Design And Fabrication of Needle Burner and Polymer Recycler

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(Received June 05, 2020; Revised June 15, 2020; Accepted June 16, 2020)

Abstract

Proper management of biomedical waste including burying, burning of polymers has been a growing global environmental concern and the problem is rising with an ever-increasing number of hospitals, clinic and healthcare laboratories. In order to curb or solve the problem for a long period of time, the development of a biomedical instrument was greatly considered. This paper deals with the design and fabrication of a workable reliable and durable polymer recycler and needle burner used for recycling of polymer waste and destruction of sharp objects. The design of the proposed model concentrated on heat transfer as the principle of operation and methods for fabrication involved cutting, welding, assembling and finishing during the fabrication process. Results showed that the burner could be used to burn sharp waste such as needle into harmless steel which may be used in other industries. It would help in better sharp waste management. It was also observed that the burner is a better sharp waste management technology than the traditional incinerator and land filling.

Keywords: *Needle Burner, Polymer Recycler, Syringe,Needle, Waste Management, Safety.*

1.0 Introduction

Disposal of medical waste is a growing global environmental concern and the problem is the rising with an ever-increasing number of hospitals, clinic and healthcare laboratories universally [1]. Medical wastes are being generated from health care establishments, medical institution, diagnostic laboratories, veterinary clinics, hospital and research institutions. This includes absorbents, sharp and needles, glass gauze, paper, plastics and human anatomical remains and animal carcasses [2]. It is a waste capable of producing infectious disease. Medical waste is extremely infectious and hazardous' which threatens environmental health. Therefore, it must be treated before its final disposal [3]. Medical waste constitutes a minor quota of the entire municipal solid waste. However, the potential environmental and health hazard could be dangerous if not properly handled [4]. In modern times, the removal of these unwanted materials that has posed more risks with appearance of disposable needles, syringes and polymer items [5] generated in the hospital is too dangerous to be treated and carefully managed. These wastes carry infections and pollute the immediate environment prevailing in the hospital [6] and as such, should be properly and specially cared for quite different from the municipal wastes [7].

It is a general knowledge that the re-use of syringes can cause the spread of infections such as AIDS and hepatitis. The collection of disposable medical items and its potential re-use without sterilization could also cause serious diseases [1].20% of the medical waste is hazardous and should be taken with utmost caution while the remaining 80% is regarded as normal municipal waste infectious and anatomic waste together made up about 15% of the total health care waste. Sharp are major sources of disease transmission and is just about 1% of the total waste' [8].

Recycling an utmost waste-management strategy, may be also known as an example of implementing the concept of industrial ecology, whereas in a natural ecosystem there are no wastes but only products [9]. Plastics recycling an important tool for eliminating environmental impact and resource depletion can reduce the use of energy and material per unit of output and thus enhance the yield eco-efficiency. Also, recycling, reduction; reuse; repair or re-manufacturing may permit a given

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level of product service with small material inputs than needed [10].

Wastes are unwanted or unusable materials. The United Nations Statistics Division (UNSD) on Environment described wastes as materials that are irrelevant in areas of production, transformation or consumption. These materials are generated during the extraction and processing of raw materials into intermediate and final products, consumption of final product and other human activities [11]. Waste includes all the items that people no longer have any use for, intent to get rid of or already discarded. Many technologies that have been employed to manage waste include incineration, source reduction, recycling and plastic biodegradability. Whereas paper, wood and other wastes may be burned in incinerators with minimum damage to the environment, incineration of plastic can result to emission of hazardous products and other pollutants [12].

