International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 04 | Apr 2020 www.irjet.net p-ISSN: 2395-0072

AUTOMATION OF BRIQUETTING USING HYDRAULIC ACTUATORS

Kenneth Onzere Buliva[1], Bernard Okich Odera[2], Alex Munyasya Muumbo[3]

[1]*Post Graduate Student, School of Mechanical Engineering, Technical University of Kenya, Nairobi, Kenya*
[2]*Associate Professor, School of Mechanical Engineering, Technical University of Kenya, Nairobi, Kenya*
[3]*Professor, School of Mechanical Engineering, Technical University of Kenya, Nairobi, Kenya*

---***---

Abstract - *The approach to this research project is dedicated toassist the informal manufacturing sector in developing countries to modernize their briquette production techniques, streamlining and standardizing their end products. Informal sector briquette production methods are mostly rudimentary and labor intensive. Technical constraints and the lack of knowledge in adopting automation is a major drawback in manufacturing modernization. The solution to this operational challenge lies in the ability to create a modern and efficient briquetting machine technology that can satisfy the informal sector market requirements. This is aimed at simplifying the sequence of operations of a complex process for the benefit of the local industries and the end user. The combined use of variables such as heated die technology, hydraulic pressure and dwell time enable production line automation using Hydraulic actuation and PLC technology. The hydraulic prototype machine fabricated was used to produce and practically test the theory of combination of these variables and establish the most appropriate factors in order to achieve complete automation in hydraulic actuator briquette production. Through Programmable Logic Control (PLC) technology, a single input signal from the operator controls the automation of three hydraulic cylinder actuators to function in a programmed sequence that includes raw material filling of heated die cavities, compaction densification and ejection of the final products. This process is programmed and automated such that it operates continuously ensuring optimum output thus reducing production costs.*

Key Words: Briquettes, Production Automation, Hydraulic Actuators, control elements, hydraulic power pack, PLC Controller.

1. INTRODUCTION

The concept of hydraulic transmission is made possible through the application of Pascal's law which states that, "Pressure applied to any part of a confined fluid transmits to every other part with no loss. The pressure acts with equal force on all equal areas of the confining walls and perpendicular to the walls." .The incompressible nature of hydraulic fluid enables it to transmit high compounded power instantly and therefore widely used to achieve significant work through applications such as lifting and pressing (Gurdil & Demirel, 2017) (Mambo, Kamugasha, Ochieng, Okwalinga, & Namagembe, 2016). When integrated with an accurate control system, the hydraulic system can be adapted by having various inputs and outputs interlinked with sensors and a control module to achieve automated production. In briquette production automation, the hydraulic system required for densification has three double acting cylinder actuators automatically working in a pre determined sequence. One cylinder is arranged vertically and serves to compact the biomass. Another cylinder is used for the ejection stages of the briquettes while a horizontally mounted cylinder incorporates a hopper that is used to push the ejected finished products to a chute and simultaneously filling the molds with raw materials. The three double acting hydraulic cylinders and the briquette ejection mechanism are supported on an ergonomically designed and fabricated rigid steel frame structure. An integrated programmable logic control circuit (PLC) was designed and incorporated to operate the three hydraulic cylinders in a pre determined logical sequence. The PLC system ensures that with one push of a button, the machine continuously operates with minimal operator intervention (Alkrunz, 2015). A heated die system in conjunction with the hydraulic cylinders utilizes the parameters of temperature and pressure to optimize quality briquette production.

2. HYDRAULIC SYSTEM COMPONENTS

The main components that make up a typical hydraulic system are as illustrated in Fig 1 and include (A Parker Corporation PLC., 2017) (Hydraulics Online, 2018) :

(a) Power Unit or Power pack: This consists of a reservoir for storing hydraulic oil, electric motor coupling a hydraulic pump for energizing the fluid, an adjustable internal pressure relief valve for safety and a pressure gauge to indicate the system pressure (TECO Corporation, 2017).

