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Conceptual Design for Computer Aided Manufacturing (CIM) in Production of Palm Kernel Oil

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Abstract: This paper work analyzes and develops an improved method of getting quantity and quality palm kernel oil .The computer integrated system is using full digital automation and computer monitoring production process replacing the existing traditional system that is mechanically operated. The old traditional system involves much handling that may attract dirts and contaminations leading to poor quality[6]. Production efficiency and performance index would increase if any production line is computer integrated to monitor parameters like feed rate, output capacity, mass of cake produced, quality of oil , as they are function of machine speed, toasting time and temperature. Consequently, introducing a control loop based on Proportional-Integral-Derivative (PID) controllers for the process control since the basic structure of the PID controllers makes it easy to regulate the process output leading to optimal and effective operations that are economically vital for process industries. Hence, a robust control in the presence of saturation effects is pursued for stability within the linear region with 100% efficiency. An embedded system framework design for groundnut oil extraction system is developed considering temperature monitor, weight monitor, speed monitor with related input and output interfaces. This control algorithm for the embedded process automation was developed and tested on a unified Proteus and MatLab environments with a satisfactory performance. Computer integrated manufacturing (CIM) provides visual monitoring of this computer embedded program on parametric control of the production of quality palm kernel oil through automation and use of computers for process monitoring, control and optimization, thus improving the robustness and stability of the system.

Keywords: Microcontroller, PID-Controller, Zeigler-Nichols, Temperature, Stability, CIM, palm kernel oil extraction

INTRODUCTION

The most common method of extracting edible oil from oilseeds is by mechanically pressing of the oilseed [1]. Traditionally, oil is extracted from palm kernel by roasting in clay pot to allow the oil bud to give oil in it. The weak point of another process are grating or crushing steps, they are time consuming and drudgery, yet crushing is generally not fine enough. Thorough crushing can improve the oil recovery considerably. However, this is tedious as much labour is involved besides the poor quality of the oil that will be produced.

This work observes that the traditional system of palm kernel oil extraction could have complex performance issues resulting from its mechanical or electro-mechanical systems integrations without adequate process controls. Control engineering deals with understanding the plant under operation, and obtaining a desired output response in presence of system constraints. The use of Proportional Integral Derivative (PID) controllers in process industry, there always has been a significant endeavor to obtain effective PID controller design methods, which will meet certain design criteria and provide system robustness for computer integrated manufacturing (CIM) as quality oil is targeted, less labour cost, and operation as handling is relieved. Modern control engineering deals with improving manufacturing processes, efficiency of energy use, advanced automobile control, chemical processes, traffic control systems, and robotic systems, among others [2]. Integrating the basics of classical control, and the flexibilities offered by robust control, a new era of stable, sustainable, and reliable control systems can be designed. Plant parametric uncertainties and time-delays always tend to haunt production output and prevent optimal use of available resources. Processing or extracting or expressing oil from palm kernel involves a wide range of traditional, mechanical, chemical and mechano-chemical methods [3, 4], opined that the traditional method involves roasting and crushing the groundnuts into fine particles, after which the crushed mass is mixed with water and boiled so as to allow the oil to float. The oil is then skimmed off and dried by heating. This method is time consuming, labour intensive, low output and low efficiency with lots of drudgery. The mechanical methods involve the use of screw and hydraulic presses. The screw press is more reliable than the hydraulic press, but is slower and produces less pressure. The hydraulic press is more expensive, needs more maintenance and risk contaminating the oil with poisonous hydraulic fluid,[5].Generally, the mechanical methods have relatively higher operating cost than the traditional methods; however, they have higher efficiencies and are usually more adaptable for small and medium scale producers [1].

CIM makes full use of the capabilities of the digital computer to improve manufacturing. Two of them are:

- Variable and Programmable automation
- Real time optimization

The computer has the capability to accomplish the above for hardware components of manufacturing (the manufacturing machinery and equipment) and software component of manufacturing (the application software, the information flow, database and so on).

Types of Manufacturing

The term “manufacturing” embraces a spectrum of activities. It used in all facets of production including metal working industries, process industries like chemical plants, oil refineries, food processing industries, electronic industries making microelectronic components, printed circuit boards, computers and entertainment electronic products etc. are examples of manufacturing industries. Manufacturing does not only involve fabrication, assembly and testing in a majority of situations but also processes involve in the actualization of the organizational goal. However, operations are of a different nature in process industries .Manufacturing industries can be grouped into four categories:

Continuous Process Industries

These industries can be easily automated and computers are widely used for process monitoring, control and optimization. The production process generally follows specific sequence. Oil refineries, chemical plants, food processing industries, etc. are examples of continuous process industries.

Mass Production Industries

Industries where production lines are specially designed and optimized to ensure automatic and cost effective operation. These include industries manufacturing fasteners (nuts, bolts etc.), integrated chips, automobiles, entertainment electronic products, bicycles, and bearings etc. which are all mass produced. Automation can be either fixed type or flexible. Automobile industries have been using the transfer line concept not only for machining of components but also for assembly.

Batch Production (Discrete Manufacturing)

These are the small to medium size of the batch, and varieties of such products to be taken up in a single shop. Due to the variety of components handled, work centres should have broader specifications. Another important fact is that small batch size involves loss of production time associated with product changeover. The largest percentage of manufacturing industries can be classified as batch production industries.

