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Artículos

Design and manufacturing of an ultrasonic reactor for biodiesel obtaining by transesterification

Diseño y fabricación de un reactor ultrasónico para obtención de biodiesel por transesterificación

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Abstract: It presents the design, development, and implementation of the ultrasonic reactor in laboratory level for batch transesterification with temperature variation, with a mechanic and electronic modular development; its operational characteristics were obtained through commercial equipment revision. To evaluate its performance, a mixture was made using castor oil, methanol, and potassium hydroxide, to obtain biodiesel and glycerin; by taking the glycerin stoichiometric value obtained in the reaction as the reference production value, an efficiency of 97% was reached with only the ultrasound incidence. In the processes with external temperature incidence, it was observed that it influences the reaction speed, since the stabilization times are around 30% less than the other observed processes.

Keywords: ultrasound, transesterification, biodiesel, modular development, efficiency.

Resumen: Se presenta el diseño, desarrollo e implementación de un reactor ultrasónico a nivel de laboratorio para transesterificación por lotes con variación de temperatura; por medio de un desarrollo modular mecánico y electrónico, cuyas características de operación se obtuvieron a partir de una revisión de equipos comerciales. Para evaluar su desempeño se realiza una mezcla de aceite de higuerilla, metanol e hidróxido de potasio, para obtener biodiesel y glicerina; tomando el valor estequiométrico de la glicerina obtenida en la reacción como valor de referencia de producción, se alcanza un 97% de eficiencia con sólo la incidencia del ultrasonido, en los procesos con incidencia de temperatura externa se observa que esta influye en la velocidad de reacción, ya que los tiempos de estabilización son alrededor del 30% menores respecto a los demás procesos observados.

Palabras clave: ultrasonido, transesterificación, biodiesel, desarrollo modular, eficiencia.

1. Introduction

Considering that fossil fuels are nonrenewable, and the environmental pollution they generate after their use; currently, other energy fluids should be sought as a replacement, one of these options is biodiesel (alternative fuel for diesel engines) [1]. Biodiesel is a mixture of vegetable or animal oil combined with an alcohol (usually methanol or ethanol because of its cost). Ethanol is obtained from foods such as corn or sugar cane, Colombia has been the second largest producer in Latin America of this alcohol;[2] and in relation to vegetable oils, specifically palm oil, is the fifth producer country worldwide [3], so that generating a national production of biodiesel provides a better use of the natural resources that are available [4] , being a competitive advantage since 70% of the production costs of biodiesel are related to the raw material [5]. However, the production of biodiesel is subject to different variables that alter both the quality of the final product and its performance, among these are: temperature and reaction time, molar concentration of alcohol, vegetable oil, type of alcohol, type and concentration of catalyst, speed of mixing, reaction time, free fatty acid content (FFA) and humidity [6]. The most common way to produce biodiesel is by transesterification.

Transesterification refers to three processes of mixing an ester: with alcohol (alcoholysis), with a carboxylic acid (acidolysis), or with another ester (interesterification) [7]. The present article works on the alcoholysis of triglyceride with alcohol, under the action of a catalyst. At the end of the reaction, two byproducts are obtained: methyl esters of fatty acids and glycerin [8-9]. The main applications of methyl esters are as plasticizing agents, thickeners, additives, the raw material in the production of noncaloric edible oils [10], and biodiesel [11]. Obtaining biodiesel occurs in two ways [12]: batch production, where the catalyst (potassium hydroxide) is diluted in methanol by constantly stirring mechanically in the processing tank, then the transesterification tank is filled with vegetable oil. After dilution, the pump feeds the transesterification tank with the mixture, converting the oil into biodiesel, ending with the separation of the glycerin from the biodiesel. The second form is continuous production, where the ultrasound devices for the transesterification reaction replace the mechanical agitators. The ultrasonic reactors are installed to mix two substances, in this case: oil and methanol-catalyst, the pre-mix is pumped to the ultrasonic reactor, on leaving the transesterification tank, the glycerin is separated by gravity; The resulting mixture passes through a centrifuge to make the separation process of biodiesel and glycerin more efficient.

Industrial transesterification processes, where lipid alcohols are separated, demand rigorous and expensive technologies [12]. Different studies compare transesterification reactions under various techniques for the production of biodiesel, among which are: mechanical agitation [13], thermal temperature increase [14], microwave irradiation [15] and hydrodynamic cavitation [16], however in comparison with these, the yield obtained with ultrasound for the manufacture of biodiesel is higher, obtaining processes of short duration [17], regardless of the type of catalyst and raw materials used [18-20]. In Colombia, the value of transesterification equipment is high because it is manufactured abroad and its maintenance requires specialized personnel, increasing its cost, and therefore making it an unviable alternative to implement; and in relation to the operation of existing equipment in the market, a complex user interface is observed for tuning and subsequent manipulation; so in the present investigation, an ultrasonic reactor for the production of biodiesel (at the laboratory level) is developed and evaluated in order to improve the standard production efficiency so that the process is reproducible and the system is scalable at an industrial level.

