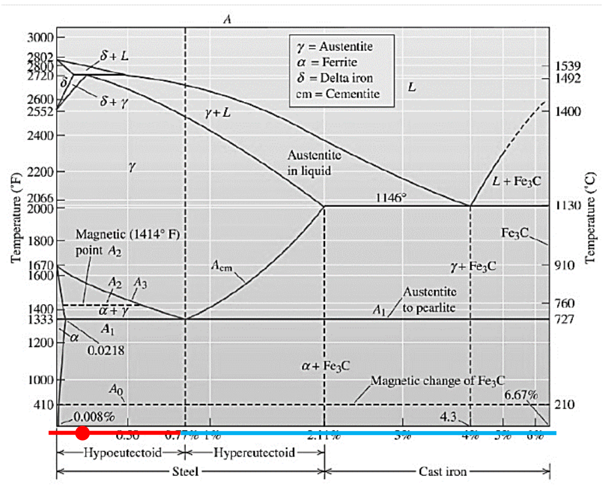

Figure 7 Metastable predominance diagram of the Fe-C system
Source: Image obtained from (Askeland, 2010).

The lever rule equations for determining the percentage of ferrite (%α), cementite (%Fe3C), and the percentage of pearlite (%P), as a function of the C content in the Fe-C diagram, are defined in **Equations 20 and 21** according to (Avner, 1982).

$$\%\alpha = \left(\frac{0.77 - \%C}{0.77 - 0.008}\right) 100 \quad (20)$$

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$$\%P = \left(\frac{\%C - 0.08}{0.77 - 0.008}\right)100 \quad (21)$$

Substituting 0.2 into **Equations 20 and 21** generates 74.8 %α and 25.2 %P values. Therefore, this defines the phase (light zone) and microconstituent (shaded zones) distribution in the micrograph of **Figure 6**. In turn, if the lever were to change to the blue line marked in **Figure 7**, the distribution of the Fe_3C cementite phase and the pearlite microconstituent is obtained through **Equations 22 and 23**, which is adopted when determining the initial concentration of carbon exceeds 0.77% by weight.

$$\%P = \left(\frac{6.7 - \%C}{6.7 - 0.77}\right)100 \quad (22)$$

$$\%Fe_3C = \left(\frac{\%C - 0.77}{6.7 - 0.77}\right)100 \quad (23)$$

Results

The microstructure obtained in the steel specimen evolves under conditions close to those dictated by the metastable Fe-C equilibrium diagram. The micrograph of **Figure 8** shows the microstructure obtained after metallographic preparation in a cross-section of the treated specimen. Notice a significant difference between the micrographs of **Figure 6 and Figure 8**. The 10X field of view allows showing just over 2 mm of surface from the edge of the specimen. The microstructure analysis determined the existence of 100% pearlite in the region just over 1 mm deep.

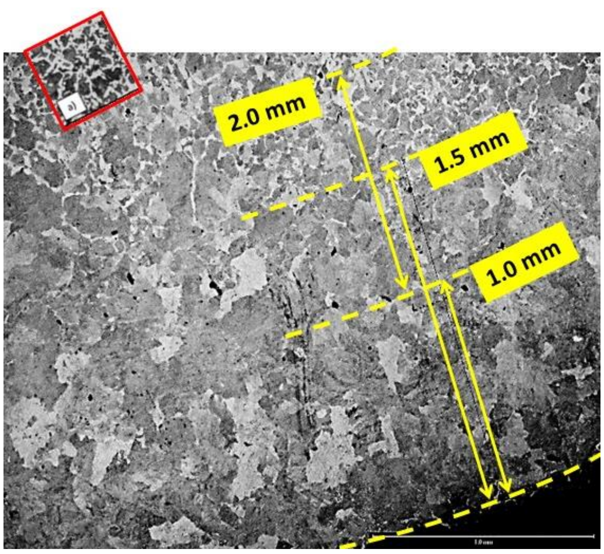


Figure 8 Micrograph obtained at 10X of the preparation of the carburized SAE 1018 steel specimen, etched with 3% Nital for 5 s
Source: Own image (PAX-it!, 2022)

The coexistence of pearlite and the cementite phase (free Fe_3C) appears before the 1 mm mark. Cementite precipitated at the grain boundary and on small, barely noticeable islands (with a decreasing distribution from the edge to the mark). Consequently, above the 1 mm mark, a distribution of the ferrite phase and the pearlite microconstituent was found.

It was necessary to obtain a percentage valuation of the ferrite and cementite phases and the pearlite microconstituent in each position relative to the marks in the micrograph of **Figure 8** to quantify the percentages of carbon clearing from **Equations 20, 21, 22, and 23**. **Table 1** summarizes the determination of ferrite and pearlite percentages based on the distribution of the ferrite and cementite phases concerning the limit of the 100% pearlite content (0.77%C).

#	Mark mm	%α	%Fe_3C	%P	%C
1	0	0	5	95	1.06
2	0.5	0	2	98	0.89
3	1	0	1	99	0.75
4	1.5	20	0	85	0.61
5	2	35	0	65	0.50
6	2.2	42	0	58	0.45

Table 1 Ferrite and pearlite percentage data associated with the carbon concentration at a point on the lines drawn in the modified microstructural region of sample A

The red framed box in **Figure 8** represents a micrograph obtained from an SAE 1045 steel (0.45% C). Given the similarity with the background microstructure, near the 2.2 mm distance, the corresponding distribution of 42%α, 58%P can be associated with the tested specimen. On the other hand, **Figure 9** shows a screenshot of the calculations obtained by solving **Equations 6 to 9**.

