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Journal of Technology and Innovation

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Presentation of content

In the first article we present, *Injection parameters study for a polypropylene probe used on tension test*, by RODRÍGUEZ-DAHMLOW, Jesus E., FUENTES-RAMIREZ, Rosalba, GÓMEZ-CASTRO, Fernando I. and MURILLO-YAÑEZ, Luis E., with adscription in the, Universidad de Guanajuato and Instituto Politécnico Nacional, in the netx article we present, *Incorporation of ZnO nanoparticles in polymeric matrices as UV protector*, by MONTERO-GUZMAN, Erika, GALINDO, R. and FUENTES-RAMIREZ, R., with adscription in the Universidad de Guanajuato, in the netx article we present, *Study of the anticorrosive properties of magnetic composites*, by MARTINEZ-MORENO, Miguel, GÁMEZ-DUEÑAS, Claudia L., FUENTES-RAMÍREZ, Rosalba and CONTRERAS-LOPEZ, David, with adscription in the Universidad de Guadalajara, in the netx article we present, *System of acquisition and processing of signals through of Arduino platform and Matlab (How tool of learning)*, by ARREGUIN-JUÁREZ, Miguel, HERNÁNDEZ-LÓPEZ, Sandra Paola, SÁNCHEZ-TORRECITAS, Enrique and QUINTANILLA-DOMÍNGUEZ, Joel, with adscription in the Universidad Politécnica de Juventino Rosas.

Content

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Injection parameters study for a polypropylene probe used on tension test

Estudio de los parámetros de inyección de polipropileno para una probeta de ensayo de tensión

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Abstract

Simulation of the melten allows us to predict the behavior of the plastic material inside the mold, clarifying that at present polymers are one of the most used materials due to the versatility of its properties. Through the simulation using the Solidworks Plastic® platform, it is proved that injection time is defined by the thickness of the part and the injection point diameter. Besides, every simulation gives a relation between pressure, cooling, and cycle time, by making changes in mold and PP temperature is possible to get a starting point to set up the conditions of real process. Simulation also involves the selection of the element type and some other parameters related to the Finite Element Method. The relevance of the study focuses on giving a starting point for processing PP using the theory and the simulation due to most of the time injection conditions are selected by previous experience of the operator. Accordingly, this work focuses on the study for the required injection pressure, cooling, and injection cycle time to process a polypropylene (PP) tensile test specimen based on the Standard ISO D638D-14, these variables are tested changing the mold and PP temperature trying to predict the best injection parameters.

Injection time, simulation Injection process, Polypropylene

Resumen

La simulación del fundido nos permite predecir el comportamiento del material plástico en el interior del molde; aclarando que en la actualidad los polímeros son uno de los materiales más empleados debido a la versatilidad de sus propiedades. Mediante la simulación con la plataforma de Solidworks Plastic® se demuestra que el tiempo de inyección se define por el grosor de la pieza y el diámetro del punto de inyección. Además, proporciona una relación entre la presión, el enfriamiento y el tiempo del ciclo, al hacer cambios en la temperatura del molde y del PP, por lo que es posible obtener un punto de partida para configurar las condiciones del proceso real. La simulación también implica la selección del tipo de elemento y algunos otros parámetros relacionados con el Método de Elementos Finitos. La relevancia del estudio se centra en dar un punto de partida para el procesamiento del PP utilizando la teoría y la simulación ya que la mayoría de las veces las condiciones de inyección son seleccionadas por la experiencia previa del operador. Por lo tanto, este trabajo se centra en el estudio de la presión de inyección requerida, el tiempo de ciclo de enfriamiento e inyección para procesar una probeta de tracción de polipropileno (PP) basada en la prueba estándar ISO D638D-14, estas variables se prueban cambiando la temperatura del molde y del PP tratando de predecir los mejores parámetros de inyección.

Tiempo de inyección, Simulación del proceso de inyección, Polipropileno

Citation: RODRÍGUEZ-DAHMLOW, Jesus E., FUENTES-RAMIREZ, Rosalba, GÓMEZ-CASTRO, Fernando I. and MURILLO-YAÑEZ, Luis E. Injection parameters study for a polypropylene probe used on tension test. Journal of Technology and Innovation. 2020. 7-20:1-6.

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Introduction

During recent years, the industry has focused on the use of polymeric materials, with an increasing demand for new materials, with specific characteristics. These materials present a low cost of production, and a great variety of applications, for example, car bumpers, handles, retainers, among others. If the processing parameters are improved the process may use less power, the cycle time can be reduced, and the mechanical properties could be improved. This has given guidelines to study both: the effect of injection and the mold temperature within the process.

Today, the simulation allows us to have a firts approach to how the real process may behave. The method used to find out the best process condition is selected according to literature.

Injection Process

Injection molding is the most important molding method for thermoplastics. It is based on the ability of thermoplastic materials to be softened by heat and to harden when cooled. The process thus consists essentially of softening the material in a heated cylinder and injecting it under pressure into the mold cavity, where it hardens by cooling. Each step is carried out in a separate zone of the same apparatus in the cyclic operation. A diagram of a typical injection-molding machine is shown in Figure 1.

The parameters to control in the injection process depend on the working material, part and mold design. Each case has its particularities but in general, the control variables are temperature, speed, pressure, distance and time [1].

In the process, granular material (the plastic resin) falls from the hopper into the barrel when the plunger is withdrawn. The plunger then pushes the material into the heating zone, where it is heated and softened (plasticized or plasticated).

Rapid heating takes place due to the spreading of the polymer into a thin film around a torpedo. The already molten polymer displaced by this new material is pushed forward through the nozzle, which is in intimate contact with the mold.

The molten polymer flows through the sprue opening in the die, down the runner, past the gate, and into the mold cavity. The mold is held tightly closed by the clamping action of the press platen. The molten polymer is thus forced into all parts of the mold cavities, giving a perfect reproduction of the mold. [2]

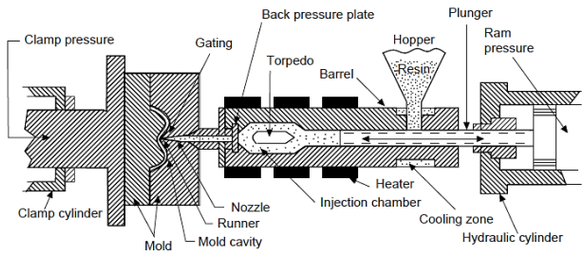

Figure 1 Diagram of a typical injection-molding machine
Source: Chanda, M, 2008

The injection cycle involves several steps, these are presented in **Figure 2**. It is observed that the injection step takes the lowest time, but parameters as temperature in both mold and plastic are modified, the time can change favorably.

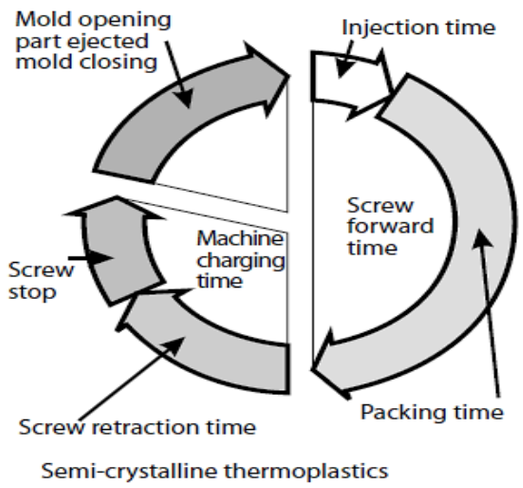

Figure 2 Injection cycle for thermoplastics
Source: (Campo, A,2006) [3]

Methodology

Process conditions

Simulation is developed in the module Plastics from the software **Solidworks®**, being helpful to understand the injection process.

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Solidworks® has a module of plastics simulation which allows to predict the behavior of the polymers under certain conditions. To develop the essay, there are some considerations to keep in mind like the following are the injection process steps followed in this work 1) Determine geometry, 2) Select the mesh control, 3) Apply material, 4) Apply injection point and 5) Solve.

Before the simulation can be done it is required to set the simulation process variables, Solidworks® has a database which includes values for the initial set point, the different variables for the simulation can be seen in Table 1.

Standard used	ISO-638D-14 shown in Figure 3
Material	Aluminum (Al) 6061
Thermal expansion coefficient for Al.	23.6 x 10^{-6} $°C^{-1}$ @ Temperature 20 - 100 °C.
Injection parameters	
Inlet flow rate	25.556 cm^3/s
Inlet normal velocity	87.090 cm/s
Inlet region area	0.293 cm^2
Inlet Reynolds No.	0.062503

Table 1 Considerations for the injection process
Source: (Solidworks and ISO standards)

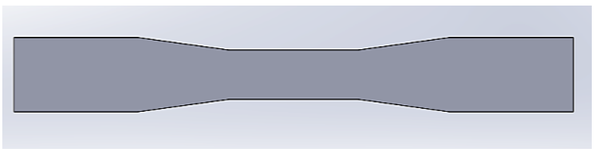

Figure 3 Standard ISO 638D-14 tensile test geometry
Source: own work [Solidworks]

One of the most important decisions associated with mold filling is determining the type, number and location of the gate(s) used for the plastic part. The gate, as the name implies, is the melt's point of entry into the mold cavity. Gates can be placed at one or more locations on the part and can have various designs. Different gating designs and locations can have a dramatic influence on the overall part quality.

The selected injection point is shown in Figure 4 (4 mm of diameter). Such a position is preferred to be to make polymer flow in only one direction [4].

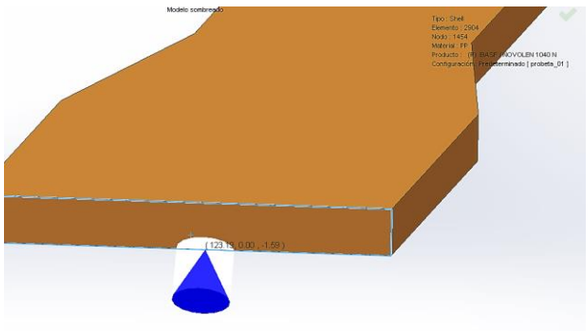

Figure 4 Injection point
Source: own work [Solidworks]

For the discretization, a shell element type with a triangle size of 3.302 mm has been selected, resulting in 2984 triangles and 4773 tetrahedrons, meshing results are shown in Figure 5. The computer time increases with the number of elements, another thing to keep in mind is the element type; solid or shell, for this study the second type was selected and the average computer time was reduced from several hours to 8 minutes for each analysis.

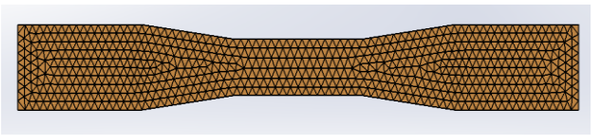

Figure 5 Meshing of the studied geometry
Source: own work [Solidworks]

There are two main features to modified: molding temperature and Injection Time. Commonly temperature is set by experience but by making a review of the literature the processing temperature for Polypropylene can be set in a range from 220 to 240 °C [5]. If the temperature goes below this parameters it makes hard process the polymer increasing the pressure required in the other hand if it goes above 240 °C the polymer begins to degrade, this causes a change in color and the loss of its mechanical properties due to the chains break reducing its length.

