Universidad Continental

FACULTAD DE INGENIERÍA

Escuela Académico Profesional de Ingeniería Mecatrónica

Tesis

Design of a Machine for the Treatment of Organic and Inorganic Waste to Obtain Energy for Hybrid

Juan Carlos Bueno Rojas

Para optar el Título Profesional de
Ingeniero Mecatrónico

Huancayo, 2025

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DESIGN OF A MACHINE FOR THE TREATMENT OF ORGANIC AND INORGANIC WASTE TO OBTAIN ENERGY FOR HYBRID

URL / DOI:
https://doi.org/10.1109/mepe56451.2022.10146693

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DESIGN OF A MACHINE FOR THE TREATMENT OF ORGANIC AND INORGANIC WASTE TO OBTAIN ENERGY FOR HYBRID

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***Abstract*— In this article, a solid waste treatment machine is designed and implemented to obtain liquid energy that deals with the problem of the agglomeration of solid waste that causes environmental, ecological and health consequences. A hydrocarbon production machine will reduce climate change and dependence on fossil resources, improving the quality of life. Therefore, a plastic waste treatment machine was designed to obtain fuel through the pyrolysis process that integrated a control system for the time of classification of the waste and the temperature of the thermal process to identify the best conditions with respect to the speed and temperature with respect to the amount of input waste. Finally, the experimentally found results of the efficiency of the System demonstrate the effectiveness sought.**

Keywords—pyrolysis, hydrocarbons, plastic waste, control systems, efficiency

I. INTRODUCTION

In Peru, 21,000 tons of garbage are generated per day, approximately 0.8 kg per person, of which only 15% is recycled. Of all the tons of garbage generated, 54% goes to landfills and the rest ends up in dumps, streets, rivers and streams (1). What's more, currently all the products we consume are packaged in different types of plastics, which later become garbage; Although many of these are recycled, most of the plastic waste is agglomerated in dumps or is thrown in the streets, generating pollution due to its slow degradation capacity that takes many years (2). This project makes it possible to reduce garbage mounds, mainly from sanitary landfills, and also improves decoration and afforestation with the respective treatment of waste; It will also reduce the appearance of new diseases in agriculture by reducing the use of pesticides that harm health. The purpose is to design a machine for the treatment of organic and inorganic waste to obtain energy for hybrid use by the population in Huancayo and to design a system for the pyrolysis process to obtain fuel from plastic; where it is sought that the waste treatment machine allows to take advantage of 60% of organic and inorganic waste to obtain fuel and that the design of the pyrolysis process system produces 0.5 liters of hydrocarbon per kilogram of garbage.

II. DESIGN METHOD

The methodology used is the VDI 2206 for the investigation of mechatronic systems that will be used in the investigation is shown in Fig. 1, which will allow the optimal development of the system in which the stages are developed to develop the plastics processing machine for obtaining hydrocarbons and obtain the mechanical, electrical and control design to apply in the field of study.

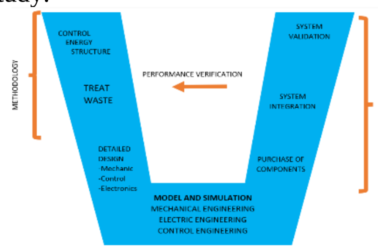

Fig. 1. Mechatronic Model V according to VDI 2206 guideline

A. Block diagram

The block diagram of the project is divided into four development phases is shown in Fig. 2, the first being the collection of pyrolysis information to obtain energy; mathematical analysis for dimensioning and obtaining results; design of the treatment machine for the pyrolysis, control and classification processes; and prototype simulation to determine the efficiency and speed of the plastic waste treatment machine.

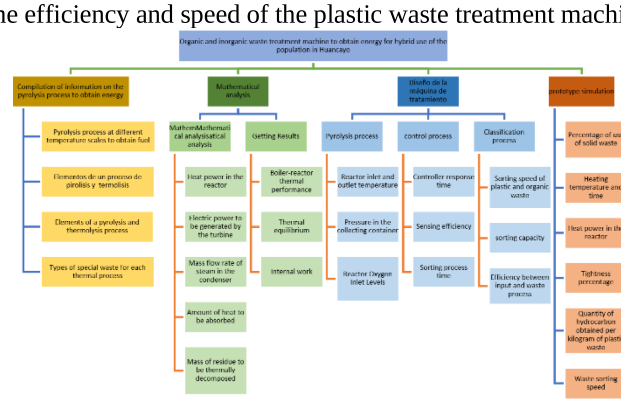

Fig. 2. Blocks diagram

The design of a waste treatment machine to obtain liquid energy where plastic waste will be used to carry out the depolymerization process by the pyrolysis process, reduced the garbage mounds from the sanitary landfills on the banks of the Mantaro River that affect to the surrounding people. On the other hand, hydrocarbons will be obtained that can be used in combustion engines and kitchens with biofuel, leaving aside the existing energies that have high prices.