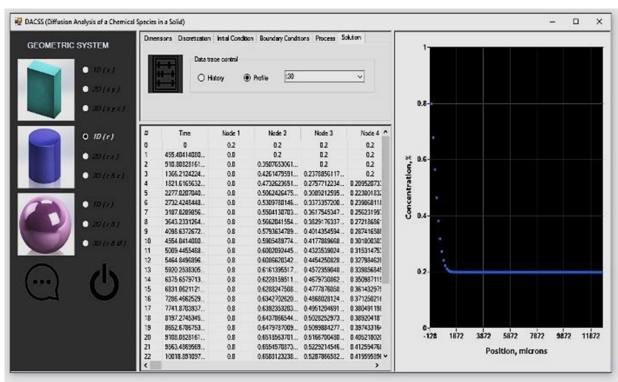
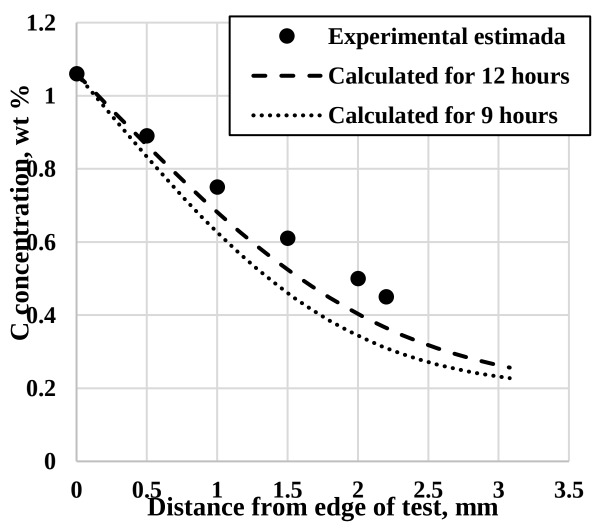


Figure 9 Developmental graphical user interface for calculating carbon concentration histories and profiles in the carburization process
Source: Image by screenshot of the development in MS Visual Studio Express 2010

The developmental graphical user interface for calculating carbon concentration histories and profiles in the carburization process is shown in **Figure 9**. It was possible to obtain the value of the diffusion coefficient [$D = 3.039E-11\, m^2 s^{-1}$] for calculations with the application using **Equation 17** and the parameters obtained from the table in **Figure 2** [$Q = 32900\, cal\, mol^{-1}\quad Do = 0.23\, cm^2\, s^{-1}$]. As well as considering a process temperature value T=1223.15 K. Additionally, a constant value of the concentration of carbon percent in the boundary condition $r = R$ of $C_b = 1.06$ (refer to **Equation 7**), a constant value of the concentration of initial of carbon percent in the steel $C_0 = 0.2$ (refer to **Equation 9**). Finally, a homogeneous discretization considering 99 control volumes and two processing times, 9 and 12 hours.

Graphic 1 shows the results of the %C calculation according to 1) the experimental estimates tabulated in **Table 1** (filled circles) and 2) the data calculated from the concentration field by mathematical modeling for 9 and 12 hours of process (lines segmented and dotted, respectively).



Graphic 1 Carbon concentration profiles in the carburization process were estimated experimentally (filled circles) and calculated with the mathematical model (dotted and segmented lines). *Own creation in Microsoft Excel 2016*.

The graphcis of the curves show that the calculations with the mathematical model and the experimental estimation differ more when establishing profiles with 9 hours of holding in the oven at 950 °C (dotted line).

However, suppose three hours to consider that diffusion originated and continued during the heating and cooling ramps. In that case, the calculation fits much better with the experimental determination. In this sense, the application can help adjust these offsets by correlating the solution to some of the predefined parameters.

On the other hand, the appreciation of the distribution of the ferrite phase and the pearlite microconstituent may also be overestimated in the micrographic analysis since the analyst's judgment is implicit.

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Conclusions

The validation of the transport model of chemical species determines that the estimated diffusion is well determined considering the existence of the phase with high solubility at high temperature (austenite) of the Fe-C system.

However, appreciating the phase distribution under qualitative equilibrium conditions is not a well-founded reference since it depends on the analyst. A best practice for comparing information should be based on an analysis of carbon concentration obtained with specialized chemical analysis equipment, such as an X-ray energy dispersive (fluorescence) elemental analyzer that can be fitted to a scanning electron microscope (SEM).

The computer application generates results effectively, and the parameters entered to obtain various calculations are easily redefined, mainly to adjust equivalent process times that include the effect on the diffusion of the heating and cooling ramps. Furthermore, if accurate indicator measurements were available during the process, more complex models could be implemented to define new diffusion coefficient data and a more complex sample surface boundary condition.

Additionally, the application would not only be limited to the carburization process since the same phenomenology governs other processes of similar interest. Therefore, computational development can be used for any system where the diffusion of chemical species is the phenomenon of interest.

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Sustainable design and manufacturing strategies, review in an appliance company

Estrategias de diseño y manufactura sustentable, revisión en una empresa de electrodomésticos

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Abstract

This article describes an overview of the concepts and main techniques related to sustainable design and production that are being developed in companies today to maintain a balance of resources. Using an information documentation method, the practices in a Mexican company that manufactures household appliances are examined. The information obtained suggests that the company has adopted measures and strategies to improve the environmental performance of its products. The product and process design phase is fundamental not only in the search for operational excellence for companies, but also in achieving benefits that have an impact on the environment.