Results and Discussion

Simulation allows us to get an idea of the behavior of the way it may flow inside the mold, it also allows us to play with parameters without the risk of damaging the machine. Injecting in different conditions offers the opportunity of evaluating the range in which the cycle and cooling time can be improved.

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Figure 6 shows the profile for the Injection Pressure for the model, it is below the 66% of the injection limit pressure suggested by the model conditions, this means that it is within the parameters suggested by the software. Also, there is no risk of material degradation, according to the software database.

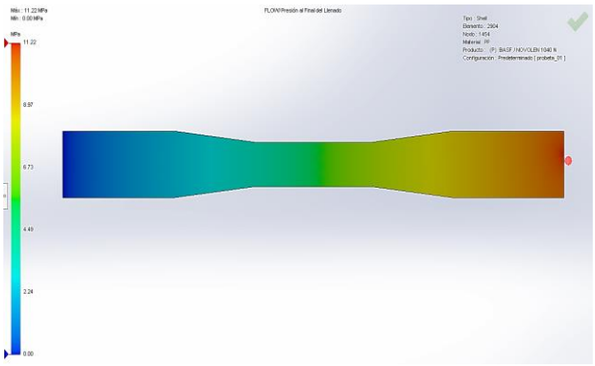

Figure 6 Pressure Profile for the simulated injection
Source: own work [Solidworks]

Simulation also allows detecting defects like air traps (shown in Figure 7) which can be avoided by putting air exhaust (ventings).

After the simulation Injection and Cooling times, these are consistent likewise for the Filling Pressure and Injection. In Figure 8 the injection time increases proportionally to the cooling time, increasing the mold temperature is not a good alternative because it requires more energy and cycle time.

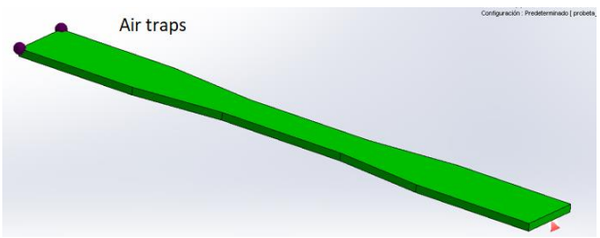

Figure 7 Air traps inside the model after the injection.
Source: own work [Solidworks]

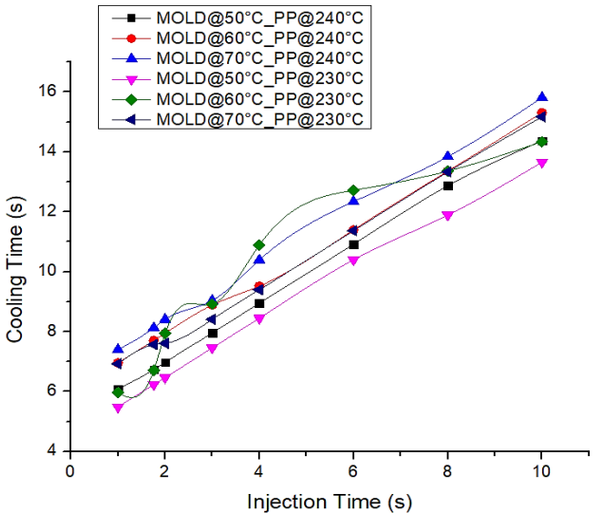

Figure 8 Injection vs Cooling time graph
Source: *0wn work [Origin]*

Figure 9 shows that pressure required decreases by adding mold temperature but for the interval from six to ten seconds the difference in pressure is not minima. After reviewing the two Figures, can be recommended mold temperature at 50 °C.

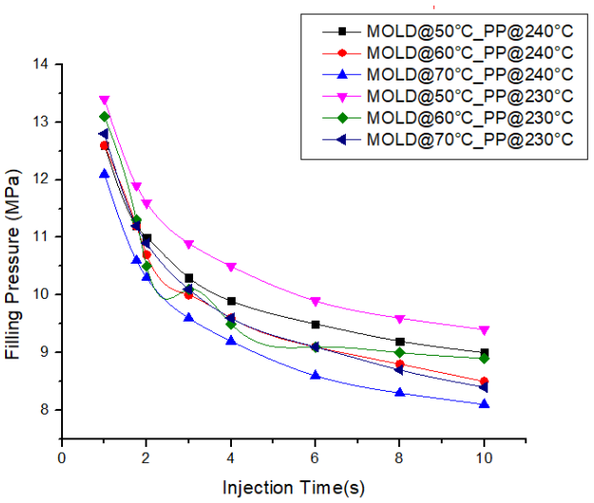

Figure 9 Injection time vs Filling pressure graph
Source: own work [Origin]

It is recommended that injection must occur in the less possible time [6]. Computing the average of the lines plotted and using regression the following polynomial equations can be obtained.

$$y = 0.1517x^2 - 0.1766x + 6.981 \quad (1)$$

Equation 1 is derived from Figure 8 and its behavior for the cooling time can be seen in Figure 10.

For the equation 2, is derivated from Figure 9 and its behavior is represented for Injection Pressure in Figure 11.

$$y = 0.0654x2 - 1.1259x + 13.597 \quad (2)$$

Both equations present a good correlation grade set in R^2=0.99 and R^2=98 respectively.

Applying the concept of stationary point for a function of one variable, they are derived giving the following points: for Injection Pressure (8.607 s, 8.75 MPa) and for the Cooling Time (0.58 s, 6.92 s). Both functions have positive second derivatives, thus both stationary points are minima.

It can be that the minimum Cooling Time the time occurs at the injection point of 0.58 s. Nevertheless, if this injection time is used, the Pressure will increase enormously and on the other hand, at 8.607 s the Pressure is at its minimum.

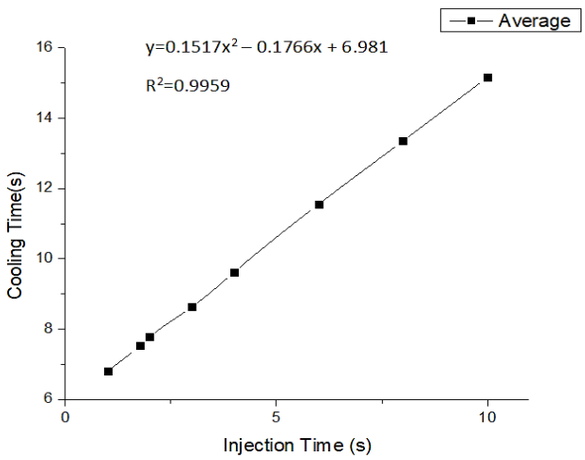

Figure 10 Regression for the injection time vs cooling time
Source: own work [Origin]

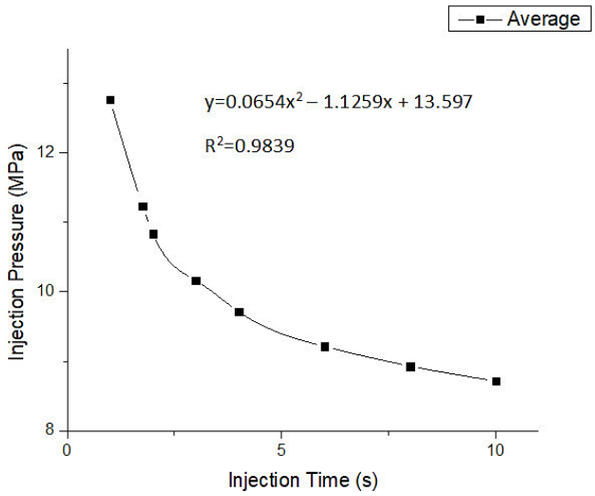

Figure 11 Regression for the injection time and injection pressure
Source: own work [Origin]

Conclusions

During the injection process, it gives a starting point before any physical test is carried out. In the practice, the user sets up the machine by a try-and-failure method. Increasing the mold temperature doesn't impact the performance significantly but injection pressure does. On the other hand, if the results obtained in the simulation are taken, the set-up time may be decreased considerably, and the machine operation can be improved. Making a good balance between injection time, mold temperature, and pressure the process is more effective, saving energy and reducing the cycle time. To decrease the cooling time it can be an option to install a cooling system based on forced convection airflow using a fan or machining cooling runners and passing water for them. By doing this the pressure can be kept and the cycle time may decrease.

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Incorporation of ZnO nanoparticles in polymeric matrices as UV protector

Incorporación de nanopartículas de ZnO en matrices poliméricas como protector de UV

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Abstract

At present there is great interest in the development of new nanomaterials that can be applied in different areas of study such as chemistry, physics, medicine, among others. In many polymeric materials, especially when used in coatings exposed to sunlight, they cause photolysis and photooxidation reactions, leading to the degradation of their physical-mechanical, optical and other properties. Therefore, the need to look for new materials capable of resisting radiation for prolonged periods, while retaining its original characteristics, such as hue and brightness, is imperative. Zinc oxide nanoparticles have attracted great interest in this aspect as they are used in most commercial sunscreens that use inorganic pigments, for their ability to adsorb ultraviolet rays. In the present work, the incorporation of the Np-ZnO in situ during the polymerization by the emulsion process of butyl acrylate was carried out. ZnO nanoparticles are incorporated into butyl polyacrylate in different concentrations of 0.3%, 0.5%, and 1% W, in which it is observed that at 1% there is greater agglomeration and in the others it does not affect the morphology of our polymer.

UV protection, Polymerization, Nanocomposites, Emulsion, Zinc oxide nanoparticles, Butyl polyacrylate, Free radicals

Resumen

En la actualidad, existe un gran interés en el desarrollo de nuevos nanomateriales que puedan aplicarse en diferentes áreas de estudio, como la química, la física, la medicina, entre otras. En muchos materiales poliméricos, especialmente cuando se usan en recubrimientos expuestos a la luz solar, causan reacciones de fotólisis y fotooxidación, lo que conduce a la degradación de sus propiedades físico-mecánicas, ópticas y de otro tipo. Por lo tanto, la necesidad de buscar nuevos materiales capaces de resistir la radiación durante períodos prolongados, manteniendo sus características originales, como el tono y el brillo, es imprescindible. Las nanopartículas de óxido de zinc han atraído un gran interés en este aspecto, ya que se usan en la mayoría de los protectores solares comerciales que usan pigmentos inorgánicos, por su capacidad de adsorber los rayos ultravioletas. En el presente trabajo, se llevó a cabo la incorporación del Np-ZnO in situ durante la polimerización mediante el proceso de emulsión de acrilato de butilo. Las nanopartículas de ZnO se incorporan al poliacrilato de butilo en diferentes concentraciones de 0.3%, 0.5% y 1% W, en las cuales se observa que al 1% hay una mayor aglomeración y en las demás no afecta la morfología del polímero.