In the system, organic and plastic waste will enter the classification system with the use of electric energy where it must be processed for a certain time; then the plastic waste enters the reactor where heat energy will be applied by means of an induction system for a certain time where pyrolytic gases will result at a certain pressure and temperature, obtaining gases with a certain heat power and kinetic energy that will be condensed, obtaining hydrocarbons as a result of the pyrolysis process and coke from thermal degradation.

B. Morphological matrix

Next, the elements that make up the three solution alternatives is shown in TABLE I, are shown according to the partial process that each element will execute, allowing us to choose the best solution to the problem posed. Likewise, the matrix will allow to carry out an optimal conceptual scheme for the respective analysis of the solutions.

TABLE I. MORPHOLOGICAL MATRIX

N °	PARTIAL PROCESS	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3
1	Construction material	A36 steel	Stainless steel	Alloy steel
2	Waste selection	conveyor belt	Venting system	
3	Motor para accountment de selection	12V DC motor	Servomotor	Stepper motor
4	Selector drive motor	Gate and hinge	Bolts	
5	Flow and transfer of gases	Metal pipes	Silicone hoses	PVC for high temperatures
6	heat producing element	Boiler	Induction cooker	
7	Temperature sensor	Type K Thermocouple	RTD platinum	Type J Thermocouple
8	microcontroller	PIC	Arduino development board	Raspberry pi
9	gas condenser	Downflow Vertical Condenser	Upflow Vertical Condenser	
10	Filter	Stages	Fluid filters	
11	Layers for heat conservation	Clay	Cement	

Once the morphological matrix has been generated, combinations are made, looking at and analyzing prices and effectiveness of the component.

C. Structure of functions

In the Fig. 3, The information process is described where the data, control and system are detailed; electronic design where data entry and actuators are explained; and the mechanical design where the entire process of obtaining hydrocarbons is detailed.

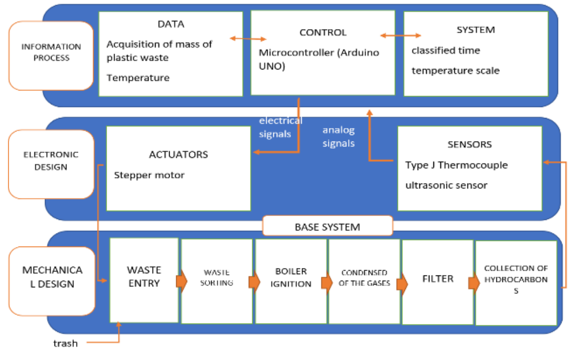

Fig. 3. Function structure

Mechanical design

The pyrolysis process consists of entering unconventional waste which enters a performance reactor where a decomposition process is carried out, the resulting products are divided into two streams, the first for the remaining conventional solids and the other for only ashes, and another that after the condensate at room temperature is divided into the processes for obtaining gaseous products and the other stream for obtaining synthetic products (3,4). To obtain high temperatures and a slow pyrolysis process, the use of a fixed bed reactor is considered (5). From this, the mechanical design consisted of six stages is shown in Fig. 4, the first being the input of waste to the classification system to process only plastic waste; then it entered the reactor where the boiler was turned on for the thermal process and to obtain the greatest amount of pyrolytic gases; the reactor allows degradation by means of heat, which allows the result to be used as fuel feed in water boilers or generation of hydrocarbons by depolymerization (6,7). After these gases were condensed by a water-cooled system, finally the fluid passed through a filtering system and was collected in a collection container.
This proposed system is shown in Fig. 4 and Fig. 5 presents at the entrance a classification system by venting system which will be driven by a 12V DC motor, then it will integrate an A36 steel reactor that will integrate a layer of clay to conserve heat and will be sealed by bolts that can avoid leaks, this reactor will increase its temperature with the use of an induction cooker, in addition to identify the temperature a K-type thermocouple sensor will be used.
The water-cooled condenser allows converting the fluid in the form of gas to liquid, where heat transmission between gases and steam is improved with more surface area of tubes, increasing the pressure of the condenser (8). In addition, there are 4 types of water-cooled condensers, among them the vertical condensers in flow tubes, found higher heat transfer and lower volumetric condensate consumption. (9,10). For this reason, it is proposed, for the transfer of the gas flow, 1/2 "metal pipes will be used that will enter a vertical condenser in a downward flow for the condensation of the gases by means of water to obtain a higher percentage of hydrocarbons, also A fluid filter will be used to obtain the hydrocarbons in a liquid state. Finally, the entire temperature and time selection supervision and control system will be carried out with an Arduino development board.