Sustainable, Strategies, Environmental

Resumen

Este artículo describe una revisión de los conceptos y las principales técnicas en torno al diseño y manufactura sustentable que se están desarrollando en las organizaciones hoy en día con el propósito de mantener un equilibrio en los recursos. Mediante una metodología de documentación de información, se realiza una revisión de las prácticas emprendidas en una empresa dedicada a la fabricación de electrodomésticos en México. Con la información obtenida se concluye que la empresa ha emprendido acciones y estrategias para que sus productos tengan un mejor desempeño ambiental. La etapa de diseño de productos y procesos definitivamente es fundamental no solo en la búsqueda de la excelencia operativa para las organizaciones, sino además para la obtención de beneficios que impactan el medio ambiente.

Sostenible, Estrategias, Medio ambiente

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Introduction

Today, it is recognized that manufacturing must play an essential role in the quest for sustainability due to the large amount of resources it consumes and the waste it generates. In this sense, it is possible to obtain greater efficiency in production as a result of the implementation of sustainable design and manufacturing strategies.

The adoption of sustainable initiatives by manufacturing companies is decisive, favoring practices of lower energy consumption, reduced air and water emissions, and less generation of solid waste that can be hazardous to humans.

The rational use of energy and materials by companies cannot be seen as an isolated action. However, it must be linked to a minimization of environmental impact, the conservation of natural resources, a reduction in energy dependence and a better quality of life for society.

From the earliest stages of the design process, considering the environment facilitates the environmental management of the resulting product's life cycle. It makes sense to say that you are unlikely to achieve an environmentally friendly product if you don't start with green design.

Conceptual framework

Sustainable manufacturing

Several studies show that sustainable manufacturing can help organizations achieve better operational performance and improve environmental performance, supporting the sustainability efforts of manufacturing organizations (Monge et al., 2013).

The issue becomes necessary when considering that global manufacturing consumes large amounts of resources and generates huge amounts of waste; it can be said that global manufacturing consumes one third of energy and generates 36% of total CO 2, the main greenhouse gas (GHG)(Perez et al., 2022).

In Mexico, the power generation industry contributes 21% and manufacturing 8% of the gas emission as mentioned above; however, it is the industry that consumes the most energy, representing 60%, while only 30% of the companies in Mexico have an energy measurement system, which shows the low environmental awareness of the companies. Therefore, manufacturing plants should adopt sustainable practices or manufacturing (Monge et al., 2013).

In recent years there have been trends towards a change in the attitude of senior executives in organizations. They prefer to consider the issue of sustainability and its adoption as essential only if it brings short-term economic benefits rather than considering sustainability as an important differentiating factor to achieve competitive and strategic advantages through product and process innovation (Monge et al., 2013) (Perez et al., 2022).

Life cycle analysis

Life Cycle Assessment (LCA), according to (Sonnemann et al., 2004), is an environmental management tool whose purpose is to objectively, methodically, systematically and scientifically analyze the environmental impact caused by a process/product throughout its life cycle, from cradle to grave.

The current economic-productive model that affects the entire global system, whatever the activity or sector, is still mostly linear. The process begins with the extraction of virgin natural resources, which become raw materials to be transformed into products or services that will be packaged, distributed, sold and used, after their cycle of use, ending up in a landfill.

ISO 14040:1997 states that "LCA is a technique for determining the environmental aspects and potential impacts associated with a product, which is performed by compiling an inventory of the relevant inputs and outputs of the system; assessing the potential environmental impacts associated with those inputs and outputs; and interpreting the results of the inventory and impact phases in relation to the objectives of the study" (Boersema & Reijnders, 2009).

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According to ISO 14040:997, LCA consists of four phases: 1. definition of objectives and scope, 2. inventory analysis, 3. impact assessment and 4. interpretation of results (Finkbeiner et al., 2006). The active or dynamic phases, in which data are collected and evaluated, are the inventory analysis and impact assessment. The first and fourth phases can be considered static phases. Based on the results of one phase, the hypotheses of the previous phase can be reconsidered and redirected towards the path offered by the newly acquired knowledge. LCA is therefore a process that feeds back and is enriched as it is carried out.

Design tools

Concurrent engineering is a systematic approach to the integrated design of products and related processes, from conceptual design to market availability, including quality, cost and user requirements (Savii, 2003). One of the design methodologies used in concurrent engineering is Design for Manufacturing (DFM), which is defined as a set of programs, techniques, metrics, tools, and methods to improve the manufacturing of parts or simplify the assembly of part products (Kuo et al., 2001).

The goal of using design for manufacturing applied to a particular process is to design products that are easy to maintain, reliable, take less time, and are simpler and less expensive to manufacture while maintaining their quality (Kuo et al., 2001).

International regulations

Remarkable progress has been made in the field of international regulation. Adopted by the First International Conference on Chemicals Management (ICCM1) on February 6, 2006 in Dubai, the Strategic Approach to International Chemicals Management (SAICM) is a policy framework to promote chemical safety worldwide (Perez et al., 2022). It aims to achieve sound management of chemicals throughout their life cycle, seeking in the future to ensure that chemicals are used and produced in ways that minimize significant adverse effects on human health and the environment. SAICM's strategic approach is a landmark initiative in international cooperation aimed at protecting human health and the environment (Ministerie van Buitenlandse Zaken, 2004).

Chemicals and waste management play an essential and increasingly important role in all economic and social sectors (IOMC, 2019). Sound management of chemicals throughout their life cycle is essential to avoid complex risks to human health and ecosystems and substantial costs to national economies. Similarly, waste management is necessary to maximize the potential benefits of its contribution to human well-being. The Strategic Approach to International Chemicals Management is a landmark initiative in international cooperation to protect human health and the environment.