2. Ultrasound transesterification technique

Biodiesel is the result of the alcoholysis of oil with alcohol in the presence of an acid or alkaline catalyst [8]. The main oils used in the production of biodiesel [21-22] are sunflower oil, soybean, palm, castor oil, and high oleic sunflower, animal fats, used deep-frying oils, and microalgae. Among the alcohols, methanol and ethanol are used, highlighting methanol for its physicochemical advantages, reaction with triglycerides at low temperature and natural dissolution of alkaline catalysts [21]. In the alcoholysis, catalysts are commonly used: basic homogeneous (NaOH, KOH, $NaHCO_3$), homogeneous acids (sulfuric acid, sulfonic), heterogeneous (ZrO_2, ZnO, CaO, $SO^2{}_4{}^-/SnO_2$, $SO^2{}_4{}^-/ZrO_2$, KNO_3/KI, zeolitas), and enzymatic catalysis (lipases) [23].

The process for obtaining small scale biodiesel (Fig. 1) [12], consists of the following equipment: ultrasonic actuator, ultrasonic device with positive pressure module, probe and flow (power of 500 - 1,000 W with operating frequency of 20 kHz); electric power and energy meter; processing tank (80 L capacity); heating element (1 to 2 kW); pre-mixed catalyst tank (capacity 10 L); catalyst premix agitator; centrifugal pump (10-20 L / min with pressure from 1 to 3 bar); back pressure valve to adjust the pressure in the flow cell; manometer for feeding pressure. The processing and pre-mixing tanks are made of high-density polyethylene.

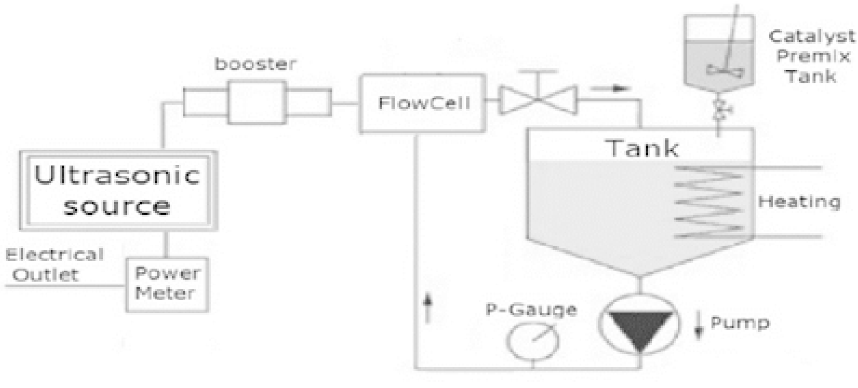


Figure 1
Batch transesterification with ultrasound.
Source: The Authors.

In the analysis of the technical specifications of the existing equipment in the market for transesterification processes, there are similarities and some differences in the design of their equipment. These range from the actuator used to the different functionalities and modes of operation by the user. For the analysis of this equipment, the following characteristics are taken into account: actuator power, processing capacity and operating frequency (Table 1).

Table 1
Commercial transesterification equipment

Manufacturer	Model	Frequency [kHz]	Power [W]	Capacity [gph]
Hielscher Ultrasonic [24]	UIP500hd	20	500	80-160
		18	16.000	12.800-25.600
Ultrasonic Power Corporation (UPC) [25]	UPR 2000	40	2000	13
	UPR 1000	40	1000	13
	UPR 500	40	500	13
CTSYSTEM [26]	Blazar-CT	40	30	500
	CT 1000Z	40	32	1.000
Bejing Ultrasonic [27]	Tb26-5-2	25-27	500-2.000	500-1.500
ClangsonicUltrasonic Technology Corporation [28]	20KHz - 500 W	20	500-3.000	500-2.500
Hainertec (Suzhou) Co. Ltd [29]	Hnt-8se-5020	20-28	500-3.000	500-2.500

Source: The Authors.

The methodology used to reach the investigation's goal is defined in the following steps:

1. Establishing functional requirements of the reactor.
2. Dividing the requirements into mechanical and electronic.
3. Making appropriate designs for each requirement.
4. Implementing the designs.
5. Executing performance tests.

3. Design and implementation of an ultrasonic reactor for transesterification

Based on the existing equipment in the market, a work plan structured in a modular way is established for the construction of an ultrasonic reactor for transesterification, it derives from the established functional requirements of the analysis of the aforementioned operation characteristics (Table 1).

3.1. Functional requirements

The frequencies used for ultrasound equipment in transesterification processes range from 18 to 40 kHz [30], each working frequency is used to manufacture biodiesel with a specific actuator, raw material, molar ratio, and temperature. The working frequency is determined at 20 kHz to generate small bubbles which will absorb the energy and reach a size of 170 μm [20], this frequency is in accordance with the use of raw materials and conditions of the experiment [31-32].

The power of the ultrasound signal allows the rapid growth of the bubbles generated by high power cavitation; a small bubble grows and implodes quickly [20], being convenient to choose an actuator that radiates great ultrasonic power to generate in a short time greater collapse of bubbles and accelerate the reaction, the power of ultrasound actuators in the market range from 70 to 16000 W [32], the higher the radiation power, the higher the price.

The transesterification processes that use ultrasound require an increase in temperature in the mixture, the operating values are in the range of 25 to 80 ° C [30], from this entire range 42 ° C is chosen [12,31,33], value used to reduce the energy consumption of the process and to determine the influence of the variables: mixing speed and transit time in the reaction. According to the previous considerations and the characteristics of the equipment (Table 1), an electromechanical system with the following technical characteristics will be designed:

- Mix temperature 42 ° C.
- Processing of 1.6 L / hour.
- The frequency of the actuator to be used 20 kHz.
- Power of the actuator 500 W.
- Complete automation level.
- Batch processing.