Poor development of recycling products creates an issue. The usual way of disposing syringes after use was either by putting them in different types of bins, burning, incinerating or burying the same in the landfills without proper care[13]. The healthcare facilities in developing countries are undergoing the challenges of syringe handling and treatment after injection or used for the purpose of avoiding injuries and infections to healthcare workers, patients and people who scavenge through the municipal and medical wastes [14]. It is important to note that preliminary surveys as reported by [15] shows that, 'introducing a syringe burner and cutter should be considered by healthcare personnel as an additional part for solid waste management in their works [14]. The management of sharp discarded needles is the responsibility of health care institution whose health care workers (HCWs) routinely use them. In this setting, there are procedures and policies for the handling and disposal of sharp discarded needles which may expose waste workers to potential needle stick injuries and infection, since used needles can transmit diseases such as HIV and hepatitis B. Hepatitis B and C and human immunodeficiency virus (HIV) are the deadliest of 20 blood-borne pathogens. HIV infection is a chief threat in the workplace due to the serious consequences it has on the affected worker. Health Care Workers (HCWs) are increasingly at risk of getting blood-borne infections in their work through job-related factors like accidental needle-stick injuries (NSIs) and subcutaneous exposure to body fluids. NSIs are injuries caused by penetration of the skin by an injection needle.

2.0 Materials and Methods

2.1 Materials

The materials used are classified into electrical and mechanical appliance with specifications and quantity as presented in Table 1 and 2, respectively. Tools used to fabricate the designed needle burner and polymer recycler include measuring tape, lister generator (alternator) 220v, 32.2A, 60Hz, 1500R/min, Lincoln welding machine, 450watt 220v, filing or cutting machine 9 inch and 5-inch 250w, folding machine, harmer, earth cable and welding cable, hand saw, square rule, sprint level, welding electrode (mild steel), roller safety booths, leather welding glove and aluminum electrode gauge (size 12).

Table 1: Mechanical materials for needle burner and polymer recycler model.

S/No	*Materials*	*Quantity*	*Specification*
1	Mild steel metal plate	2	0.7mm, 4 by 4ft
2	Angle rod	1	1inch, 1.5mm
3	Pulley	2	
4	Spindle rod	1	130MM (Long)
5	Bearing	2	6205RS, 3.2×3.2 ×1(L×W×H) 0.04(kg)
6	Belt	1	0.5mm,
7	Aluminum stainless steel	1	1mm
8	Mild steel metal/electrode	½	0.8m
9	Bolts, nuts	4	8mm, $^1/_2$inch
10	Screw nut	8	Screw nut $^1/_2$inch
11	Rubber	4	$^1/_2$inch

2.2 Methods

2.2.1 Theoretical Framework

The designed needle burner and polymer recycler employs heat transfer as the principle of operation and it is based on two theoretical frameworks as fol-

Table 2: Electrical materials for needle burner and polymer recycler model

S/N	*Materials*	*Quantity*	*Specification*
1	Electric motor	1	Single phase, 220V, 250W, 400RPM
2	Dry element	4	1000watt x 4
3	LED (indicator circuit breaker) Red and green	2	220v, 3amp
4	Contactor	1	10amp
5	Fuse/box	2	10amp, 220v AC
6	Wire (white)	2	2.5mm
7	Power cord	1	5mm
8	Power plug	1	15amp
9	Electrical screw driver	1	1000v
10	Transformer	1	24v
11	Switch (off/on) Red	1	220v, 2.5amp
12	Wire (Red/Black)	2	2mm
13	Wire (Red/Black)	2	220v AC 3amp
14	Screw driver (electrical)	1	1000v

lows:

1. The principle of operation of polymer recycler is basically by heat transfer mechanism through convection which involves deviation and difference in temperature. The heat penetrates through the hopper. A thermostat is used to regulate the temperature. The element converts electric energy into heat energy.
2. The principle of operation of needle destroyer is basically by conversion of electrical energy into electrostatic energy or heat to burn the needle. The secondary terminal of the transformer is connected to the electrode plate separated from each other. The needle is inserted to bridge the two-electrode plate metal together thereby causing electrostatic energy or spat in the form of heat that burn the needle.

2.2.2 Design Specification

The design employed heat transfer mechanism in the circulation and distribution of heat. The materials used can withstand and withhold heat for maximum heat impact. It is made of the electrical aspect and burning chamber: the electrical components were connected to the element that produced heat to burning chamber. The burning chamber or the hopper is where the polymer materials is being burnt or recycle, from hopper it flows into container through the outlet. The electrical energy was obtained from alternating current (AC) and converted to electrostatic energy (heat).

