DESIGN AND FABRICATION OF COMBINED ELECTROMAGNETIC AND MAGNETIC DRUM-BELT CONVEYOR SEPARATOR

Ajibola O.O.*[1], Adebayo A.O.[1], Borisade S.G.[1], Oladimeji H.T.[1], Oluwalana E.[1], Daramola M.P.[1], Adeleke A.E[2], Omoyeni D.O.[3]

[1]Department of Materials and Metallurgical Engineering, Federal University Oye-Ekiti, Nigeria
[2] Department of Mechanical Engineering, Federal University Oye-Ekiti, Nigeria
[3] Department of Mineral and Petroleum Resources Engineering Technology, Federal Polytechnic, Ado-Ekiti, Nigeria
*Corresponding Author email: olawale.ajibola@fuoye.edu.ng

ABSTRACT

Mineral processing operations are faced with many challenges which include effective separation of unwanted materials generated through the extraction process from the bulk material. Magnetic device is a machine used for separating magnetic materials from non-magnetic materials by inducing the magnetic flux. Magnetic and electromagnetic separators are widely used as primary separation equipment. This work was centred on the design and construction of a laboratory-sized dual purpose magnetic and electromagnetic separator for separating the magnetic particles from the rest of the bulk mineral or ferrous materials from foundry sand in a single system. The main components of the equipment include: the hopper, conveyor belt rotating drums, pulley and belt, electromagnet. The approaches to achieving the result reported include the design conceptualization, design calculation, design drawing using the AutoCAD and Inventor software, fabrication and assembly of components. The evaluation showed that electromagnetic separation is more efficient than magnetic separation. The equipment was fabricated at an average cost of 224,000:00 naira.

Keywords: Drum-belt conveyor, electromagnet, fabrication, magnet, separator
DOI: https://doi.org/10.54043/laujet.2021.15.02.06

1.0 Introduction

Among the challenges of the solid mineral mining, ore beneficiation, chemical and food processing industries are the efficient and effective separation of unwanted materials generated during the extraction process from the valuable materials (Gaudin, 2016). Magnetic separation is principled on the magnetic property or susceptibility of a mineral in a mixture. Magnetism is a phenomenon that makes a material or mineral to be attracted to or repelled under a certain magnetic pole. The magnetic behaviour of materials can be classified as: ferromagnetism, diamagnetism and para-magnetism (Allen, 1980; Spaldin, 2011). These attributes could be either permanent or induced. To exploit either of these behaviours, a permanent magnet or an electromagnet is employed. Both have similarities in separation, though, may be also different in some other instances. It is possible to induce certain amount of magnetism or magnetic flux on a material and makes it behaves as a magnetic material as long as it is under such influences of magnetically controlled force (John, 1992).

Magnetic mineral deposits in Nigeria include iron ore and wolframite. Itakpe in Kogi State has been established to have the purest deposits of iron ore, meanwhile other states where iron ore is deposited include: Anambra, Abia, Benue, Kwara, Bauchi, Plateau and Nasarawa (Thomas *et al.,* 2019). Iron ore is the main material in pig iron production and subsequently, steelmaking for automobiles, ships, structural beams used in building and other applications. (finelib.com). Wolframite (Fe,Mn)WO_4 is the chief ore of Tungsten. It is made up of Iron and Manganese, and Tungsten minerals. It can be found in the Northern parts of Nigeria such as Kano, Kaduna, Bauchi, Plateau and Niger States (Gebi *et al.,* 2016). The areas of applications include electric filaments and armour-piercing ammunition. It is also used widely in the making of glass-to-metal seals (Srinivas and Natarajan, 2000).
Separators are widely used for concentration in the mineral processing, mining, food processing, paper manufacturing, pharmaceutical and chemical engineering (Zhu *et al.,* 2021; Wołosiewicz-Głąb *et al.,* 2016; Li *et al.,* 2011; Fan *et al.,* 2015; Eskibalci *et al.,* 2012; Styriakova *et al.,* 2006; Liu *et al.,* 2021; Omran *et al.,* 2014; Tripathy *et al.,* 2014; Ozturk *et al.,* 2020 and Watson, 1994). Either magnetic separators or electromagnetic separators are usually placed at the beginning of production line to remove tramp metals before it could cause harm to "downstream" equipment such as ore crushers and