(b) Working Lines (Hoses): They act as conduits for the hydraulic fluid transmitted from one unit to another. They work in conjunction with pressure gauges which indicate the system pressure, couplers and T connection junctions with adapter sleeves that connect them to other units.

(c) Actuators: These are the devices that perform the actual work from the hydraulic pressure. They can be divided into two categories i.e. rotary actuators as in the case of hydraulic motors and linear actuators in the form of either single or double acting cylinders.

(d) Valves: They control, direct, limit or relief the pressure or direction of flow of the hydraulic fluid. A directional control valve is used to determine whether a cylinder can advance, retract or remain at a neutral position. The control mechanism for this valve can either be manual (lever or pedal), pushbutton, pilot operated or by means of an electromagnetic solenoid.

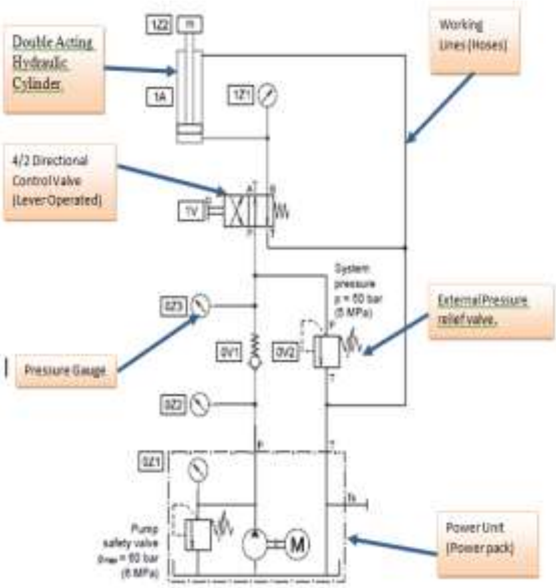

Fig 1: Typical Hydraulic Circuit (FESTO Didactics 2001)

3. THE CONCEPT OF PLC

The sequence of operation of the three hydraulic cylinders is controlled by means of a Programmable Logic Control (PLC) module to operate the solenoid valves and position sensors, the controller module is robust and flexible enough to meet the requirements of the system.

An input stimulus is received from operator and position of the actuators in relation to inbuilt parameters such as voltage and current. The PLC control module then accurately interprets and converts the signal for the central processing unit (CPU) which in turn, defines a set of instructions to the output systems that control actuators for the machine (Gatmaitan, Guanlo, Guting, Janairo, & Chua, 2013). The PLC control module has a robust design can work flawlessly without having a breakdown in an informal sector industrial environment that is abusive and hazardous to the delicate microelectronic precision. The system has the ability to be locally assembled and serviced using the available technology so as to minimize the costs.

4. HYDRAULIC CYLINDERS MOVEMENT STEPS.

The designation of the movement of the hydraulic cylinders is that Cylinder 1 is the filling of the raw biomass material then transporting the biomass to a chute, Cylinder 2 is concerned in compressing the raw material inside the die cavity and Cylinder 3 is responsible for ejecting the final briquette. Fig 2 outlines the sequential movement of the cylinders.

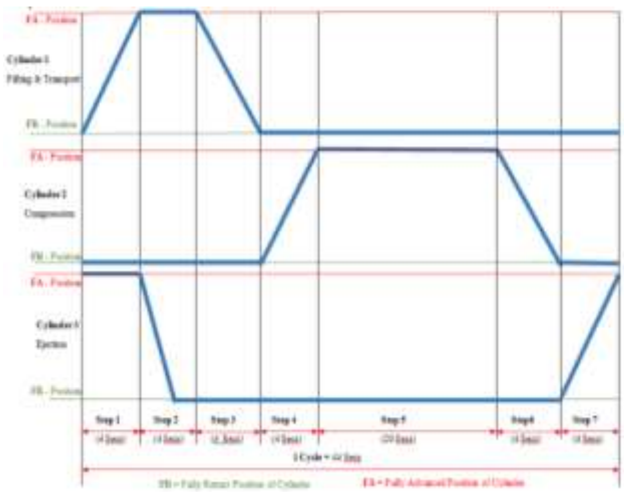

Fig 2: Sequential Hydraulic Cylinder Movement Steps.