The materials used are the quality that can withstand and withhold the flow of current. The insulator attaches with the metal to insulate the flow of current. It is constructed with the use of electrical section connected with the burning chamber. The electrical section comprises of power transformer, electric heat resistance wire, etc.

Power Unit: The voltage supplies from the main (220V – 230V) flowed to power unit; it uses alternating current (AC). The source voltage is 220V AC at 50Hz, electric motor single phase, 400 rmp, 250 watts, dry element (4) connected as single phase, 400 watts and transformer step down the voltage to a lower value of 24V AC.

Choice Values: Electric motor 220V, 50Hz, 400 rmp, 250 watts, Element (4) 1000 watt, 220V, LED AC 220V – 15amp (2), contactor switch 10amp. Transformer – primary transformer voltage 220V, 50Hz, secondary transformer 24V, 73VA.

Heating Element: A heating element that have 220V with 1000-watt x 4 specified heat capacity was used to convert electrical energy into heat energy through the process of resistance or joule heating electric current 4.35A. passing through the element encounters resistance, resulting in heating of the element. This process is independent of the direction of current flow.

Casting: The device was wrapped with mild steel metal of 0.88mm.

Vent: This was achieved by perforation.

2.2.3 Electrical Connection

The elements were connected in series inside the hopper. The electric motor was connected to the spindle rod via pulley and belt. The transformer is also connected separately. The top panel contains the four indicators, two red and two green LED. Contactor or circuit breaker and OFF/ON switch, two fuse, power cord and 15amp plugs were also connected.

The machine is divided into two parts:

In the Polymer recycler section =

Power cord is connected with 15amp plug. The power cord is connected in series to the two fuses, from the fuse wire is connected to the OFF position of the circuit breaker and red LED. Wire is also used to connect from the ON position of the circuit breaker and the green LED to the elements and motor.

In the needle burner section =

Wire was used to loop from the OFF position of the circuit breaker to the off position of the switch and red LED. Wire is connected from the ON position of the switch and the green LED to the primary coil of the transformer, from the secondary coil of the transformer and green LED to the metal were the needle will be burned by using the needle to bridge the metal.

2.2.4 Design Models

The design models employed for size hopper, heating chamber power driver system, heat or energy supplied, heat element and heat transfer through the hopper are presented in sub section 2.2.3.1 – 2.2.3.6.

2.2.4.1 Design of the hopper size

The hopper shape is a pyramidal fulcrum with a base capacity of 40m³ with feed hopper diameter and outlet hopper diameter of 0.08 and 0.03m, respectively. The height of the hopper (H) was evaluated using the equation (2.1).

The volume of pyramidal (Vp) could be expressed as

$$Vp = 1/3H(D^2 - d^2) \quad (2.1)$$

Rearranging the equation (2.1) gives equation 2.2

$$H = \frac{3Vp}{D^2 - d^2} \quad (2.2)$$

where H, Vp, D and d represents height, volume, feed diameter and diameter of the hopper respectively.

2.2.4.2 Heating chamber, syringe recycler and metal/needle sections.

The capacity of the heating chamber V_H was considered to be 5% of the hopper capacity as represented in equation (2.3)

$$V_H = \frac{5}{100} x\, Vp \quad (2.3)$$

The capacity of the syringe recycler section Vsr was designed to be three quarter of the hopper capacity as presented in equation (2.4)

$$V_{sr} = \frac{3Vp}{4} \quad (2.4)$$

The capacity of the smelt needle section (Vsn) is represented by equation (2.5)

$$V_{sn} = Vp - Vsr \quad (2.5)$$

2.2.4.3 Power required for drive machine

The AC motor drive was used to drive the designed syringe recycler and smelt needle machine at a speed of 400rpm. The power required for the AC motor drive is given by equation for the AC motor drive (2.6)

$$P = P_{ST} + P_H + P_N \quad (2.6)$$

where Pst, P_H, P_N are startup power of the material, screw driving power at the load and inclination power of the conveyor.