Therefore, the equipment to be developed must have certain functional parameters that make efficient use of resources and easy handling. For the prototype to be developed, the following functional characteristics are established:

- HMI (Human Machine Interface)
- Local alarm to turn on the equipment and pause the process.
- Emergency stop button.
- Remote connection.
- Modular electronic design.
- Easy tunning device.

The product is a system divided into a mechanical and an electronic part. These two subsystems must be designed in such a way that they allow the interaction of the product in a production line. The electronic part will generate the working frequency and the optimum voltage levels for the operation of the actuator, in addition to the temperature monitoring of the sample and the communication of the equipment with the exterior; the mechanical part is a chamber responsible for containing the actuator, housing the flow of the liquid on which the ultrasound will radiate and casing a temperature sensor (Fig. 2).

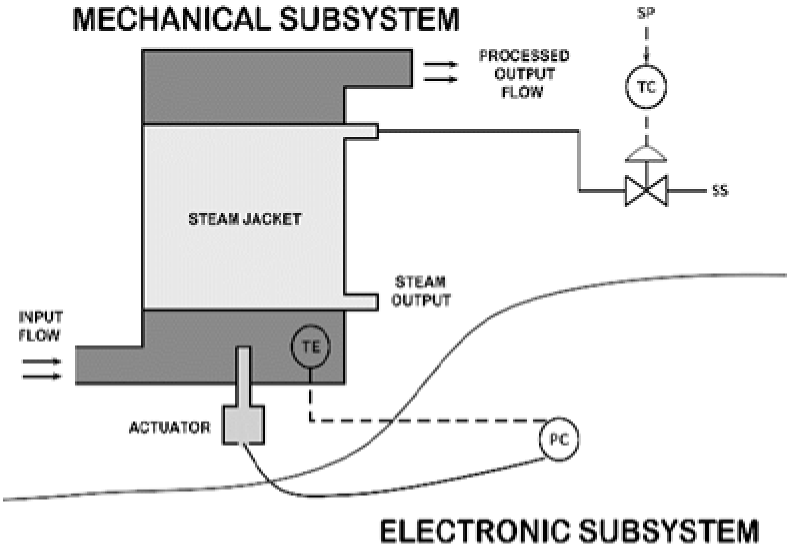


Figure 2
Diagram of the mechanical and electronic subsystem.
Source: The Authors.

3.2. Mechanical design

3.2.1. Ultrasonic actuator

The ultrasonic actuator is a device that converts an electrical signal to an ultrasound (pressure) signal of 20 kHz, which will be radiating the present fluid. According to the established technical specifications, the ultrasonic actuator reference HND-8AE-4020 developed by the company Hainertec [26] is chosen, which has as main characteristic a working frequency of 20 ± 0.8 kHz, capacitance of 16 nF ± 10%, an impedance of 180 Ω and a power of 500 W, according to previous studies [12], its working frequency is in the optimum frequency range to speed up transesterification processes.

The actuator HND-8AE-4020 has its aluminum body and the emitter is made of titanium [34] (Fig. 3), resistant to corrosion and work in harsh environments, providing high reliability in its performance, in its structure there is a thread of triangular section, which will be used as a means to embed the actuator to a liquid containment system, called the transesterification tank.

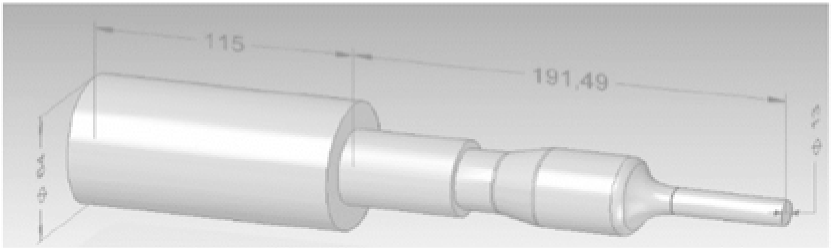


Figure 3
Ultrasonic actuator HND-8AE-4020.
Source: The Authors.

3.2.2. Transesterification tank

The transesterification tank is responsible for housing the liquid to process while it is subjected to ultrasound. This module has different inputs and outputs (Fig. 4); the input flow is composed of the liquids to be processed (alcohol and vegetable oil), the steam is a fluid that circulates inside the transesterification tank increasing the temperature of the substances, the ultrasound waves indicate the use of the ultrasonic actuator inside of the reservoir, the processed outflow refers to liquids that have been subjected to ultrasound irradiation, the temperature of the mixture is the value inside the transesterification reservoir, when the processed substance is irradiated by ultrasound and subjected to a thermal bath by steam.