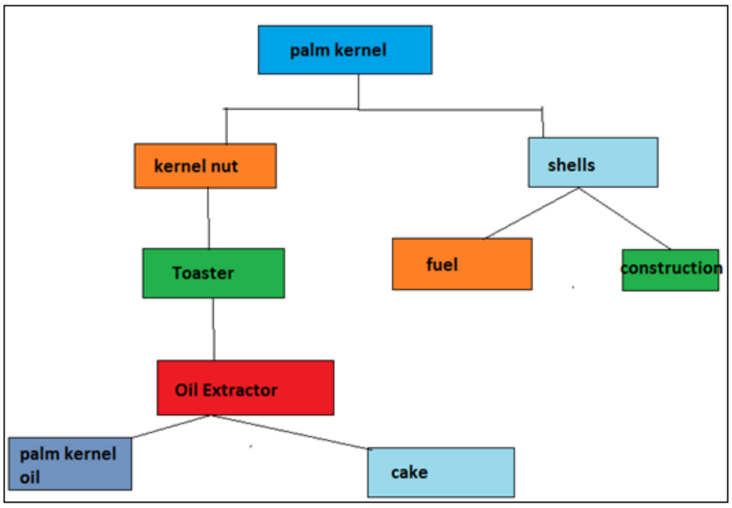


Fig-1: Flow chart for processing of palm kernel into palm kernel oil

Existing Physical System

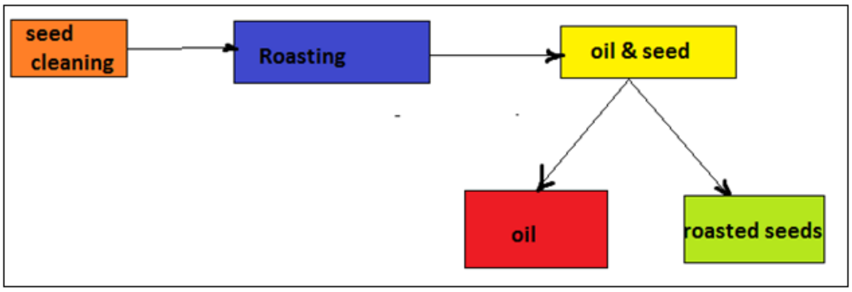


Fig-2: Physical system of palm kernel oil Extraction System

Aims and Objectives

This work is therefore aimed at improving electro-mechanical method of extracting oil from oilseed by incorporating embedded controller and PID and CIM to regulate and monitor the temperature at the preparatory chamber for improved the stability and quality oil production of the system. Adopting a full automation system in which PID controller is implemented in microcontroller and CIM. Some specific objectives include:

- To ensure temperature stability in toasting chamber and weight monitoring.
- To visualise and analysed production process on screen for precision and quality production.
- Enabling the adoption of such systems for production maximization and output forecast from input

Problem Statement

Temperature instability at the toasting drum and speed of palm kernel oil extraction machine has always been a serious problem as it affects the quality of oil been extracted. Control problems of time delay systems have been solved since the very beginning of modern control theory, but satisfactory results from control engineering perspective have not been adequately achieved in the local groundnut extraction system. Having examined the existing palm kernel extraction system operational procedures, while articulating the merits of introducing embedded automation and CIM, for stability and other performance enhancement processes.

Scope of the Work

Existing methods of extracting oil from palm kernel, as well as related works and proposals by researchers were reviewed. Control system models, applications and frameworks relevant to the proposed system were discussed. Stability process model with MATLAB was developed as well as input interface circuit (transducers) which measures and convert two process variable parameters viz: temperature and weight into voltage values and signals read. An automation algorithm for the system is developed and encrypted accordingly.

Limitations of the Research

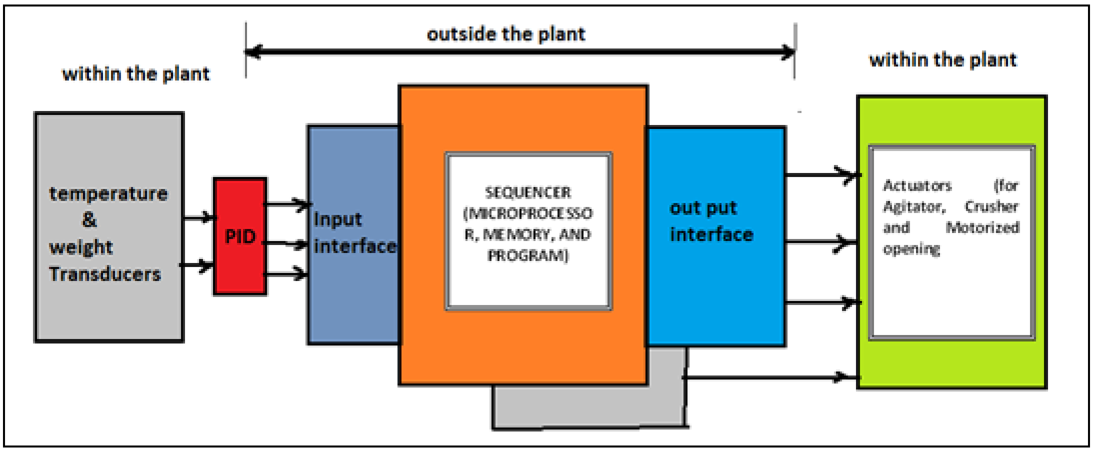
It was a bit difficult to implement the actual physical processes that take place in the real plant with a simulation tool. Hence, the transducers used for transduction purposes in the plant will only be simulated by virtual laboratory equivalents. A virtual Laboratory tool which was used is Proteus ISIS. Suitable equivalents of the transducers were used though with some limitations as is common with virtual processes. As is already known that virtual environment cannot accurately represent the physical scenario with all the factors present. However, the realization of the objective of this work was not affected by these shortcomings.