The power required to start the system can be evaluated using equation (2.7) as given by ref

$$P_H = m_f L\lambda g \quad (2.7)$$

where m_f, L, λ and g represents mass flow rate, length of the wire, progress resistant coefficient and acceleration due to gravity (9.8m/s²).

The power required to drive the rotary blade screw at no load is evaluated using equation (2.8) (ref)

$$P_N = \frac{DL/m_f W_2 L_2}{20} \quad (2.8)$$

where m_f, W^2, L^2 are

The power acquired as a result of inclination (P_{ST}) can be evaluated using equation (2.9) (ref)

$$P_{ST} = m_f \lambda g \quad (2.9)$$

2.2.4.4 Heat supplied for fusion

The heat supplied for melting the syringe and needle can be determined using equation (2.10) (ref)

$$Q = mc\,\Delta T \quad (2.10)$$

where Q, m, c and ΔT are amount of heat supplied to melt syringe and needle quantity of the syringe and needle, specific heat capacity of the syringe and needle and temperature change i.e. from room temperature to melting point.

The melting time or period can be determined using equation (2.11)

$$t = Q / iv \qquad (2.11)$$

The power supplied to heating element

$$I = I1 + I2$$

$$I2 = I3 + I4$$

$$I = I1 + I3 + I4$$

2.2.4.5 Power heating element

The power supplied to the heating element can be evaluated by equation (2.12) ref

$$P_h = V^2 / R = I^2 R \qquad (2.12)$$

where P, V, R and I are power, voltage supplied, resistance of wire and current supplied respectively

Since the quantity of work done to melt the syringe and needle is equivalent to the energy of the heating element. The melting time can be evaluated using equation (2.13)

$$Q = Pt$$

$$And \; t = Q / P \qquad 2.13$$

2.2.4.6 Current required for designed recycler syringe and needle.

Hence the current required to melt the syringe and needle can be determined using equation (2.14).

$$I = \frac{P}{V} = \frac{Q}{T} \qquad (2.14)$$

The current required by AC motor to drive is given by equation (2.15).

$$I = \frac{P}{V} \qquad (2.15)$$

The total current (I) for designed recycled syringe and smelt needle based on figure 4.1 is given by equation (2.16)

$$I_T = I_1 + I_2 \qquad (2.16)$$

2.2.4.7 Heat transfer rate to the hopper

The heat transfer to the heating element is by conduction and it is given by equation (2.17)

$$Q_h = KA \frac{T1 - T2}{X} \qquad (2.17)$$

$$= KA \frac{\Delta T}{X}$$

where Q_h and K are the amount of heat transfer in joules and thermal conductivity of the hopper makeup of mild steel in w/mk. T_1, T_2 and X represents the initial temperature and final temperature of temperature difference and thickness of the hopper. A is the surface area of the hopper.

Figure 1: Inside the machine before welding

2.2.4.8 The input parameters for the design

The impact parameter for the design are presented in Table 3

Table 3 Input Parameters

S/N	*Parameters*	*Value*
1	L (m)	1.5m
2	λ (m)	
3	G (m/s^2)	9.8m/s^2
4	P_H (W)	2300W
5	Q (KJ)	1187.5KJ
6	t (Sec)	516 sec
7	K (J/km)	79,617.8J/km

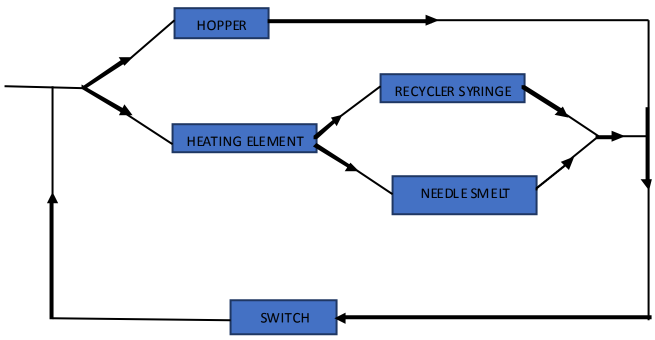


Figure 2 The block diagram for the proposed model

2.2.5 The block diagram for the proposed model

The block diagram is depicted in Figure 1.