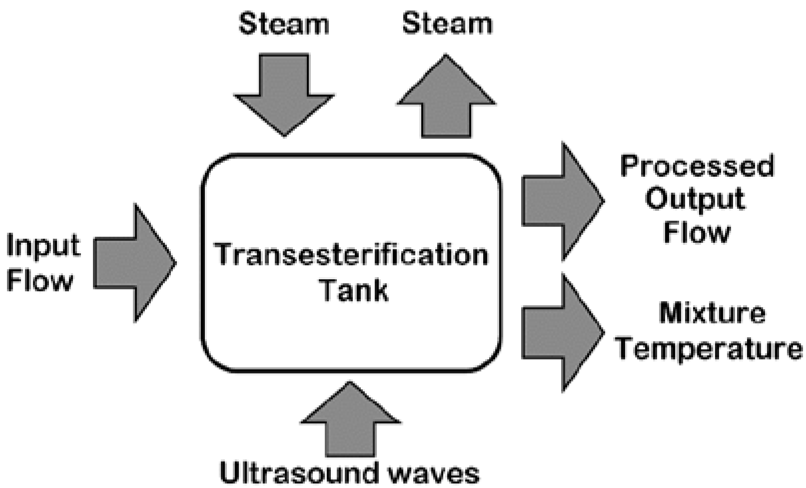
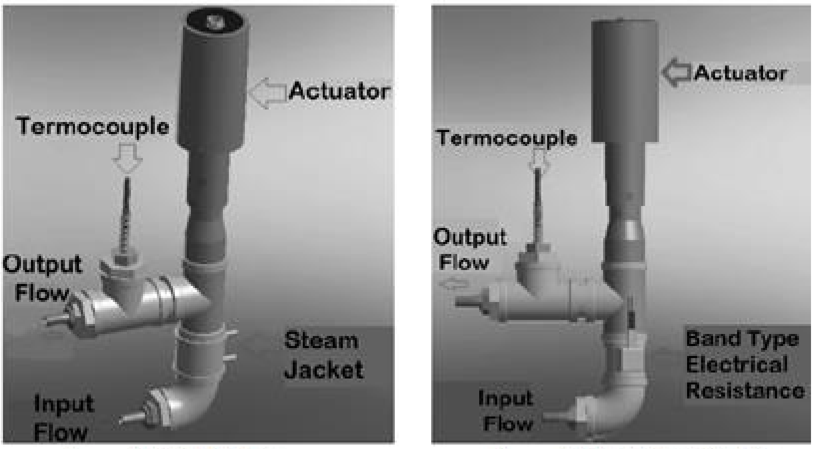


Figure 4
Transesterification deposit module.
Source: The Authors.

The geometry of the transesterification tank is related to the hydrodynamic behavior of the substance when subjected to the action of ultrasound, this behavior depends on the physicochemical properties of liquid, in addition to the operating parameters such as power dissipation, work frequency, acoustic transmission, etc. [35] The acoustic transmission through the liquid has already been reported [36], the results indicate that the maximum axial speed (1.6 m / s) was obtained relatively close to the irradiation surface and this decreases as it moves away from the transducer along the axial direction at a minimum speed in the lower part of the reactor.

Once the factors present in the transesterification tank have been analyzed, the tank is designed in stainless steel of reference AISI 304 [37]. The tank design calculations start from the mentioned considerations and the volume of the liquid contained in the transesterification tank (162 ml), with a transit time of fewer than 6 minutes, to comply with the technical characteristic. For the proposed industrial mechanical design, it is recommended to use an AISI 304 stainless steel tube with a diameter of 2.54 mm and a length of 200 mm, the diameter of the inlet/outlet flow is 38.1 mm. In the upper part it has a threaded surface to house the ultrasonic actuator and in the outlet pipe, there is a thermocouple type K, to sense the temperature increase in the processed substance (Fig. 5.a). To increase the temperature of the liquid to be processed in laboratory tests, a band-type electrical resistance will be used (Fig. 5.b). Once the characteristics present in the mechanical subsystem are defined, the transducer is coupled to the transesterification tank, the band-type resistance to the metal structure and the thermocouple to the output of the processed flow, finalizing the design of the transesterification tank.



a. Steam jacket. b. Electric resistance.

Figure 5
Transesterification tank.
Source: The Authors.

3.3. Electronic design

The operation of the electronic subsystem is subject to the interaction of three blocks designed in such a way that the signal that is delivered to the actuator is free of noise, with stable values of voltage, current, and frequency. The detailed study of the electronic subsystem involves describing three blocks:

- Block of integrated circuits composed of the following modules: frequency generator, resonator, remote connection, temperature monitor, alarm, and controller.
- Power block.
- HMI block.

Where the block of integrated circuits is the most complex since it is organized in six modules. There is an interaction of the three blocks present (Fig. 6), where the power block will be responsible for supplying specific voltage levels to each of the modules present, both in the block of integrated circuits and in the HMI block. The block of integrated circuits provides the necessary resources to the actuator by means of its modules and the HMI block, allows a local configuration of the system.

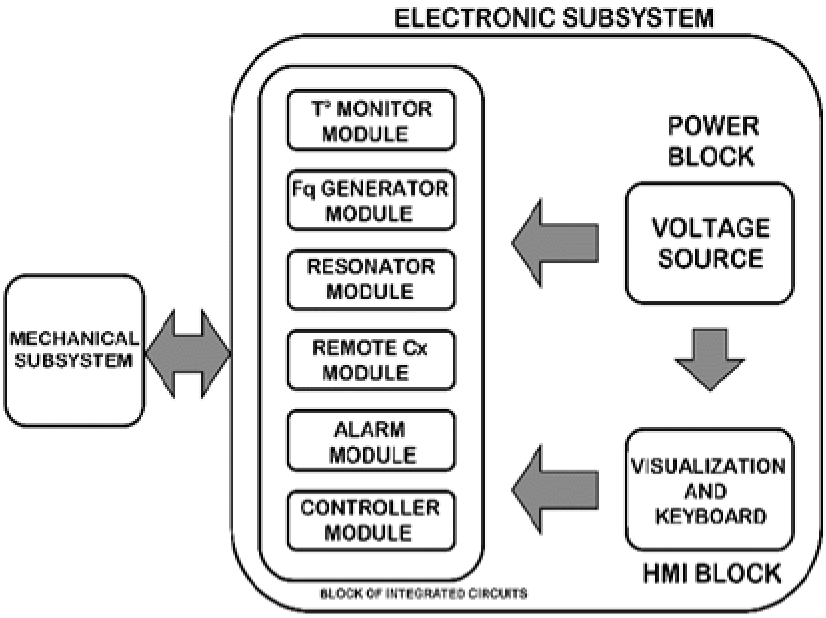


Figure 6

The module of the electronic subsystem.