The management of chemicals and wastes plays an essential role and is increasingly important in all economic and social sectors. Sound management of chemicals throughout their life cycle is essential to avoid complex risks to human health and ecosystems, and substantial costs to national economies. Similarly, waste management is necessary to maximize the potential benefits of its contribution to human well-being.
cc).

The United States of America has a variety of regulatory agencies, standards and laws on chemical safety. In this country they are very concerned about the health and safety of people who use chemicals, so they are concerned about protecting the safety of employees and hold employers responsible for keeping their workers safe. This article discusses some of the laws, regulators, codes and standards and their implications for chemical workers. One of the most important chemical safety laws in this country is the Toxic Substances Control Act (TSCA), which ensures that chemicals are used, stored, and disposed of in a manner that is safe for human health and the environment (Grossman, 2016). This law was passed in 1976 and regulated the use, importation, and disposal of many new and existing commercial chemicals in the United States. It does not regulate food, packaging, pharmaceuticals, pesticides, or chemicals used in cosmetics and personal care products. TSCA gives the Environmental Protection Agency (EPA) the authority to request reports and impose restrictions on chemical substances and mixtures (Grossman, 2016).

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On the other hand, manufacturers and producers who market their products in the European Union (EU) must comply with regulations and certifications such as REACH and RoHS.

REACH is a European Union regulation that came into force on June 1, 2007. Its purpose is to improve the protection of human health and the environment from the risks posed by chemicals (Foth & Hayes, 2008). It also encourages alternative methods of hazard assessment of substances to reduce the number of tests performed on animals. In principle, REACH applies to all chemicals used in industrial and everyday processes such as cleaning products, paints or articles such as clothing, furniture and electrical appliances. Consequently, the regulation affects most companies in the EU.

Another necessary regulation is RoHS, an acronym for Restriction of Hazardous Substances, a European directive that deals with aspects related to electronics and the manufacture of electronic devices (Parliament Europian, 2003). It was created to control the use of hazardous materials often found in electrical and electronic equipment and devices. In addition, it was developed to protect human health and the state of the environment and ensure that electrical and electronic products can be recycled or disposed of safely.

The RoHS regulation affects any company that sells, distributes or manufactures electronic or electrical equipment in the EU. In addition, companies that, for example, sell such products to a third party that distributes them in the EU are also indirectly bound by the directive. As a directive and not a regulation, it is legally binding on all member states. It therefore leaves a particular framework for action when it comes to implementing it and ensuring compliance. The main groups related to the RoHS directive comprise 11 categories, in which various products are listed, the first category being large household appliances such as refrigerators, stoves, dishwashers and washing machines.

Technical and business strategies related to sustainability

A recent study conducted in SMEs in the United Arab Emirates to determine the relationship between total quality management (TQM), green innovation (GI) and corporate sustainable development (CSD) showed that there is a positive influence between them. In addition, green innovation favorably impacts corporate sustainable development and fully mediates the relationship between TQM and corporate sustainable development (Albloushi et al., 2023). It is important to consider the environmental aspect in quality indicators in order to achieve sustainability objectives.

On the other hand, (Farghali et al., 2023) conducted a review of current and new policies regarding energy sufficiency and conservation, concluding that it is only possible to envision a sustainable future if it is considered, as part of the solution, the application of a systemic approach that includes on the one hand the reduction in energy demand, and the promotion of the use of renewable energies in all sectors.
While (Mignon & Bankel, 2023) address the problem of companies struggling to identify, develop and implement sustainable business models adapted to their needs. The authors reviewed 87 cases of companies that have innovated their business models to achieve sustainable models. They identify four main sustainable business models that have been achieved through different innovation strategies (1) involving improvements towards efficiency, (2) that are based on new ways of making the business sustainable, (3) that have a greater orientation towards society and/or the environment, or (4) that are born sustainable. Finally, (Jayawardane et al., 2023) conduct research to adopt circular economy strategies, such as plastic recycling in industrial applications, to reduce waste management. The research group used recycled polylactic acid (PLA) material as raw material for 3D printing of a pump impeller and the performance was compared with using virgin PLA material. They highlight in their results that 3D printed recycled PLA impellers are more eco-efficient compared to 3D printed virgin PLA impellers. The eco-efficiency assessment revealed that recycled materials significantly improve eco-efficiency performance, in addition to revealing positive social impacts of additive manufacturing for employees in terms of health and safety.

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More and more companies are adopting sustainability-related strategies that contribute significantly to economic and social development by helping to solve ecological problems such as water, air pollution and erosion of natural resources.

Methodology

The desk research at the company involved the systematic review and analysis of various types of documents to gather information, knowledge and data related to the factory's operations, processes and performance. The following is an overview of the methodology for the desk research conducted at the companym.

1. The research objectives were defined. The main objective of the research was to carry out a review of the main sustainable manufacturing strategies in a home appliance company.

2. Relevant documents were identified such as publications in specialized magazines, newspapers, safety manuals, regulatory documents and reports that the company allowed to review on site, as well as interviews with personnel from various departments.

3. An analysis of the data collected was conducted and cross-checked for validation to ensure that the research clearly and accurately reflects the company's operations and challenges.

Results

In the company under study, the corporate supplier quality department aims to verify that the parts supplied by its suppliers comply with the specifications established by the company, adhering to the requirements of REACH and RoHS, toxicity regulations in the European Union.

As mentioned above, REACH requires the registration, evaluation and authorization of chemicals produced, used or imported into the European market. RoHS refers to the directive on the restriction of certain hazardous substances in electrical and electronic equipment.

In this context, the "Company Regulatory Declaration" project was initiated in 2020, with the aim of conducting a strict review of suppliers' compliance with the established requirements. Some of the materials are composed of different chemical substances that, if present in a higher percentage than established, would have severe consequences on the health of customers and the environment.