The sequence of action is as per the following positional steps:

Initial Position: Cylinder 1 and Cylinder 2 are in full retract position while cylinder 3 is in full extended position. This is important as it makes it easy to clean the surfaces and clear the chute in preparation for the next production sequence as shown in Figure 3.

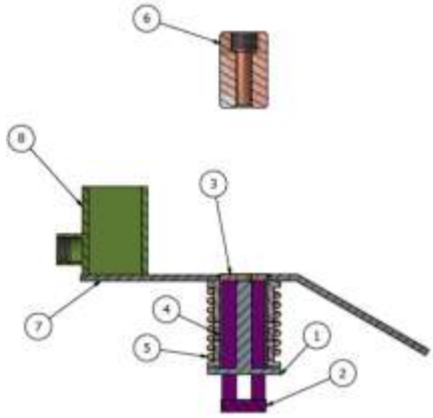

Fig 3: Schematic view of initial position of actuators.

COMPRESSION CHAMBER PARTS LIST		
No.	PART	ACTUATOR/PART CONNECTED TO:
1	**Part 1**: Compression Pin	Fixed to Frame
2	**Part 2**: Ejector	Cylinder 3
3	**Part 3**: Counter pressure Plug	Cylinder 3
4	**Part 4**: Compression Chamber	Fixed to Frame
5	**Part 5**: Heating Coil	Fixed to Chamber
6	**Part 6**: Compression Plug	Cylinder 2
7	**Part 7**: Top Support Plate	Fixed to Frame
8	**Part 8**: Transport & Fill Hopper	Cylinder 1

Fig 4: Parts list of compression chamber components.

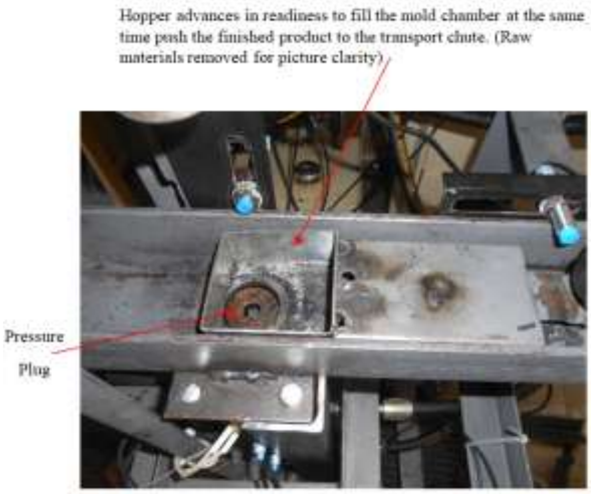

Fig 5: Actual view of initial position of actuators.

Step 1: Cylinder 1 extends and its attached hopper is used to transport (push) the ejected briquettes to the chute as well as prepare to fill in the die cavity when exposed.

Step 2: Cylinder 1 maintains its advanced position for 4 seconds and at the same time, the ejection cylinder 3 retracts to expose the cavity space of the mold. This will enable the hopper attached in Cylinder 1 to fill the cavity with the biomass raw material as shown in figure 5.

Step 3: As the transport cylinder 1 fully retracts, the attached hopper scraps off any excess biomass raw material from the top of the die cavity as shown in Figure 7.

Step 4: The compression cylinder 2 advances to the preset full compaction position in the heated die cavity.