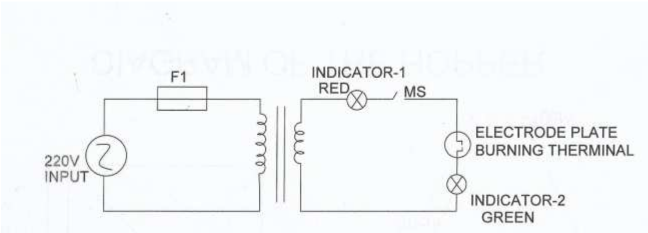


Figure 3: The circuit diagram of the needle burner

2.2.6 The circuit diagram for the proposed model

The circuit diagram is illustrated in Figure 3.

2.2.7 Fabrication Process

The fabrication process is broadly divided into the following:

- Cutting
- Welding/Bolting
- Electrical works
- Assemblage
- Finishing and Painting

Cutting: This is the first stage of fabrication after the dimension has been taken. The metal and the angle bar iron were cut into sizes using electric cutler.

Welding/Bolting: Welding is a fabrication process that join materials together usually metal by causing coalescence. This process was achieved by using a lister generator to power the arc welding machine. Arc welding is a fusion welding process in which the heat is obtained from the electric arc between the electrodes. The electric arc is produced when two conductor of an electric circuit or the cathode and anode wire with the electrode are touched together. The anode lead from arch field is placed on the metal until the cathode is used to hold the electrode; the cathode electrode is used to touch the metal to produce the lead used for welding.

