DEVELOPMENT OF AN AUTOMATED CONTROL SYSTEM OF A ROTARY KILN FOR ACTIVATED CARBON PRODUCTION

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ABSTRACT: *The study focuses to innovate a rotary kiln dryer to support the needs of the local farmer giving value-adding to their production of charcoal or carbon. Likewise, giving them the opportunity to enhance their skills and alleviate their economic activities. The study seeks to identify ways to reconsider the current process in the production of activated carbon through the utilization of interface systems interconnecting Variable Frequency Drive (VFD) with a Programmable Logic Controller (PLC) and Human Machine Interface (HMI) to control the Rotary kiln machine for activated carbon production.*

Keywords: Automated Control, Rotary Kiln, Activated Carbon, Production, Variable Frequency Drive, Programmable Logic Controller, Human Machine Interface

1.INTRODUCTION

Activated carbon (AC) is a well-known adsorbent substance that is used in the chemical, mining, and food sectors as well as other crucial activities including water treatment, deodorization, and medicine [1]. Activated carbon, also known as activated charcoal or activated coal, is a type of carbon that has undergone processing to produce numerous tiny, low-volume pores that increase the surface area accessible for material absorption, purification, and filtering. One of the many applications for activated carbon is the adsorption and chemical reactions required for the purification of water and gases. Activated carbon is a treated, porous form of carbon. The large surface areas tucked into the holes and tunnels all over the surface of activated carbon particles result from their extreme porosity. For various applications, alternative materials may be used to fill these spaces. For instance, in the process of purifying water for residential consumption, silver is incorporated into the carbon pores to filter out impurities like mercury and organic arsenic. Carbon can be obtained in large amounts for a variety of uses since it is created from charcoal using a cheap and straightforward set of activation methods [2].

Recent studies have concentrated on improving the performance of activated carbon by altering certain characteristics that allow the carbon to form an affinity for particular pollutants. Scientists have looked at ways to make activated carbon work better at collecting particles by changing it physically, chemically, or biologically. Research indicates that activated carbon treated with chemicals demonstrated the highest ability to attract and hold dye and heavy metals from water. Chemical changes, such as using acid, base, or impregnation, are studied a lot because it is easy to get the necessary substances, make modifications, and adjust the properties of surface functional groups [3].

Coal, wood, coconut shell and other carbonaceous sources are used to make activated carbon. It can be created using either the physical reactivation or chemical activation techniques. The materials used to make activated carbon mostly come from plants and have a lot of carbon, like coconut shells, coal, wood, animal bones, leftover materials from farming, olive pits, and chestnut shells, among other things. Activated carbons are special types of carbon materials that have a lot of small holes in them. These holes make them very good at absorbing things. When the coal is turned on, it becomes porous like a network of tunnels that split into smaller channels. These different types of porosity are sorted by their size into large, medium, and small porosity. There are two methods to make activated carbon: one involves physical action, and the other using chemicals [4].

Most activation processes are variations of a basic procedure called carbonization or pyrolysis of the raw material. Carbonization or pyrolysis is a process where raw materials are heated without any air. This helps to get rid of certain substances like nitrogen, oxygen, and hydrogen, and increases the amount of carbon in order to make biochar (a kind of charcoal made from organic matter). When the devolatilization process happens, small holes in the precursor begin to form, causing sticky substances to be deposited as the temperature increases [5].This coconut shell was physically reactivated utilizing the rotary kilns' activation/oxidation technique, which was properly heated. The continual drying, calcining, processing, or sintering of bulk materials is the sole purpose of rotary kilns. The working temperature of this Rotary kiln can attain the precise temperature needed to activate the carbon.

A rotary kiln is a cylinder that rotates around its cylindrical axis and serves as a heat exchanger. For physical activation, the direct heated rotary kiln is widely used. The kiln's construction and position alignment are critical to the entire process. Rotary kilns are used in the thermal processing of residual materials of various origins, most notably in the fire treatment of hazardous wastes. In metallurgy, they are used for heating solid particles such as oxide ores reduction, limestone calcination, and swarf removal from machine oil. Furthermore, these units are widely used in the silicate, chemical, and pharmaceutical industries, as well as in the minerals, metallurgical, cement, sugar, and food industries as an incinerator and pyrolyzer. They are primarily used in these industries for heating and drying bulk materials of various dimensions. Rotary kilns are well-established devices for a wide range of industrial applications such as waste lime recovery, proppent manufacture, activated carbon manufacture, sugar industry, food processing, pulp and paper industry, clays, thermal desorption of organic/hazardous wastes, mineral roasting, speciality ceramics, plastic processing, gypsum calcining, Tyre pyrolysis, bauxite calcining, pigments, catalysts, and phosphate production [6].