Source: The Authors.

It is important to keep in mind that in the design of ultrasound equipment both the actuator and the electronic system form a single piece, and the entire system is designed based on the requirements of the actuator, that is why each module has components with special features that provide a high degree of confidence in the performance of the entire equipment.

3.3.1. Integrated circuit block

This block has been organized in six modules, which provide the necessary resources for the operation of the chosen actuator: frequency generator module, resonator, temperature monitor, remote connection, alarm and controller (Fig. 7).

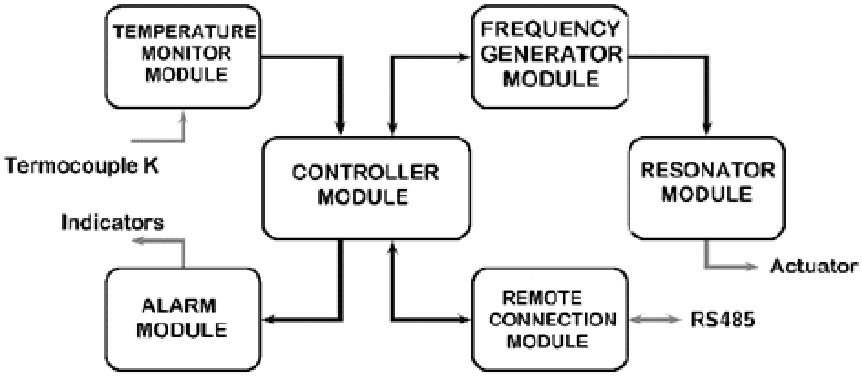


Figure 7
Interaction of modules of the electronic subsystem.
Source: The Authors.

3.3.2. Frequency generator module

The ultrasound systems must be stable and the key parameter for its operation is the operating frequency, which must be in the ranges preset by the manufacturer of the actuator to be used. The inputs and outputs of this module (Fig. 8) are: external clock reference, time base to obtain the desired frequency; configuration allows the interaction of the module with the controller module, in order to set working parameters; 5 Vdc power supply, is the energizing voltage of the devices present, as the output signal is the operating frequency of 20 kHz.

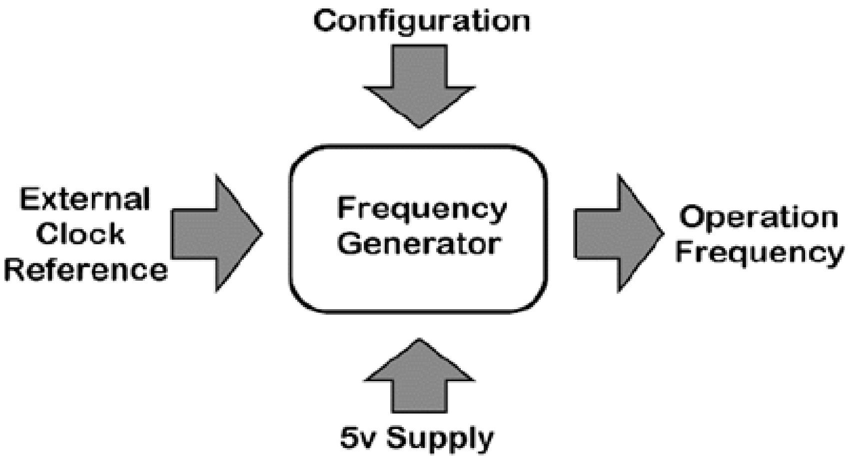


Fig. 8
Frequency generator module.
Source: The Authors.

Taking as reference the frequency of work of the ultrasonic actuator (20kHz), it is decided to generate this signal with an electronic device of easy configuration, the integrated circuit reference AD9833, which has a wide range of configurable frequencies by means of the SPI communication protocol (serial peripheral interface) [38].

3.3.3. Electrical resonator module

The ultrasonic actuator used requires certain voltage and frequency levels; the voltage levels are attained through series and parallel resonant circuits. This module has a power supply of 45 Vdc, as input a low-intensity frequency signal, and output a high-intensity sinusoidal frequency signal, responsible for activating the actuator to generate the ultrasound signal.

3.3.4. Remote connection module

For remote connection, we choose to use the MODBUS serial communication protocol, which is based on the master/slave model (this protocol is implemented over RS485 communication networks) [39]. The module has as input the signal sent by the controller through the RS-232 protocol, this signal is converted by an electronic circuit to a signal with higher voltage values providing as output the industrial network signal with RS-485 communication protocol; the module is powered at 5 Vdc. According to the design needs established for this module, the integrated reference circuit SN75176 is chosen, which fulfills the function of migrating from the RS232 communication protocol to the RS485.

3.3.5. Temperature monitor module

A variable of interest is the temperature value of the process inside the transesterification tank, since depending on the type of raw material to be used, the value of the reaction temperature must acquire a different value. The module is powered at 5 Vdc, it has as input the temperature inside the tank, and as output the normalized temperature signal, captured by a thermocouple type K and conditioned by the integrated circuit AD595 [40], which allows interaction with the controller module, who later performs the visualization process.

