Firewood Production Machine

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Firewood Production Machine

Project Team:

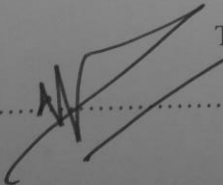Ahmad Bradieah   Dawoud Abu Saleh

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In partial fulfillment of the requirements for the
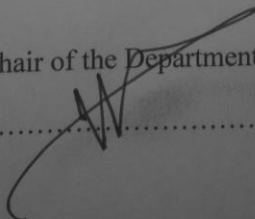
Bachelor degree in Mechatronics Engineering.

Supervisor Signature

Testing Committee Signature

Chair of the Department Signature

Abstract

Various sides of life in Palestine mainly depend on electricity and diesel, including heating side with many problems facing electricity and diesel, resulting in lack of access to the required energy. In addition to many residuals from industrial processes and productivity that can be used to compensate for energy shortages or to be an alternative source, there is a tendency to provide energy sources from these residuals. This project aims to design a machine to produce firewood to be a source of thermal energy from the olive cake (Jeft), which contains high energy. In addition to sawdust from wood industrial operations and the peels of pistachios; to produce firewood with higher energy, more ignition time and less price.

الملخص

يتم الاعتماد بشكل رئيسي على الكهرباء والديزل في مختلف جوانب الحياة في فلسطين، بما في ذلك جانب التدفئة مع العديد من المشاكل التي تواجه الكهرباء وقطاع النفط، مما أدى إلى عدم الوصول إلى الطاقة المطلوبة. ومع وجود العديد من بقايا العمليات الصناعية والإنتاجية التي يمكن استخدامها للتعويض عن نقص الطاقة أو لتكون مصدرا بديلا، فأصبح هناك ميل لتوفير مصادر الطاقة من هذه المخلفات. يهدف هذا المشروع إلى تصميم ماكينة لإنتاج الحطب ليكون مصدرًا للطاقة الحرارية من جفت الزيتون الذي يحتوي على طاقة عالية. بالإضافة إلى نشارة الخشب الناتجة من العمليات الصناعية الخشبية وقشر الفستق الحلبي؛ لإنتاج الحطب مع طاقة أعلى، والمزيد من وقت الاشتعال وسعر أقل.

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Chapter 1

Introduction

1.1 Introduction

Despite the dependence of Palestine on electricity in various sides of life, including heating, but the amount of electricity that is obtained by the Palestinian is much lower than the amount obtained by the Israeli settlers, where the electricity available to the Palestinian citizen does not exceed 15% of what is available to the Israeli settlers [1], which prompted the Palestinian community to resort to nature and its sources.

Wood is the second most important source of heating in Palestine according to the Palestinian central bureau of statistics. The statistics indicate that the proportion of dependence on wood in heating amounted to 29%[2], which came in the second place after electricity, which is amounted of 39%[2] and the proportion is still increasing.

Because of the cost of wood in heating, where the price of tons of wood from 215-400 US Dollar. This is considered a high cost compared to the average per capita income of the Palestinian individual, which is equivalent to about 450 US Dollar[2], there has been a trend to produce alternative firewood produced from olive peat(olive cake) instead of disposing of it without exploitation.

1.2 Problem definition

The Palestinian people faces difficulties in getting proper heating in the winter due to the problems that are raised by electricity and diesel in Palestine as well as the lack of natural resources for wood with an increasing demand for it.

1.3 Motivation

1- Provide an alternative source of heating to avoid problems and difficulties resulting

   from the use of electricity and natural firewood.

2- An alternative source of higher thermal energy, more ignition time and lower prices.

3- Exploitation of some of the materials that society faces difficulty in disposal from it.

1.4 Method

This project is concepted on the design a machine that produces firewood consisting of a mixture of materials, and these materials are:

1) Peat (jeft)

   Peat is the solid waste produced by the olive sorting process as shown in Figure 1.1 .

Figure 1.1: peat

According to statistics, the results of the olive sorting process are oil by 16%, peat by 40% and liquid waste[2] .

Figure 1.2 shown the percentage of peat as a source of energy besides other sources like diesel, electricity and solar energy .
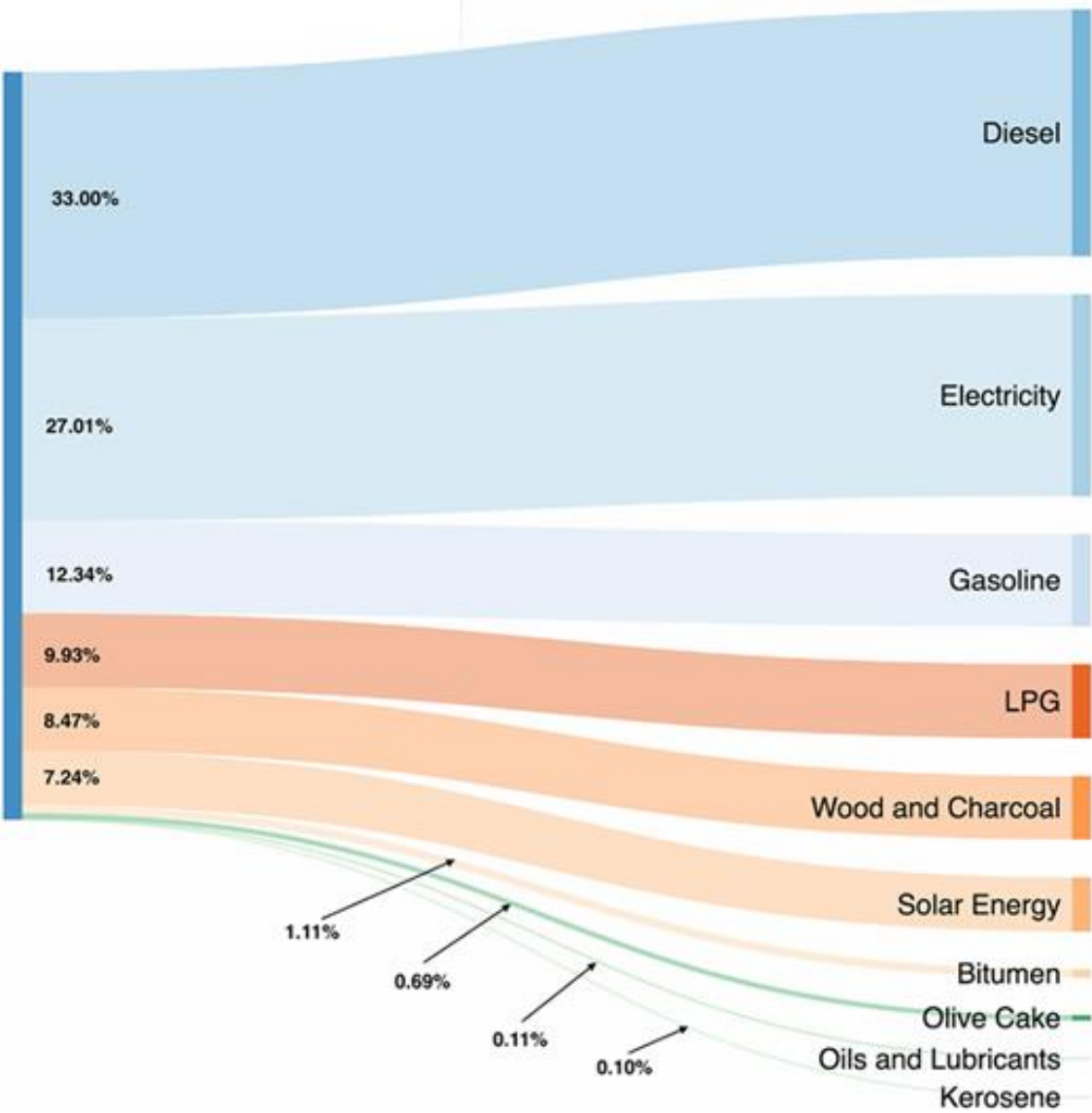
Figure 1.2: Energy balance in Palestine

Peat will be the main ingredient in the mixture and the highest ratio; to give the produced wood high thermal energy and more ignition time[3].