Protección UV, Polimerización, Nanocompuesto, Emulsión, Óxido de zinc, Nanopartículas, Poliacrilato de butilo, Radicales libres

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† Researcher contributing as first author.

Introduction

After World War II, emulsion polymerization became a process widely used at the industrial level due to the ease of producing materials from vinyl monomers, these contain in their molecular structure a double bond C = C (-CH = CH_2)[1].

Due to the ease of reaction control by the emulsion process, it is possible to simultaneously obtain high molecular weights of the desired polymer, as well as high reaction rates and excellent heat transfer in higher volume reactors, in contrast to other processes of polymerization, such as mass, solution and suspension [2,3].

The polymers that are used as coatings in plastics, metals, wood, crystals among others and that are exposed to the Sun, suffer damage over time. This is largely caused by ultraviolet (UV) radiation, causing them to have great wear and loss of their original properties. That said, in the present research project a polymeric material is sought that has a better resistance to UV radiation, in order to increase the useful life of the substrates to be protected [4].

The rise of nanotechnology has brought with it the development of many technologies, capable of improving aspects such as the durability or comfort of things, thus several industries have benefited.

Overall objective

To evaluate the effect produced by the incorporation of ZnO nanoparticles (in situ process) from the polymerization of butyl acrylate by the emulsion process.

Specific objectives

– Synthesize polymers of butyl acrylate under the emulsion process via free radicals.

– Analyze the emulsion process based on the variables that affect it such as temperature, rpm, concentration of the continuous and dispersed phase.

– Incorporate zinc oxide NP (in situ) into the polymer matrix for UV protection.

– Perform mechanical tests of materials obtained on different surfaces.

Materials and methods

Reagents

The reagents used for the investigation are butyl acrylate (BA), potassium persulfate was used as an initiator, all of these are analytical grade (Sigma-Aldrich) and purity ≥ 99%. The monomer used in the first experimental part was washed to remove the inhibitor, using a solution of 1 N sodium hydroxide and subsequently with distilled water, sodium dodecyl sulfate as surfactant (SDS).

For the synthesis of the nanoparticles zinc acetate dihydrate, sodium hydroxide was used.

Synthesis of zinc oxide nanoparticles by the sol gel method

Was prepared a solution 0.8% of dihydrate acetate in methanol and another 0.5 M solution of sodium hydroxide in methanol were prepared. The NaOH solution was added dropwise in the zinc acetate solution under magnetic stirring until an approximate pH of 9 of the final solution was achieved. The solution was placed in a water bath at 60 °C for one hour under magnetic stirring. Once the time is up, the reaction flask is subjected to a cold bath to stop the growth. The nanoparticles were separated by centrifugation for 10 minutes at 6000 RPM in 50 mL falcon tubes. At the end of the centrifugation, the ethanol is discarded, and the zinc oxide is collected in a crucible. Finally, it was dried for 12 hours at 60 °C in a convection oven.

Polymerization of butilo acrylate

Emulsion polymerization process via FRP. In a typical procedure, the reaction was carried out, using a constant volume of distilled water for the aqueous phase, with a concentration of Sodium Dodecyl Sulfate (SDS), while for the dispersed phase butyl acrylate with sodium persulfate initiator is added. The synthesis was carried out at a stirring speed of 1300 rpm at a temperature of 70 ± 5 ° C for 6 hours.

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Polymerization of emulsion butilo acrylate with incorporation of zinc oxide nanoparticles

Emulsion polymerization process via FRP. The reaction is carried out, using a constant volume of distilled water for the aqueous phase, with a concentration of Sodium Dodecyl Sulfate (SDS), while for the dispersed phase butyl acrylate is added with the zinc oxide nanoparticles, they are incorporated by sonication, with sodium persulfate initiator. The synthesis will take place at a stirring speed of 1300 rpm at a temperature of 70 ± 5 °C for 6 hours.

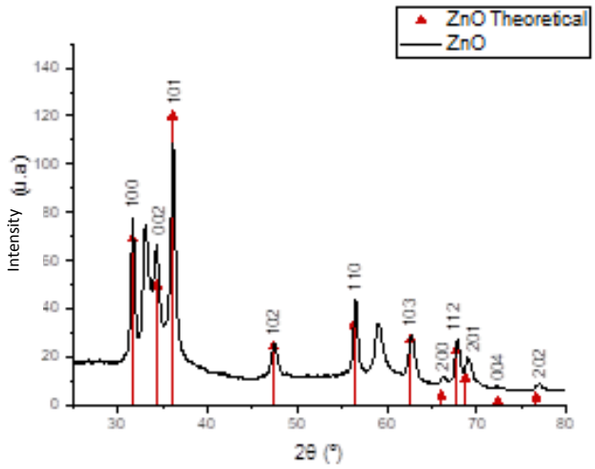
Characterization ZnO

Diffraction X-ray

Part of the structural characterization was done by X-ray diffraction, in order to corroborate that the synthesis had been carried out properly and that zinc oxide nanoparticles were effectively obtained, their level of purity, the crystalline phase obtained, as well as Crystal size calculation. The crystal size is determined using the Debye-Scherrer equation, in which it must be taken into account that the widening of the diffraction peak is caused by the size of the crystal of the sample and by the optics of the X-ray instrument [5].

$$t = \frac{0.9\lambda}{B\cos\theta_B} \quad (1)$$

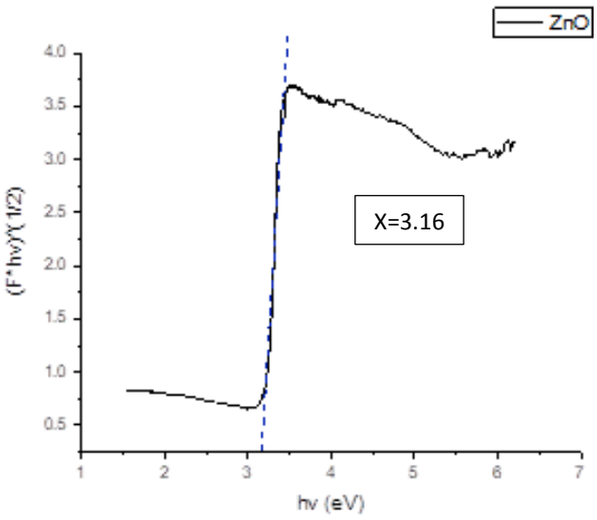
The nanoparticles ZnO showed the known XRD pattern of the hexagonal phase of the wurtzite structure, which according to what is reported in the literature, The pattern which is shown in Graphic 1 of XRD showed peaks at a value of 2θ of 31.83 (100), 34.38 (002), 36.22 (101), 47.62 (102), 56.62 (110), 62.86 (103), 66.42 (200), 67.98 (112), 69.2 (201), 72.49 (), and 77.02 (022) [6].



Graphic 1 Diffractogram ZnO synthesized via sol-gel pH 9

Diffuse reflectance UV-Vis spectroscopy

In order to obtain a better approximation, the diffuse reflectance UV-Vis spectroscopy technique was used and the absorption coefficient of the sample for each wavelength was estimated from the absorption spectrum and a graph of (αʎυ) 2 vs (ʎυ) for the estimation of the banned band energy according to the Kubelka-Munk model for which the following Egap value = 3.16 eV (see Graphic 2) was obtained, the decrease in value with respect to what is reported in the literature indicates that The particle size is smaller.



Graphic 2 Kubelka Munk graph for the ZnO sample

Forbidden band energy is influenced by several factors of nanoparticles like the morphology, particle size, composition and presence of defects (oxygen vacancies).

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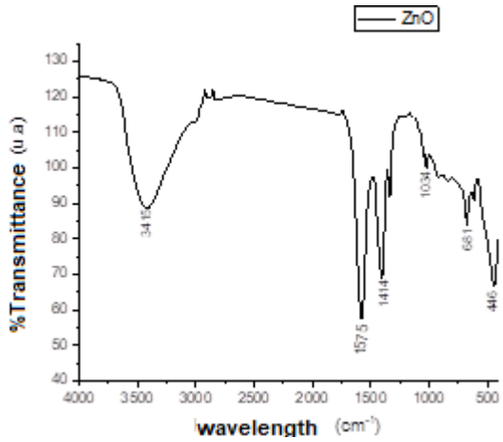
Infrared Spectroscopy ZnO

The IR spectrum for ZnO (see Graphic 3), is observed. The signal at 447 cm^{-1} is a characteristic signal of the stretching vibrations of the Zn-O bond. The 3420 cm^{-1} signal belongs to the voltage vibration of the chemically unbound OH groups present in the sample, this because it was not completely dried and because it contains residues of the ethanol with which it was washed. The 1042 cm^{-1} signal belongs to a C-O bond of a primary alcohol, in this case, ethanol.



Graphic 3 Infrared spectrum on KBr plates for the sample ZnO in MeOH

The Graphic 3 shows a peak at 446 cm^{-1} belonging to the link stretch band Zn-O, the 681 cm^{-1} peak belongs to the Zn-Zn link and corresponds to the tetrahedral coordination of Zn. The peaks in 1414cm^{-1} and 1575cm^{-1} are due to vibrations of symmetric and asymmetric stretches C=O probably of zinc acetate precursor, for Last, the weak wide peak at 3415cm^{-1} is due to OH stretching vibration.

The results confirmed that the ZnO sample obtained via sol-gel contains zinc oxide.

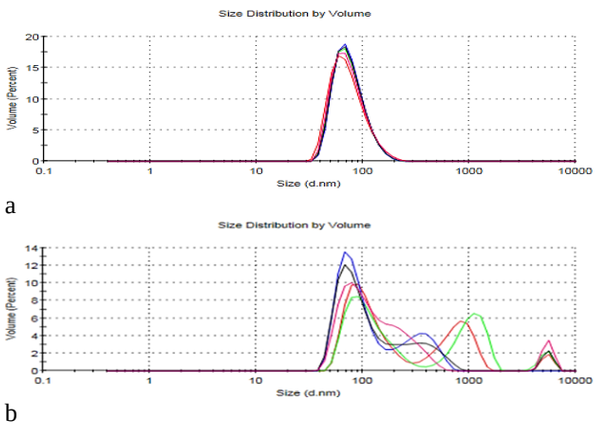
Characterization PAB

In order to carry out the emulsion polymerization via free radicals, it was carried out at different percentages, of which the one that gave us the best results was at 25% monomer, 1300 rpm, at a temperature of 70 ± 2 °C, for 6 h. At 10 h a phase separation is observed, (see Figure 1) this is due to the size of the micelles since a growth of these is observed and indicating that it can no longer be supported by the micelles generated by the surfactant.