Kiln control is one of the most important aspects, and the kiln is extremely sensitive to operation. Controlling the kiln while it is operating, as well as the assembly of various components and process parameters, is critical in today's rapidly changing environment. Generally, kilns are used for processes such as activated coal regeneration, lignite degasification, municipal waste disposal, scrap tyre recycling, sewage sludge disposal, soil cleaning, and waste wood recycling. Indirect heated rotary kilns are used for pyrolysis and thermolysis processes because of the benefits of continuous processing, very good product blending versus batch processing, and simple plant layouts [6].

In the Philippines, the National Statistics Office has calculated a specific percentage of charcoal users in terms of household energy consumption. 1989 (32.1%), 1995 (38.5%), and 2004 (34.2%) all based on the three-survey conducted. According to Bensel and Remegio's estimation from 2002, household charcoal use amounts to between 1.2 million and 2 million metric tons annually (estimate range). In metric tons, this is the same as 7.2 million tons of wood. This merely demonstrates that despite technological advancements, Filipinos continue to utilize charcoal. (electricity, LPG, and Kerosene). Charcoal is clearly in high demand, and in response, despite the risk it poses to the environment and human life, it is manufactured for a variety of reasons.

The kiln is made through piling the woodcuts in uniform length but different in diameter. Then, as it fires inside it is covered with grass and soil until the woodcuts are fully carbonized. The fire is being controlled in the production of charcoal. Beneath the pile of woodcuts covered with grass or soil is a created small hole for the air ventilation and support the combustion and carbonization process inside the kiln. The time to complete the carbonization depends solely on the number of woodcuts. The charcoal producer keeps an eye and sees to it that the carbonization process does not create fire outside; or else the entire pile of woodcuts results to ashes. If ever there is a hole outside the kiln due to the deoxidation of the woodcuts, the producer must cover it each time with hay and soil to fully control the carbonization process to produce large amount of charcoal harvest.

Charcoal is produced by mostly underprivileged farmer sectors who are truly left behind in their human and economic development. Relationship between poverty and charcoal production can truly be observed. Charcoal production are sources of fuel and income for the poor. Charcoal production supports both its producers as source of income and consumers for cooking purposes. Its practice needs an ethical consideration not only on the economic aspects. The producers must import knowledge and develop skills and techniques which increase charcoal yields. Only few of these charcoal producers had college education [7]. This implies the necessity for financial resources to acquire knowledge and develop skills. Their poverty situation hinders them to fully and humanly develop themselves.

The purpose of this research is to develop a rotary kiln dryer to meet the needs of local farmers by adding value to their charcoal or carbon production. Similarly, providing them with the opportunity to improve their skills and alleviating their economic activities.

The study seeks to identify ways to reconsider the current process in the production of activated carbon through the utilization of interface systems interconnecting Variable Frequency Drive (VFD) with Programmable Logic Controller (PLC) and Human Machine Interface (HMI) to control the Rotary kiln machine for activated carbon production. The design of the automated control innovations introduced for rotary kiln for small scale farmers. In order to accomplish a

complete set of the research, the researchers established some basic objectives and studies to make the research efficient. The general objectives of the research study are to design and develop an automated control system for rotary kiln for activated carbon production.

The following are the objectives of the research study:

a. To develop the automated control system for rotary kiln for active carbon production.

b. To evaluate the effectiveness and acceptability of the automated control system for rotary kiln dryer in terms of;

b.1. User friendly/ Easy to operate
b.2. Safety
b.3. Durability
b.4. Portability
b.5. Functionality
b.6. Efficiency (Input/Output)

2. Methodology

The methods and techniques on how the study is undertaken in order to give substantial answers to the objectives of this study, the researcher set a procedure as approach to solve the problem and based on the results, the researcher made a conclusion on its operation and preventive maintenance.