2) Sawdust and peels of pistachios

Sawdust or wood dust is a waste product of woodworking operations such as sawing, milling, planning, routing, drilling and sanding. It is composed of fine particles of wood as shown in Figure 1.3.

Figure 1.3: Sawdust

The average rate of sawdust burning is 0.00252kg / min [3]. The efficiency of the sawdust stove is 34.6%[3] and the efficiency of the kerosene stove is 32.1%[3]. In addition sawdust cheaper and readily available.

The using peels of pistachios is based on the experiences of some factories such as Royal Factory for plastic industries, where the peels of pistachios is used as a source of energy in the convection oven in the rotary machine for the manufacture of water tanks.

In other experience peels of pistachios used as an alternative source of energy for the manufacture of cement in cement factories in Jordan[4].

1.5 Literature review

There are many industrial and production processes that result in a lot of residues, which have been studied and experimented to use them in a useful method.

El-Bashiti, Mansour in 2017 improving the methods of production of bioethanol from the peat, where 10 grams of peat was added to a solution of acids. The result is that: one liter of the solution produces 9.3 grams of bioethanol, which is used as a source of alternative energy sources, especially in automotive fuel[5].

Regel, Waelkens in 2011discusses the possibility of producing biogas from olive residues. Where they made several attempts through specialized fermentation processes. The result was that they produced 720 liters of biogas per kg of dry organic matter from the peat (solid olive residues), which is more than the amount of gas that can be produced from corn fermentation. In addition to producing 3600 kWhper ton [6].

Abu Hamed, Alsharein 2015, a study entitled "The potential of using olive cake in Palestinian territories "is made to examine the possibility of producing energy from the olive cake in the West Bank and the Gaza Strip. The study concluded that peat contains a high amount of energy that can reach up to 18 MJ / kg. This means that approximately 28,000 tons of peat is capable of producing about 1.3% of the total energy consumed in 2009 in the West Bank and the Gaza Strip. This means that the peat can produce enough electricity to cover the needs of about 60,000 Palestinians, or need a city like Jericho [7].

Akgun, Doymaz in 2005, a study entitled "Modelling of olive cake thin-layer drying process "focused on drying and modelling of olive cake over a wide temperature range by using mathematical models. In addition, the activation energy were calculated, where the energy accounts indicated that the amount of energy produced is 17.97 kJ/mol [8].

Away from theoretical research, in the city of Gian in Andalusia, south of Spain, there is an energy plant mainly operated by olive peat, where 100,000 tons of peat are processed annually, producing 126,144,000 kWh[9].

There has been a trend towards the production of firewood from the olive peat, where simple machines is used to compress the peat in the form of a cylinder, each piece length of 20 centimeters and the weight of 600 grams ignites for half an hour more than natural firewood [10].

1.6 Project schedule

This section shows the project work time that is needed to achieve our goals. This schedule is divided into sixteen weeks of the first semester and sixteen weeks of the second semester as following in Table 1.1 and Table 1.2.

Table 1.1: First semester time plan

Tasks \ Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
T1	■	■	■	■												
T2				■	■											
T3					■	■	■	■								
T4							■	■	■	■	■					
T5											■	■	■	■		
T6														■	■	■

Where:

T1: Selection the idea of the project.

T2: Research about the idea of the project.

T3: Introduction (Chapter 1).

T4: Conceptual design and mechanical design (Chapter 2).

T5: Electrical system (Chapter 3).

T6: Control system (Chapter 4).

Table 1.2: Second semester time plan

Weeks\Tasks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
T7	■	■														
T8		■	■	■	■											
T9					■	■										
T10							■	■	■							
T11										■	■	■	■	■		
T12													■	■	■	■

Where:

T7: Order the components.

T8: Selection the motor.

T9: Assembly the machine parts.

T10: Testing and calibration.

T11: Implementation and validation.

T12: Write final report.

Chapter 2

Conceptual design and machine design

This chapter shows the conceptual design and mechanical components of machine.

2.1 Conceptual design

The operation of the machine is either through the smartphone application or through the control panel according to the following steps:

1- When pressed on the start switch on the control panel or the smartphone application, the conveyors and the mix screw start running.

2-The humidity sensor measures humidity in the mixing tank. If the humidity is higher than 20% (the best level of humidity to treat the peat as an energy source)[11], the heater is turned on.

3-When the humidity level reaches 20%, the heater is stopped.

4-The machine is stopped when the stop switch is pressed through the control panel or the smartphone application.

5-When the emergency switch is pressed, the system stops directly from working.

The prototype we implemented was the machine operated by the smartphone application and the control panel. The conveyors, the humidity sensor and the heater were kept in the theoretical part only.