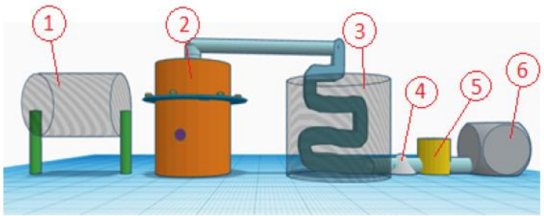

Fig. 4. Diagram of the alternative solution

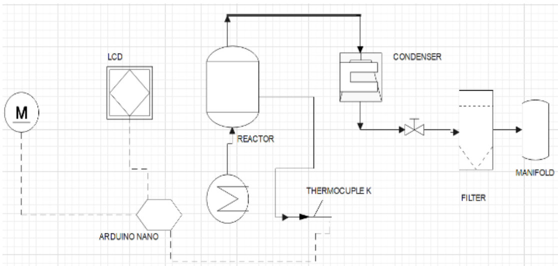

Fig. 5. Diagram P&ID

Electronic design

The pyrolysis process depends largely on the process variables according to the ranges of temperature, time, presence or absence of gases or reactive liquids and catalysts that allow the production of some products to be increased or others to be minimized(11,12,13). For this reason, in the electronic design, the automatic control of the process is foreseen to monitor the time and temperature of the process is shown in Fig. 6, which will consist of 6 parts, the first one is the button that will start the system through an external interruption which is configured by an INPUT_PULLUP, the second one is the type k thermocouple sensor which will sense the temperature of the reactor and the data will be digitized by the MAX6675 module, the third which is the Arduino which is the development board where the internal interruption of timer 1 will allow control of the ignition time of the motors, as well as the reading and display of data, the fourth part is the relay module which allows to control the switching on and off of an AC motor which will make the classified system work, the fifth which is the control of the heater or boiler through a relay module during the thermal process and finally the data sample that is the LCD which will show the temperature, process time and process status.

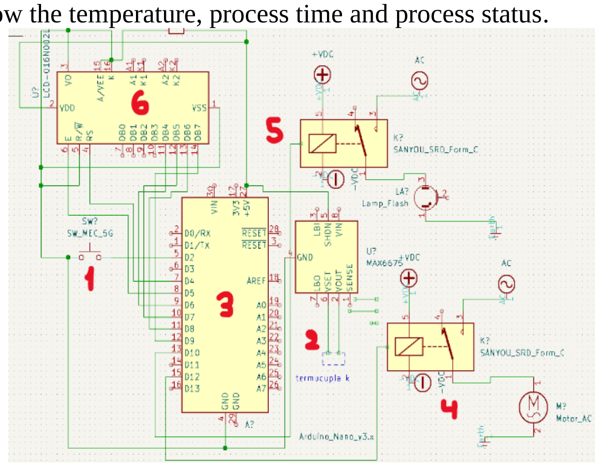

Fig. 6. Electronic design

Control design

Conventional pyrolysis occurs between temperature ranges from 300 to 550°C with a process time of 5 to 30 minutes and a heating rate of 0.1 to 1°C/s, resulting in solid, liquid and gas products in medium proportion (14,15). The control system will be based on the use of the internal timer of the Arduino nano to control the time after the start of the process is shown in Fig. 7. The time control will be given when the start button is pressed to turn on the motors of the vented system during 10 minutes of process, after that, the microcontroller will take a time of 3 minutes of rest of the system to be able to perform the entry of the plastic waste to the reactor and the boiler will be turned on for the thermal process, controlling a time of 30 minutes, in addition to showing the temperature inside the reactor and the time elapsed during the process; and after that time, the boiler will turn off and wait for the temperature to be less than or equal to 30°C so that the process is finishedin addition to showing the temperature inside the reactor and the time elapsed during the process; and after that time has elapsed, the boiler will be turned off and the pyrolytic gas process will be finished.