conveyor belts, which can be easily damaged by sharp objects. Beside the magnetic nature of the particles to the separated, magnetic flux, strength, intensity and field of the electromagnet/magnet play most essential role in the separation. The strength or intensity of a coil magnetic field depends on the factors such as the number of turns of wire within the coil, the amount of current flowing in the coil and type of core material. An electromagnet loses its magnetic power every time an electric current is removed and becomes magnetic once again when the electric field is introduced. Contrarily, if a permanent magnet loses its magnetic properties, it will be rendered useless and its magnetic properties can be only recovered by re-magnetizing (Papiewski, 2018).

Magnetic separators and electromagnetic separators are seldom available in most research centres around. Whereas, cottage industries need either to process ores (such as iron ore) and metal scraps much available in our local areas. Reports have shown diverse developments in magnetic and electromagnetic separation methods: in food processing, (Zhu *et al.,* 2021); using fairly dilute, low-cost and low-viscosity water-soluble ferromagnetic fluids (Walker and Devernoe, 1991); An innovative superconducting magnetic separator design for kaolinitic clay in Brazil and Germany (Watson, 1994); modeling and optimizing dry high intensity magnetic separator for separation of hematite minerals (Tripathy *et al.,* 2014); recovery of boron minerals (colemanite and ulexite) based on electrostatic properties difference and influenced heat treatment (Eskibalci *et al.,* 2012); alteration of the microwave parameters on the magnetic properties of iron ore (Omran *et al.,* 2014); thermodynamical manufacture of magnetic manganese ferrite ore (Liu *et al.,* 2021); combination of bioleaching processes with electromagnetic separation to enhance the quality of feldspar raw materials recovery (Styriakova *et al.,* 2006); separation density exploitation technique for dense medium cyclones by magnetic field application (Fan *et al*., 2015); applying high gradient superconducting magnetic separation (HGSMS) system to recover the ultra-fine red mud particles (<100 lm) into high iron and low iron content parts (Li *et al.,* 2011); while Wołosiewicz-Głąb *et al.,* (2016) had fabricated an inventive electromagnetic mill that provided a significant reduction of energy consumption and higher technological performance as compared to conventional mills.

The current work incorporates principles and ideas emanating from the above mentioned literatures to conceptualise and design this dual purpose magnetic separation machine reported in the paper.

This report forms part of large project on the design and fabrication of some basic equipment for mineral processing and metal extraction for cottage industries in Nigeria (Ajibola *et al.,* 2020 and 2021). It aims at the design and construction of a laboratory-sized dual-purpose magnetic/electromagnetic separator. The dual purpose separator will enhance understanding mineral processing, material separation, plant design and appreciation of basic engineering practices.

2.0 Methodology

The approach to the design and fabrication is based on the concept of magnetic separator, principle of operation, features of the magnetic or electromagnetic separator, and design parameter calculations.

2.1 Concept of Magnetic Separator

The separator is designed to accommodate both magnet and electromagnet segment to facilitate the separation of the mineral of interest from the gangue. It comprised of a hopper, a conveyor belt (to aid in conveying the minerals to be separated), an electric motor (prime mover), two containers for mineral collection and two drums that move the conveyor belt.

The work incorporates the engineering design calculations, design drawings using AutoCAD and INVENTOR software; fabrication and test running. The machine is designed as rotating drums-belt conveyor type; for the separation of magnetic particles from non-magnetic particles due to the existence of a magnetic or electromagnetic flux. Magnetic particles are attracted to the magnet/electromagnet during the rotation of the drums, while non-magnetic minerals will be separated out under gravity and the magnetic field will disappear after disconnecting the electromagnet, the magnetic minerals fall due to gravity on the moving belt conveyor. The machine combines both the magnetic and electromagnetic separators in a single unit that reduces the cost of buying/importing the machine at a higher price and also saving the foreign exchange of the nation. The production cost is about 224,000.00 naira