3.3.6. Alarm module

In any electronic device, it must be known when there is an interruption in the process due to technical failures or generated by the user; the alarm module (Fig. 9), has as inputs: the ignition signal of the equipment, and a signal called ultrasonic emission interruption; and as outputs: light signals, one is activated when the device is on (led indicator (on / off) and another that is activated with the interruption of the ultrasound emission (led indicator Ultrasound).

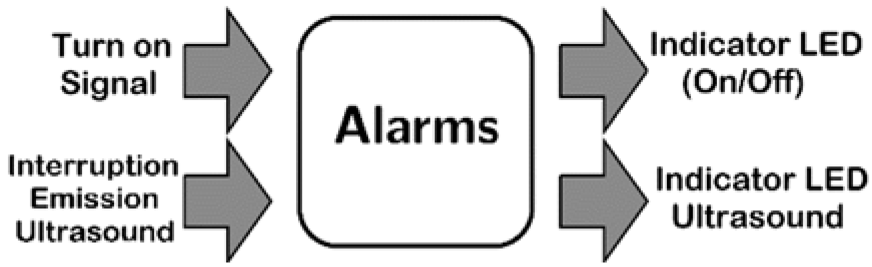


Figure 9
Alarm module.
Source: The Authors.

3.3.7. Controller module

Once the peripheral devices present in the system have been defined, the controller that best adapts to the needs of communication and management of electronic resources is selected, this module (Fig. 10) has as inputs: the signal Power 5 Vdc, voltage necessary to allow the energization of the present devices and temperature monitor, which will be the signal coming from the transesterification tank, as output signals the generator of frequencies and alarms, signals that allow to configure integrated circuits present in the system, the signal "HMI block" and "Remote Connection" are bidirectional signals that will be in continuous interaction with this module.

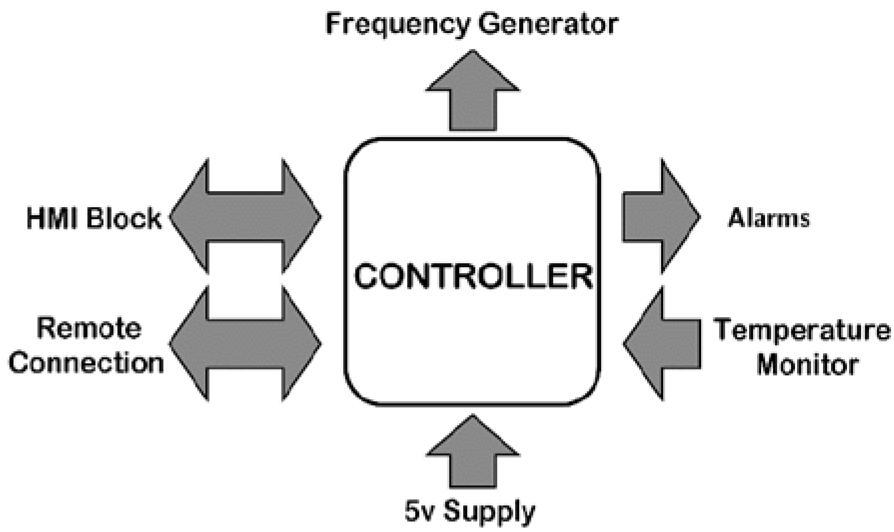


Figure 10
Controller module.
Source: The Authors.

Once the signals present in this module are defined, the general purpose microcontroller PIC18F452 [41] is chosen, due to its technical and peripheral characteristics, making it a versatile device for the operation to be developed. Fig. 11 illustrates the flow chart to be implemented to operate the equipment and put all its functions into operation.

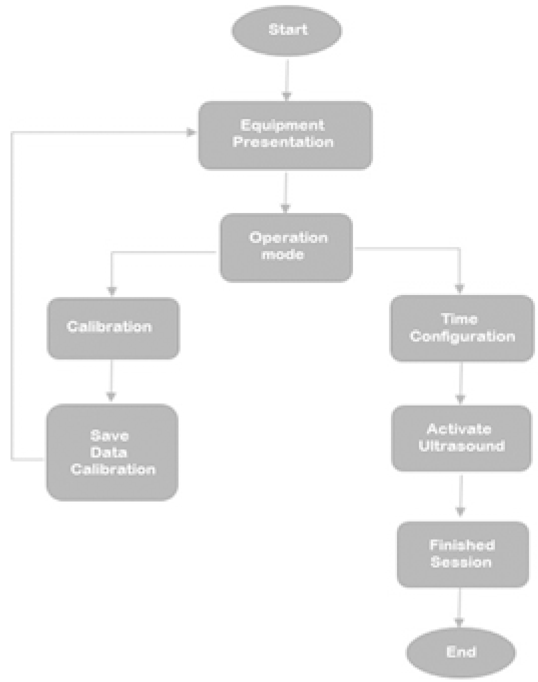


Figure 11
Operation diagram of the controller module.
Source: The Authors.

3.3.8. Power block

The electronic subsystem for its operation and coupling of signals, needs different levels of voltage, the power block has 120 Vac - 60 Hz as its input voltage. From this voltage level, the internal component power supply output voltages of 5, 12 and 45 Vdc are obtained. The 5 Vdc power supply is responsible for energizing the following modules: frequency generator module, remote connection module, alarm module, controller module. The 45 Vdc power supplies the resonator module. The 12 Vdc feeds the fans for heat extraction inside the equipment. For the generation of 5 and 12 Vdc, switched sources are used, due to their efficiency, size and functionality. The 45 Vdc are obtained from a TR-17 reference transformer, then a diode bridge and later capacitors for the elimination of noise.