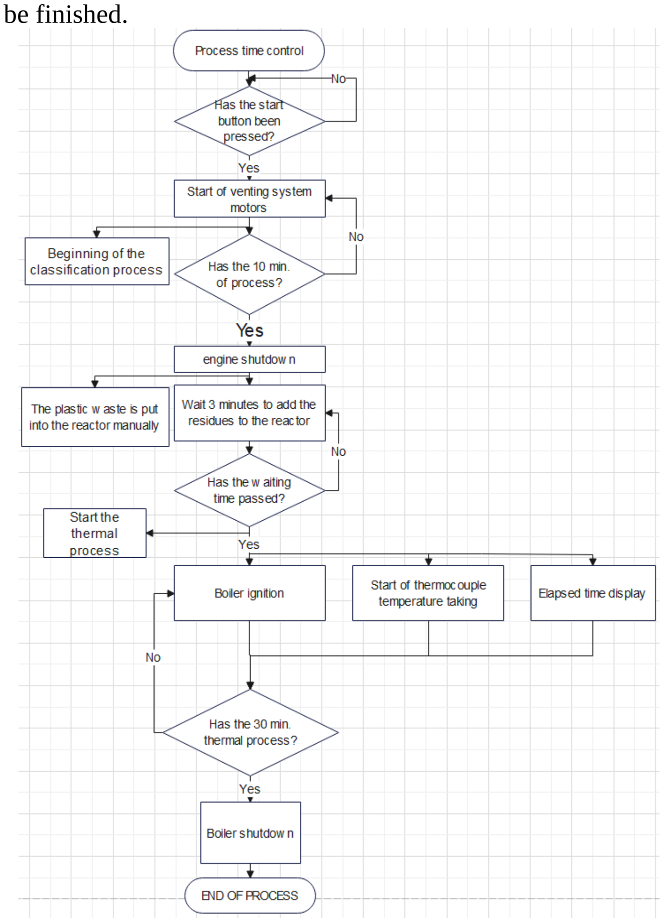

Fig. 7. Control desing

In addition, a comparison of economic, technical and technological aspects of the three proposed solution alternatives is made in TABLE II, where each of the important aspects is analyzed.

TABLE II. TECHNICAL AND TECHNOLOGICAL EVALUATION

SOLUTION EVALUATION FORM -TECHNICAL CRITERIA					
SCALE OF VALUES (score "p" between 0-3)					
0=Not satisfied 1=Tolerable 2=Sufficient 3=Good					
N°	**TECHNICAL CRITERIA**	**IMPORTANCE i**	**SOLUTIONS**		
			SOLUTION 1	***SOLUTION 2***	***SOLUTION 3***
1	Function	8%	3	2	2
3	Energy	12%	3	2	2
4	Geometry	15%	2	1	2
5	Operability	10%	3	2	3
6	Manufacturing	20%	2	2	1
7	Assembly	20%	3	2	3
8	Security	8%	2	2	2
9	Portability	7%	2	1	2
10	Robust	8%	3	2	2
11	Maintenance	12%	3	2	3
TOTAL SCORE PT		100%	1.82	1.27	1.55
Unit score			60.6%	42.4%	51.5%
SOLUTION EVALUATION FORM - TECHNOLOGICAL CRITERIA					
N°	**TECHNICAL CRITERIA**	**IMPORTANCE i**	**SOLUTIONS**		
			SOLUTION 1	***SOLUCION 2***	***SOLUCION 3***
1	Sorting Efficiency	8%	3	2	3
3	sensing efficiency	20%	3	2	2
4	Actuator drive efficiency	12%	2	1	2
5	Microcontroller Efficiency	15%	3	2	3
6	External Microcontroller Interrupts	10%	2	2	1
7	Communication interface	5%	3	2	2
8	Interaction menu	5%	2	2	2
9	Visual display	10%	2	1	2
10	Feeding system	10%	2	2	2
11	P&ID design software	5%	3	2	2
TOTAL SCORE PT		100%	2.5	1.8	2.1
Unit score			Unit score	60%	70%

Next, the comparative graph is shown where the proposed alternatives were compared where solution alternative 1 presents an average of 73.5% of economic, technical and technological evaluation, demonstrating that it is the most appropriate to develop compared to the others.