The company has a Technology and Project Development Center (T&D Center), where it has been able to improve its products and the technology associated with the conceptualization, design and implementation of new products. The T&P Center liaises with the other areas for project development and for the solution of specific projects related to the product, materials and service.

Currently, the T&P center is in a design stage to include the topic of eco-design, based on the product life cycle, relating environmental, health and safety objectives throughout the entire life cycle of its products and processes, from inputs to final product packaging (Technology and Projects, 2003), (Alejandro, 2014).

Being aware of the issue of sustainability in all its processes, the company is implementing environmental impact strategies based on the 3Rs. Examples of this can be identified in the reduction of the use of electrical energy that comes from the change to LED lighting in its operational areas; the reduction of waste of its materials, such as the standardization and reduction of screws in the assembly; the reuse of obsolete station modules, for the construction of its new manufacturing cells. Likewise, the rational use of water, by recycling wastewater for irrigation of its green areas.

Regarding design methodologies, those currently practiced and which have predominated in the company are Design for Manufacturing (DFM), Design for Safety (DFS) and Design for Performance (DFPE). The company's own techniques can be summarized as follows.

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Design for Six Sigma (DFSS). It is based on a methodological analysis, by means of the IDOV structure (Identify, Design, Optimize, Validate), achieving the descent of the customer's requirements from the product to the specification of each component, ensuring that the contribution of each one meets the customer's needs (Tecnología y Proyectos, 2003). Within the Six Sigma methodology, the Quality Function Deployment (QFD) tool is used. The QFD technique ensures that the properties, characteristics, design and specifications of its products, as well as the selection and development of equipment, methods and process controls are oriented to the demands of the user (Alejandro, 2014).

Design for Reliability (DFR). In order to guarantee that a component will fulfill its purpose, the evaluation of these is done taking into account the expected useful life of the component and the environment to which it will be exposed (Alejandro, 2014).

The company collaborates with FirstBuild. FirstBuild is GE Appliances' collaborative innovation platform that engages a diverse community in co-creating home appliances. Through open innovation and rapid prototyping, it fosters the development of cutting-edge ideas and solutions. Maker spaces and microfactories provide the tools for participants to bring their designs to life. Challenges and competitions further incentivize the collaborative design process, contributing to the evolution of appliance technology (Alänge & Steiber, 2018).

In the concept of environmental performance of its products, for the Life Cycle Analysis, the company frames issues such as materials, manufacturing processes, means of transportation, type of energy required at different stages of its life cycle and delivery to the distributor or final customer.

Mabe prioritizes innovation, dedicating approximately 1% of its annual sales to research and development, focusing particularly on energy efficiency and the integration of technologies such as the Internet of Things, according to the director of the Technology Center, in an interview for El Financiero (Almanza, 2018).

Emphasizing the market demand for energy efficiency and environmental responsibility, he highlighted the company's commitment to address the carbon footprint and contribute to a greener world. The executive noted that development in these areas not only aligns with market demands, but also generates substantial savings in energy costs for consumers who use Mabe appliances.

In summary, the company focuses on developing sustainable solutions and practices that can be integrated into the life cycle of its products. It focuses on the development of two categories that enable it to strengthen its sustainability strategy. Product. Sustainable features are integrated into products to reduce environmental impacts for the benefit of society. Institutions. Strategic alliances are established and strengthened to maximize the impact of our efforts worldwide.

Conclusions

Sustainable design should be incorporated into conventional design to ensure minimal impact on the resources available for life on the planet. In addition, the life cycle analysis favors sustainable manufacturing, from the extraction and procurement of materials, use, recycling and return of materials to their origin, allowing a lesser effect on the degradation and depletion of natural resources.

According to the company's research, it can be concluded that the initiatives it has undertaken as strategies to reduce pollution and prevent environmental damage caused by materials are the beginning to reduce the health risks associated with exposure to them.

On the subject of design methodologies, it can be stated that the company is making efforts to ensure that its methodologies are focused on the needs of its market. While, in parallel, it seeks to improve the environmental performance of its products, it faces significant challenges as its products become solid waste at the end of their useful life, with risks to humans and the environment.

Finally, the eco-environmental concept is taking on great relevance for the company, creating awareness of its benefits both for sustainability and for optimizing the value of its products.

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Energy analysis of lighting in high-impact buildings with transparent envelopes

Análisis energético de iluminación en edificaciones de alto impacto con envolventes transparentes

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Abstract

This article exposes the process of energy analysis through the lighting study in an office space in a building with transparent envelopes. With this analysis it will be possible to determine the optimal lighting and therefore the reduction of energy consumption. With the analysis of the results, a lighting design was proposed with improvements to the luminaires. The results show a more efficient way to take advantage of the natural resources of the envelope. For the new proposal, aspects in the design of the building were considered, as well as the standards NOM-025-STPS-2008 and NOM-025-STPS-1994, which establish the minimum lighting levels that must affect a health center. job. And the energy consumption of the building to be considered sustainable.

Lighting, Comfort, Workplace

Resumen

Este articulo expone el proceso del análisis energético a través del estudio de iluminación en un espacio para oficinas en un edificio con envolventes transparentes. Con este análisis se podrá determinar la óptima iluminación y por ende la reducción del consumo energético. Con el análisis de los resultados se propuso un diseño de iluminación con mejoramientos de las luminarias. Los resultados muestran una manera más eficiente para aprovechar los recursos naturales de la envolvente. Para la nueva propuesta se tomaron en cuenta aspectos en el diseño del edificio, Así como las normas NOM-025-STPS-2008 y NOM-025-STPS- 1994, las cuales establecen los niveles mínimos de iluminación que deben incidir en un centro de trabajo. Y los consumos de energía del edificio para considerarse sustentable.