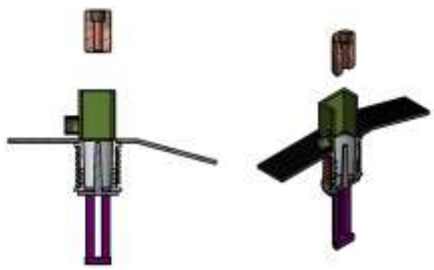

Fig 6: Schematic view of steps 1-4 of the actuators.

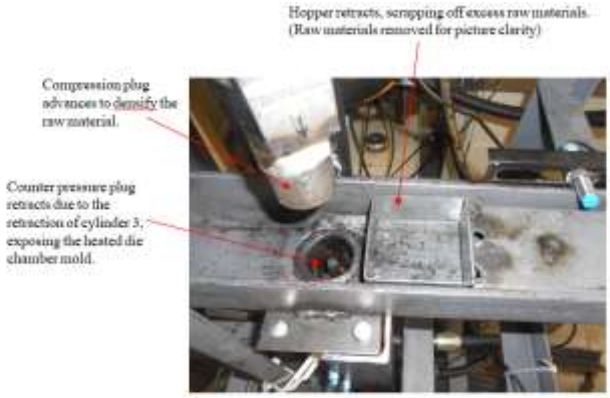

Fig 7: Actual view of steps 1-4 of the actuators.

Step 5: The compression cylinder 2 holds extended position for the time range set (5 to 20 seconds) so that the properties of dwell time, pressure and heat in the die cavity induce biomass briquette densification and drying (Yang, Ryu, Khor, Yate, Sharifi, & Swithenbank, 2005). This is shown in figures 8 and 9

Step 6: After the compression time, cylinder 2 retracts to its initial position.

Step 7: The compressed briquette is ejected from the die cavity by the extension of cylinder 3. This will expose them to the surface in readiness for transportation to the chute by cylinder 1 as shown in figure 10.

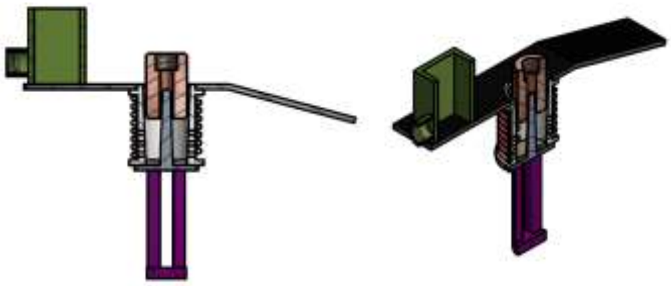

Fig 8: Schematic view of steps 5-6 of the actuators.

Fig 9: Actual view of steps 5-6 of the actuators.

Fig 10: Actual view of ejected briquette

The cycle steps from 1 to 7which take about 44 seconds are repeated again automatically. This sequential movement of the hydraulic cylinders is controlled by a Programmable logic controller (PLC) in conjunction with proximity sensors and relays (Siemens, 2006) .

5. HYDRAULIC CIRCUIT CONNECTION.

The design of the hydraulic circuit ensures the sequential movement of the cylinders in the manufacturing process. FESTO Didactics Fluid SIM software was used to design, modify and calibrate the hydraulic circuit. The components considered in the design of the circuit are;

(a) Electromagnetic solenoid 4/2 or 4/3 valves: They are actuated using an electromagnetic signal input and they provide a quick response to an incoming signal as required by the program design thus minimizing time delays.
(b) Double acting hydraulic cylinders: They are robust and require minimal maintenance and thus suitable for the rough and abusive conditions as set out by a client.
(c) Pressure Relief Valves (NC): These are used as safety devices for the hydraulic pressure to be limited to a preset value. This prevents any excessive pressure from damaging the system.
(d) One way Flow Control Valves: Used as speed control devices for the 3 double acting hydraulic cylinders. They are special combination valves that consist of a throttling element mounted parallel to a non return valve.