2.2 Principle of Operation

The material is fed through the hopper and falls onto the conveyor belt in motion; then the material comes in contact with the magnetic or electromagnetic field. The magnetic minerals are magnetized to a magnet or electromagnet. The non-magnetic minerals flow through the magnetic region and are discharged into the collector. After the collection of the non-magnetic materials, the magnetic field disappears when the current is turned off. Therefore, the magnetic materials are demagnetized onto the revolving belt and after leaving the magnetic region they are discharged freely into another collector being provided. This principle of operation is in a batch process. Choice of an ideal separator depends on several factors such as materials flow and flow rate, particle grains, pre-treatments, belt surface area and rotating speed (Tripathy *et al.,* 2014; Fan *et al*., 2015; Wołosiewicz-Głąb *et al.,* 2016)

2.3 Design Features of the Magnetic and Electromagnetic Separators

The following features are essential in the design of a separator that will combine both magnetic and electromagnetism in a single unit: The hopper that serves as channel for materials to be fed into the machine with an electric motor to driven belt conveyor to move the materials to the magnetic zone of the machine. The coil of the electromagnetic separator is specially made of material with good oxidation and corrosion resistance, thus ensuring the heat transferring capacity and insulation performance of the coil with big magnetic penetration depth and strong suction force. The separator has low energy consumption and stable performance with compact structure. The magnet and electromagnet are easy to install and maintain. The dual-purpose separator operates in a batch process.

2.4 Design Parameter Calculations

All component dimensions and specifications are calculated and derived based on scientific principles of mechanics of machines and magnetism as illustrated in equations (1) to (24).

2.5 Mineral feed hopper design

The magnetic/electromagnetic separator consists of a prism hopper with a cylindrical hollow pipe tapered at one end for even distribution of materials. The repose angle of the solid material product on mild steel is 35° (Wondra, *et al.,* 1995). Inclination angle is greater than the product repose angle which allows total product migration from the front and side faces loading bucket are into the feed throat (Erameh and Adingwupu, 2019). The volume of the feed hopper is determined using equations (1) to (3.2) derived from Adetunji and Quadri (2011)

$$V_{frustum} = V_b - V_s \quad (1)$$

where $V_{frustum}$ is volume of inverted frustum prism, V_b is volume of big inverted pyramid and V_s is volume of small inverted pyramid.

Volume of rectangular base pyramid is

$$V_{pyramid} = \frac{lwh}{3} \quad (1.1)$$

$$V_{\text{frustum}} = \frac{l_b w_b h_b - l_s w_s h_s}{3} \quad (1.2)$$

Where ***l*** is base length, ***w*** is base width and ***h*** is the pyramid height

For the cylindrical hollow pipe, the surface area A of the discharge orifice (cylindrical in shape) is given by;