Iluminación, confort, centro de trabajo

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Introduction

One of the places where people spend the most time in their lives is the workplace, which is why it is a place that must have the ergonomic conditions for their work activity to be carried out efficiently, it must be safe and comfortable. In order to develop effectively, light and vision need to complement each other, as it is considered that 50% of the sensory information received by man is visual, i.e. its primary origin is light, which is why it is a fundamental part of the ergonomic conditioning of the work area. [1].

In this article, an analysis was made of the lighting conditions in the Torres de Plata work centre, located in Camino Real de La Plata, Zona Plateada, Pachuca de Soto, Hgo. in order to make a lighting proposal for the building according to the requirements of the workplace and the tasks to be carried out.

Theoretical Framework

The atmosphere of a workplace is very important, since having a range of colours influences the mood of the people, so a correct lighting has a direct influence on the actions, improves the capabilities when performing tasks enhancing activities and skills achieving greater productivity, It also helps to prevent health problems, and also the type of lighting in places makes customers pay more attention to what they are interested in, which is why lighting can create an atmosphere that favours the image of the place.

Concepts

Workplace: All places such as buildings, premises, facilities and areas where production, marketing, transport, storage or service activities are carried out, or where people are subject to an employment relationship. [2]

Work area: is the place in the workplace where a worker normally carries out his or her activities.

Ergonomic analysis and characteristics of a functional lighting system

Correct lighting is that which allows shapes, colours and moving objects to be distinguished, allowing reliefs to be appreciated easily and without fatigue, i.e. to have permanent visual comfort. Therefore, the ergonomic analysis of the lighting of a work area must consider the conditions of the observer determined by his visual capacity (visual acuity, sensitivity to contrast, speed of perception), conditions of the environment (dimensions, colours, shape, function and texture), conditions of the task (dimensions of the objects to be observed or manipulated, contrast, difficulty of the task (duration, speed of response, etc.) and conditions of the structure of the place (position of the light points, light distribution, typology and design of the light points, natural light-artificial light ratio). [3, 4]

Conditions for visual comfort

An important factor is that workplaces must have natural or artificial lighting, even if there is enough natural light, sometimes it does not guarantee correct lighting, because it varies depending on the weather, the structure of the place, the location of the work area, so to ensure visual comfort, the level of lighting, glare and the balance of luminance must be taken into account. [5]

Lighting levels for visual tasks and work areas

The optimum lighting level for an activity or task corresponds to that which results in the highest performance with minimum fatigue.

According to NOM-025-STPS-2008 [3], the minimum lighting levels that should affect the work plane, for each type of visual task or work area, are those set out in Table 1.

Visual Workplace Task	Working Area	Minimum Illumination Levels (lux)
Outdoors: distinguishing traffic area, walking, surveillance, vehicle movements.	General exteriors: courtyards and car parks.	20
Indoors: distinguishing the traffic area, walking, surveillance, vehicle movement.	General interiors: low movement warehouses, corridors, stairways, covered parking lots, subway mine workings, emergency lighting.	50
Indoors.	Circulation areas and corridors; waiting rooms; rest rooms; storage rooms; platforms; boiler rooms; boiler rooms; storage rooms; storage rooms; platforms; boiler rooms; boiler rooms; boiler rooms storage rooms; platforms; boiler rooms; storage rooms; boiler rooms.	100
Simple visual requirement: visual inspection, parts counting, bench and machine work.	Personnel services: heavy-duty storage, reception and dispatch, guard booths, rooms, etc. of compressors and piling.	200
Moderate detail distinction: simple assembly, medium bench and machine work, simple inspection, packaging and clerical work.	Workshops: packaging and assembly areas, classrooms and offices.	300
Clear distinction of details: delicate machining and finishing, moderately difficult inspection assembly, data capture and processing, handling of instruments and laboratory equipment.	Precision workshops: computer rooms, drawing areas, laboratories, etc.	500
Fine detail distinction: precision machining, assembly and inspection of delicate work, handling of precision instruments and equipment, handling of small parts.	High-precision painting and surface finishing shops and quality control laboratories.	750
High accuracy in detail distinction: assembly, processing and inspection of small and complex parts, finishing with fine polishings.	Process: assembly and inspection of complex parts and fine polished finishes.	1000
Alto grado de especialización en la distinción de detalles.	High accuracy process. Execution of visual tasks: - low contrast and very small size for prolonged periods of time; - accurate and very prolonged, and - very special tasks of extremely low contrast and small size.	2000

Table 1 Lighting Levels
Source: NOM-025-STPS-2008

Methodology

We started with the site reconnaissance, functional program, survey and architectural plans, materials and construction system, virtual model and the lighting study of a Work Center of the Torres de Plata building, located in Camino Real de La Plata, Zona Plateada, Pachuca de Soto, Hgo,

It was necessary to contemplate the location of the place to trace a faster route of arrival to the place of study, as shown in Figure 1 the location of the Torres de Plata building.

Figure 1 Location of the Torres de Plata Work Center, Pachuca, Hgo.
Source: Google Maps.

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The building contains at sight: reception, office floors, meeting room, bathrooms, corridors, subway parking, as well as the construction materials, colors, and the building envelope. Figure 2 shows the main façade of the Torres de Plata Work Center, Pachuca, Hgo. It can be seen that more than 70% of the building envelope is transparent.

Figure 2 Silver Towers, Pachuca, Hgo.
Source: Own elaboration

As can be seen, the building has large windows that provide natural light. However, the analysis will be made of space 7, first floor of the building.