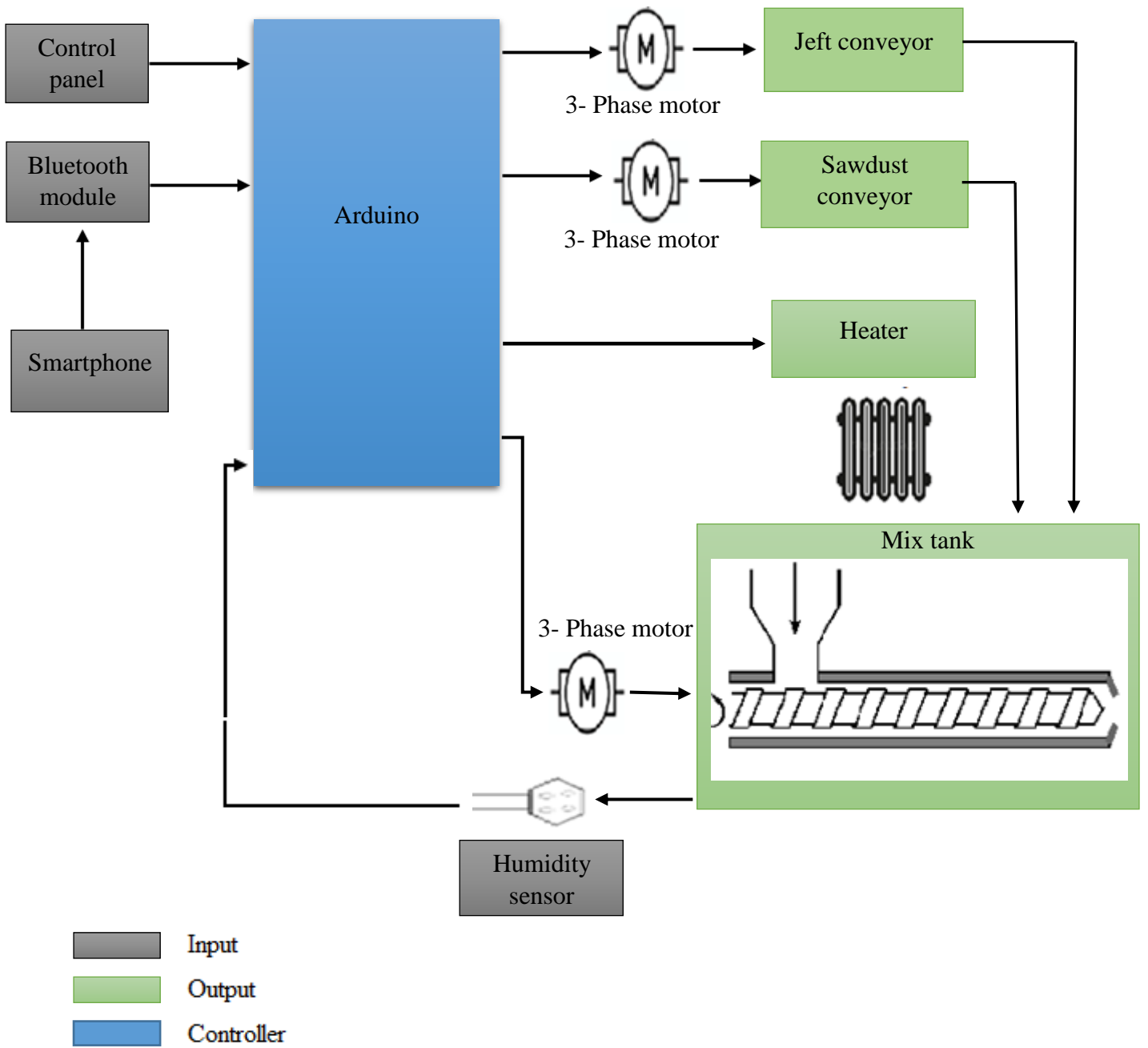The conceptual design shown in Figure 2.1

Figure 2.1: Conceptual design

2.2 Machine design

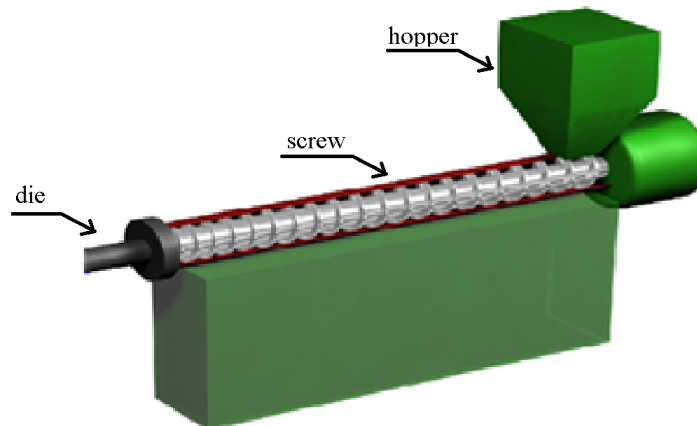A machine is a single extrusion die screw press as shown in Figure 2.2

Figure 2.2: A single extrusion die screw press.

The main parts of machine are:

The hopper : this is where the raw material (saw dust) is feed into the machine.

The screw : takes the material from the hopper through the barrel and compresses it.

The die: this is where the raw material extruded through it.

The Machine Description: a machine is a single extrusion die screw press. It consists mainly of driving motor, screw, die and the housing with a hopper. When the motor is started, raw materials are fed into the machine through the hopper; the raw materials are compressed in the barrel, and extruded through the die. During operation, the rotating screw takes the material from the hopper through the barrel and compresses it against the die which forms a buildup of pressure gradient along the screw. The screw continuously forces the materials into the die.

Pressure is built up along the screw rather than in a single zone as in the piston type machines as shown in Figure 2.3
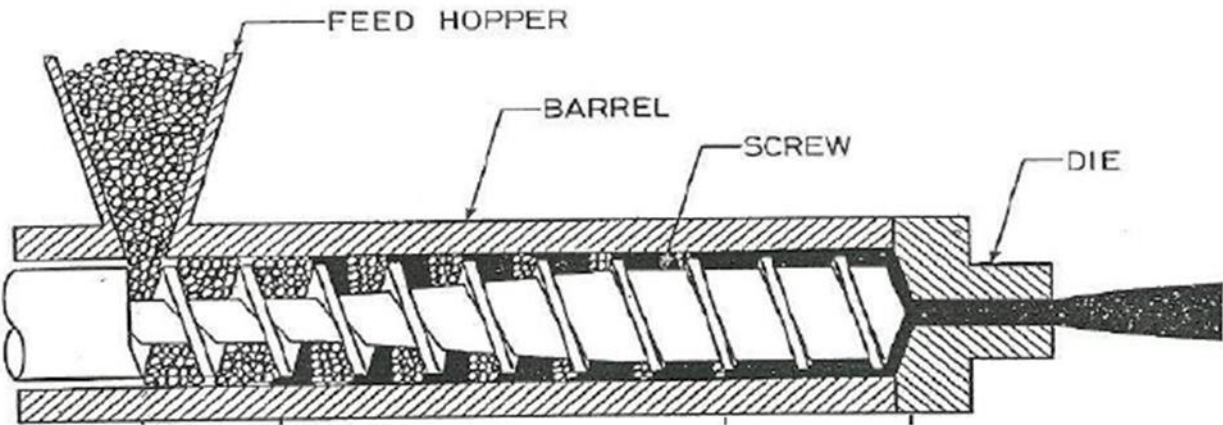

Figure 2.3: A single extrusion die screw press

2.2.1: The hopper design

The hopper: this is where the raw material is feed into the machine. It is made of mild steel, and conical in shape. It is welded to the barrel housing.

The hopper is designed as a frustum of a square pyramid as shown in Figure 2.4
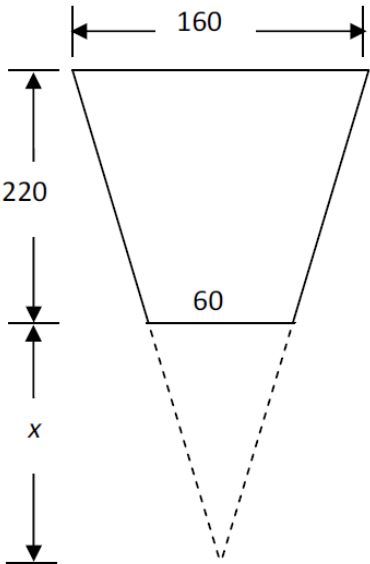
Figure 2.4: The hopper

$$\frac{220 + x}{160} = \frac{x}{60}$$

x = 132 mm

Volume of hopper = volume of the big cone – volume of the small cone.

= 2.235 x 10^{-3} m^3

2.2.2: The barrel housing design:

The barrel housing: this is where the raw materials are it comprises of a cylindrical housing with a tapered die attached to it. It is the housing for the screw extruder. The housing is 250 mm long and 100 mm diameter. A die, 170 mm long and 100 mm entry diameter and 30 mm exit diameter.