CIM

Computer Integrated Manufacturing (CIM) encompasses the entire range of product development and manufacturing activities with all the functions being carried out with the help of dedicated software packages. This data has to be transferred from the modeling softwareto manufacturing software without any loss of data. CIM uses a common database wherever feasible and communication technologies to integrate design, manufacturing and associated business functions that combine the automated segments of a factory ora manufacturing facility. CIM reduces the human component of manufacturing and thereby relieves the process of its slow, expensive and error-prone component. CIM stands for a holistic and methodological approach to the activities of the manufacturing enterprise in order to achieve vast improvement in its performance. CIM also encompasses the whole lot of enabling technologies including total quality management, business process reengineering, concurrent engineering, workflow automation, enterprise resource planning and flexible manufacturing. Manufacturing industries strive to reduce the cost of the product continuously to remain competitive in the face of global competition. In addition, there is the need to improve thequality and performance levels on a continuing basis. Another important requirement is on time delivery. Manufacturing engineers are required to achieve the following objectives to be competitive in a global context:

- Reduction in inventory
- Lower the cost of the product
- Reduce waste
- Improve quality
- Increase flexibility in manufacturing to achieve immediate and rapid response to:
- Product changes
- Production changes
- Process change
- Equipment change
- Change of personnel
-

CIM technology is an enabling technology to meet the above challenges to themanufacturing



THE PROPOSED SYSTEM BLOCK DIAGRAM

Fig-3: Block Diagram of the conceptualized palm kernel Extraction System

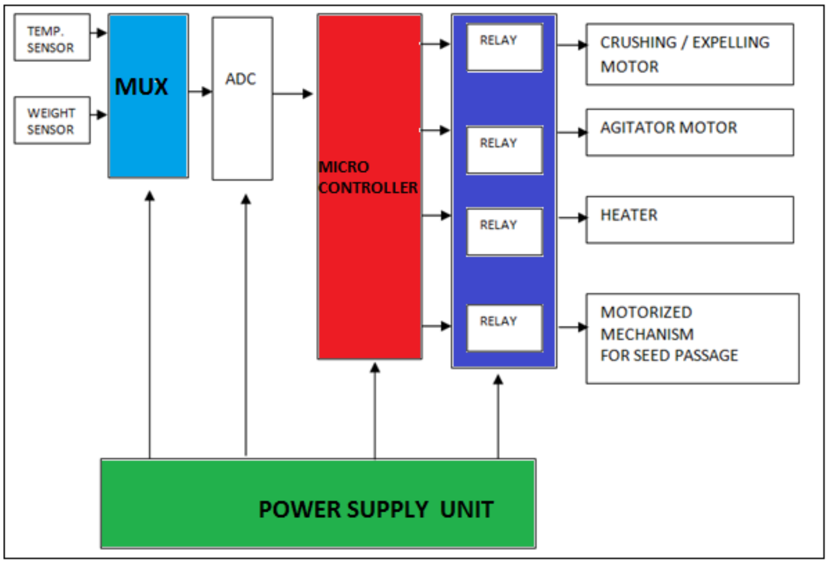
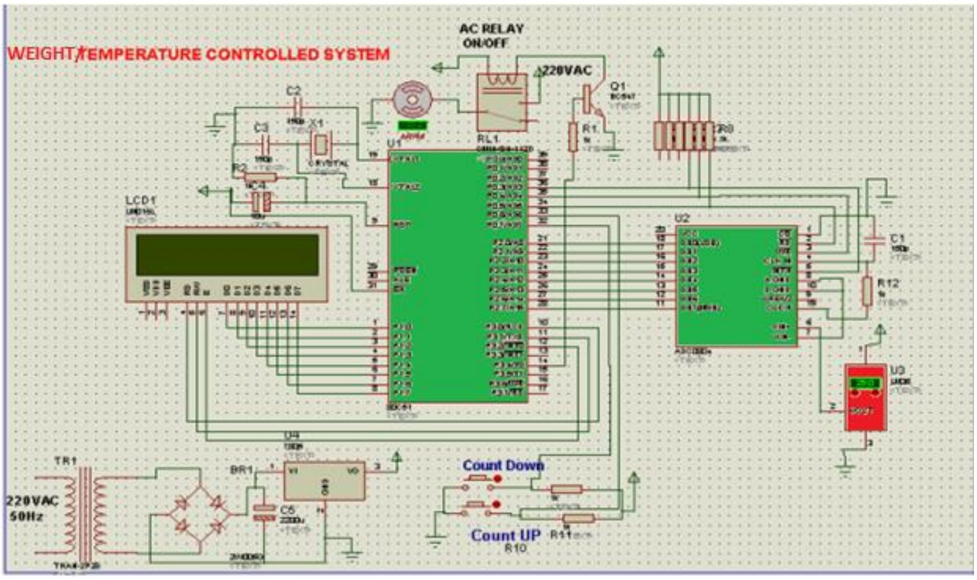


Fig-4: Block diagram of the proposed palm kernel oil Extraction System



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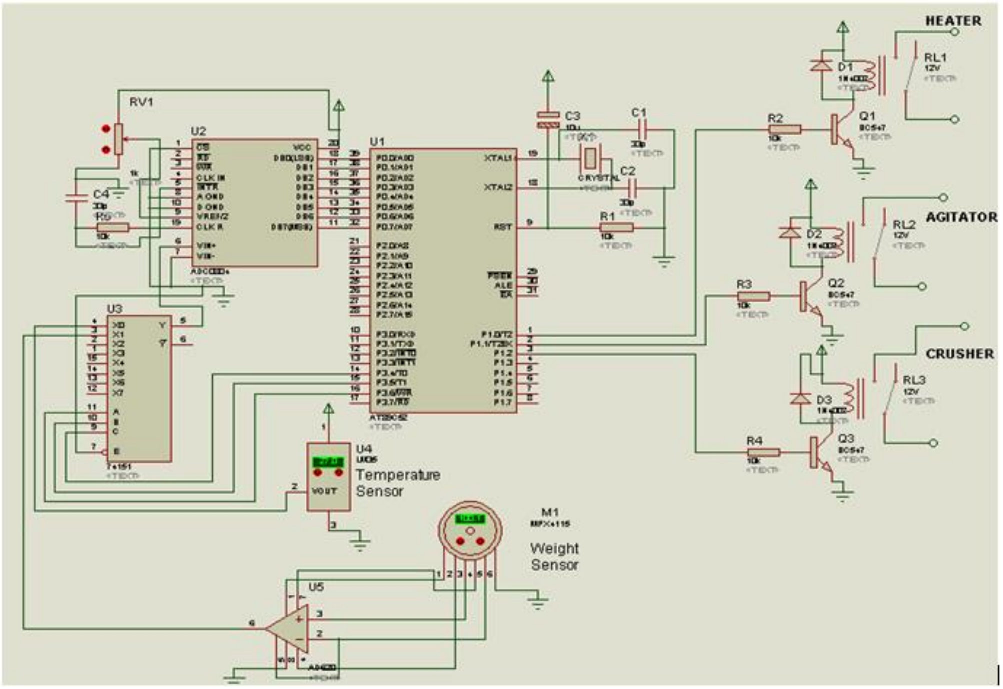