AutoCAD Drawings

Once the information on the Torres de Plata building was available, we began to transfer the data of the first floor to the AutoCAD 2019 program (a program for the design of 2D plans, using lines, points and particular characteristics such as hatch, blocks in general and dimensions), to generate the architectural plan to identify the study area (work office) in the plan, analyze it and propose the lighting guided by the Mexican standard NOM-025-STPS-1994. Figure 3 shows the architectural plan of the first floor and Figure 4 shows the work office in the current context of the Torres de Plata building.

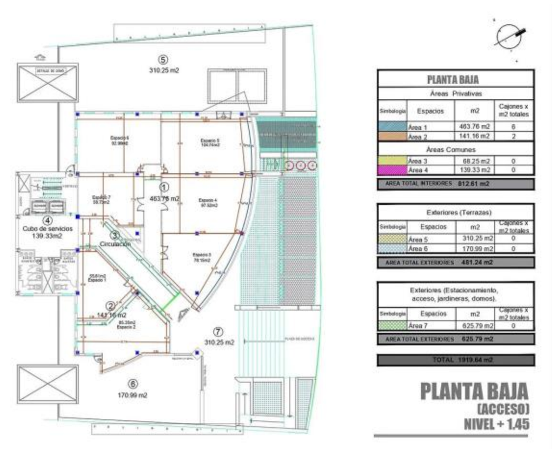

Figure 3 Architectural floor survey
Source: General Information Torres de Plata (torresdeplatapachuca.com

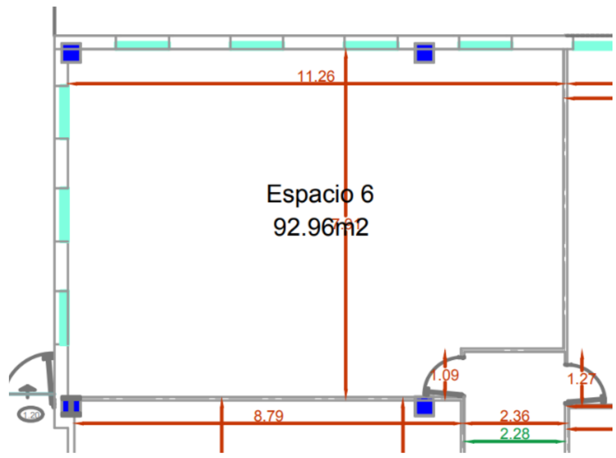

Figure 4 Plan view of the office to be worked on measuring 12 m x 8 m.
Source: General information Torres de Plata (torresdeplatapachuca.com)

Architectural modeling

With the architectural plan in AutoCAD 2019 we started with the 3D modeling with ArchiCad 22 (a three-dimensional modeling program that generates volume, perspectives and rendering), designing a proposal for the design of a work office, which brings to solve all the problems of lighting, comfort and safety. [7]. The design is divided in a translucent way for visual improvement, incorporating furniture and decorations for user comfort and above all provide satisfaction when working, as shown in Figure 5 and 6, shows a rendering of the proposed design of the office.

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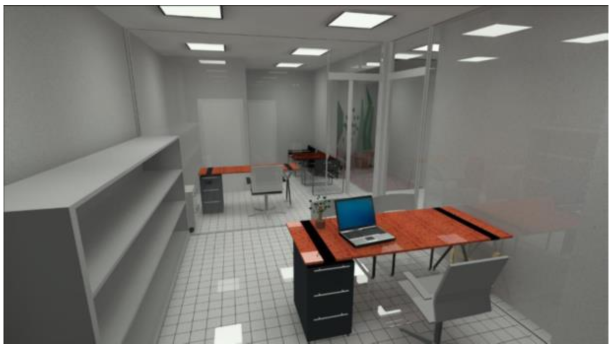


Figure 5 Office design proposal
Source: Own elaboration

Figure 6 Plan view of the proposed office design
Source: Own elaboration.

Modeling with the current context in DIALux evo 8.0 software

The modeling and simulation of the lighting of space 6, on the first floor of the Torres de plata building, was carried out with the DIALux evo 8.0 program, which allows us to analyze the artificial lighting aspects such as the luminaires that are installed and the natural ones such as the windows and doors that are on the site, based on its platform.

Having the modeling in archicad 22 was transported to the DIALux program to analyze the current interior context of luminosity of space 6, on the first floor of the Torres de plata building, as shown in figure 7 the interior modeling with the DIALux evo 8.0 program.

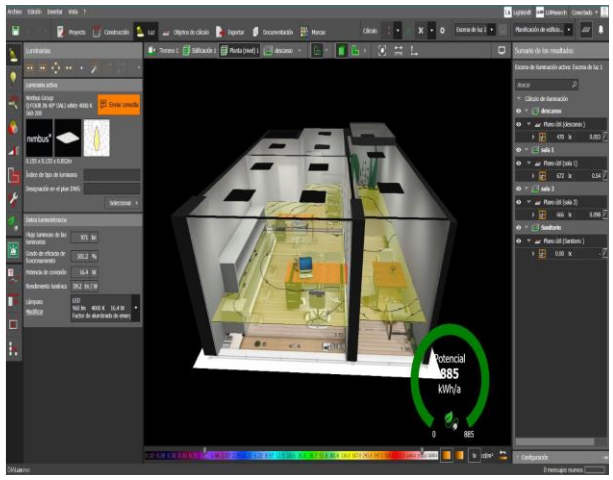


Figure 7 Geometry of the office proposal in the Dialux program for processing
Source: Own elaboration