The hydraulic transmission comprehensive experimental training equipment that is available at the Technical University of Kenya hydraulics laboratory was used as part of the prototype machine (Fig 11). This significantly lowered the costs required to purchase new equipment and the device can be calibrated to suit the parameters specified in the prototype design.

Fig 11: Assembled Hydraulic Circuit

6. ELECTRICAL AND PLC CONTROLS

The PLC design features are divided into two categories of input elements and output elements. The input elements provide the signals to the Programmable Logic Controller (PLC) unit which is then processed to give a specific output function according to the program developed (Wright, 2016). The input elements include:

- Main switch: This is of dented (toggle) type and its function is to initialize the automatic start process of the machine. It is ergonomically located at a place convenient for the machine operator.
- Fully Automatic Control Switches: The automatic on switch is a normally opened (NO). When closed it sends a signal to the PLC to operate the three cylinders in the programmed sequence. The off switch is Normally Closed (NC) and when opened, it breaks the contact and interrupts the power supply to the directional control valves thus stopping the operation sequence of the hydraulic cylinders.

- Proximity Sensors**:** These are electromagnetic proximity sensors that act as limit switches by detecting the presence of the cylinder head as it advances or retracts then communicate the signal to the relays (figure 13). They are six in number and are located in pairs at each end of the three cylinders. Once activated, they send signals to the PLC unit which will execute various commands in line with the program design.

The output elements receive processed electrical signals from the PLC and convert them to a mechanical function or display function. There are two elements in this category which include:

- 4/2 Directional Control Valves: They control the three double acting cylinders which are responsible for the sequential movement of the three cylinders (refer to figure 2):
  Cylinder 1: Transportation of compacted biomass to the exit chute while feeding raw material into the mold cavity.
  Cylinder 2: Compression of the briquettes in the mold cavities in order to induce densification.
  Cylinder 3: Eject the compacted briquettes from the mold cavity.

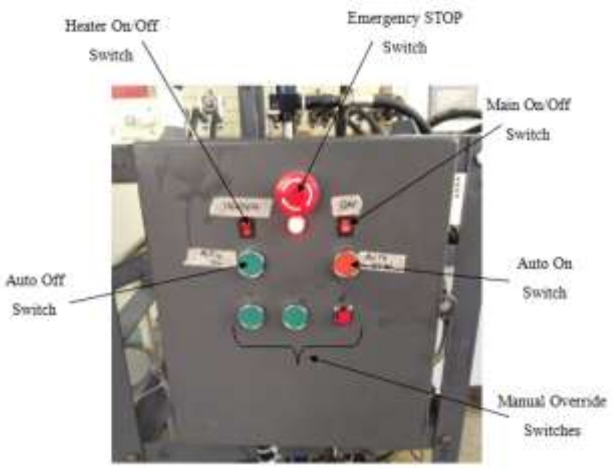

Fig 12: Control Panel.

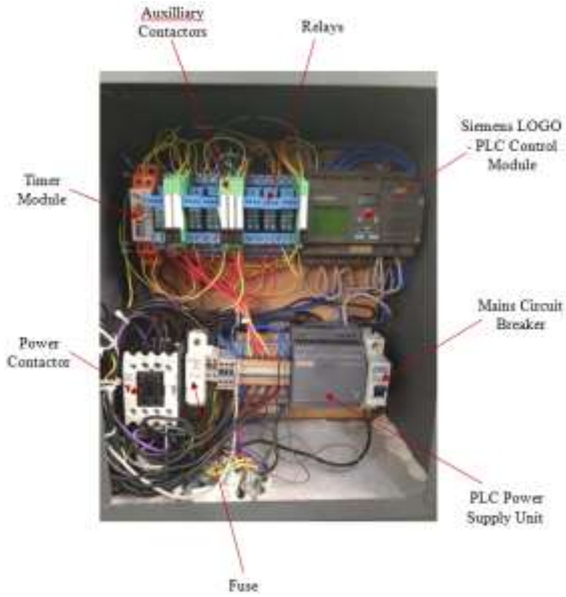

Fig 13: Control Panel Electrical Connections.