Figure 1 Emulsion at 6 and 10 h reaction

Size of micelas at 6 and 10 hours

By means of the dynamic light scattering technique, the measurement of the micelles was enhanced to measure the size (hydrodynamic diameter) and size distribution of the butyl polyacrylate nanospheres, it was determined by dynamic light scattering (DLS) with the equipment Nano Zetasizer Malvern, model ZEN 3600 (see Graphic 4).



Graphic 4 Size of the micelles at 6:00 h in which the size is observed between 74 and 120 nm. and b) micelles at 10 h in which a large variation in micelle size is observed

Incorporation of nanoparticles to our polymer (Composite formation)

The incorporation of the nanoparticles was made from the emulsion, it was successfully carried out since the nanoparticles were correctly distributed in the butyl polyacrylate monomer and at the same time without water insoluble. The more nanoparticles added, the greater its resemblance to a coating, as it is more transparent (see Figure 2).

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Figure 2 Incorporation of nanoparticles at 0.3%, 0.5% and 1%

UV light exposure tests

The exposure of our compound was carried out in an FTO glass, in one, a layer of PBA was placed alone and in the other PAB with 0.3% of zinc oxide nanoparticles. We exposed it to UV light for 30 minutes, after that time it is observed that the sample that does not have nanoparticles is burned, and that which has nanoparticles has greater resistance to UV radiation (see Figure 3).

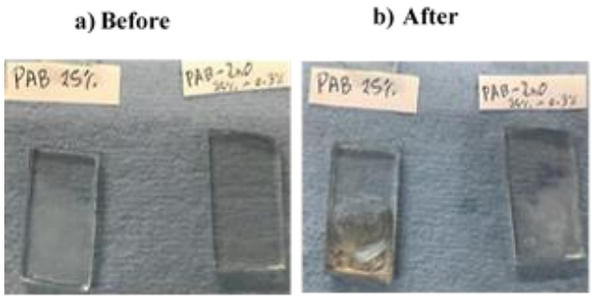

Figure 3 a) before being exposed to UV radiation. b) after being exposed to UV radiation

Application of the composite in different surfaces and sun exposure

In order to verify the influence of the nanoparticles against UV radiation, 16 samples were exposed to the sun for 15 days, corresponding to each of the characteristics of the synthesis (butyl polyacrylate with different concentrations of nanoparticles-ZnO, 0.3%. 0.5 % and 1%) as well as on different surfaces (glass, wood, metal, acrylic) (see Figure 4).

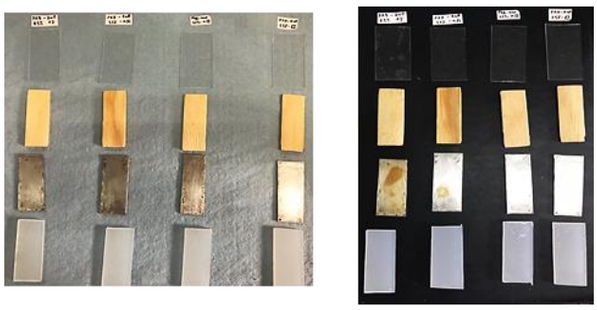

Figure 4 a) before sun exposure b) after one week in the sun

In Figure 4 different surfaces are observed with polymer (PAB, PAB-Zno-0.3%, PAB-Zno-0.5%, PAB-Zno-1%) before being exposed to the sun's radiation and in the following image after a week exposed to the sun, where it is clear that the polymer in addition to giving UV protection to the metal also makes it more resistant to corrosion.

Noting that when applying the coating it has a better adhesion in the acrylic, then in the metal, in the glass and in the wood it does not adhere, on the contrary it is observed that it is absorbed**.**

Conclusions

The emulsion polymerization is less aggressive to the environment due to its composition is based on water and not to aggressive reagents to the environment, and the obtaining of a greener material.

When you have nanoparticles, you get a more transparent composite, this is because the polymer only makes zones of chain accommodation and crystallizes, the nanoparticles prevent this accommodation, causing an amorphous arrangement, which does not have nanoparticles, is more opaque and whitish, affecting the hue of the surface on which it is applied.

In all cases, the coating that has the nanoparticles incorporated was found to be more resistant to exposure to UV radiation.

The polymeric coating has better adhesion on the acrylic substrate, then on the metal one, later the glass and finally on the wooden substrate. Because it is absorbed in wood.

In the metallic substrate, corrosion protection is also observed, as the concentration of nanoparticles increases, the metal retains its hue, where only the polymer is, the metal corrodes, this happens because butyl acrylate has a more acidic pH. , and as the nanoparticles are added it becomes more basic.

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Study of the anticorrosive properties of magnetic composites

Estudio de las propiedades anticorrosivas de compositos magnéticos

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Abstract

Metal corrosion affects various sectors: construction, ships, pipes in the chemical industry, etc. Organic materials have been used as coatings to counteract it; recently improvements have been observed when magnetic polymers are used. These are materials formed by a polymeric matrix and a metal with magnetic properties, such as magnetic nanoparticles. The metal is sacrificed, preventing contact with the surface. Here we show the results of composites formed by magnetic nanoparticles of cobalt ferrite and magnetite obtained by coprecipitation, immersed in polystyrene, butyl polyacrylate and styrene-butyl acrylate copolymer matrices. The nanoparticles were incorporated by ultrasonic bath using different weights of nanoparticles (0.05%, 0.25%, 0.5% and 1%) using toluene as solvent. There is an acceptable dispersion of the nanoparticles in the polyacrylate and copolymer after 4 hours of cavitation, the styrene had acceptable dispersion after 5 hours. The composites were tested on a 316 Cal. 14 stainless steel film of 6 cm2 area, the specimens were dipped in acid to evaluate the corrosion protection with electrochemical techniques, having good results in the ferrite and magnetite composites where the protection capacity was better in the styrene-butyl acrylate copolymer.

Magnetic nanoparticles, Magnetic polymers, Corrosion inhibitors

Resumen

La corrosión de metales afecta diversos sectores: construcciones, embarcaciones, tuberías en la industria química, etc. Los materiales orgánicos han sido empleados como recubrimientos para contrarrestarla; últimamente se han observado mejoras cuando se usan polímeros magnéticos. Estos son materiales formados por una matriz polimérica y un metal con propiedades magnéticas, como las nanopartículas magnéticas. El metal se sacrifica, impidiendo el contacto con la superficie. Aquí se muestran los resultados de compositos formados por nanopartículas magnéticas de ferrita de cobalto y magnetita obtenidas por coprecipitación, inmersas en matrices de poliestireno, poliacrilato de butilo y copolímero estireno-acrilato de butilo. Las nanopartículas se incorporaron mediante baño ultrasónico usando diferentes pesos de nanopartícula (0.05%, 0.25%, 0.5% y 1%) usando tolueno como disolvente. Hay una dispersión aceptable de las nanopartículas en el poliacrilato y copolímero después de 4 horas de cavitación, el estireno tuvo dispersión aceptable después de 5 horas. Se probaron los compositos en una película de acero inoxidable 316 Cal. 14 de área 6 cm2, las probetas se sumergieron en ácido para evaluar la protección ante la corrosión con técnicas electroquímicas, teniendo buenos resultados en los compositos de ferrita y magnetita donde la capacidad de protección mejor fue en el copolímero estireno-acrilato de butilo.

Nanopartículas magnéticas, Polímeros magnéticos, Inhibidores de corrosión

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Introduction

Organic compounds are effective inhibitors of aqueous corrosion of many metals and alloys. The search for new and efficient corrosion inhibitors requires the study between the dependence of the protection efficiency on the size of the inhibitor molecule and the distribution in the inhibitor molecule in the composite. [1,3,5,6,8]. Magnetite belongs to class spinel ferrites, which have crystal lattice noble spinel $MgAl_2O_4$ [1] of the general formula MeFe2O4. Many uses of magnetite nanoparticles due to its special physical and chemical properties. Magnetic nanoparticles can be prepared by different methods and embedding into the polymer solution [9]. This method is very flexible since it allows for the preparation of magnetite nanoparticles carrying a wide variety of stabilizers including copolymers, surfactants, and mixtures of them. However, polymer nanomaterials provide a variety of advantages over other materials because they have a wide range of source materials and tunable surface functionalities [7].

The superparamagnetic Fe_3O_4 and ferrite nanoparticles coated with polymers are usually composed of the magnetic cores to ensure a strong magnetic response and a polymeric shell to provide favorable functional groups and features [4]. The magnetic nanoparticles, which possesses strong magnetic property and superparamagnetic behavior, is of relatively low toxicity to the human body when encapsulated in the protective polymer shell, which is cross-linked polymer composites.

The polymer prevents the magnetic from oxidation and aggregation. In this respect, it was expected that the using of nanoparticles in the field of corrosion inhibition protection for steel instead of normal organic inhibitors can produce uniform thin film (without any pine hole due to cross-linked polymers) on the surface of steel to cover all surface without any defects which provide advantages over.

Methodology

The synthesis of the polymers was via free radicals (FRP). The reaction carried out at 80 °C and magnetic agitation at 600 rpm for 3 h. The emulsion was broken using NaCl to recover the polymer and washed with toluene and methanol, then left to dry for two days at 60-70 °C.

The copolymer was made with the same methodology using a 50:50 mass percentage of styrene and butyl acrylate.

The nanoparticles were synthesized by the (co)precipitation method. The cobalt ferrite was obtained using 0.2M KOH as dispersing agent with 0.1M $FeCl_3$ and 0.5M $CoCl_2$ as metal precursor solutions, added by dripping into the KOH solution at 60 °C and 250 rpm, after dripping it was left to magnetic stir for 30 min. The nanoparticles were recovered using water washings and finally a methanol wash, then the sample was decanted and left to dry for a day at 70-80 °C. Magnetite was made using the same method but replacing $CoCl_2$ with 0.5M $FeCl_2$.

The nanoparticles were incorporated into the polymeric matrix by means of an ultrasonic bath at a temperature between 18-30°C. For each sample, 0.2 g of polymer was fixed and the percentage of the nanoparticle (0.05,0.25, 0.5, 1%) in weight of the polymer was varied using toluene as the solvent medium. The dispersion of the nanoparticles at different times (0.5, 1 and 4 h) was analyzed to know the stability of the matrix. The nanocomposites were placed in conductive glasses and a cyclic voltammetry was performed on each composite from -1.5 to 1.5 V, 2 cycles at 50 mV/s in $Na_2S_2O_3$ 1M. The nanocomposite was placed in stainless steel sheet of 316 Cal. 14 and subjected to H_2SO_4 0.5M for 30 min to determine the resistance of the material to aggressive media. Impedance spectroscopy was performed with a potentiostat SP-150 Biologic Science Instruments with Software Ec-Lab V10.19 and a three-electrode cell at room temperature, as a reference electrode (0.1 M KCl solution), as a counter electrode a platinum wire, in 1M H_2SO_4 acid medium. Under conditions of 20000 to 0.1 Hz frequency, 10 points, and a voltage range of -10 V:10 V.