$$A = \pi r^2 = \frac{\pi d^2}{4} \quad (2)$$

where $r = \frac{d}{2}$

Volume of pipe,

$$V_p = \pi r^2 \, l_p \quad (3)$$

Total volume hopper

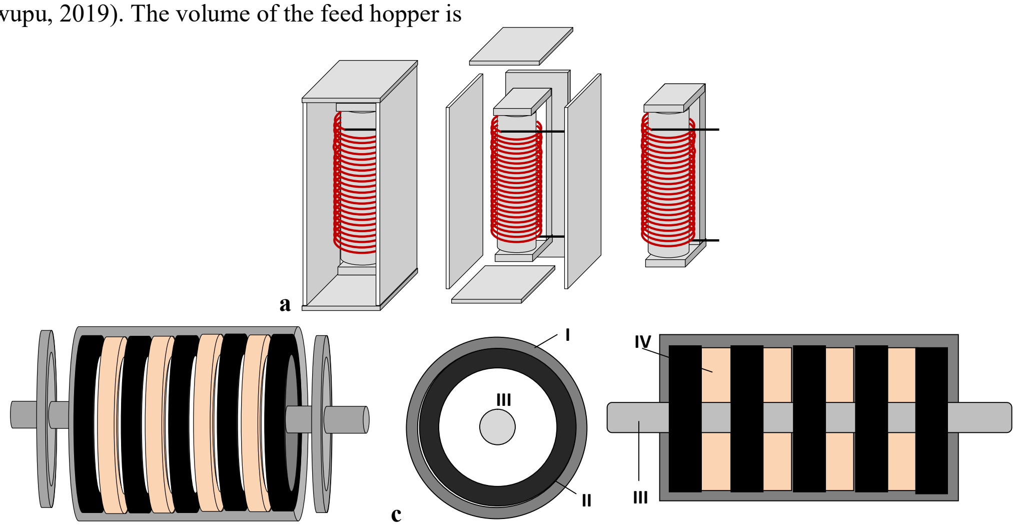
$$V_H = V_f + V_p \quad (3.1)$$

$$V_H = \frac{l_b w_b h_b - l_s w_s h_s}{3} + \pi r^2 \, l_p \quad (3.2)$$

r = radius of cylindrical pipe discharge orifice, $\boldsymbol{l_{pipe}}$ is length of cylindrical pipe, **π** is constant

2.6 Electromagnet and Magnetic drum designs

Figure 1 illustrates the cross sections of the electromagnet and magnetic drum components of the separator.



i -Steel case, ii - round bar magnet, iii -shaft rod, iv - porous lagging material

Figure 1: (a) electromagnet and (b & c) magnetic drum components of the separator

2.6.1 Electromagnetic separation

The magnetic field strength for an electromagnet is obtained using Equations (4) and (5) (Olson, 2018); for a coil of wire:

$$H = \frac{I \times N}{L} \quad (4)$$

For a straight conductor

$$H = \frac{I}{2\pi r} \quad (5)$$

where: H = the magnetic field strength in ampere-turns/meter (**At/m**),N = the number of turns of coil, I = the current flowing through the coil in amperes (**A**), L = the length of the coil in meters (**m**).

The equations (6) to (8.1) were used to calculate the force between a solenoid and a piece of a ferromagnetic material separated by a gap of distance (g) (Iwai, 2012).

$$F = (F_m)^2 \mu_0 \frac{A}{2g^2} \quad (6)$$

$$F = (NI)^2 \mu_0 \frac{A}{2g^2} \quad (7)$$

where: Permittivity (μ_0) = $4\pi \times 10^{-7}$, F is the force (Newtons), F_m is electromagnetic force, N is the number of turns (coils), A is the area, I is the current in Amperes, g is the distance between the solenoid and the piece of metal,

For an electric current induced magnetism;

$$\text{Power, } P = IV \quad (8)$$

Considering the power factor (PF) of the material used;

$$PF = \frac{true\ power}{apparent\ power} = \frac{W}{VA} \quad (8.1)$$

where true power in Watts, and apparent power (VA)**,** V is Volts, and A is ampere,

2.6.2 Permanent magnet bars drum

The magnetic drum composes of steel case that embeds set of round permanent magnet bars spaced with intermittent porous plastic partitions to fix the round magnets in position (Figure 1b and c).

2.7 Drum speed, belt and pulley design

Consider the big pulley (P_1) at the upper shaft nearer to the electric motor, the size of the shaft depends on the shaft-hole diameter of the large pulley. Also, for the small pulley (P_2,) the size of the electric motors' shaft depends on the shaft-hole diameter of the small pulley. The relationship in Equation (9) determines the transmitted speed. (Burr and Cheatham, 2002)

$$\frac{n_2}{n_1} = \frac{D_1}{D_2} \quad (9)$$

n_1 = speed of the driver pulley, n_2 = speed of the driven pulley, D_1 = diameter of the driver pulley, D_2 = diameter of the driven pulley.

2.8 Conveyor Belt Design

The purpose of the conveyor belt is to transfer the minerals from the hopper to the magnet and electromagnetic regions while the pulley belt conveys energy transmitted from the electric motor to the drums to move the conveyor belt (Figure 2). Equations (10) and (11) are used in calculating the conveyor length in the design of the belt (Khurmi and Gupta, 2005).

$$L = \pi/2\,(D_1 + D_2) + 2C + \frac{(D_1 + D_2)^2}{4C} \quad (10)$$

Since the diameter of the drums are the same in this case, (10) may be simplified further;

$$L = (\pi D) + 2C + \frac{(D)^2}{C} \quad (11)$$

D= the diameter of drum, C is the centre distance, L is belt length (Table 1)

2.9 Power pulley belt design calculation

The method applied for the selection of belt is to rate the standard thickness of belt in power capacity per unit length of the width at different velocities.