3.3.9. User interface

Given the need to manipulate variables such as frequency during the set-up of equipment and time, it is necessary to use components that allow the entry and display of system information, as an input device there is keyboard, responsible for increasing or decreasing the numerical value of the variables as time, in addition to an emergency stop button with which the entire process is disabled. As an output, a 4 line LCD screen by 20 characters (4x20 LCD) is used, where the configuration information and process status is displayed, this module is powered by 5 Vdc.

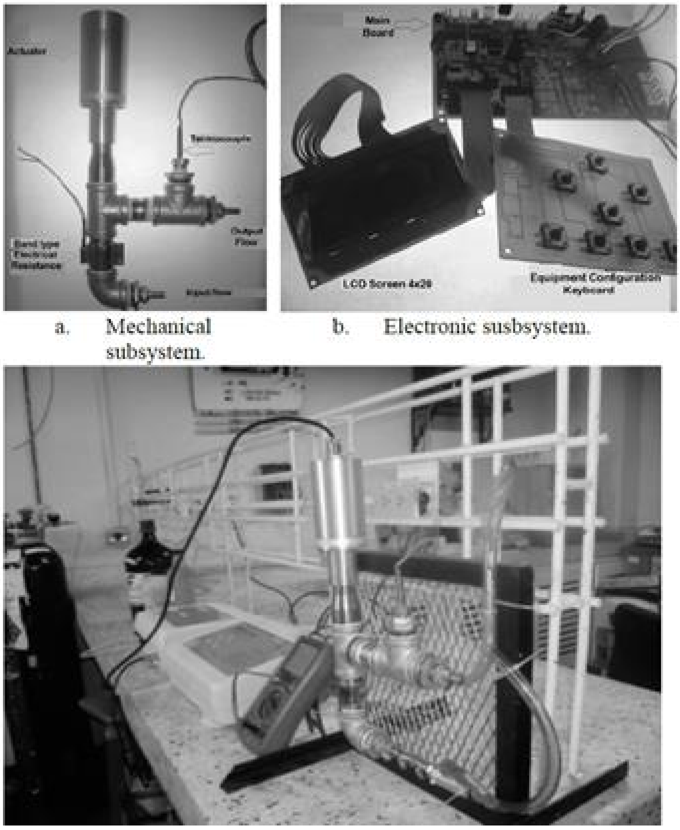
3.3.10. Electric resistance controller

The electrical resistance applied requires AC voltage for its operation, the design of this equipment is made in several modules. The zero crossing module, phase control and controller all stand out, and in their continuous interaction offer the electrical resistance the signal necessary for its activation. The zero crossing signal provides the controller with a reference to activate an SCR device by allowing the flow of part of the mains voltage, by keyboard the instruction is given to the controller of increase or decrease of the percentage of mains voltage that must pass to the electrical resistance.

4. Results and discussion

4.1. Implementation of the ultrasonic reactor

As a result of the mechanical and electronic development fulfilling the functional requirements, two main modules were obtained: the physical one, where all the mechanical components necessary for the operation of the reactor are located (Fig. 12.a). and the processing, consisting of the electrical and electronic components used in the control, manipulation and communication of the equipment (Fig. 12.b), the final device is the ultrasonic reactor (Fig. 12.c).



a. Mechanical subsystem. b. Electronic susbsystem.

Figure 12
Transesterification system implemented.
Source: The Authors.

The ultrasonic reactor has specific operating characteristics (Table 2), which determine its operating time, power consumption, processing capacity and sonic radiation power.

Table 2
Ultrasonic reactor technical sheet.

Characteristic	Value	Characteristic	Value
Time Setting	0-30 mins	Material	Galvanised steel
Supply voltage	120 Vac	Deposit volume	162 cm^3
Feed current	2,4 A	Temperature control	Manual
Network frequency	60 Hz	Ultrasound emission	Continua
Ultrasound	20 kHz	Termocouple	Tipo K
Ultrasoun power	500 W	Electric resistance	Band type

Source: The Authors.

4.2. Reaction conditions

To evaluate the operation and performance of the ultrasonic reactor for transesterification, experimental biodiesel will be obtained from a mixture composed of 130 mL of castor oil, 31 mL of methanol and 3 g of potassium hydroxide (KOH) [42]. When mixing the substances, use a glass beaker and manual stirring using a glass rod for one minute before subjecting it to the experimental conditions.

The quantities of raw material are calculated so as not to overflow the capacity of the transesterification tank (162 cm^3). The stoichiometric calculations start from the number of moles of the oil used; there is 125 g of castor oil (approximate molar mass of 936.38 g/mol) the number of moles of oils is 0.13. The oil / alcohol molar ratio is 1/6, then 0.78 mole of alcohol, represented in 25 g of methanol (molar mass 32.04 g/mol), is required. The glycerin formation (expected molar mass 92 g/mol) is 11.96 g. The catalyst is 2% of the total mixture [42] (125 g of oil + 25 g of alcohol = 150 g of mixture) in this case is 3 g. For the preparation of the catalyst, the potassium hydroxide was completely dissolved in the methanol with the aid of a mechanical stirrer. The products of the reaction are biodiesel and glycerin; its stoichiometry gives the reference value for the process of 9.5 mL of glycerin, which will be used in the calculation of the efficiency of the reaction.