(ii)

Fig-5: Schematic Representation of the System using proteus

The operation of the circuit is based on a PID controller implemented on a microcontroller in order to regulate the chamber temperature to a desired temperature. According to figure 4 below, the feedback sensor compares the chamber temperature with the set point temperature of 95°C and generates an error signal which goes to PID controller. The PID controller computes the proportional, integral and derivatives components of the error which it uses to control the actuator [7]. The weight sensor monitors the weight of the groundnut seed at the chamber and automatically closes the motorized seed passage when the groundnut seed in the chamber finishes. The analog-to-digital converter (ADC) converts the analog signal from both the temperature and weight sensors (i.e.LM35 and piezoelectric crystal) to 8-bits binary code which goes to the controller. 2 inputs to 1 output multiplexer are used to select the particular input that goes to the ADC at any given time. Finally, a pulse- width modulation (PWM) output from the microcontroller is used to drive a relay which switches the heater and motor ON and OFF.

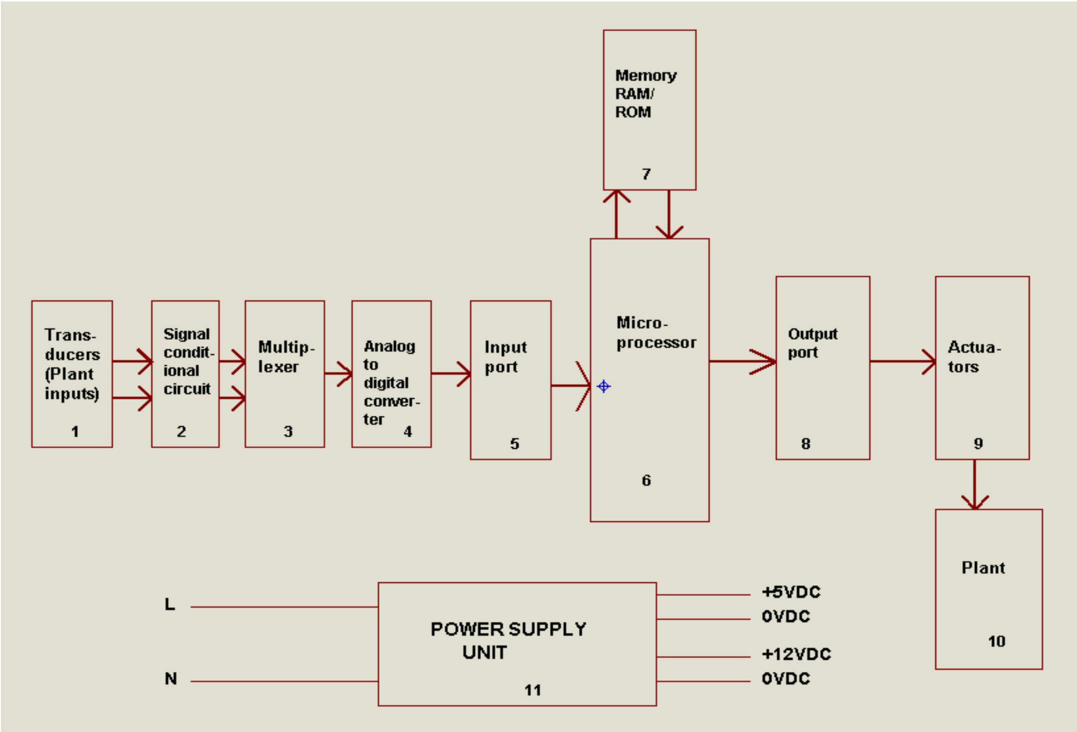
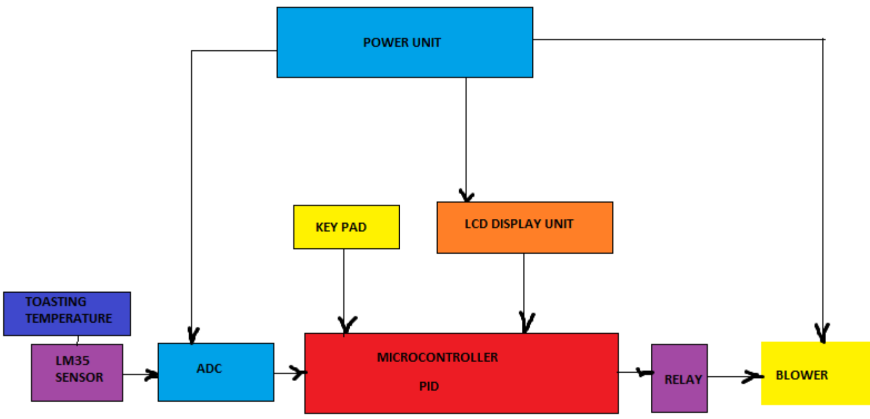