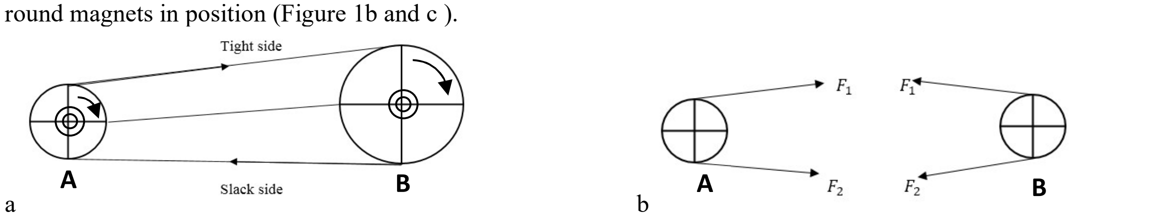


Figure 2: (a) Tight and slack side of belt tension and (b) force exerted by the belt.

The thicknesses of the belt and corresponding values of power capacity per unit length of the belt are selected from the standard belt table. The latter is divided into the required power and multiplied by service factors to give the required belt width. The belt is selected based on the nature of the load it carries, type of driving unit, horsepower rating, the speed of the driver and driven units and the plant layout.

$$kW = HP \times [0.746]\ Kw \quad (12)$$

where Power required (kW), design horse power (in HP) and 0 .746 is constant

From standard tables, service factor = 1.25

For driver speed of 1430 rpm, type *Ax*-belt is selected

2.10 Calculation of torque acting on the shaft

When forces are exerted on the shaft of the machine, both of the belt sides are in tension (Figure 2). The net force F_N, exerted by the belt on the shaft can be determined in equations 13 to 14 (Cornish, 1991).

$$F_N = F_1 + F_2 \quad (13)$$

where, F_N is the net force, F_1 is the tight side tension of the belt, F_2 is tension on the belt slack side.

Considering the two pulleys; the torque T_A, acting on the pulley "A" was calculated using equation (14):

T_A = force × radius of pulley "A"

$$T_A = (F_1 + F_2)\left(\frac{D_A}{2}\right) \quad (14)$$

Torque T_B, acting on the pulley "B", T_B was calculated from equation (15):

$$T_B = (F_1 + F_2)\left(\frac{D_B}{2}\right) \quad (15)$$

The magnitude of the net driving force is computed from the torque transmitted in equation (16) (Cornish, 1991).

$$F_N = \frac{M_t}{D/2} \quad (16)$$

Combining equations (13) and (16) yields

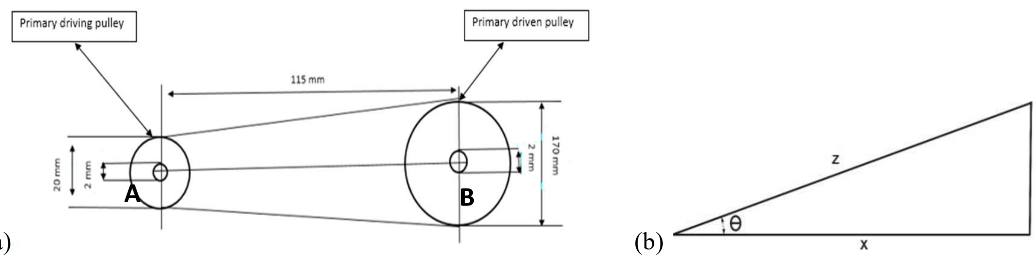
$$F_1 - F_2 = \frac{M_t}{R_2} \quad (17)$$

$$M_t = R_2\,(F_1 - F_2) \quad (18)$$

where, M_t is Torsional moment on the shaft, F_1 is tight side tension, F_2 is Slack side tension and R_2 is Radius of driven pulley.

2.11 Determination of centre distance

The equation for the calculation of the pulley belt shown in Figure 3 is presented as follows:



(a) (b)

Figure 3: (a) Schematic diagram of the pulley system and (b) resolving the forces on the pulley system

The pulley belt length is calculated using equation (19) and (20)

Using Pythagoras theorem

$$Z^2 = Y^2 + X^2 \quad (19)$$

$$BL = \frac{\pi}{4}(d_1 + d_2) + 2Z \quad (20)$$

where BL is belt length , d_1= diameter of the primary driver pulley, d_2 = diameter of the primary driven pulley.