The weight of the barrel is calculated thus:

The material used is mild steel, ρ mild steel = 7861.09 kg /m^3

Where L = length of the cylinder = 250 mm

d = diameter of the cylinder = 100 mm

Therefore, Volume of cylinder = = 1.9634 x $10^{-3} m^3$

The die is a frustum of a cone and is designed, using similar triangles in Figure 2.5
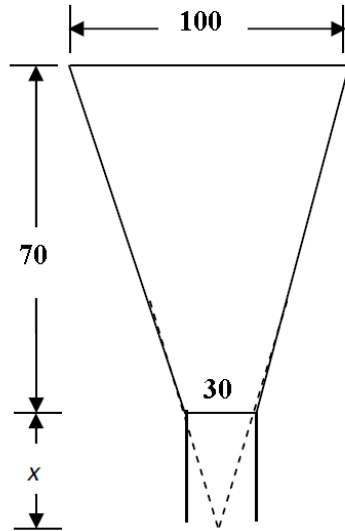
Figure 2.5: Tapered die

$$\frac{70 + x}{100} = \frac{x}{30}$$

x=30 mm

volume of tapered die = volume of big cone – volume of small cone

=3.33 X 10^{-4} m^3

Total volume of the Barrel = volume of the cylinder + volume of the tapered end

= 2.2964 x $10^{-3} m^3$

20

Calculating the weight of mixture

density of mixture (assuming 20% moisture content)

$=910 \text{ kg} /\text{m}^3$

Volume of mixture = volume of hopper + volume of barrel

$$= 4.5314 \text{ x } 10^{-3} \text{ m}^3$$

The mass of mixture = volume of mixture X density of mixture

$$= 4.12 \text{ kg}$$

Therefore, weight of mixture = 40.45 N

2.2.3: The shaft design:

The shaft is made of mild steel. The yield strength of the material in tension, $S_{yt} = 770$ N/mm^2 and ultimate tensile strength $= 580$ N/mm^2 .

Assuming the load is gradually applied, the combined shock and fatigue factor applied to bending moment, Kb =1.5 and combined shock and fatigue factor applied to torsional moment, Kt = 1.0

The permissible shear stress τ is taken to be 30% of the yield strength or 18% of the ultimate tensile strength of the material or whichever is minimum .

Therefore, $\tau = 0.3 \text{ X } S_{yt} = 0.3 (580) = 174$ N/mm^2

$\tau = 0.18 \text{ X } S_{ut} = 0.18 (770) = 138.6$ N/mm^2

and the lower is 138.6 N/mm^2

Let d = diameter of shaft

M_t = torque transmitted by the shaft

P = power transmitted by the shaft (W)

N = rpm of the shaft

τ = permissible shearing stress

M_b = bending moment

A machine driven by a 0.37 kW, 1380 rpm electric motor driving the screw shaft at 480 revolutions per minute (rpm)

$$d = 36.5 \times \left(\frac{P}{\tau N} \right)^{0.33} \text{ mm}$$

$d = 6.6$ mm

Mt , the torque transmitted by the shaft

$M_t = 7.4$ Nm

Mb = 127, 306 N mm

Use d = 20mm

2.2.4 Die design

This is where the raw material extruded through it, which forms a buildup pressure gradient along the screw as shown in Figure 2.6.
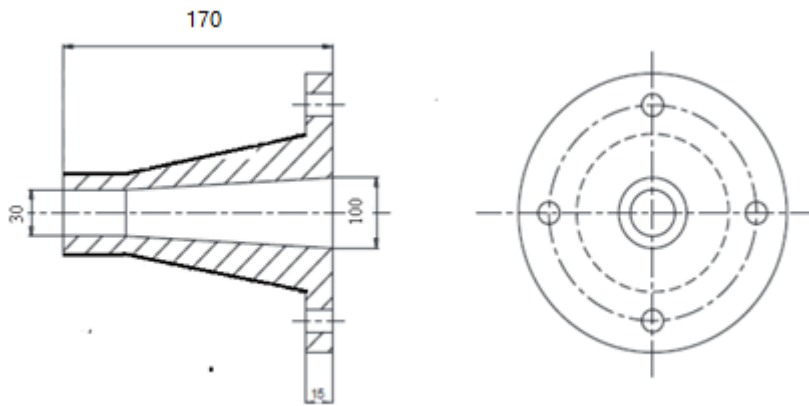
Figure 2.6: Die section

Entry diameter = 100 mm

Exit diameter = 30 mm

Taper angle = 35.5°

Compression ratio = 3.3 : 1

2.2.5 Screw design

Takes the material from the hopper through the barrel and compresses it and the pressure is built up along the screw as shown in Figure 2.8.
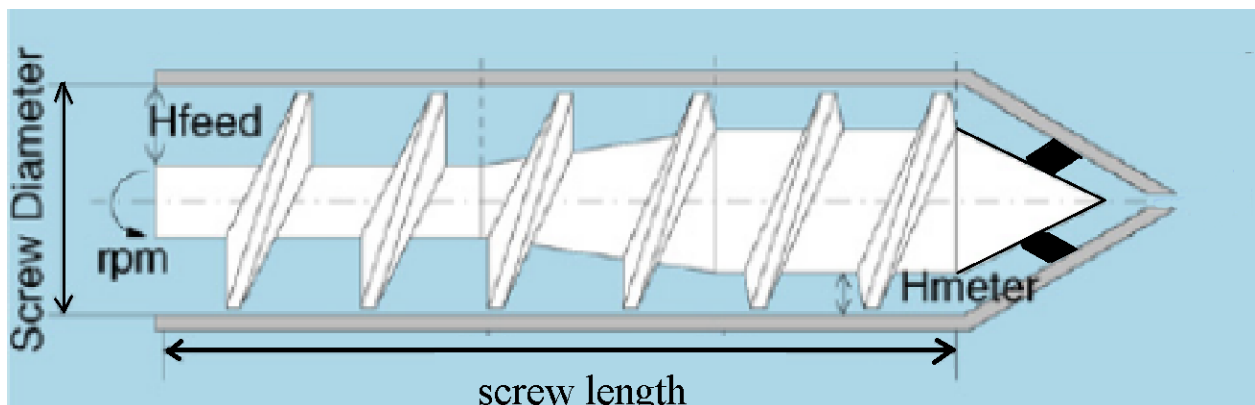

Figure 2.7: screw

Screw diameter = 98 mm

Feed depth (Hfeed) = 30 mm

Metering depth (Hmeter) = 20 mm

Screw length = 280 mm

Compression ratio = 3 : 2

2.2.6 Conveyor belt

A conveyor system is a common piece of mechanical handling equipment that moves

materials from one location to another.

A belt conveyor system consists of two or more pulleys, with an endless loop of carrying

medium—the conveyor belt—that rotates about them. One or both of the pulleys are

powered, moving the belt and the material on the belt forward. The powered pulley is

called the drive pulley while the unpowered pulley is called the idler pulley.

The design of the conveyor frame is dependent on the total belt length.

• Short conveyors: maximum 2m (6ft)

In this case, belt support on the return side can be omitted.

• Medium conveyors: (2 – 4) m (6 – 12ft)

Belt on return way support by slider frame or wear strips.

• Long conveyors: over 4m (over 12ft)

Require more than one section for catenary sag.