Results

Figures 1, 2 and 3 show the infrared spectrum of polystyrene, butyl polyacrylate and S-AB copolymer respectively. In the case of polystyrene, band of an aromatic monosubstituted is in region to 1940-1745 cm^{-1}, bands of stretching C-H bonds between 3080-3090 cm^{-1}, bands of stretching CH_2 bonds between 2920-2850 cm^{-1} and the band between 750 to 690 cm^{-1} corresponds to the mono-substitution of the ring. Perhaps, 1600 cm^{-1} correspond the bond C=C and between 1490-1450 cm^{-1} the bond C-C.

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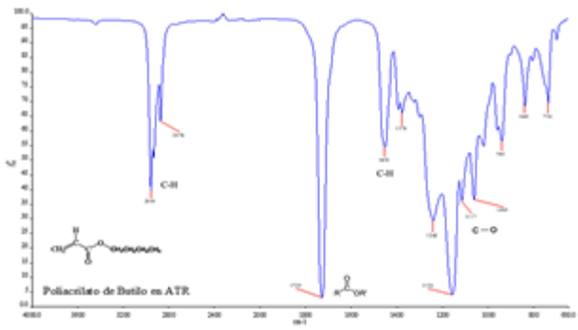

Figure 1 Infrared spectrum of polystyrene
Source: own work [Origin Pro 9]

Figure 2 shows the bands of the C-H bonds between 3000 to 2870 cm^{-1} band, at 1729 cm^{-1} due to the presence of carbonyl groups C=O and between 1060-1120 cm^{-1} the C-O link. Figure 3 shows the linkage bands of the polystyrene and butyl polyacrylate structures are present.

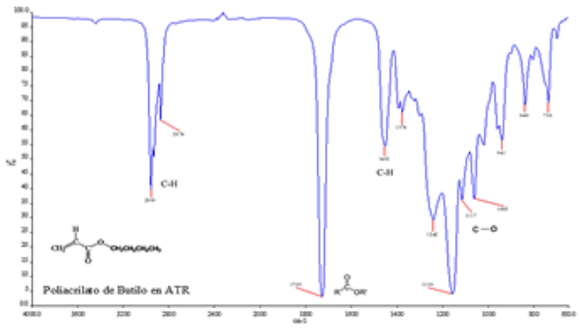

Figure 2 Infrared spectrum of butyl polyacrylate
Source: own work [Origin Pro 9]

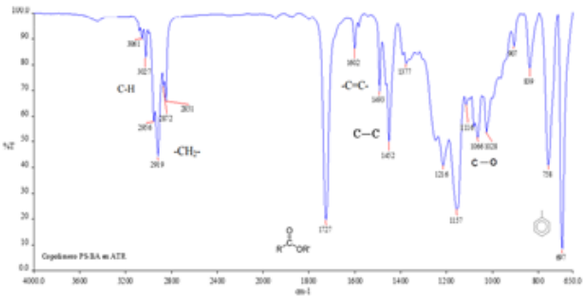

Figure 3 Infrared spectrum of S-AB copolymer
Source: own work [Origin Pro 9]

As can be seen, the copolymer has the characteristic bands of its corresponding homopolymers, confirming the presence of polymeric matrices for the present study.

The micrographics to the Figure 4 and 5 showed the morphology and sizes of the nanoparticles of magnetite and cobalt ferrite respectively.

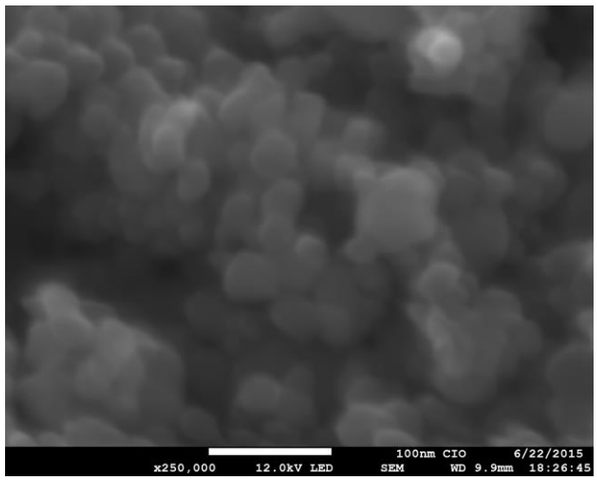

Figure 4 Magnetite micrograph
Source: own work [JEOL SU 3500 SEM Hitachi]

As can see been, in Figure 4a it is possible to observe an average particle size of 30 nm, spherical shape and a small distribution. similarly, a slight agglomeration of the nanoparticles is observed due to the magnetic attraction Fe^{+2}/Fe^{+3} atoms.

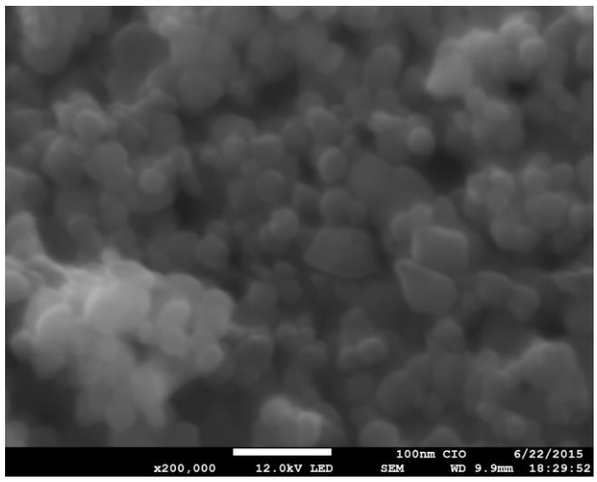

Figure 5 Cobalt ferrite micrograph
Source: own work [JEOL SU 3500 SEM Hitachi]

The Figure 5 showed that the nanoparticles have an average particle size of 20 nm and have different shapes, with a agglomeration of the nanoparticles.

In spite of sonication times by ultrasonic bath showed that for 1 hour the NPs did not show good dispersion. After 4 hours, most of the blending were stable. This can be understood since the NP's are agglomerated by magnetic attraction, with the sonication time the energy separates the NP's avoiding the agglomerates, increasing the time the energy increases, having less drift, increasing the NP's available to distribute uniformly throughout the matrix.

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Before, the composite was placed on steel plaque and subjected to a sulfuric acid medium, Table 1 shows the weight loss when subjected to the acid medium.

	Weight plaque only polymeric film [g]	Weight plaque after acid [g]	lost weight [g]	% lost weight
Ferrite-Copolym.				≤ 0.129
0.05%	13.4701	13.4530	0.0171	0.127
0.25%	15.6879	15.6712	0.0167	0.106
0.50%	14.3716	14.3532	0.0184	0.128
1.00%	14.0692	14.0564	0.0128	0.091
Magnetite-Copolym.				≤ 0.129
0.05%	13.5932	13.5759	0.0173	0.127
0.25%	14.2136	14.2004	0.0132	0.093
0.50%	13.4820	13.4670	0.0150	0.111
1.00%	13.9677	13.9572	0.0105	0.075

Table 1 Percentage weight loss due to corrosion in a H_2SO_4 0.5M
Source: own work [Word]

An uncoated steel plate was taken as a reference. It was obtained that weight should be lost in percentage of less than or equal to 0.129% (as can see been on the Table 1), only the steel plaque with the copolymer with both nanoparticles resulted in weight lost within the mentioned percentage.

In Figure 6a and Figure 6b, we can see the steel plaques coated with the samples of magnetic polymer after exposure in acidic medium. Where the PS and PBuA plaques showed greater wear, the coating was able to pass through and cause wear on the steel. In the case of the PBuA/PS copolymer composite, the complete coating was maintained without corrosion damage.

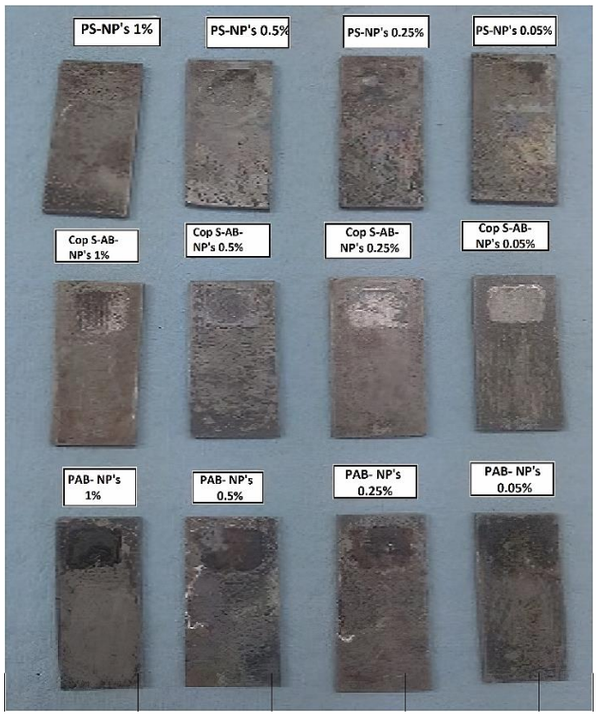

Figure 6 Nanocomposite films on metal plaques. Nanocomposite of Ferrite-PS, Ferrite-Copolym, Ferrite-PBuA
Source: own work

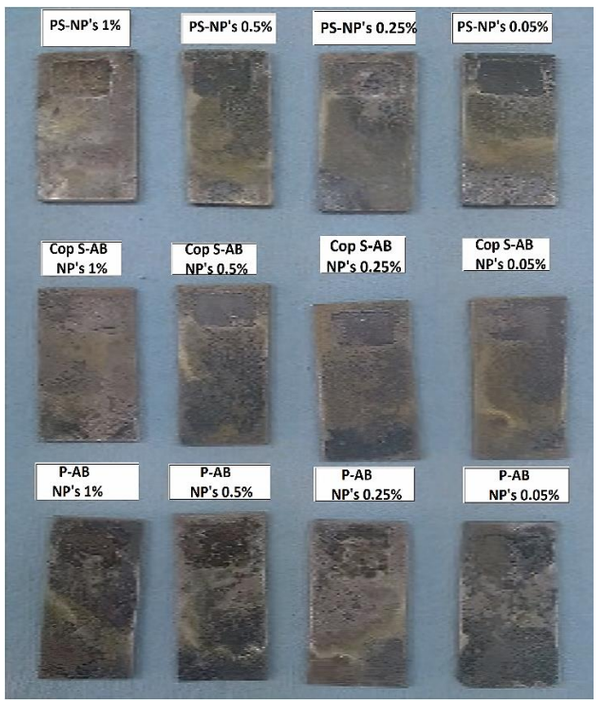

Figure 7 Nanocomposite of Magnetite-PS, Magnetite, Copolym, Magnetite-PBuA
Source: own work

Electrochemical impedance spectroscopy (EIS) measurements were performed with a traditional three-electrode cell using biologic potentiostate/galvanostate and EC-Lab software.