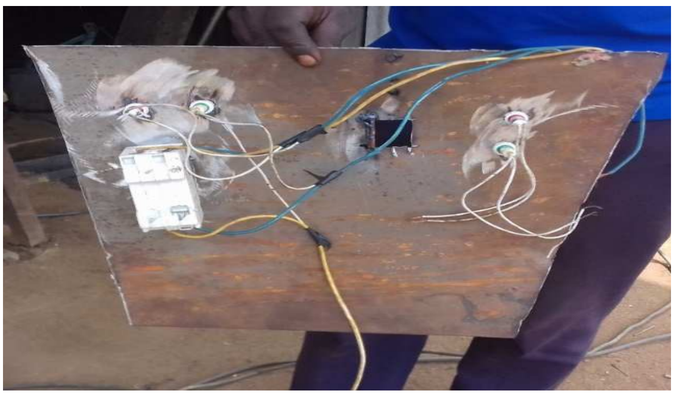


Figure 4: Connection of some electrical component

Figure 5: Top View of the Machine Before Painting

Figure 6: Side View of the Machine

Figure 7: Front view of the machine

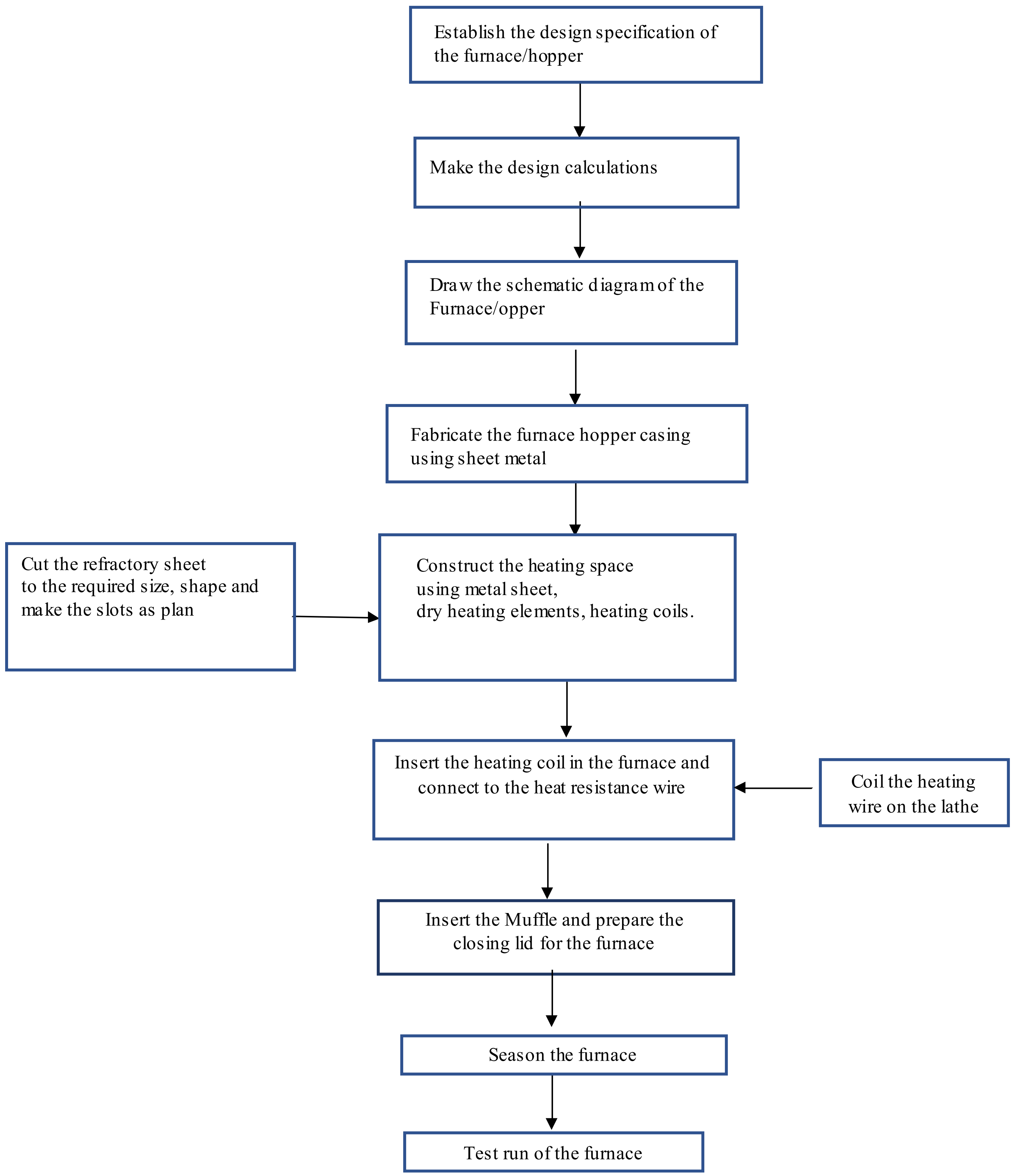


Figure 8: Workflow in the Fabrication Process of the Furnace

2.3 Safety Consideration

1. The metal used are properly painted with rust proof paint
2. The equipment was earthed properly to avoid shock
3. The cables were highly insulated with heat resistance wire used to avoid burn and for shock prevention.

3.0 Results and Discussion

3.1 Results

The developed model of the needle burner and polymer recycler are presented in dimensional view as shown in Figure 3.1.