The admissible speed according to the length of the used conveyor shown in Table 2.1

Table 2.1: Admissible speed of long conveyors

Length	Max speed
Up to 15m (45ft)	50m/min
15 – 25 m (45 – 75ft)	30m/min
Over 25m (75ft)	15m/min

The specifications of the conveyors that used to transition the raw materials shown in the Table 2.2

Table 2.2: Conveyors Specifications

Pulleys	Cast iron to reduce weight
Belts	Rubber
Driven pulley shaft	Mild steel
Length	2m
Width	400mm
Driving pulley diameter	200mm
Driven pulley diameter	200mm
Thickness	14mm

Chapter 3

Electrical design

This chapter explains the electrical component that will be used in the project. Generally, Figure 3.1 shows the electrical hardware components that will be used in the project and the interactions between them.
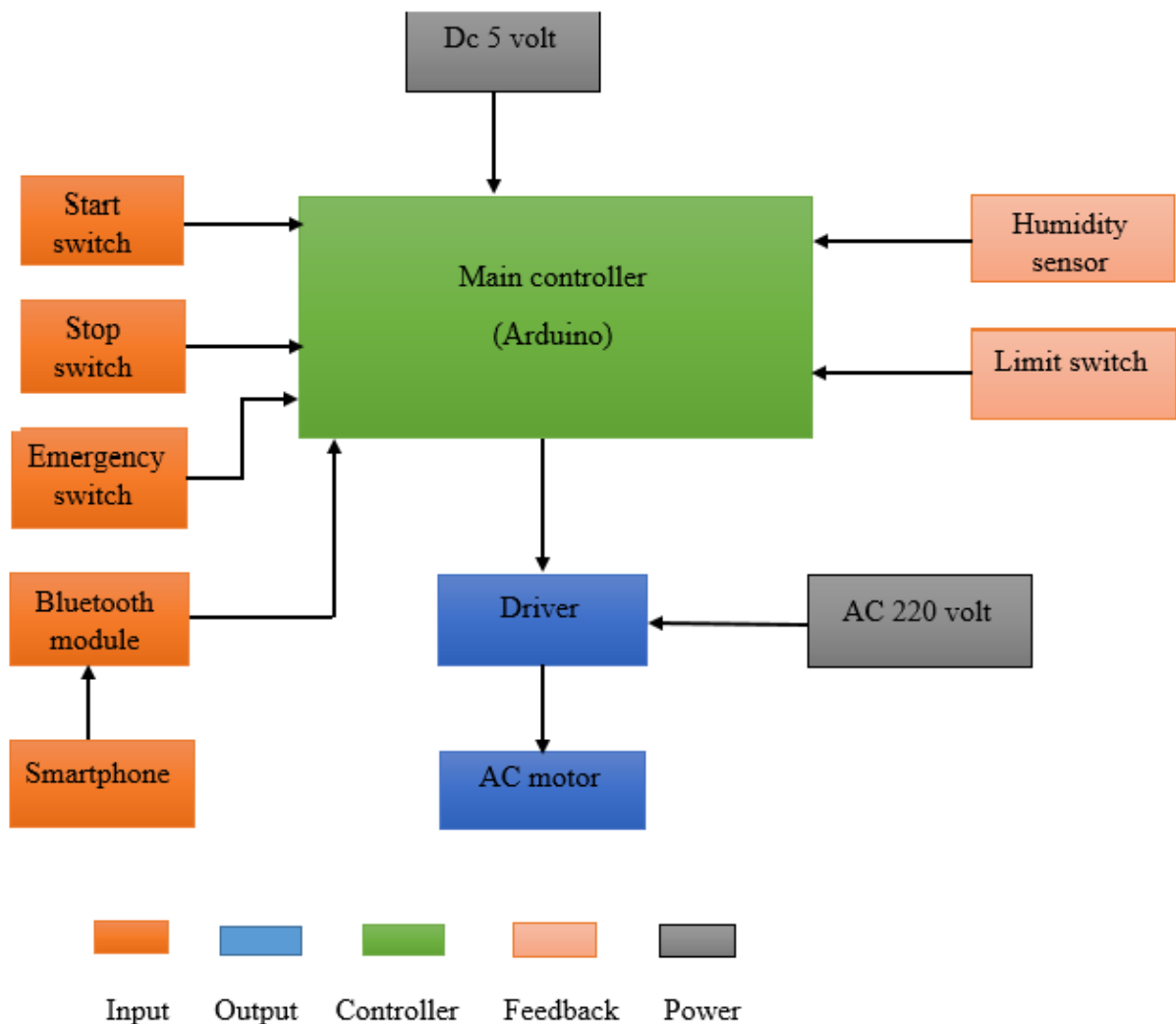

Figure 3.1: Electrical project components

In the following is an explanation of the electrical components:

3.1 Electrical motor

The speed of electrical motor always depends on the properties of the electrical signals (voltage and frequency) that comes from drivers which are connected to the controller[12]. Gearbox it is used to transfer the motion from motor to the shaft to reduce the speed and increase the torque.

In this project, three-phase AC motor will be used. Table 3.1 shows the nameplate of the motor for the implemented prototype.

Table 3.1: Nameplate of motor

Volts	220V
Power	0.37 kw
Speed	1380 rpm
Frequency	50 HZ

3.2 Variable frequency drive (VFD):

A variable frequency drive (VFD) is a type of motor controller that drives an electric motor by varying the frequency and voltage of its power supply. The VFD also has the capacity to control ramp-up and ramp-down of the motor during start or stop, respectively[13].

A (VFD) works by converting the incoming electrical supply of fixed frequency into a variable frequency output. This variation in frequency allows the drive to control the way in which the motor operates (a low frequency for a slow speed or a higher frequency for a faster speed). The output can be change to enable the motor to generate more or less torque as required[13].

It used to control the number of pieces produced by controlling the speed of the motor and the Figure 3.2 show the VFD that used in the prototype

Figure 3.2: AS2 – IPM inverter

A VFD will be used to achieve the following:

1) Convert power.

2) Match the speed of the drive to the process requirements.

3) Match the torque or power of a drive to the process requirements.

4) Reduce mechanical stress on machines to extend their lifetime.

5) Save energy and improve system efficiency.

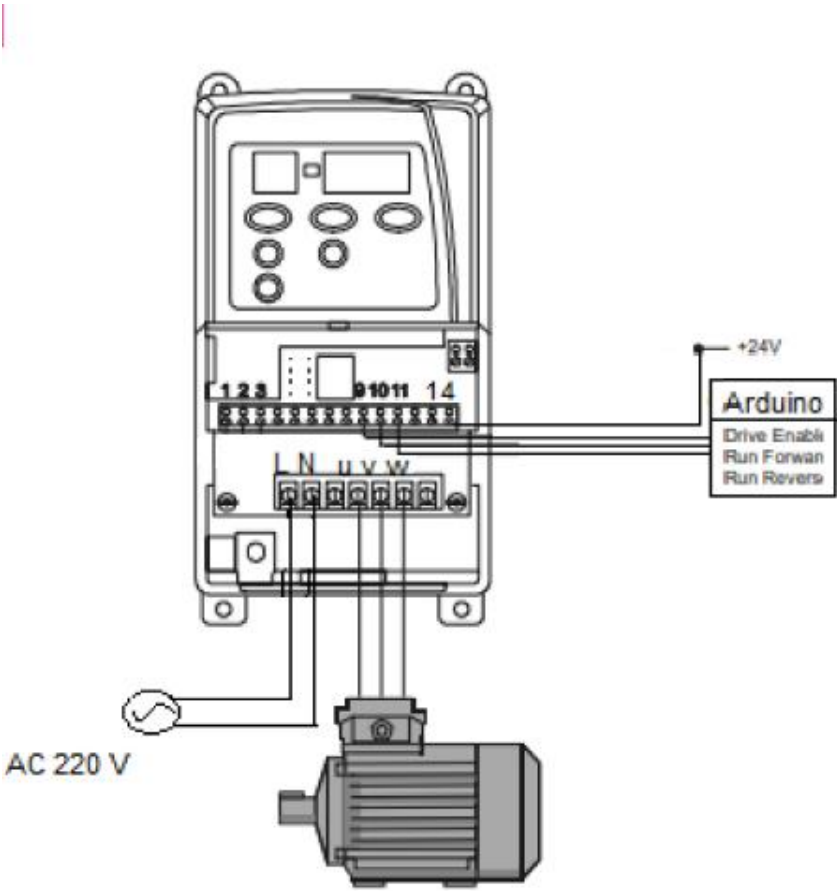The Figure 3.3 show the typical connection of the inverter.