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A platinum electrode and saturated calomel electrodes (SCE) were used as auxiliary and reference electrodes, respectively. The working electrode was prepared from a carbon steel lamine 4 cm^2 electroactive area.

With the percentages of lost weights, Nyquist diagrams were analyzed by impedance spectroscopy, highlighting the 0.05% ferrite copolymer and 0.05% magnetite copolymer composites as shown in Figure 7.

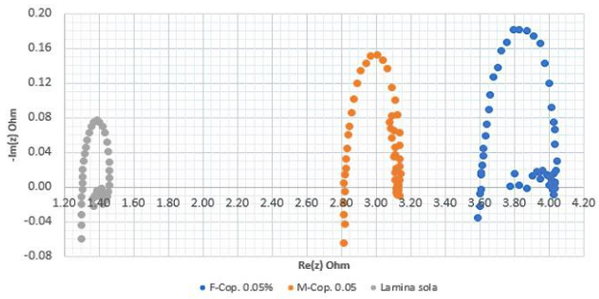

Figure 7 Impedance spectroscopy, reference uncoated steel sheet, Cop-Magnetite and Cop-Ferrite composite
Source: own work [EC Lab and Excel]

So, the best nanocomposites produced were those with a PBuA/PS copolymer polymer matrix, with either reinforcement. Corrosion protection is better with copolymer composites at 0.05% magnetite and ferrite because increase the semicircle diameter. The diameter of the capacitive loop is approximately equal to the value of the charge-transfer resistance of the process of corrosion reaction and is associated with the corrosion resistance ability of the films in H_2SO_4 solution. Then the charge-transfer resistances of the modified electrodes are larger than that of the carbon steel electrode, which indicates that the self-assembled films can protect iron from corrosion

All EIS spectra can be analyzed and fitted with the equivalent circuit shown in Figure 8, so obtain the double-layer capacitance (Cdl), the frequency at which the imaginary component of the impedance is maximum.

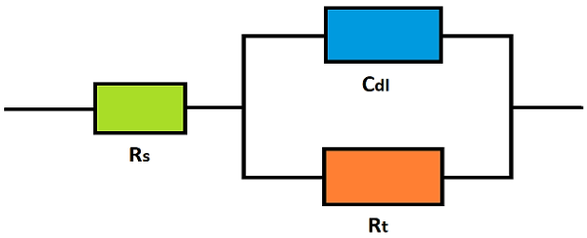

Figure 8 The equivalent circuit model for the electrochemical impedance measurements
Source [2]

Conclusions

By means of the ultrasonic bath it is possible to obtain magnetic polymeric nanocomposites, with good stability for their applications. The stability and dispersion of polymeric nanocomposites depends on the molecular weight and viscosity of the polymer. At low viscosities, the nanoparticles disperse easily but are less stable than at high viscosities although dispersion requires more time.

Acknowledgement

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System of acquisition and processing of signals through of Arduino platform and Matlab (How tool of learning)

Sistema de adquisición y procesamiento de señales a través de la plataforma Arduino y Matlab (como herramienta de enseñanza)

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Abstract

This work presents a real time system of acquisition, monitoring and signal processing based on the synergy of hardware and software. In the stage of signal acquisition, a circuit board was built. This circuit board acquires two signals, one from a phototransistor sensor and other one from an ultrasonic sensor. The sending and processing of the data was through the Arduino platform. A graphical user interface (GUI) using Matlab® was implemented for the stages of monitoring and processing. For these stages two interfaces were designed and implemented with the aim of show the signals of two forms, continuous and digital, and their processing. For the processing stage, several operations such as convolution, median filter and the Fast Fourier Transform were applied to the signal. On the other hand, another aim of the implementation of this system was with the purpose to obtain a didactic tool to complement and support learning in the area of signal processing and thus generate a bigger interest and motivation of the students to practice the knowledge acquired in classes.

Signal processing, Signal acquisition, Monitoring

Resumen

En este trabajo se presenta un sistema de adquisición, monitoreo y procesamiento de señales en tiempo real basado en la sinergia de hardware y software. En la etapa de adquisición se construyó una tarjeta, la cual se encarga de la adquisición de señales provenientes de dos sensores, un fototransistor y uno ultrasónico. Una vez adquiridas las señales, el envío de los datos para el monitoreo y el procesamiento fue a través de la plataforma Arduino. Para las etapas de monitoreo y de procesamiento se diseñó y se implementó una interfaz gráfica de usuario (GUI) mediante el software MatLab®. Para la etapa de monitoreo y procesamiento se diseñaron ventanas para mostrar las señales de forma continua, digital y su procesamiento. En la etapa de procesamiento se realizaron las operaciones de convolución, aplicación de un filtro de medias, así como la transformada rápida de Fourier. Otro de los objetivos de la implementación del sistema de adquisición y procesamiento fue con la finalidad de contar con una herramienta didáctica como complemento y refuerzo en la enseñanza, aprendizaje en el área de procesamiento de señales generando un mayor interés y motivación sobre el alumnado a que se aplique de forma práctica y dinámica la teoría vista en el aula de clases.

Procesamiento de señales, Adquisición de señales, Monitoreo

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Introduction

In recent years, communications are the main information tools and they continue to be the most powerful at a social, cultural, political, technical level, etc. (Santos Peñas & Farias Castro, 2010).

Digital signal processing is an area of science and engineering whose development has increased very rapidly in recent years. This development is mainly due to advances in technology in the field of computing, as well as the manufacture of electronic circuits (Proakis & Manolakis, 2007).

Physical systems, under the context of signal processing, can be considered as a process in which the input signal is transformed by the system which responds in some way and results in another signal, but an output signal. Under the same context, systems can be classified in two ways: continuous system or discrete system. The continuous system is characterized in that the continuous input signals are transformed into continuous output signals. On the other hand, the discrete system is characterized by transforming the continuous or discrete input signal into a discrete output signal (Oppenheim & Willsky, 1998).

Signal processing alone cannot do many things. From the outset, it has been mentioned that it is about manipulating signals. Therefore, these signals must be obtained first, so they require sensors to read them. Another step will be to translate these signals that the sensors generate into electrical signals. This is what will be done using a transducer. In addition, if the signal is analog, that is, continuous in time and in amplitude, the signal will need to be digitized or sampled to end up having a set of numerical values every certain time interval, which can be recorded in a computer to be able to be conveniently processed. This is the process for analog-to-digital converter devices. All this process that must be done to have a set of zeros and ones in a computer ready to be manipulated, must often be repeated in reverse, once the signal has been processed (which has manipulated "0" and "1") must be returned to the tangible world (Solé i Casals, 2010)

In (Shah & Vyas, 2014) they propose an algorithm for the detection of objects using image processing, as well as the monitoring of the movement of objects by means of an Arduino-based control. The object detection algorithm was developed in Matlab® using some image processing techniques.

According to (Paucar Guaman, 2018) they developed an interface that makes the acquisition of electrocardiogram signals through the Arduino platform for its subsequent storage in the cloud and finally its processing and visualization in an interface developed in Matlab®.

In (Soares, Valente, Silva, & Marcelino, 2015) they present an approach to digital sound processing through an Arduino and Matlab®, through some examples they showed how Arduino can be used together with Matlab® to achieve the connection of the world physicist with computing.

In (Loreto Gómez, 2020) she presents a teaching methodology that allows validating the ability of students to apply the knowledge acquired in simulation sessions to physical platforms. The virtual platforms that were developed are based on the Simscape Multibody and Simulink / Matlab® libraries.

(Boluda Segura, 2017) mentions that for the realization of the project I opted for the Carriots platform, they carried out integration tests where the Arduino board, Carriots and freeboard are used, obtaining the temperature readings which are shown to the user, using This platform sends a high temperature alarm to email by SMS, thus obtaining a feasible system for a specific application.

In order to have a didactic tool to complement and reinforce teaching and learning in the area of signal processing, in this work we present a system for acquiring, monitoring and processing signals in real time based on the synergy of hardware and software. For the acquisition stage, a card was built, which is responsible for the acquisition of signals from two sensors, a phototransistor and an ultrasonic one. Once the signals were acquired, the data was sent for monitoring and processing through the Arduino platform.

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For the monitoring and processing stages, a graphical user interface (GUI) was designed and implemented using MatLab®. For the monitoring and processing stage, windows were designed to show the signals continuously, digitally and their processing. In the processing stage, the convolution operations, application of a mean filter, as well as the fast Fourier transform were carried out.

This document is organized as follows: this section shows an introduction to signals and systems, as well as a brief state of the art in which this work is framed. Section 2 describes the development and implementation of the stages of the proposed system. Likewise, section 3 of the results describes the implementation of the signal acquisition and processing system. Finally, section 4 presents the conclusions of the work carried out.

System Proposal

This article is focused on the result of a signal acquisition and processing system, with an interface developed in Matlab®, in which each of the system's functions were introduced. For the development of the system, different functions were used which are essential to make it work. The signal acquisition and processing system is made up of two stages, one made up of hardware and the other one made up of software, in which the acquisition of physical variables is incorporated by means of two transducers, an infrared sensor for continuous signals. and an ultrasonic sensor for the discrete signals. Said signals are sent through an electronic design or Printed Circuit Board (PCB) to later couple them with the data acquisition system and can be sent to the second block that is made up of the software. Once the signals are conditioned, they are sent to Matlab® with a connection of the data acquisition system (Arduino), through the USB port and RS232 protocol through an established data or COM port, in which the variables and they are processed to later show a result. Figure 1 shows the block diagram of the proposed system.

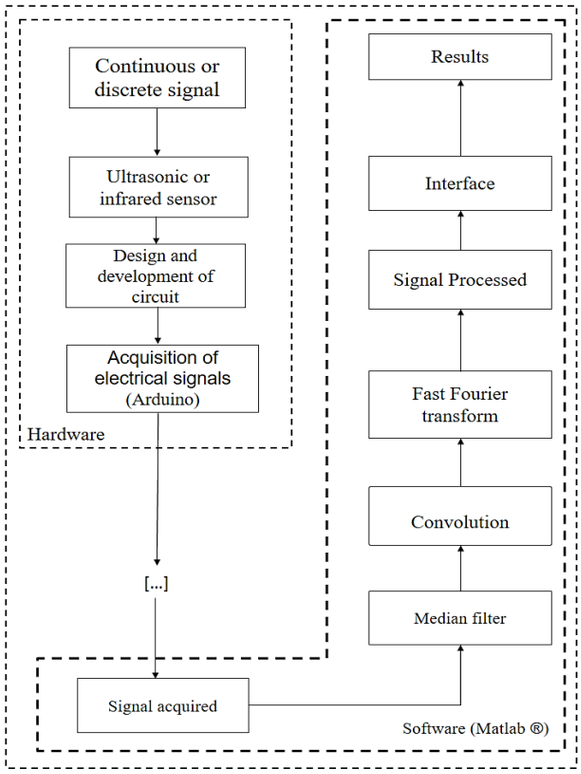

Figure 1 Block diagram of the signal acquisition and processing system
Source: own elaboration [Gimp]

Among the main functions used are the Graphical User Interfaces (GUIDES) with Matlab®, which are already integrated into the software. These functions are essential to give a graphical environment to the system and are very similar to the graphical interfaces of Java or C # / C ++. Figure 2 shows the menu design of the guide.