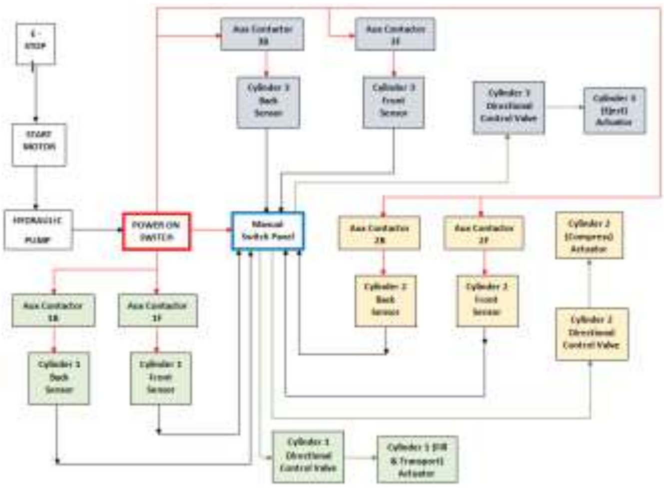

Fig 14: Manual Control Function Block Diagram

Figure 14 represents the manual control function where the operator has the ability to advance or recall each cylinder manually using the manual override switches as shown in figure 12. This gives the operator an overriding capability in the event of a system failure in automatic mode and also a useful consideration during maintenance. The entire unit is mounted on a rigid support frame as indicated in figure 14. Before fabrication, the frame was designed and simulated (SolidWorks, 2016) to establish if it can withstand the calculated forces that it is expected to bear.

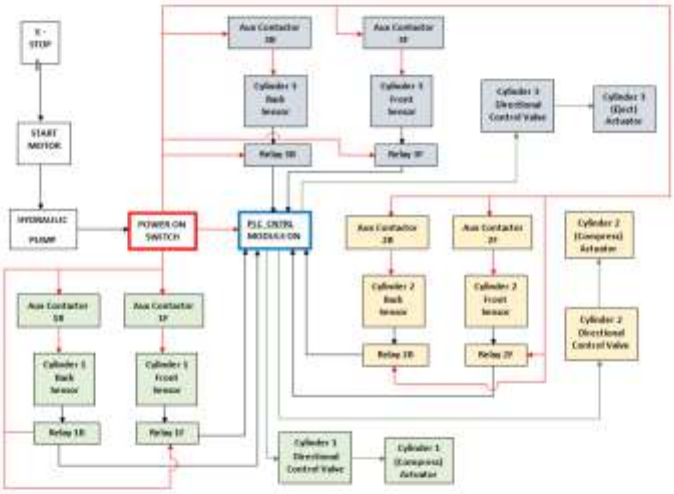

Fig 15: Automatic Control Mode Function Block Diagram

Figure 15 represents the automatic mode function block diagram where the Programmable Logic Controller Unit (PLC), controls the automated sequence of operations of the three cylinders. The position of the cylinders is detected by proximity sensors which are powered by auxiliary contactors shown in Figure 13. The safety features of the control panel design have seen the incorporation of a circuit breaker and a fuse. The power contactor is responsible for providing and disconnecting electrical power to the band heater as regulated by the variable temperature control unit. The sensors then relay signals to the PLC unit via relay coils in order for the sequence of operations to be executed as per the program design in the PLC. The automated step diagram showing the sequential movement of the hydraulic cylinders is as shown in Figure 2.

Fig 14: Actual Fabricated Machine Prototype.