Figure 3.3: Inverter connection

3.3 Relay

A relay is an electromagnetic switch operated by a relatively small electric current that can turn on or off a much larger electric current.

The Figure 3.4 show the relay that used in the prototype

Figure 3.4: Relay
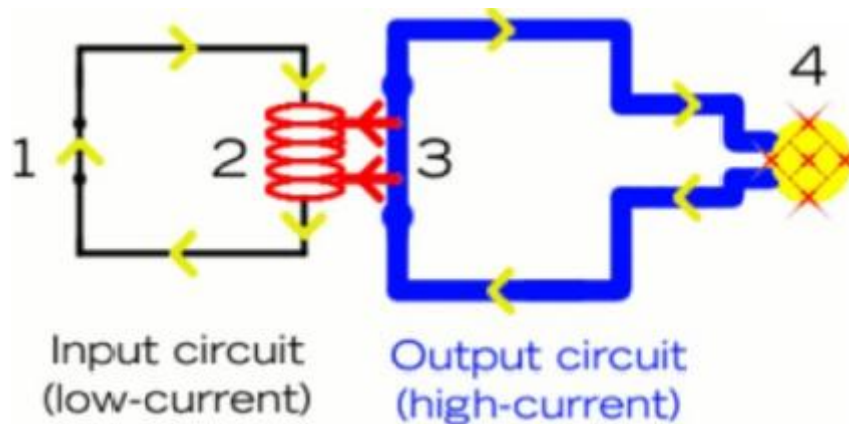
The Figure 3.5 shows components of the relay.

Figure 3.5: components of the relay

Where numbers in the figure mean [14]:

1. The input circuit is switched off and no current flows through it until something (either a sensor or a switch closing) turns it on.

2. When a small current flow in the input circuit, it activates the electromagnetic (shown here as a red coil) which produce a magnetic field around it.

3. The energized electromagnetic pulls the metal bar in the output circuit toward it, closing the switch and allowing a much bigger current to flow through the output circuit.

4. The output circuit operates a high-current appliance such as a lamp or an electric motor.

3.4 Limit switch

A limit switch is a switch operated by the motion of a machine part or presence of an object. They are used for controlling machinery as part of a control system, as a safety interlocks or to count objects passing a point.

It consists of an actuator mechanically linked to a set of contacts. When an object comes into contact with the actuator, the device operates the contacts to make or break an electrical connection as shown in Figure 3.6
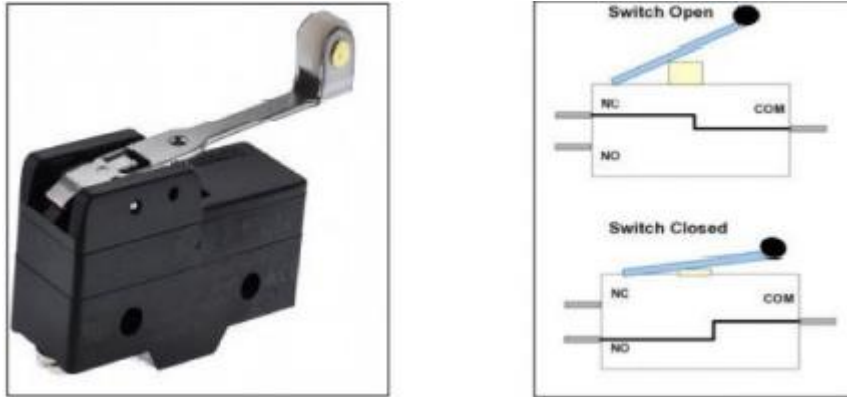
Figure 3.6: Limit switch

A limit switch will be used to determine the length of the compressed cylinder pieces. When the piece arrives and touch the key, the cutting command is given to cut the product into equal pieces and to stop the running of the conveyors when the mix tank is full.

3.5 Electrical Switches:

Are electromechanical devices that are used in electrical circuits to control power, detect when systems are outside their operating ranges, signal controllers of the whereabouts of machine members and work pieces, provide a means for manual control of machine and process functions, control lighting, and so on. Switches come in a variety of styles and are actuated by hand, foot, or through the detection of pressure, level, or objects. Switches can be simple on-off types or can have multiple positions that, for instance, can control the speed of a multi-speed fan. Switch operators can be found in various shapes and sizes as shown in Figure 3. 7 such as toggles or buttons and can be furnished in a variety of colors.

Figure 3.7: Electrical switches

The two types of momentary contact switches are

1. Normally open (NO): in a normally open switch, the default state of the contacts is open. When you push the button, the contacts are closed. When you release the button, the contacts open again. Thus, current flows only when you press and hold the button.

2. Normally closed (NC): in a normally closed switch, the default state of the contacts is closed. Thus, current flows until you press the button. When you press the button, the contacts are opened and current does not flow. When you release the button, the contacts close again and current resumes.

3.6 humidity sensor:

The humidity sensor is a sensor designed for continuous measurement of humidity on dry bulk solids. The moisture sensor can be used in container outlets, conveyor belts, conveyor screws, mixers and dryers[15].
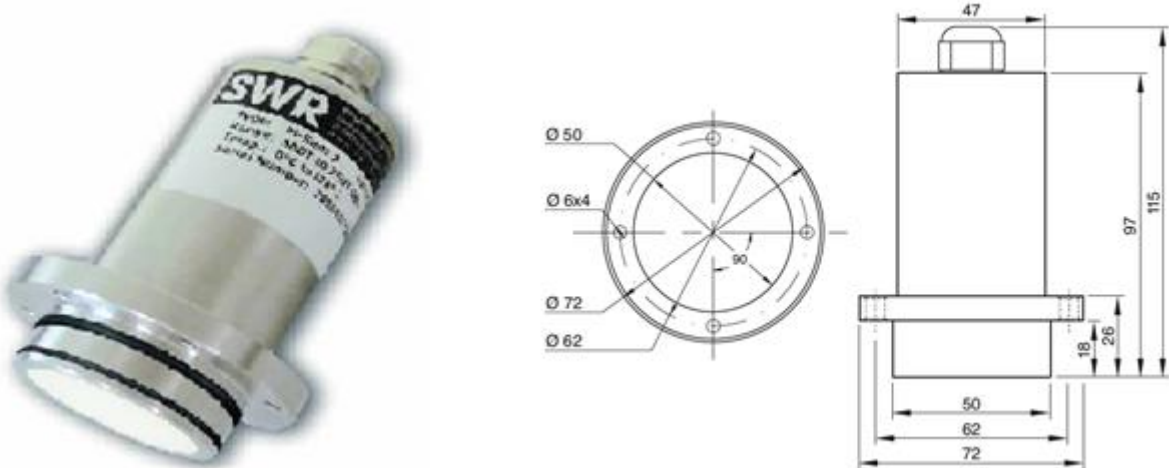