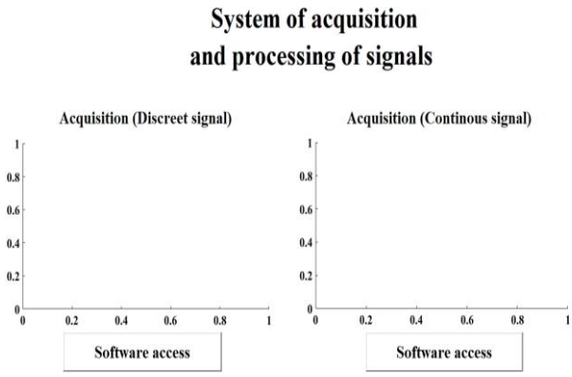

Figure 2 Layout of the Matlab® guide
Source: own elaboration [Matlab]

The guide has a main menu, which can give access to the acquisition of signals from an infrared sensor with a phototransistor and an ultrasonic sensor, Figure 3 shows the main menu of the proposed system.

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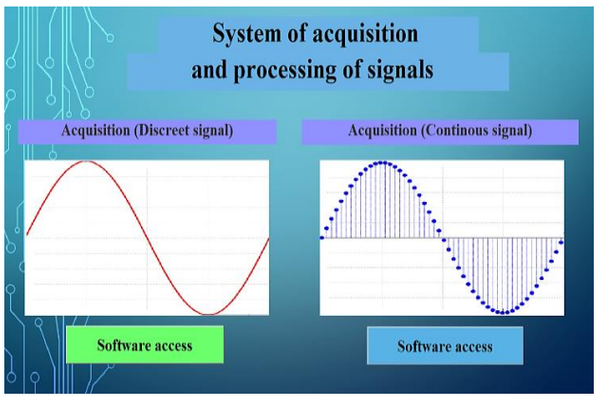

Figure 3 Menu of the signal acquisition and processing system
Source: own elaboration [Matlab]

When the user selects the function of acquisition and processing of a continuous signal, the analog reading is obtained that is obtained from the phototransistor, when the pin of the same is subjected to an intensity of light emitted by the infrared led, it enters saturation mode and allows the current flow, according to the intensity of light that enters through the base of the transistor, so it will be regulated to send an electrical signal to the arduino to acquire the analog signal and be sent through the serial port to the Matlab® software . The data are called from the button assigned in the guide, these data are analog that are between 0 and 1023 values which are converted to a continuous voltage signal with a sampling period which is obtained through the frequency of data acquisition from the arduino, 3 processes are applied to these values.

The first consists of the Fast Fourier Transform (FFT), so that the process of the function is carried out, it is important to acquire the signal sampling in the form of a row vector, taking into account that the signal of the amplitude (ordinate axis) is found as a function of time (abscissa axis), since the vector is extracted in the same way, for a time interval of 100 ms in relation to the sampling frequency with a value of 10 Hz The signal conditioning is carried out in the data acquisition system (Arduino) which has a resolution of 10 bits or 1023 analog values, with a range from 0v to 5v, detecting voltage ranges of 0.004v, for which it is performed the calculation of the conversion from analog to voltage or amplitude using the following formula: ((Current analog value) * (5/1023)), it is worth mentioning that the acquisition and conversion process is carried out for the three processing of the continuous signals or infrared sensor.

For the processing of the discrete signals or ultrasonic sensor in the three processes, the conversion is easier because it is a digital signal and only a comparator was used to verify whether there is (5v) or not (0v) detection. Once the signal is already converted or conditioned, by means of the Matlab® software and the FFT function, the Fourier transform to the resulting row vector is calculated in which Matlab® executes the application of equations (1) and (two):

$$Y(k) = \sum_{j=1}^{n} X(j) w_{n^{(j-1)(k-1)}} \quad (1)$$

$$X(j) = \frac{1}{n} \sum_{k=1}^{n} Y(k) w_{n-(j-1)(k-1)} \quad (2)$$

Equation (1) belongs to the Fourier Transform and equation (2) to the Inverse Fourier Transform where: y (k) and x (j) belong to a continuous independent variable energy signal and $wn = e^{(-2\pi i)/n}$ to a periodic function in relation to time.

According to (Barajas, 2015) the Fourier coefficients allow the characterization of a continuous signal in time x (t) with the property of periodicity. These coefficients provide the signal information in the frequency domain x (f). According to Fourier theory, it is possible to take these coefficients and reconstruct a periodic signal. In various cases, you cannot count on a continuous signal in time that offers the opportunity to calculate your Fourier Transform directly. In these cases, samples of the signal under study are taken through the sampling theorem. Mathematically the Fourier transform for a continuous signal at time x (t) is defined by the equation $x\,(w) = \int_{-\infty}^{+\infty} x(t) e^{-jw} dt$, while for the analysis of the discrete signal of N samples x (n) the Discrete Fourier Transform (DFT) is used through the equation $x\,(k) \sum_{n=0}^{N-1} x(n) e^{-j\frac{2\pi kn}{N}}$ It is necessary to take into account that when directly implementing the Discrete Fourier Transform (DFT) through an algorithm, little computational efficiency is obtained. For this reason, it is proposed in this article to implement an efficient method for calculating the DFT, taking advantage of its symmetry properties.

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In accordance with the above, the Matlab® software allows the above calculations to be carried out by means of the functions integrated in the same software and allows interaction with the students to be able to see the analysis of the equation, offering visual and practical learning strategies. In the case of the Means and Convolution Filter, the sample of both continuous and discrete signals was acquired with the same Fourier Transform process. In this case, the first seven values of the row vector were taken to apply a Mean Filter, which is evaluated by means of a kernel that contains a vector of 1 row by 3 columns, acquiring the mean of each of the seven values. To calculate the mean of the extreme values it is necessary to fill the row vector with ones and zeros depending on the selection, in this case a function was created in Matlab® to be filled by ones, so that the evaluation kernel is applied correctly and the size of the vectors are equal. In a mathematical way, the evaluation of each of the components of the vector vector was performed according to equation (3):

$$\mu = \frac{1}{N}\sum_{i=1}^{N} Ai \qquad (3)$$

Where A corresponds to a random variable vector and N is the number of scalar observations.

According to (Smith, 1997) a digital filter is a filter that operates on digital signals, with a mathematical operation that takes a sequence of numbers (the input signal) and modifies it producing another sequence of numbers (the output signal). In the application, it separates the signals that were combined with noise (interference), recovery of distorted signals, sound synthesis and audio effect. In this case, for digital and analog filtering, its performance is superior to filters. If the impulse response is known, the filter response to any input can be calculated. If you have a frequency, the discrete time Fourier transform is used.

The applications of digital filters, the area to which the Media Filter belongs, are of utmost importance and also involve mathematics and their interaction with the software will allow a better association with the topic. The third and final processing is the Convolution, which is very similar to the Means Filter.

For Convolution it is also necessary to have a data vector with seven values, which will be evaluated with the help of a convolution kernel that contains values of one, being a vector of 1 row by 3 columns that contains the following structure [1 1 1], which is intercepted in the values of the vector to be evaluated and the sum of products is obtained in each iteration, giving if a vector of data with the convolution values that were executed from equation (4):

$$w(k) = \sum_j u(j)v(k-j+1) \qquad (4)$$

Where u and v correspond to the values of two vectors that represent the area of overlap under the points as v slides to u. Algebraically, the Convolution is the same operation as multiplying polynomials whose coefficients are the elements of u and v, the sum is over all the j values that lead to legal subscripts for u (j) and v (k-j + 1).

In summary, the Convolution of signals in the time domain is equivalent to the multiplication of their spectra in the frequency domain; likewise, the multiplication of signals in the time domain is equivalent to the convolution of their spectra in the frequency domain. The convolution is commutative, associative and distributive, (Márquez, 2012).

From the above processes, it can be shown that it is a bit difficult for students to understand the information transmitted by the topic, but through teaching or interactive tools, the applications of digital filters can be more comprehensive. Also have a virtual laboratory that with the help of mathematical equations can observe their behavior based on graphs of results. The vector of data that the user enters (sample), can be of any size. Once the process is carried out and it is shown in the horizontal and vertical axes, which are the windows that the software has, the data is saved in a .csv file or file separated by commas, so that it can be used as a database and the numerical results are extracted by the user or displayed. In Figure 4 you can see the process window of a continuous signal and the results obtained in the graphs.

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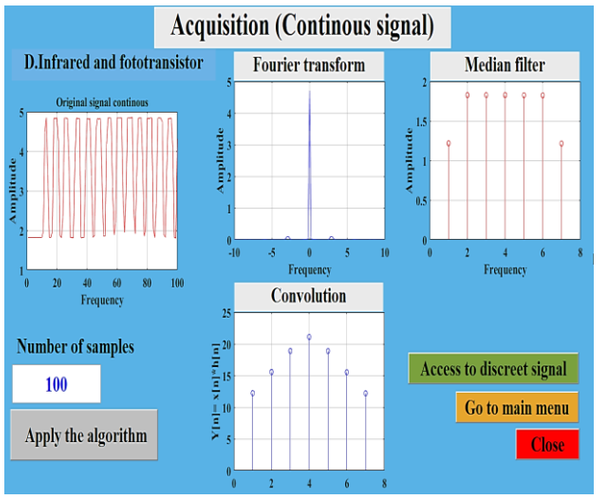

Figure 4 Acquisition and processing of a signal continues
Source: own elaboration [Matlab]

Figure 5 shows the graph of the sampling process for the acquisition of the signal in real time.

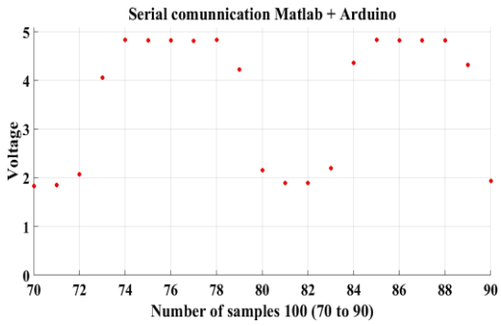

Figure 5 Continuous signal sampling in real time
Source: own elaboration [Matlab]

The process to acquire the discrete signal is the same as for the continuous signal and for this an ultrasonic sensor is used, which sends the distance variable that is acquired with the Arduino hardware through the port (RS232).