2.1 Design and Development

Figure 1 shows the Complete Design of the Activated Carbon Rotary Kiln. The support-based assembly consists of steel bars and angle bars built in together to form a support based for supporting the kiln which will be too heavy. Attaching them with bolts and proper welding to secure the sturdiness for better and good foundation. Electric motor is attached together with the reduction gear which is also attached into the sprocket with chain. This equipment is attached together and it drives the kiln to turn. The gear motor is set to turn for about 10-15 turns per minute. The roller supports the kiln from turning. It consists of two supports from end to end. It is be placed 60 degrees from the center of the kiln holding. Riding ring attached to the body of the kiln and in both roller for better balance and support. The kiln is anticipated to be heavy. This funnel is where the Coconut shell charcoals will be feed which the researchers will be using. This is the main entrance of the kiln. Together with this is the blower that helps the cooking process in burning the coal inside. This will be a time-dependent control using timer for its operation. The outlet is the exit way of the baked coal inside the kiln. The spiral pathway is designed for cooling to reduce the temperature level of the coal before it reaches the exit direct to the container. The pathway temperature is monitored by the temperature sensing device (Thermocouple) to ensure the right temperature in the pathway before the product gets out from the kiln. The chimney will be the exhaust of the heat coming from the burning of coal. The main and center part of the equipment is the kiln it is made of a metal tube used in processing the coal to be activated. Clay is installed inside the kiln as an inner protective covering to prevent the metal from burning or melting inside the baking area.

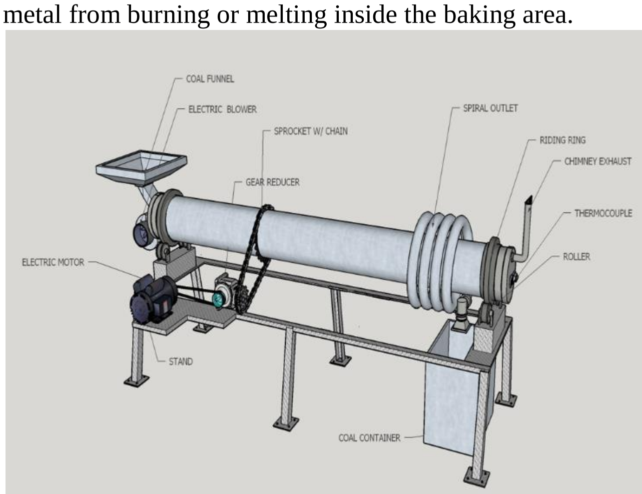

Figure 1 Complete Design of the Activated Carbon Rotary Kiln

The control circuit in Figure 2 depicts the connection of the Programmable Logic Controller (PLC) interfaced with the Variable Frequency Drive (VFD) to automate the control system of the Rotary Kiln.

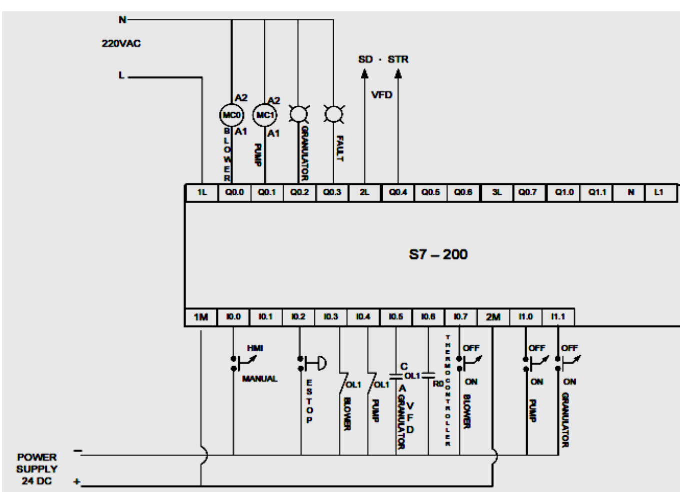

Figure 2. Control Circuit

The prototype implementation was done at University of Science and Technology of Southern Philippines shown in Figure 3.

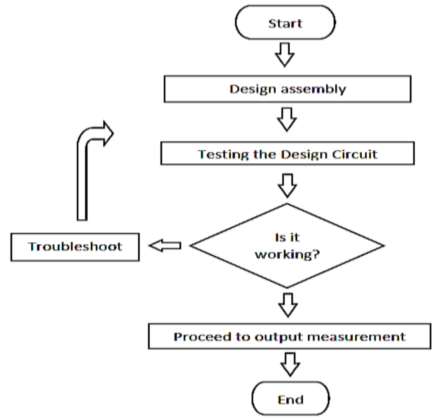

Figure3. Implementation Flow Chart

The researcher utilized required tools in the assembly and integration of the components. After component assembly, installation of the circuit design is done. Testing and trial run of the system is applied to assess functionality and identify problems during operation. Troubleshooting is applied when malfunctions occur. This procedure is done to determine possible causes like the connections, and the power source. If the system works, the researcher proceeds to measuring of the required parameters for attaining standard of the system.