Fig-6: Detailed System Block Diagram

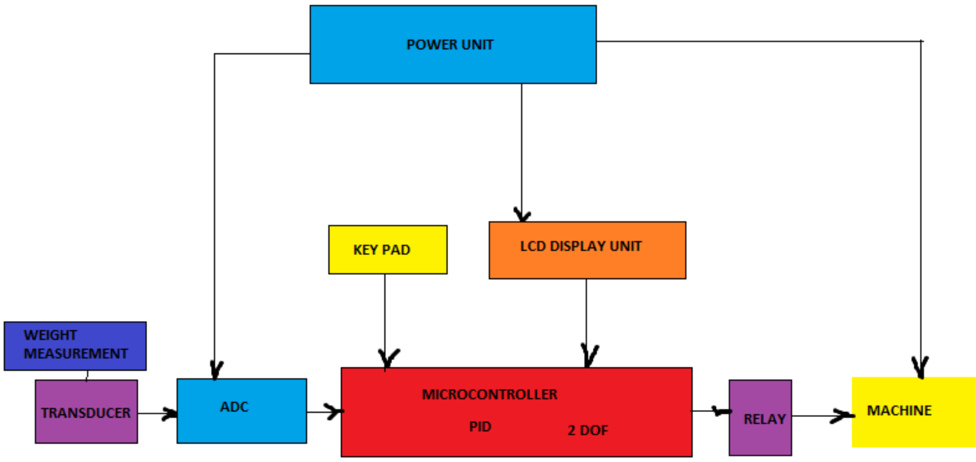
The design and fine tuning of the PID controller will be the subject of the analysis. The system will be validated by simulating the controller model with the plant model, sensor and actuators or any combination of these components. The system should track and/or regulate the desired preparatory chamber temperature with minimum peak time, rise time, settling time and overshoot

Temperature Control Process Design

The temperature control system was built around several mathematical models needed for the analysis of the system dynamics and the design and evaluation of the control system using a closed loop structure of a temperature controlled system [8, 9]. This structure comprises the models of the system dynamics; sensors, actuators and computational effects are the basic elements which often cannot be changed for any reason since the system will be validated by simulating the PID controller model with the plant model, sensor and actuators or any combination of these components. The design and fine tuning of the PID controller will be the subject of the analysis which requires application of control system design theory to the dynamic models of the other elements from figure 7. A simplified mathematical model of the overall system will be derived separately for gelatinization and frying chamber. The system should track and/or regulate the desired gelatinization and frying chambers temperature with minimum peak time, rise time, settling time and overshoot.



(A.)Block diagram of the circuit design for Toasting temperature chamber control.



(b).Block Diagram of the Circuit Design for Weight Control into the Extractor

Fig-7: Block Diagramme of a Close Loop Temperature Control System for (a) Toasting Chamber and (b) Weight Control Mechanism

Mathematical Models of Toasting Drum

If a mass $M\ (Kg)$of palm kernel nuts at a temperature T is delivered into the toasting drum environment at a prevailing temperature T_2. Heat is transferred from this environment to the mass $M\ (Kg)$ of the palm kernel nuts will lead to a rise in temperature of the mash. Therefore, it showed that the heat added is proportional to the rise in temperature of the mass of the mash.

$Heat\ Added\ to$ palm kernel nuts $\propto$

$Rise\ in\ temperature\ of\ the$palm kernel nuts

$dq = MCdT_i$ (1a)

$\frac{dq}{M} = CdT_i$ (heat transfer per unit mass of palm kernel nuts in the toasting drum (1b)

Where,

$dq = elemental\ heat\ added\ (joule)$

$C =$ $Specific\ heat\ capacity\ of$ palm kernel nuts $(joule/kg.kelvin)$

$M = mass\ of$ palm kernel nuts (Kg)

$CM = thermal\ capacitance\ (joule/kelvin)$

If the rate of temperature rise in the drum is a function of time, hence

$$\frac{dq}{dt} = \emptyset = C\frac{dT_i}{dt}_{i=1} \quad (2)$$

$$\frac{dq}{dt} = C\frac{d\theta_1}{dt}$$

Where,

$\emptyset =$ $is\ the\ rate\ of\ heat\ transfer\ per\ unit\ mass\ of\ the$ palm kernel nuts and this is governed by thermal resistance between the hot air and the palm kernel nuts which analytically similar to the popular ohm's law of electricity.

$$\emptyset = \frac{T_i}{R}_{i=1,2} \quad (3)$$

$$\emptyset = \frac{T_2 - T_1}{R}$$

R is the thermal resistance $(K/watt)$

$$\emptyset = C\frac{dT_i}{dt} = \frac{T_2 - T_1}{R} \quad (4)$$

$$C\frac{dT_i}{dt} = \frac{T_2 - T_1}{R}$$

$$\frac{dT_i}{dt} = \frac{T_2 - T_1}{CR} \quad (5)$$

$$\frac{dT_i}{dt}_{i=1} = \frac{T_2}{CR} - \frac{T_1}{CR} \quad (6)$$

$$\frac{dT_1}{dt} + \frac{T_1}{CR} = \frac{T_2}{CR} \quad (7)$$

$if\ \tau = CR$ (*)

$\tau\ is\ the\ product\ of\ the\ thermal\ resistance\ and\ thermal\ capacitance\ and\ it\ is\ the\ time\ constant$

$$\frac{dT_1}{dt} + \frac{T_1}{\tau} = \frac{T_2}{\tau} \quad (8)$$

Migrating from a time function $\frac{d}{dt}$ to an S function the equation becomes