2.12 Bearing Pillow Calculation

The approximate rating (or service) life of ball or roller bearings is based on the fundamental equation (Shigley, 2007)

$$L_b = \left\{\frac{C_b}{W_b}\right\}^K \times 10^6 rev \quad (21)$$

where: **k** = 3 for small bearings, L_b is rating life of bearing, C_b is basic dynamic load rating of bearing, and W_b is equivalent dynamic load of bearing.

2.13 Magnetic Mineral Recovery

The recovery in the case of the concentration of magnetic ore concentrate is the percentage of the total magnetic mineral contained in the magnetic ore that is recovered in the concentrate.

The magnetic separation efficiency

$$S.E = R_m - R_g = \frac{100C_m(c-f)}{(m-f)f} \quad (22)$$

R_m is % recovery of the valuable mineral, R_g is % recovery of the gangue into concentrate, **f** is feed material assaying % metal, **c** is concentrate assaying (%), **t** is tailing assaying %metal, C is the fraction of the total feed weight that reports to the concentrate, and **m** is %metal content in the valuable magnetic mineral.

2.14 Design realiability and useful life Assessment

The realiability and useful life of the machine can be assessed based on the parameters by Smith, (1976);

Mean time to failure (MTTF) is the mean time to experience the first failure:

$$MTTF = \int_0^\infty R(t)dt$$

$$= \int_0^\infty \left\{exp\left[-\int_0^t \lambda(\tau)dt\right]\right\}dt \quad (23)$$

The useful life period of the machine shows when there constant failure rate:

$$R(t) = \exp\left[-\int_0^t \lambda dt\right] = e^{-\lambda t} \quad (24)$$

R is reliability of the device, t is operating periods of the same length, λ is the failure rate constant (Smith, (1976).