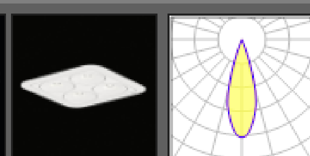
Results and lighting proposal

The following are the characteristics of the luminaire to be used for the work center in space 6 of the Torre de Plata, in order to achieve adequate lighting for users so they can perform their daily activities effectively without adversity, also respecting and complying with the Mexican standard NOM-025-STPS-1994. [3]

Luminaria X

Hoja de datos de luminarias

nimbus*



Q FOUR IN 40° DALI white 4000 K
560-208

Flujo luminoso total 960 lm

Potencia de conexión 16.4 W

Descripción

Recessed LED ceiling spot for cavity mounting in a suspended ceiling, 4 integrated Bartenbach lenses for focussing light and reducing glare, narrow beam (beam angle 40° or 80°) for accentuated illumination of surfaces and rooms, the full light performance thus appears on the illuminated area, design formally adapting to the Nimbus families Q ONE, Q FOUR and FRAME, operation by means of an external converter (within the scope of delivery), dimmable via DALI or via trailing/leading edge in combination with a conventional wall dimmer.

Table 2 Characteristics of the proposed lighting for the offices in space 6 of the Silver Tower

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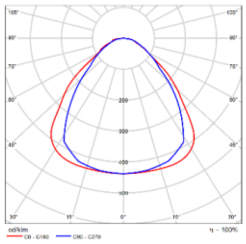
Likewise, the proposal of luminaires for the space is made, as shown in Figures 8 and 9, general characteristics of the type of luminaire to be implemented, such as degrees of reflection and energy consumption.

Ficha de producto

LEDS-C4 S.A. - Ecofit Plus 60 x 60 Sensor autonom

N° de artículo	AP31-35W8MPWR14
P	34.7 W
$\Phi_{Lámpara}$	3697 lm
$\Phi_{Luminaria}$	3697 lm
η	100.00 %
Rendimiento lumínico	106.5 lm/W
CCT	3000 K
CRI	80



CDL polar

Figures 8 General characteristics of the proposed luminaire type

A metal halide lamp was chosen for its aesthetics, energy savings and easy maintenance. Figure 9 shows the luminous intensity that the project will obtain with the proposed luminaires, taking into account the luminous intensity in this type of areas. [7]

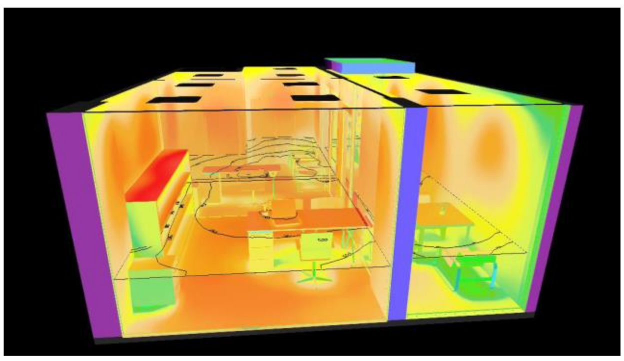


Figure 9 Luminous intensity with the proposed luminaires for space 6 inside the Silver Towers
Source: Own elaboration

It is important to consider the lighting levels in workplaces, because if there is too much natural-artificial light due to inadequate conditions, it can cause glare from natural light entering through windows or lights, causing discomfort that reduces visual perception and causing discomfort, so it is important to eliminate bothersome reflections and maintain a balance by conditioning the places with sufficient natural light and adequate lighting according to the area of the workplace and activities to be carried out.

Conclusions

All workplaces should consider the regulations to establish adequate lighting levels as it helps to prevent occupational hazards in workers. The balance between the structure, environmental conditions: temperature, wall colors and a correct natural and artificial lighting will help people feel in a comfortable environment improving their skills and abilities, increasing productivity.

Therefore, the design must be oriented to safety, for that same reason, it is convenient to consider design elements such as: the orientation of the space to provide natural lighting according to the envelope. This in accordance with the artificial lighting according to the study area, in such a way that they complement each other to obtain the necessary lux at any time. This complies with the regulations. Another important consideration is to change traditional walls for translucent walls, so that with an adequate design it will reduce the energy consumption of the work center. In addition, providing a safe and healthy environment for workers.

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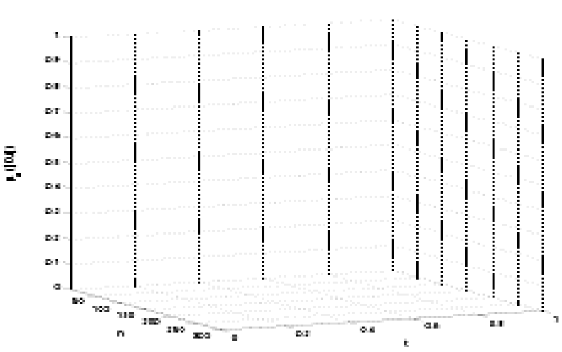

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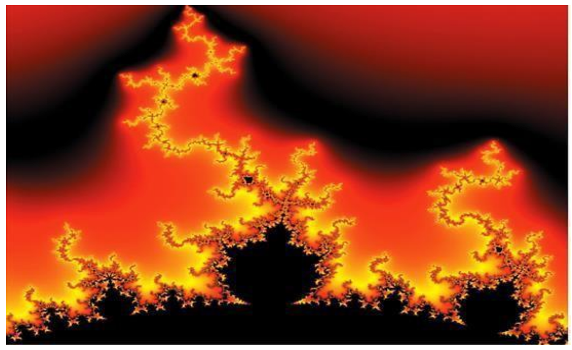

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