$$\frac{d(T_1)}{dt} + \frac{T_1}{\tau} = \frac{T_2}{\tau} \quad (9)$$

$$S(T_1) + \frac{T_1}{\tau} = \frac{T_2}{\tau} \quad (10)$$

$$\frac{S\tau(T_1 + T_1)}{\tau} = \frac{T_2}{\tau} \quad (11)$$

$$T_1(S\tau + 1) = T_2 \quad (12)$$

$$\frac{T_1}{T_2}(S) = \frac{1}{S\tau + 1} \quad (13)$$

Where,

τ is the resident time for the mass M (kg) in the toasting drum

$\tau = 45minutes = 2700seconds$

Equation .13 becomes

$$\frac{\theta_1}{\theta_2}(S) = \frac{1}{2700S + 1}$$

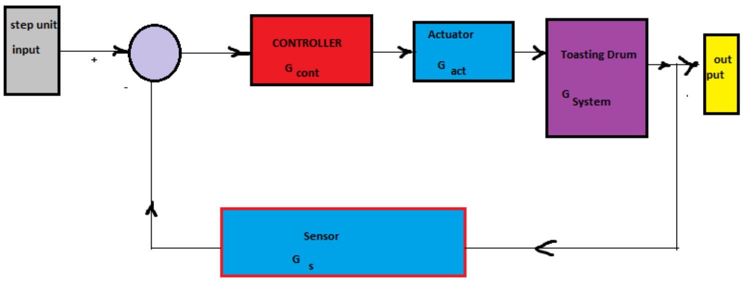


Fig-8: **Block Diagramme For Toasting Drum Model**

Model For The Actuator

Temperature fluctuation is nonlinear owing to conditions like losses and surge from heating and this impose the disturbing challenge of temperature control. The relationship between the applied voltage and the energy generated by electrical heating elements is non-linear. This work aimed to linearised the relationship by driving the blower supplying hot air to the gelatinization chamber from a Pulse Width Modulated (PWM) signal. A pulse width modulated signal is generated from the microcontroller as shown in Fig. 5 where M and S are the mark and the space of the waveform, and T is the period, i.e.

$T = M + S.$ (14)

This waveform is used to control a power MOSFET switch where the fan element is connected as the load of this device. The votalge applied to the blowere has a r.m.s. value of the current through the blower can be calculated as:

$$I_{r.m.s} = \sqrt{\frac{1}{T}\int_O^T i^2(t)\, dt} \quad (15a)$$

$$I_{r.m.s} = \sqrt{\frac{1}{T}\int_O^M I_O{}^2} \quad (15b)$$

$$I_{r.m.s} = I_O\sqrt{\frac{M}{T}} \quad (15c)$$

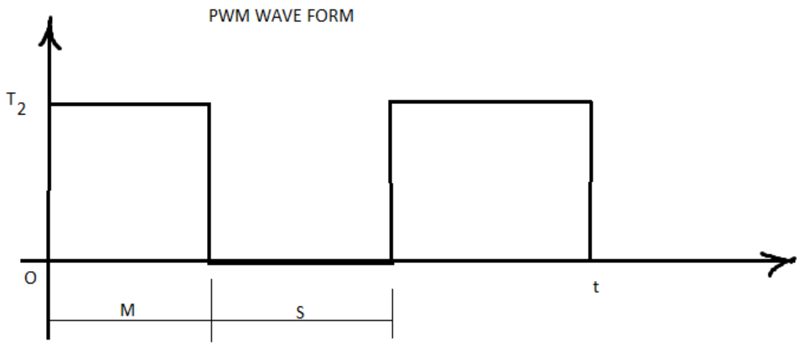


Fig-9: PWM Wave form for the blower to toasting drum.

Model For The Sensor (Lm135)

The temperature sensor is a semiconductor device with a linear voltage-temperature relationship specified as $10\,\frac{mV}{{}^oC}$

$\frac{V_0}{T} = 0.01$ (16)

Where,

V_0 is the sensor output voltage in volts and

T is the temperature in °C.

For a range of temperature of (80-100)^{0}C, the voltage range will be (0.8 to 1) volts.

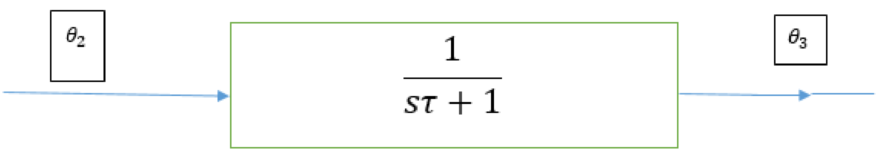


Fig-10: Simplified transfer function

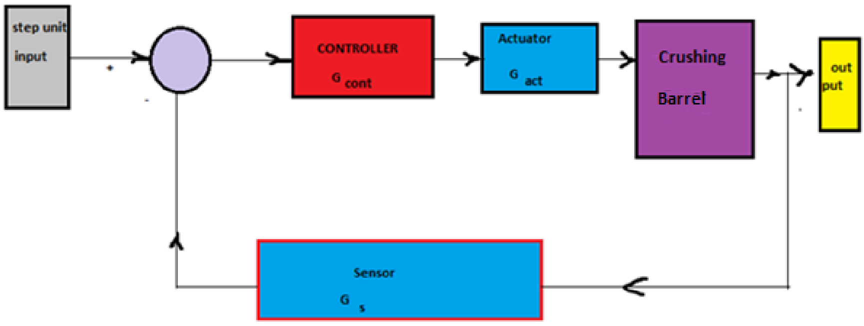


Fig-11 .Block Diagrame for Crushing Barrel Model

Model for the Microcontroller

Modeling the controller, the PID controller was selected because of it versatile extensive use in industrial applications and processes. Zeigler Nichols tuning method was applied in the design and simulation of the parallel proportional-Integral-Derivative Controller for optimal gelatinization and frying temperatures stabilization.

Considering the algorithms

$$Ut = K_p e_{(t)} + \frac{K_p}{T_i}\int_o^t e_{(t)}dt + K_p T_d \frac{de_{(t)}}{dt} \quad (17)$$

Migrating to S domain fron t domain

$$U_{(S)} = K_P\left[1 + \frac{1}{T_i.S} + T_D.S\right]E_S \quad (18)$$

PID controller can be determined by Z-transfer of the equation ---in a descret form,thus

$$U_{(Z)} = E_{(Z)}K_p\left[1 + \frac{T}{T_i(1-Z^{-1})} + T_d(1-Z^{-1})\right] \quad (19)$$