III. RESULTS

As results obtained, the schematic design is presented based on a modeling in Solidworks is show in Fig. 8, the design of the waste treatment machine for obtaining energy presented dimensions of 0.5 m wide, 0.7 m long and 0.6 m high with a mass of 50 Kg, it is also made of alloy steel to withstand high temperatures and avoid corrosion due to the presence of moisture, this also made it possible to take advantage of up to 40 to 50% of the organic waste due to the use of reactors that can withstand temperatures between 350 and 500ºC and boilers that can transmit homogeneously between 20 and 30% more thermal energy to all waste; in addition, the reactor will be able to withstand up to 70 psi and hold a mass of 19.6Kg.

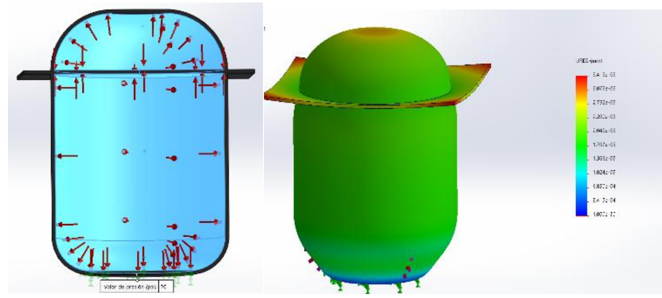

Fig. 8. Pressure test

On the other hand in Fig. 9, the design of the pyrolysis system presented a reactor that is made of 0.5 mm chrome-alloyed steel and internally coated with a mixture of chambota and andalusite that allowed reaching a temperature between 300 and 450ºC in 60 minutes, obtaining 1,800 to 2,500Kcal/Kg, in addition, the use of rotary-type boilers allowed the greatest amount of plastic waste to be consumed in the shortest time, transmitting the same temperature throughout the reactor, in addition, the hydraulic test in the upflow condenser allowed a reduction between 20 and 30% loss after sealing, obtaining between 0.2 and 0.4 liters of hydrocarbon per kilogram of plastic waste, according the simulation in Factory IO y Labview.

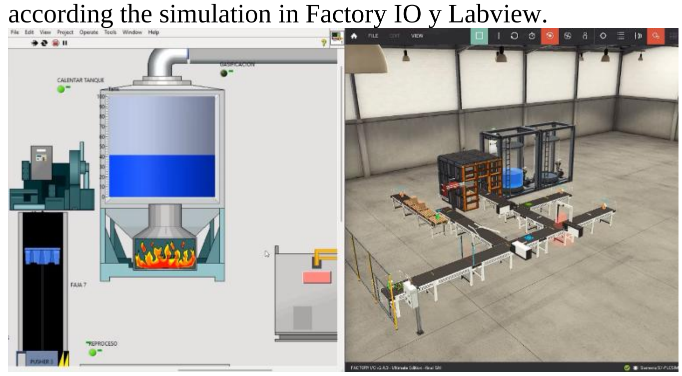

Fig. 9. Treatment machine design

IV. DISCUSSION

The solid waste treatment machine was designed with alloy steel to withstand temperatures between 350 and 500ºC, which allowed it to improve thermal degradation performance; In addition, the use of chambota and andalusite caused the heat to disperse, allowing temperatures to reach over 350°C, reducing the process time. The time, the temperature transmission and the use of rotary type boilers allowed to reach a calorific power greater than 1800Kcal/Kg due to the fact that they improved the thermal degradation of the residues; In addition, the hydraulic test reduced losses due to the fact that there was no high percentage of oxygen present in the process, nor pyrolytic gas leaks, achieving better hermeticity.

Among the possible improvements for the System is to add a cascade filter to be able to obtain different fuels, either diesel or LPG at different octane levels. On the other hand, also add the thermolysis process to take advantage of the combustion of carbon from organic waste and obtain electrical energy thanks to the calorific value and pressure by steam turbines after the process.

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