7. CONCLUSIONS

The prototype machine fabricated has only one die chamber as compared to the 40 die chamber cavities in the proposed final production machine). The compressed density of a briquette sample produced is $1.1 g/cm^3$ and the mass of the briquette is 41.1 g. Taking the mold capacity of the proposed final production machine as 40 cavities, then in 1 cycle the estimated production rate is approximately 1644 g = 1.6kg

The design of the machine enables an average 30 seconds per production cycle. In an ideal setting, the linear speed of the preferred hydraulic cylinder is 74mm/s. However, due to resistant from control valves, pressure regulating valves, flexible hose elements and the hydraulic pump capacity, slow cylinder speeds of around 50mm/sec were witnessed.

To calculate the production capacity of the prototype, then: 3600 x 41.1g/30 = **4.9 kg/hr.**

To calculate the production rate / hour for a complete 40 mold production machine, then; 4.9 x 40 = **197 kg/hour.**

This is can be concluded as a satisfactory machine for automated briquette production.

REFERENCES

1. A Parker Corporation PLC. (2017, July). Metric Hydraulic Cylinders Series HMI. Catalogue HY08-1151- 1/NA . Parker.

2. Alkrunz, E. M. (2015). PLC Information. Retrieved January 7, 2019, from An infoPLC Web site.: www.infoPLC.netBolton, W. (1996). Programmable Logic Controllers ISBN:9780750681124. Coventry: Newnespress.

3. FESTO Didactics. (2001). Hydraulics Workbook Basic Level : A learning System for Automation TP 501 ISSN D.S501-C-SIBU-GB (Vol. 04/01). Denkendorf: Festo Didactic GmbH & Co.

4. Gatmaitan, A., Guanlo, J., Guting, R., Janairo, C., & Chua, A. (2013). Development of an Automated Briquetting Machine. DLSU Research Congress 2013 (pp. 1-4). Manila: Mechanical Engineering Department: De La Selle University Manila.

5. Gurdil, A., & Demirel, B. (2017). DESIGN AND CONSTRUCTION OF A HYDRAULIC BRIQUETTING MACHINE FOR HAZELNUT HUSK AGRICULTURAL RESIDUE. In B. Demirel (Ed.), 58th ICMD 2017(pp. 104 - 109). Prague: Department of Agricultural Machinery and Technologies Engineering, Faculty of Agriculture, Ondokuz Mayis University, Samsun, Turkey.

6. Hydraulics Online. (2018, June). A Hydraulics Online Corporation: Let us take the pressure. Retrieved September 10, 2018, from A Hydraulics Online Corporation Website.: http://www.hydraulicsonline.com/an-introduction-to-hydraulics

7. Oluyinka, J. (2017). DEVELOPMENT AND PERFORMANCE EVALUATION OF HYDRAULIC PISTON PRESS BIOMASS HOOLOW BRIQUETTE MAKINGMACHINE. Ahmadu Bello University, Department of Agricultural Engineering. Zaria - Nigeria: Faculty of Engineering.

8. SIEMENS PLC. (2006). Manual: Simatic - Programming with STEP 7. A5E00706944-01. Nurnberg: Siemens AG Automation and Drives.

9. SolidWorks. (2016, October 19). Solid Works 2016 Simulation. Nairobi.

10. TECO Corporation. (2017, January). Standard Motor Catalogue AESV2E/AESU2E Series. TECO e motion IE2/IE3 . TECO Corporation.

11. Wright, H. (2016, 11). Maxim Intergrated: Introduction to Programmable Logic Controllers (PLCs) and the Operational Function of Main System Modules: Tutorial 4701. Retrieved September 10, 2018, from A Maxim Intergrated Website: https://www.maximintegrated.com/en/app-notes/index.mvp/id/4701

12. Yang, Y. B., Ryu, C., Khor, A., Yate, N. E., Sharifi, V. N., & Swithenbank, J. (2005, November 2). Effect of fuel properties on biomass combustion. part II modelling approach-identification of controllingfactors. A Journal on Fuel , 2116 - 2130.