Expanding the equation 32 ,this is simply

$$\frac{U_{(Z)}}{E_{(S)}} = a + \frac{b}{1-Z^{-1}} + c(1-Z^{-1}) \quad (20)$$

Where

$a = K_p$

$b = \frac{K_p}{T_i}T$ `

$c = \frac{K_p T_d}{T}$

For a continous parallel PID Controller

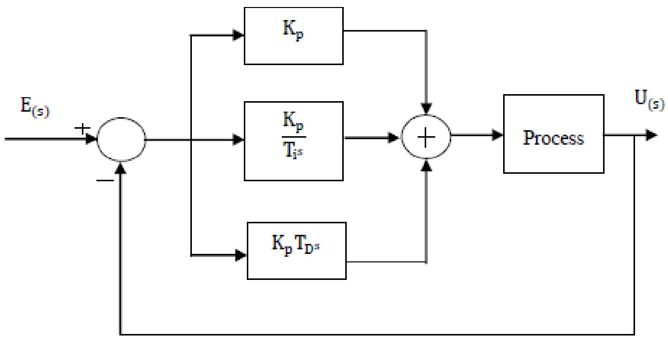


Fig-12: Block diagram of a continuous parallel PID controller

SIMULATION AND RESULTS

The system was modeled and simulated using Matlab/Simulink. The simulated results of the system control with PID tuning were analyzed. Figure 12 shows the simulink block diagram of the temperature control system

Temperature Monitor

The temperature sensor is a semiconductor device with a linear voltage-temperature relationship specified as $10\frac{mV}{°C}$, i.e. $\frac{Vo}{T}$ where, Vo is the sensor output voltage in volts and T is the temperature in °C . That is to say, the LM35 temperature sensor provides an output of 10mV per degree Celsius.

Weight Monitor

The weight sensor monitors the weight of the groundnut seed in the preparatory chamber and the system automatically closes the motorized opening mechanism whenever the groundnut seeds in the chamber finishes. In this measurement, it is assumed that weight is proportional to pressure. This is validated as follows:

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{\text{Mass} \times \text{Acceleration}}{\text{Area}} \qquad (21)$$

Replacing mass by weight, W, and acceleration by acceleration due to gravity g,

$$\text{Pressure} = \frac{\text{W} \times \text{g}}{\text{A}} \qquad (22)$$

But *g*, acceleration due to gravity is constant for all weights, and A is constant for the preparatory chamber of known constant cross – sectional area, therefore, pressure is proportional to weight. For us to measure pressure or weight in an industrial process, we can use the piezo – electric transducer and apply the following formula.

Eo = GDP (volts) (23)

Where *G* = voltage sensitivity (also known as piezo - electric constant) in voltmeter/N
D = thickness of the material (sensor) in meters
P = pressure exerted in Newton per square meter
The piezo – electric crystal is a self – generating transducer, so that, what is needed is circuitry to amplify, shift and scale the analog voltage generated so that it corresponds to a *0V* and *5V* signal. For weight measuring, we have
E_o = GDW (volts)
Where W = weight of palm kernel processed.
Voltage sensitivity (piezo-electric constant) (g) = 0.050Vm/N i.e for Quartz
Thickness of the material = 0.5mm, taking the weight of the palm kernel to be 50kg

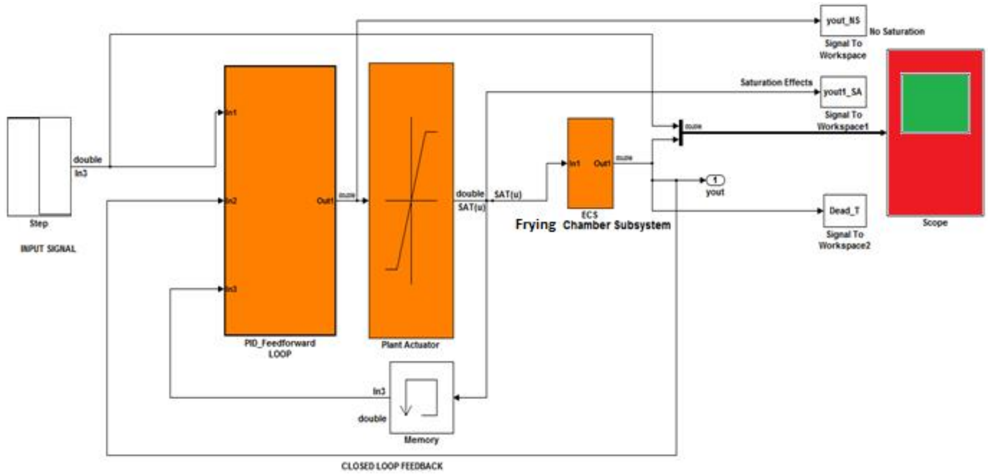
CONTROL ALGORITHM FOR THE SYSTEM

The control algorithm is implemented in the control sub-program and is used by the controller to control the entire system when the temperature (T_{max}) and palm kernel nuts weight are sensed, converted to volts, digitized and the values sent to the controller for appropriate action to be taken. The following therefore, is a complete PDL for a single batch.

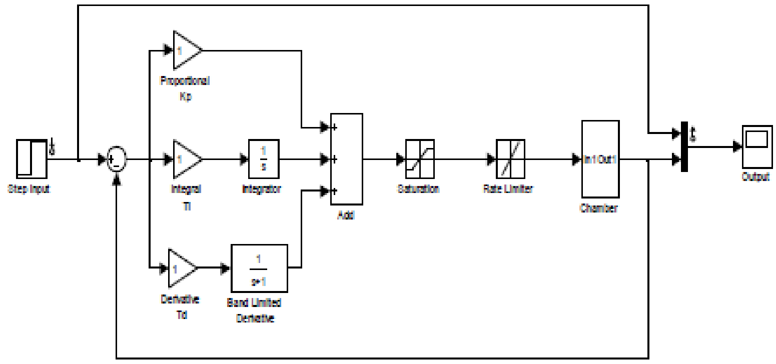
Algorithm- Algorithm for Embedded Chip Based Sequencer for palm kernel oil Extraction.
Input: *Weight, Temperature, Process a, Process b, Process c;*
Output: *Agitator, Crusher, Heater, motorized opening for seed passage*
Begin ( ): *Set Gain*
C Batch
C Process a, Process b, Process c;
C Processa
Start Heating
Begin (*Temp. Test* ***Until***
Temp = 80°C
Stop Heating
C Process b
Load palm kernel nut into the Preparatory Chamber
Start Agitator
Begin *Temp. Test* ***Until***
Temp ≥ 100°C
Start Heating
If *Agitator Runs For 45 Minutes,* ***Then***
Stop Agitator
C Process c
Open Motorized Seed Passage
Start Expeller / Crusher
Begin *Weight Test* ***Until***
Weight = Zero
Close Motorized Seed Passage
End