Figure 3.8: humidity sensor

In the case of humidity measurement of the mixture, the sensor is connected as in Figure 3.9

Figure 3.9: Connecting the sensor

Table 3.2: Technical data of sensor

Sensor	
Housing	Stainless steel 1.4571
Sensor surface	Ceramic
Ex-protection (optional)	Zone 20 (Dust), Zone 0 (Gas)
Protection category	IP 67 according to EN 60529
Material ambient temperature	0 … +80 °C, optional 120 °C
Working pressure	Max. 10 bar
Power consumption	0.6 W
Response time	0.1 sec.
Weight	Approx. 1000 g
Measuring range	0 … 65 % residual moisture (depending on material)
Accuracy	0.1 % absolutely in the calibrated measuring range
Connection cable	shielded cable 4-wired, 0.25 mm²

3.7 Arduino micro-controller

Arduino is an open-source electronics platform based on easy to use hardware and software. Arduino boards are able to read inputs process and turn it into an output. This mean one can tell the micro-controller what to do by sending a set of instructions to the microcontroller on the board as shown in Figure 3.10[16].

Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards or breadboards (shields) and other circuits. The boards feature serial communications interfaces, including universal serial bus (USB) on some models, which are also used for loading programs from personal computers.

In this project, Arduino is the main controller that receives commands from different switches and sensor then sends the desired signals to the drive.

Figure 3.10: Arduino UNO

3.8 Bluetooth module HC-05

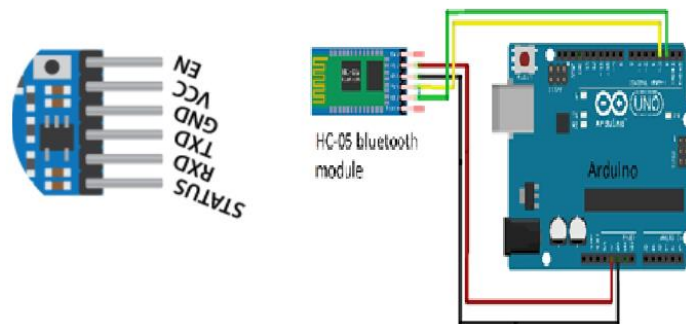Used to connect between the smartphone and the Arduino as in Figure 3.11

Figure 3.11: Bluetooth module and Arduino connect

Chapter 4

Project control

The controller acts as the brain of the machine system. All parts (electrical and mechanical) and controller are integrated together to serves the machine tasks. The primary task of the controller is to receive digital signals that represent a sequence of discrete values from a computer and translate these signals into mechanical motion through motor.

This chapter explain the controller design and the software to control the machine.

4.1 Close – loop control system

A Closed-loop control system, also known as a feedback control system is a control system which uses the concept of an open loop system as its forward path but has one or more feedback loops (hence its name) or paths between its output and its input. The reference to "feedback", simply means that some portion of the output is returned "back" to the input to form part of the systems excitation as shown in Figure 4.1[17].

Closed-loop systems are designed to automatically achieve and maintain the desired output condition by comparing it with the actual condition. It does this by generating an error signal, which is the difference between the output and the reference, input. In other words, a "closed-loop system" is a fully automatic control system in which its control action being dependent on the output in some way[17].
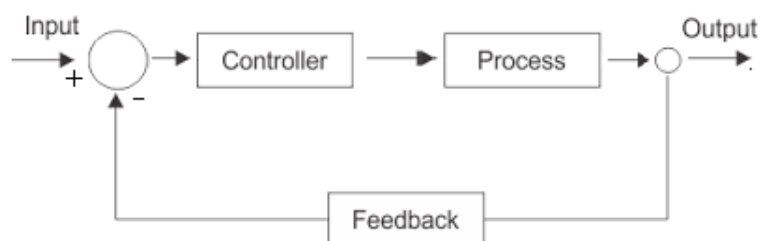

Figure 4.1: Closed - loop control system

Where:

Controller: Arduino UNO

Process: running a conveyors and mix screw

Feedback: humidity sensor and limit switch

4.2 Safety protection in project

Safety protection system includes a limit switch, which stop the running of conveyors when the mix tank is full and the emergency switch that stop overall system when pressed it.

4.3 Control switches

A machine include:

1- Control panel that contain:
   a- Start switch
   b- Stop switch

2- Smartphone application

4.4 Smartphone application software

Smartphone application used to start or stop the machine by transit signal from it to bluetooth module which connected with the controller .The smartphone application code in Appendix B.

Figure 4.2 show the smartphone application

Figure 4.2: Smartphone application

4.5 Arduino controller software

The Code has been written in C language using Arduino program, after program is completed it has been converted to Hex file to install it in Arduino uno. Where was the use of primary and non-complex instructions in writing program such as IF-statement instruction and While-loop instruction to implement the control conditions. The illustrative code in Appendix B.

Chapter 5

Conclusion

The good quality of product can be produced by controlling a number of process variable like moisture content of feed mixture, particle size of the feed, composition of additives added in the feed mixture. The power consumption can be decreased by increasing the percentage of binder in the feed. The product is economical and have high potential as an alternate fuel. The application of project can contribute significantly to the rural population. It has a great potentional as a renewable source of energy and is a good substitute for wood & coal.
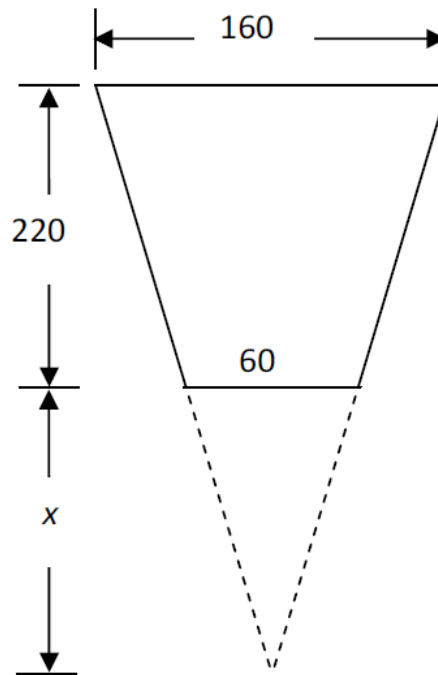
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Appendix A

Calculations:

The hopper design

$$\frac{220 + x}{160} = \frac{x}{60}$$

x = 132 mm

Volume of hopper = volume of the big cone – volume of the small cone.