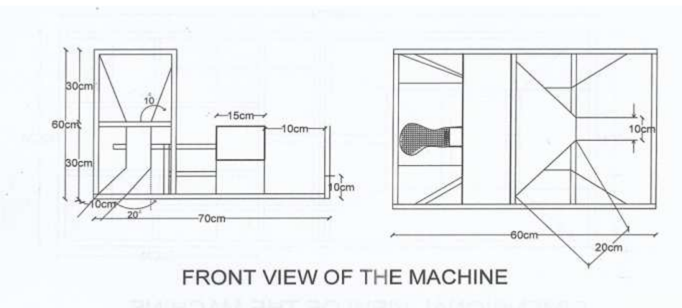


Figure 9: Measurement and Frontal View of the Machine

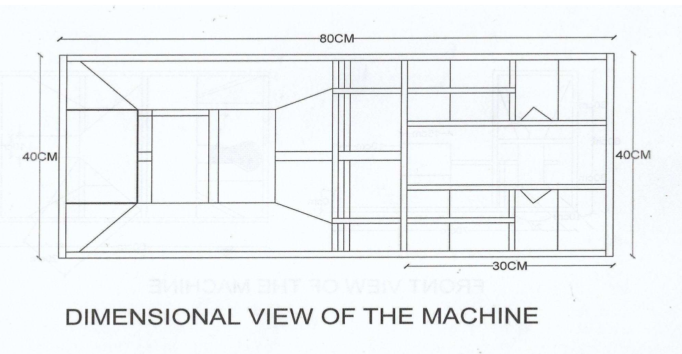


Figure 10: Olan View of the Machine and its Measurement

3.1.1 Polymer Recycler

The polymer recycler machine was fabricated and tested in order to evaluate its performance. The available non-biodegradable polymer materials were sorted and shredded not washed. The machine was powered for the operation and the heating elements were turned on. The waste polymer material (polyethylene)were introduced into the machine via the hopper, the temperature between 25˚c to 140˚c was observed, as the material or pelletized material exist the chamber in droplet form at the outbound water bucket.The following experimental result was obtained from the test conducted on the machine.

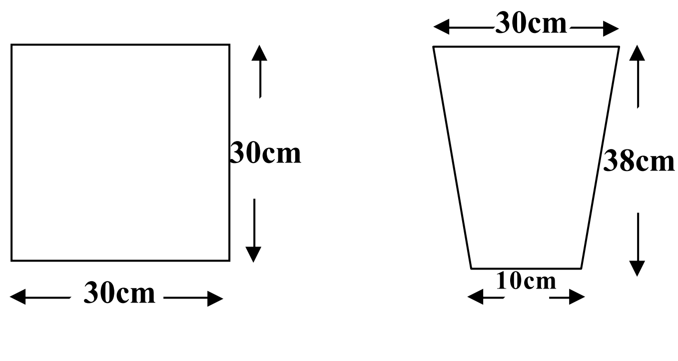
Table 4: Experimental Test Result

Trial	*Procedure*	*Temp*	*Result/Observation*
1	At room temperature	25˚C	There was free flow; the screw thread conveyed the material to the end of the hopper.
2	The hopper was heated and the material was fed into the hopper.	70˚c	The material achieved molding.
3	The temperature of the hopper was increased to carry out the test.	110˚c	The material melted and began to flow out.

3.1.2 Needle Burner

The needle burner with transformer power ranging between 220V – 230Volts was used. The fabrication burner worked with a satisfactory level of safety. It can burn needles ranging from 2millimetre(ml) to 20millimetre(ml). The needle burner burns one needle at system performance per time. The performance of the machine described the rate at which the machine operates. It is an expression of how many needles the machine can safely burn, 1needle in 5sec, the performance of the machine equals 12needles per minute.

3.1.3 Design Analysis



1. Vp = 1/3 (D 2 -d)
From the given diagram and data
D=30cm =0.30m
d = 10cm = 0.10m
H = ?
Using Pythagoras

2. $H^2 = 0.38^2 - 0.10^2$
=0.14 – 0.01
=0.13
H = √0.13 = 0.36
. Vp= $^1/_3$X0.36 $(0.30^2-0.10^2)$
= 0.12(0.09-0.01)
=0.12 (0.08)
=0.00967m3
=$9.69X10^{-3}$ m^3

3. $V_H = 5\%V_p = {}^5/_{100}$ X $9.67X10^{-3}$
= $4.84X10^{-4}$ m3

4. Vsr = ¾ Vp = $^3/_4X9.67X10^{-3}$
= $7.25X10^{-3}$ m3

5. Vsr = Vp - VSr = $9.67X10^{-3} - 7.25X10^{-3}$
=$2.42X10^{-3}$ m^3

6. Q = mcΔT
=25X500X (120-25)
=25X500X95
=1,187,500J
=1,187,5KJ

7. t = Q / P
T = 1,187.5 x 1000 / 10 x 230
= 516 Sec

8. Ph= V2/R = 1^2R =IV
= 10 X 230
= 2300 W

9. Qh =KA $(T_1 - T_2)$ / X
But:
A = D2 π/4 = 3.14 X 10^4
X = 0.002m
Qh = 1,187.5kJ
$T_1 - T_2$ = 95K
Hence,
1,187,500 = K314 x 10^{-4} x 95 / 0.002
K = 0.002 x 1187500
3.14X10-4 X95
= 79,617.8 J/km

3.1.4 Design parameters for needle burner and polymer recycler

The design parameters obtained using equations (2.1) to (2.17) are presented in Table 5.