A survey questionnaire was floated to gather information or data in the measurement of the acceptability of the proposed kiln dryer. A Five Point Likert Scale used as the statistical tools to determine the acceptability of the Automated Control System of Activated Carbon Rotary Kiln.

3. RESULTS AND DISCUSSION

3.1 Completed Prototype

The figure below shows the actual photo of the completed prototype shown below.

Figure 6. Completed Prototype

The Control Panel Board in Figure 7 is the enclosure of the specific connections of the automated control systems for the effective functionality of the Activated Carbon Rotary Kiln. The setup for the wires and buttons together with the magnetic contactors, lamps PLC and VFD systems are assembled utilizing industry standards.

Figure 7. Control Panel Board

An experimental test of the prototype was conducted via manipulation of the rotational speed Rotary Kiln and its correlation to load current and power consumption. The figures below show the graphical representation of Speed in Hz versus current in amperes shown in Figure 8a, the graph of Speed versus Power conusmption in Kilowatt-hour in Figure 8b.

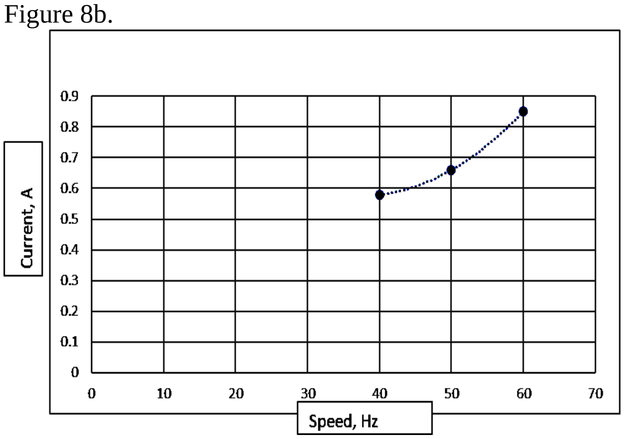

Figure 8a. Speed versus Current (A)

The graph above depicts an efficiency curve that shows the relationship between rpm and current relating to machine performance. The maximum efficiency score represents the RPM at which the motor is most efficient and the corresponding current is displayed on the graph.

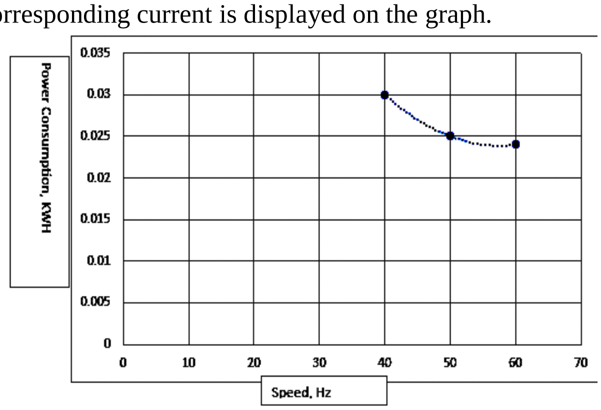

Figure 8b. Speed versus Power Consumption (KWH)

Figure 8b represents the optimal operating range for the device, where it operates at peak efficiency. The increase in energy consumption is not linear but shows a gradual increase.

The results from the Likert scale evaluation are presented in Table 1. The self–assessment instrument measured the acceptability and performance of the project prototype implementation. The self–assessment instrument bears a five (5) point rating scale that confirms the perception rating anchored on the specific test parameters.

Table 1. Summary Mean of the parameters; User friendly/ Easy to operate, Safety, Durability, Portability, Functionality and Efficiency

Parameters	Mean
1. User friendly/ Easy to operate	4.6
2. Safety	4.5
3. Durability	4.2
4. Portability	4.1
5. Functionality	4.2
6. Efficiency	4.3
Overall Mean	**4.32**

3. DISCUSSIONS AND CONCLUSION

Completion of the research prototype is an important milestone for the project. Throughout the development process, there are a number of issues and design decisions that need to be discussed. The performance of the research prototype was evaluated and evaluated in terms of achieving its intended goal. The results show promising results as the prototype successfully addresses the core questions and goals of the study. However, certain limitations have been identified that may affect effectiveness in real-world scenarios. During the development phase, researchers faced technical hurdles regarding data integration, algorithm implementation, and system compatibility. Some of these issues caused delays in the overall project schedule. During the testing phase, a survey was conducted to gather feedback from users who interacted with the prototype. Respondent's contributions have helped gain insight into the user experience and identify opportunities for improvement. In summary, a completed research prototype represents a commendable effort to solve a specific problem or address a research question. It opens up possibilities for further development and serves as a starting point for the practical application of research results.

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