$= 1/3 \pi (R^2H - r^2h)$

$= 2.235 \times 10^{-3} \text{ m}^3$

The barrel housing design:

The weight of the barrel is calculated thus:

Weight = mass x gravitational force

Mass, m = ρ x v

The material used is mild steel, $\rho_{mild\ steel}$ = 7861.09 kg /m^3

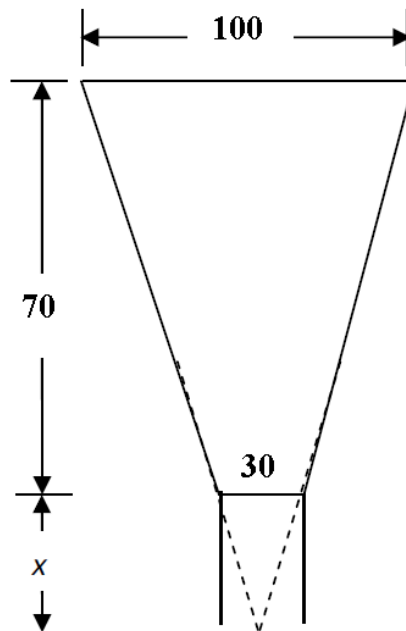Volume of the barrel = volume of cylinder + volume of the tapered end

Volume of the cylinder = ¼ πd^{2}L

Where L = length of the cylinder = 250 mm

d = diameter of the cylinder = 100 mm

Therefore, Volume of cylinder $= \dfrac{\pi \text{ X } 100^2 \text{ X } 250}{4} = = 1.9634 \text{ x } 10^{-3}\ m^3$

The die is a frustum of a cone and is designed d, using similar triangles

$$\frac{70 + x}{100} = \frac{x}{30}$$

x=30 mm

volume of tapered die = volume of big cone – volume of small cone

$$=\frac{1}{3}\ \pi\ (r_1^2\ h_1 - r_2^2\ h_2)$$

$$=\frac{1}{3} \pi (50^2 \times 130 - 15^2 \times 30)$$

$$=3.33 \times 10^{-4} \text{ m}^3$$

Total volume of the Barrel = volume of the cylinder + volume of the tapered end

$$= 1.9634 \times 10^{-3} m^3 + 3.33 \times 10^{-4} m^3$$

$$= 2.2964 \times 10^{-3} m^3$$

Calculating the weight of mixture

Weight of mixture, W = mass of mixture x density of mixture

Mass of mixture = volume x density

density of mixture (assuming 20% moisture content)

$= (\rho_{jeft} \times \text{percentage in the mixture}) + (\rho_{sawdust} \times \text{percentage in the mixture})$

$=(1300 \times 0.7) + (267 \times 0.3)$

$=910 \text{ kg /m}^3$

Volume of mixture = volume of hopper + volume of barrel

$$= 2.235 \times 10^{-3} \text{ m}^3 + 2.2964 \times 10^{-3} \text{ m}^3$$

$$= 4.5314 \times 10^{-3} \text{ m}^3$$

The mass of mixture = volume of mixture X density of mixture

$$= 4.5314 \times 10^{-3} \text{ m}^3 \times 910 \text{ kg /m}^3$$

$$= 4.12 \text{ kg}$$

Therefore, weight of mixture = $m_{mixture} \times g$ = 4.12 kg x 9.81 N

$$= 40.45 \text{ N}$$

The shaft design:

The shaft is made of mild steel. The yield strength of the material in tension, S_{yt} = 770 N/mm^2 and ultimate tensile strength = 580 N/mm2.

Assuming the load is gradually applied, the combined shock and fatigue factor applied to bending moment, K_b =1.5 and combined shock and fatigue factor applied to torsional moment , K_t = 1.0

The permissible shear stress τ is taken to be 30% of the yield strength or 18% of the ultimate tensile strength of the material or whichever is minimum.
Therefore, τ = 0.3 X Syt = 0.3 (580) = 174 N/mm2

τ = 0.18 X Sut = 0.18 (770) = 138.6 N/mm2
and the lower is 138.6 N/mm2
Let d = diameter of shaft
M_t = torque transmitted by the shaft
P = power transmitted by the shaft (W)
N = rpm of the shaft
τ = permissible shearing stress
M_b = bending moment

A machine driven by a 0.37 kW, 1380 rpm electric motor driving the screw shaft at 480 revolutions per minute (rpm)

The power transmitted by shaft and the torque in the shaft are related according to Machine elements
P = M_t ω

$\omega = 2\pi N/6$

$P = (M_t \times 2\pi \times N)/60$

$M_t = (P \times 30)/(\pi N)$

The shear stress and transmitted torque are related as

$\tau = (16 M_{(t)} \times \llbracket 10 \rrbracket^{(-3)})/(\pi d^3)$

$M_t = (\pi \tau d^3)/16 \times \llbracket 10 \rrbracket^{(-3)}$ N/mm^2

Equating the two equations together

$d = 36.5 \times (P/(\tau N))^{0.33}$ mm

$d = 36.5 \times (370/(138.6 \times 480))^{0.33} = 6.6$ mm

Mt , the torque transmitted by the shaft

$M_t = (P \times 30)/(\pi N) = (370 \times 30)/(\pi 480) = 7.4$ Nm

Mb = 127, 306 N mm

Also, the diameter of the shaft can be calculated as follows

$$d^3 = \frac{16 \sqrt{(K_b M_b)^2 + (K_t M_t)^2}}{\pi \tau}$$

$$d^3 = \frac{16 \sqrt{(1.5 \times 127.306)^2 + (1 \times 7400)^2}}{\pi \times 138.6} = 6.5 \ mm$$

Use d = 20mm

Appendix B
Code:

Smartphone application code:

```
when ListPicker1 .AfterPicking
do   if    call BluetoothClient1 .Connect
                                   address ListPicker1 . Selection
     then set ListPicker1 . Elements to BluetoothClient1 . AddressesAndNames
```

```
when ListPicker1 .BeforePicking
do   set ListPicker1 . Elements to BluetoothClient1 . AddressesAndNames
```

```
when Clock1 .Timer
do   if    BluetoothClient1 . IsConnected
     then set Label1 . Text to " Connected "
          set Label1 . TextColor to
     if    not BluetoothClient1 . IsConnected
     then set Label1 . Text to " not connected "
          set Label1 . TextColor to
```

```
when Button1 .Click
do   call BluetoothClient1 .SendText
                            text " 1 "
```

```
when Button2 .Click
do   call BluetoothClient1 .SendText
                            text " 2 "
```

Arduino code:

```
int motor = 13;
int motorCUT = 12;
int motorSTCUT = 11;
int motorSOCUT = 10;

int star = 9;
int sto = 8;
int CUT = 7;

char value;

void setup() {

  pinMode(motor, OUTPUT);
  pinMode(motorCUT, OUTPUT);
  pinMode(motorSTCUT, INPUT);
  pinMode(motorSOCUT, INPUT);
  pinMode(star, INPUT);
  pinMode(sto, INPUT);
  pinMode(CUT, INPUT);

  Serial.begin(9600);
}
```

```
void loop() {

   if (Serial.available() > 0) {  // if the data came
    value = Serial.read(); // read byte

    if(value == '1'  ) {
       digitalWrite(motor, LOW);  // if 1, switch LED Off

    }
    if(value == '2') {
       digitalWrite(motor, HIGH); // if 0, switch LED on

    }
   }
 if (digitalRead(star) == LOW)
  {
    digitalWrite(motor, HIGH);
  }
  if (digitalRead(sto) == LOW)
  {
    digitalWrite(motor, LOW);
}

if (digitalRead(motorSTCUT) == HIGH)
  {
    digitalWrite(motor, HIGH);
  }

if (digitalRead(motorSOCUT) == HIGH)
  {
    digitalWrite(motor, LOW);
  }
```