Table 5: Values of Derived Designed Parameters of Needle Burner and Polymer Recycler

S/N	*Parameters*	*Values*
1	H (m^3)	$9.69X10^{-3}$ m^3
2	V_H (m^3)	4.84 X 10^{-4} m^3
3	V_{SR} (m^3)	$7.25X10^{-3}$ m^3
4	V_{SN} (m^3)	2.42 X 10^{-3} m^3
5	Q (KJ)	1,187.5KJ
6	t (sec)	516 Sec
7	P_H (W)	2300W
8	K (J/Km)	79,617.8J/Km

3.2 Discussion

An injection needle contains steel and needles; the plastic head is about 31% while the steel is 69%. Therefore, for every injection needle disposal should conform to both the steel and plastic disposal standard. From the results of the experiment conducted on the needles, the machine at an average of 7.5% retention and 92.5% passing efficiency. The dimensioned view, isometric view, exploded view and fabricated polymer machine, thefabricated machine was evaluated for performance using plasticwaste. Table 3.1show the result of the results obtained, the three tests were carried out consecutively different quantities of plastic waste were collected, weighed and the that food waste has the highest percentage composition of household solid waste generated. Apart from food waste with approximately percentage composition of 75%, plastic and rubber waste have percentage composition of 10%, paper waste (6%), metal waste (3%), glass waste (4%) and other waste (2%). The proportion of food waste generated in Sapele (75%), Nigeria can be compost through AD process rather than disposed of that has negative impact on the environment. These options, if fully exploited would greatly reduce the quantity of solid waste disposed and also solve part of Nigeria energy crisis.

4.0 Conclusion and Recommendation

4.1 Conclusion

The polymer recycler and needle burner were designed and successfully constructed. This was aimed at solving the problems of indiscriminate dumping of waste. The machine was evaluated for performance waste collection, needles were shredded and burnt with the machine and the result obtained reveal that the machine performance is satisfactory. The machine when commercialized will meet the demand for polymer recycler and hospital sharps (needles) waste management. The feasibility of using an appropriate technology (needle burner) for the sharps waste management was explored. As previously mentioned, the sharp waste especially needle is one of the most hazardous health care wares, as it can easily transmit disease. Although control measures have been widely applied to dispose needles, the technique more or less helps in managing needle disposal as it converts it to a harmless product that can be easily separated and to produce an entirely new different thing. Comparing with old tradition of landfill or incineration, it does not require a large area of land for the disposal rather a small equipment and electricity to power it.

Nigeria has poor waste management policy. Household solid waste generated from Nigerian homes are discharged into street, market, gutter, road side, adjoining streams etc. due to poor implementation of standards, thus causing environmental and public health hazards. The results obtained from this waste survey shown that food waste has the highest percentage composition of household solid waste generated. Apart from food waste with approximately percentage composition of 75%, plastic and rubber waste have percentage composition of 10%, paper waste (6%), metal waste (3%), glass waste (4%) and other waste (2%). The proportion of food waste generated in Sapele (75%), Nigeria can be compost through AD process rather than disposed of that has negative impact on the environment. These options, if fully exploited would greatly reduce the quantity of solid waste disposed and also solve part of Nigeria energy crisis.

4.2 Recommendation

This is recommended for hospitals, health care centers, pharmacies or other organization that handles sharps such as needles and polymers such as syringes. What happens to the final waste; the final waste is properly treated and used to recast new needles. Further studies can be carried out to explore any recycling value of the product of my work.

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