4.3. Glycerin response curve with ultrasound and heat

In the research process carried out, the glycerin formation data are recorded until reaching a stable state in each test, comparing the efficiency in each experiment. As a standard curve, the reaction is obtained without any external catalyst at room temperature 22 ° C, together with response curves at 42 ° C, with the use of ultrasound, and the combination of ultrasound and temperature (yellow curve). The application of the temperature is for 6 minutes and that of the ultrasound is constant; the reaction was observed for a period of 2 hours.

In the experimental behavior (Fig. 13), the influence of the change in temperature on the reaction rate is observed, since for the first 20 minutes the slope of the curve of 42 °C is greater than the curve of ambient temperature. A similar effect occurs between the ultrasound curve (US) and the combined process curve (C), since the latter reaches a stabilization value of glycerin production at around 40 minutes, while the ultrasound curve takes 80 minutes in attaining a volume of glycerin produced almost constant (Table 3). Therefore, where a positive change in temperature occurs, the reaction stabilizes in less time.

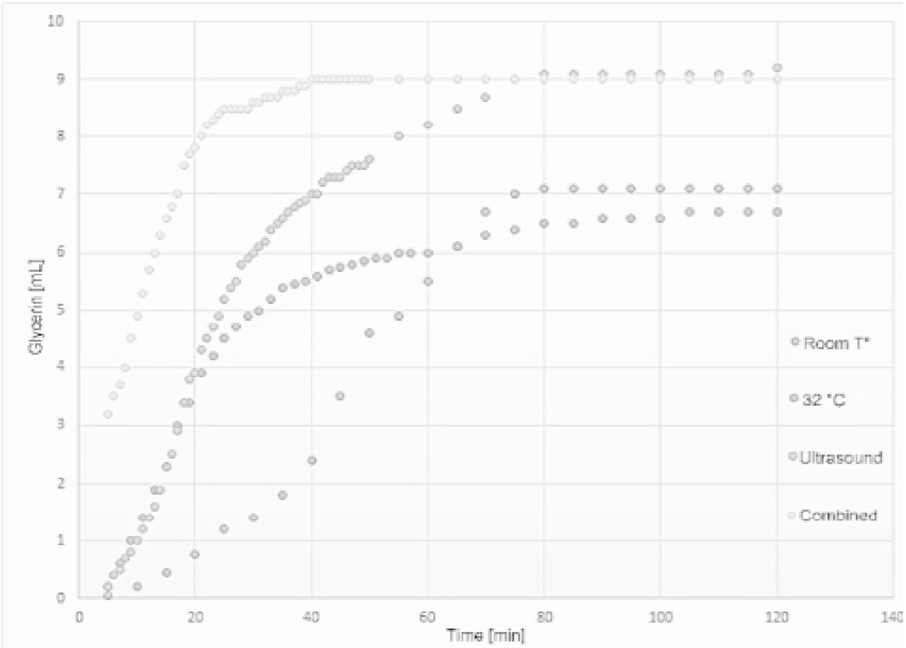


Figure 13
Glycerin response curves for external catalysts.
Source: The Authors.

Table 3
Changes in glycerin concentration.

Time (min)	Glycerine concentration (mL)				Change Slope (mL/min)			
	Room T°	US	42°C	C	Room T°	US	42°C	C
20	0,75	3,9	3,4	7,8	0,0375	0,195	0,17	0,39
40	2,4	7	5,5	9	0,0825	0,155	0,105	0,06
60	5,5	8,2	6	9	0,155	0,06	0,025	0
80	7,1	9,1	6,5	9	0,08	0,045	0,025	0
100	7,1	9,1	6,6	9	0	0	0,005	0
120	7,1	9,2	6,7	9	0	0,005	0,005	0

Source: The Authors.

The temperature also influences the rate of change of the glycerin concentration, since the curve of 42 °C has a maximum slope of 0.7 mL / min, the process with ultrasound, and the combined, have a value of 0.5 mL / min, and the ambient temperature curve of 0.22 mL / min. However, it does not have the same effect on the production efficiency of glycerin compared to the reference value (9.5 mL); because the ambient temperature curve reaches a final glycerin volume of 7.1 mL (75% efficiency), and the curve of 42 °C a value of 6.7 mL (71% efficiency). The effect with the greatest impact on the reaction efficiency is ultrasound with a final value of 9.2 mL (97% efficiency); even above combining the ultrasound and a temperature of 42 °C, in which it ends with a volume of glycerin of 9 mL (95% efficiency).

5. Conclusions

An ultrasonic reactor was designed and implemented on a laboratory scale to carry out the transesterification reaction under the effect of ultrasound. It is designed with a mechanical and electronic subsystem to irradiate a mixture of animal or vegetable oil, with a short chain alcohol and the respective catalyst with incidence of ultrasound bursts at 20 kHz during the transit time of 6 minutes, and varying the room temperature up to 42 °C.

The performance of the built equipment was evaluated in obtaining biodiesel from a mixture of methanol, castor oil and potassium hydroxide (catalyst). In which the reaction was carried out under 4 ambient temperature scenarios and at 42 °C, and causing the ultrasound to affect both temperatures; with the graphs of production of glycerin obtained it is observed that the temperature affects the reaction speed. Meanwhile the ultrasound has the greatest impact on the reaction efficiency on which 97% is obtained in relation to the theoretical value.

The system's operation allows evaluating the degree of incidence of the ultrasound and the temperature, for different processes that are related to these variables. In this case biodiesel production; and thus determine the modes of operation to improve speed and / or production efficiency.

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Notes

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