To carry out the Convolution and Media Filter operation, a train of pulses was generated, with discrete voltage levels of 0v if no activity is detected and 5v if it is detected. In addition, a 0.1v noise signal was synthetically created, which is added to the variable acquired through the arduino serial port, this solves the problem by discretizing 0.1v values on the falling edge and 5.1v on the rising edge of the square signal and pulse train. The asynchronous signal provides information that is of great importance for determining electronic systems and applying signal processing. Figure 6 shows the image with the results of the discrete signal acquired.

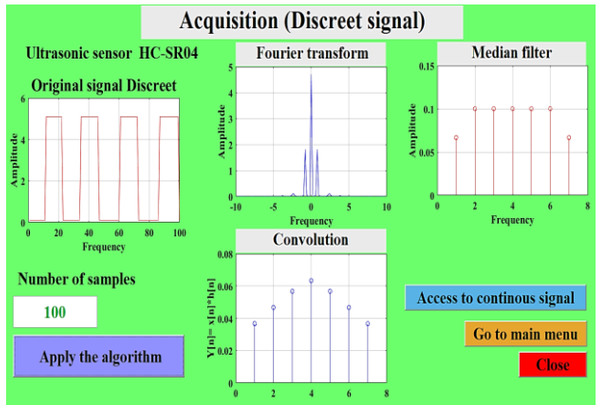

Figure 6 Acquisition and processing of a discrete signal
Source: own elaboration [Matlab]

Figure 7 shows the graph of the acquisition of signal sampling in real time.

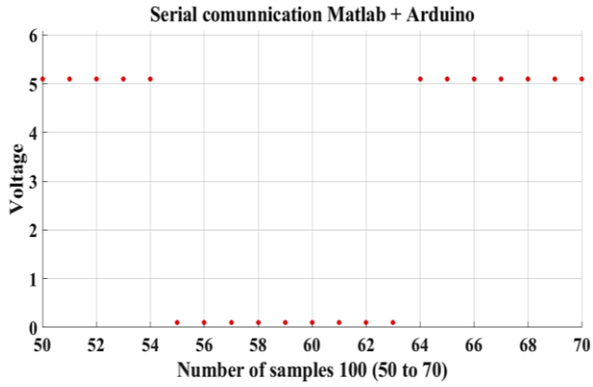

Figure 7 Discrete signal sampling in real time
Source: own elaboration [Matlab]

The information generated is stored in text files as shown in Figure 8.

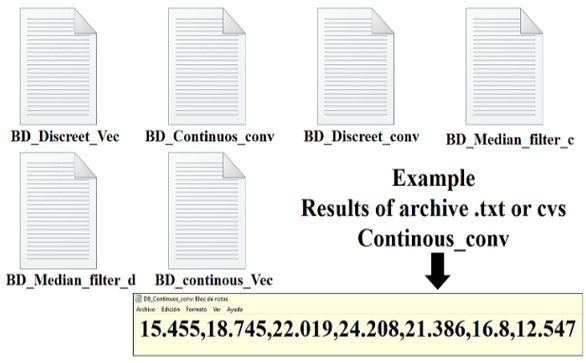

Figure 8 Txt files or comma separated file generated by the software
Source: own elaboration [Matlab]

For the hardware design, 2 Arduino Uno R3 version boards were placed in order to acquire each of the signals generated by the sensors (photodiode-phototransistor and ultrasonic) contained on the PCB. In addition, a circuit was designed that indicates the connection to the arduino and the data transmission, thus revealing the embedded system created from three important factors: hardware, software, and real-time monitoring (remember that there is a time lag and there is no real-time monitoring), as well as the acquisition of data from them.

Results

The signal acquisition and processing system involves two products obtained, one made up of software and the other of hardware. The hardware stage consists of the transducers that acquire the physical variables made up of the ultrasonic sensor and the phototransistor, later there are the data acquisition systems or arduinos that integrate their USB output port and their Serial RS232 communication protocol, through which acquired signals are transferred and conditioned so that Matlab® software can work with its due processing, Figures 9 and 10 show the prototype of the system.

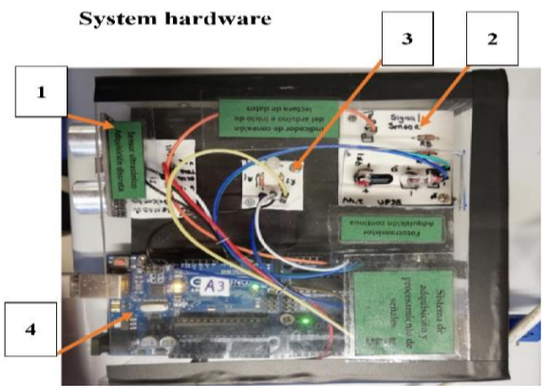

Figure 9 Parts that make up the hardware of the signal acquisition and processing system. (1) Ultrasonic sensor (discrete acquisition), (2) Phototransistor (continuous acquisition), (3) Arduino connection acquisition and data reading start
Source: own elaboration [Gimp]

Figure 10 Rear view of the embedded system hardware
Source: own elaboration [Gimp]

The software or system developed in Matlab® acquires the signal from the arduino through RS232 communication, executes a window in real time (remember that there is always a small lag in data collection) and as it acquires it, it displays them in a figure that it automatically opens when processing the number of samples required, within the system it saves this signal as a vector of data obtained and displays the signal in its real size. Figure 11 shows the total sample acquisition window, as well as its visualization within the system.

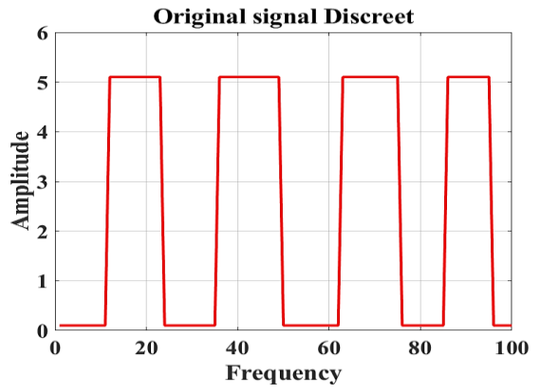

Figure 11 Complete reading of the sampling of a discrete signal in the system
Source: own elaboration [Matlab]

Once the signal is obtained, it is stored in a variable to which the function of each of the processes that it contains is applied. In Figure 12, 13 and 14 the results of the application of the Fourier Transform, Filter of Means are shown. and the operation of the Convolution of a discrete signal. It is important to mention that the same happens when the process is carried out with a continuous signal.

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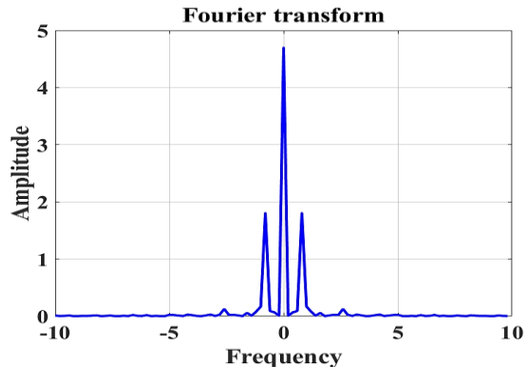

Figure 12 Application of the Fourier transform
Source: own elaboration [Matlab]

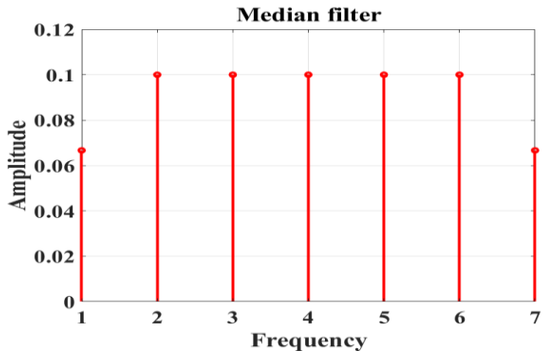

Figure 13 Media filter application
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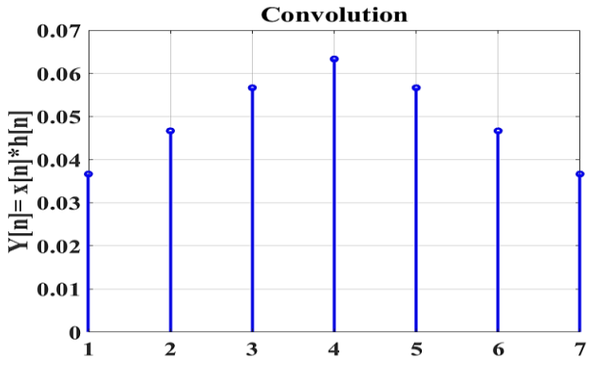

Figure 14 Application of the convolution
Source: own elaboration [Matlab]

As can be seen, the intervention of the theory through the software has enriching results for the training of the student, the signals are the result of mathematical applications and these can be done through programming or with the use of Matlab's own functions ®, which are already integrated into the program, in addition to observing their behavior according to the mathematical changes that are made in a quick and easy way.

Conclusions

Signal processing and algorithm programming are areas that have a great impact in modern technology. On the other hand, the process of technological advancement of society can be clearly observed, therefore, knowing the principles of programming and the analysis of signals, they are generated in a virtual matrix laboratory, is the great step to start in this great world of knowledge. An area of interest for these subjects and one that includes technological advances is voice recognition found in the most current security devices and in the detection of the user's voice frequencies.

The design and construction of a data acquisition system and its interface in Matlab® meets the objective for which it was developed, which is to teach signal processing to students who are just entering the telecommunications area, as well as to reaffirm the interest of those who have already started in the world of telecommunications.

It is important to mention that the use of an acquisition system from using the Arduino platform will allow the student to replicate it at a lower cost, since it uses relatively cheap materials and can be adapted to various platforms, it is also important to note that the system Acquisition, processing and display shows the principle of an embedded system and due to the capabilities of both Arduino, electronics and Matlab® an even more complete or robust system can be generated.

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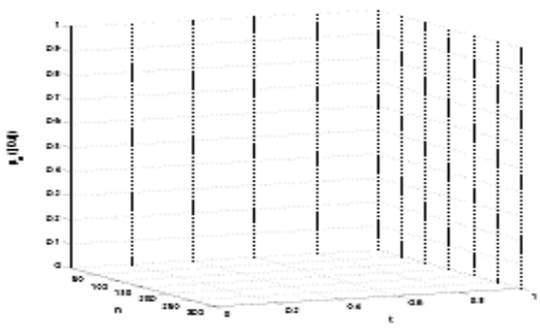

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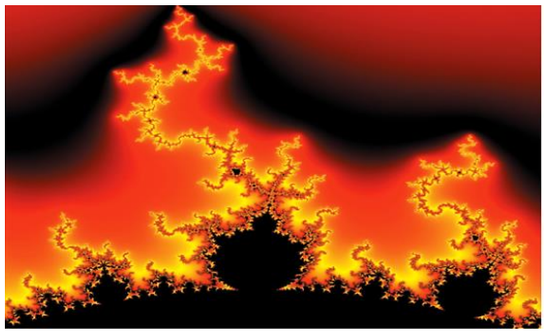

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