Close loop Stability Analysis

This work will now experiment on the close loop stability analysis involving various cases with the view to achieving the optimum system stability response. Two tests were run assuming values of the parameters of the PID controller based on Ziegler-Nichols Method, results show the performance and robustness of the system. Figures below are the matlab Simulink and scope display of the work.



(i)



(ii)

Fig-13: block diagram for a continuous parallel PID controller

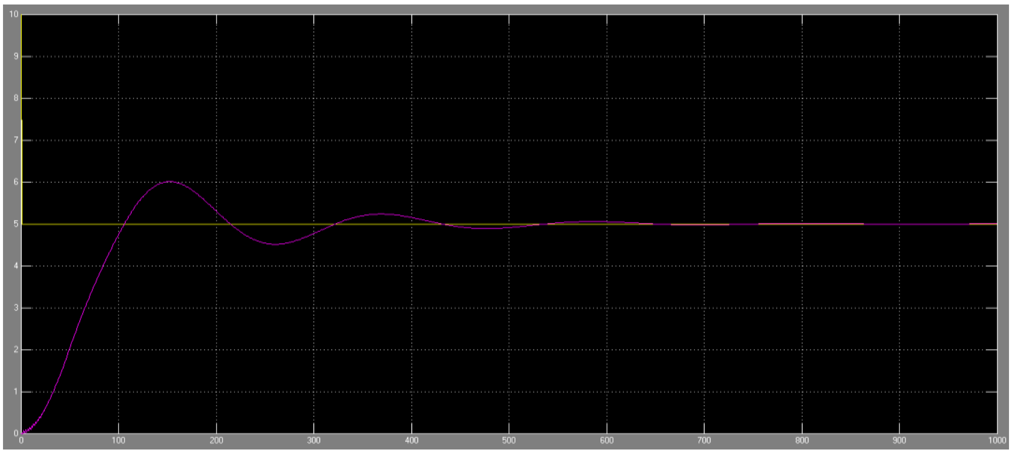


Fig-14: Scope of the unit step response of the system for test 1

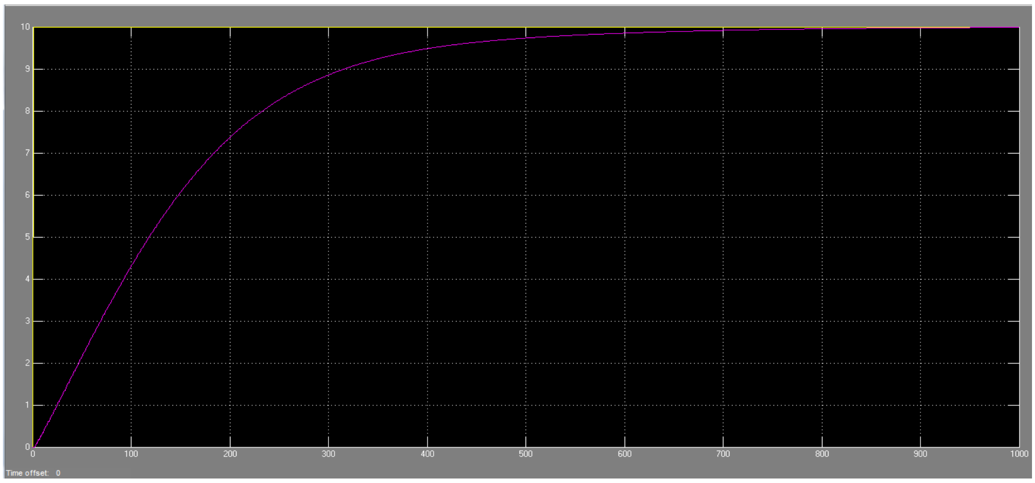


Fig-15: Scope of the Unit Step Response of The System For Test 2 (Case 2)

RESULT

The use of Mat lab/Simulink toolbox, various parameters were tested and the best parameters were used for PID implementation on the microcontroller. The results showed the system responses to a step input with varying PID controller parameters based on Zeigler-Nichols tuning method. It is concluded from the results that the optimal set of parameters that gave a more desirable transient response in terms of short rise time, low overshoot, short settling time, low steady state error. A convergence response between the block and the tuned system was observed. Hence, a PID algorithm implemented on a microcontroller, simulated and fine-tuned using the set of parameters obtained a better control performance to changing temperature conditions in the groundnut oil extraction preparatory chamber. These will be displayed in visual systems to be interpreted for the condition of the extraction process as it affects quantity and quality of palm kernel oil produced.

CONCLUSION

This conceptual work presented here is an attempt to develop an improved palm kernel nuts oil extraction system by adapting process automation technique. A validation on the performance of PID based controller for a step function was carried considering a two case scenario for K_P K_i K_d parameter variations. The aim of the proposed controller is to regulate the temperature of the system to a desired temperature in the shortest possible time with minimum or no overshoot, short rise time, small peak time and short settling time. Mathematical model was efficiently used for the design of the temperature control system. Some aspects of theoretical modeling were described. Experimental modeling was also studied and the best results were obtained with Zeigler-Nichols tuning technique. The incorporation of Computer Integrated Manufacturing (CIM) provides visual monitoring of this computer embedded program on parametric control of the production of quality palm kernel oil through automation and use of computers for process monitoring, control and optimization.

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