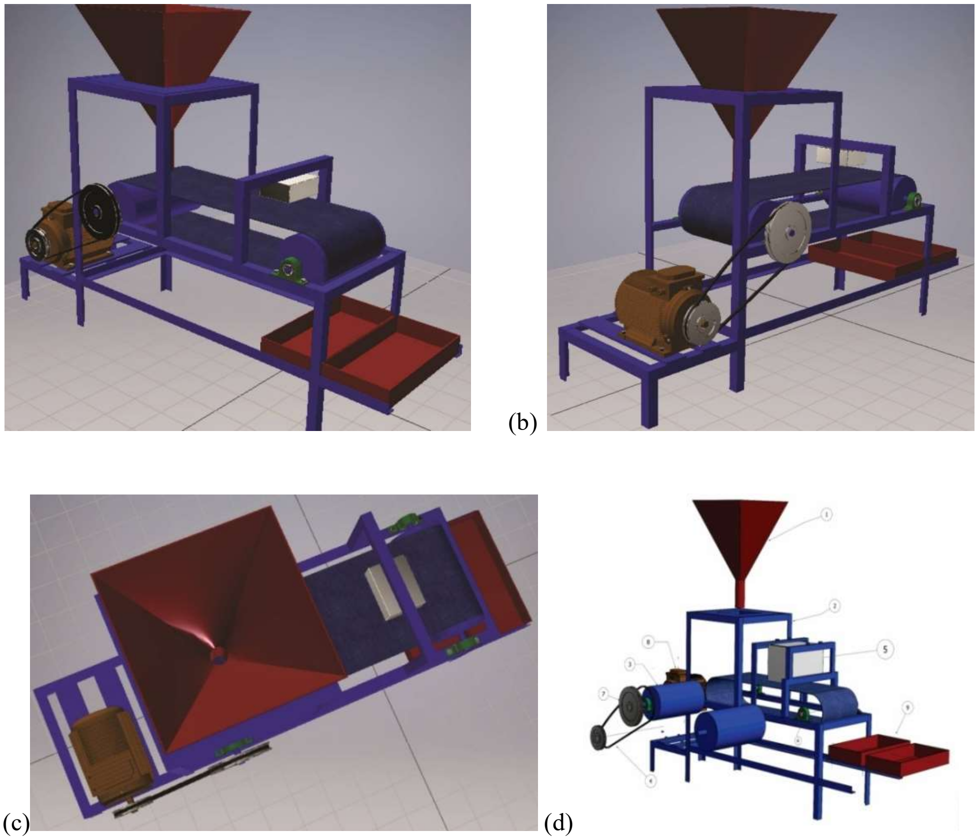
Table 1: Design parameters

Parameters	Values
Conveyor Belt Design	
The length of the belt	1728 mm
The belt thickness	0.5 mm
The belt width	150 mm
Hopper Design	
Volume of the hopper	50327.28 cm^3
Surface area of the hopper	4193.94 cm^3
Surface area of the discharge orifice	4.909 cm^3
Volume of the pipe	706.858 cm^3
Drum details	
Diameter of the drum	150 mm
Length of the drum	300 mm
Container details	
Width of the container	380 mm
Height of the container	100 mm
Dimension of some parts	
Length of the separator	1450 mm
Total height of the separator	1000 mm
Height of the separator frame	800 mm
Length of the collector holder	200 mm
Power driven pulley design and speed	
Speed of the driver pulley (n_1)	1430 rpm
Speed of the driven pulley (n_2)	168 rpm
Diameter of the driver pulley (D_1)	20 mm
Diameter of the driven pulley (D_2)	170 mm
Electric motor rating	
Wattage (Horse power)	2.5 watts (0.5 Hp)
Voltage	220 V
Motor speed	1430 rpm
Pulley belt design	
Diameter of the primary driver pulley (D_1)	20 mm
Diameter of the primary driven pulley (D_1)	170 mm
Pulley centre distance	115 mm
Length of the belt	435 mm
Type of belt selected	Ax, V- type
Selection of prime mover	
Horse power rating	0.5 Hp
Service factor	1.25
Design horse power	0.625 Hp
Actual design power rating	0.4663 kw

2.15 Design Drawings

2.15.1 Assembly Drawings

The assembly drawings are shown in Figures 4.



(a) (b) (c) (d)

Figure 4: Isometric (a) NE-view, (b) SW-view, (c) SW-plan view and (d) Disassembly (exploded) view of the separator

2.16 Material Selection

The criteria for selecting a material in this work depend on the roles which each component is expected to play. The design parameters dictated by the conditions are temperature, environment and mode of application. The materials properties determine the quality of the machine produced. The thickness and type of the materials used for the hopper and conveyor belt determine its ability to withstand the abrasion of the materials. Availability and cost are factor that are also considered in the design of this type of separator. The materials used for the machine parts alongside with their properties are stated Table 2.

2.17 Electromagnet Design

The choice of this type of magnet is due to the advantage the Bi-Polar electromagnet has over the flat-faced electromagnet.

Bi-polar electromagnet has two poles (positive poles and negative poles). It is cylindrical in shape; this type of electromagnet can pick through an air gap i.e., when it is not in direct contact with the bulk material to be separated and it also work effectively on a rough surface (Allen, 1980; Spaldin, 2011, Gaudin, 2016).

2.17.1 Production of Electromagnet

Type of electromagnet used BP-1601 Bi-polar. A 4500 turns of 26-guage insulated copper wire was winded uniformly around the piece of steel of length 11 cm and diameter of 5.5 cm; but not obligatory in an orderly manner. Insulation tape made of plastic sheet was used to secure the copper wire in place and this helps in unwinding the coil.

Fire or sand paper was used to remove the insulation at the end terminals of the copper wire for good conductivity. The coil was covered and placed inside heat shrink tube. The control terminal toggle switch and wires were connected to AC power supply (20V-60V).

Table 2: Material Selection

Machine Parts	Materials	Properties
Hopper	1.5 mm steel plate	Strong and weldablility.
Frame	5.08 cm angle steel	Strong, cheap and weldability.
Belt conveyor	Rubber 0.5 mm thick	Strong and allows the passage of magnetic flux.
Pipe	128.5 mm	Strong and allows the free flow of materials.
Electromagnet	Bi-Polar electromagnet	Low power consumption, ability to work on rough surfaces, has high magnetic strength.
Electric Motor	0.5Hp electric motor	Low power consumption, 1430 rpm.
Shaft	18mm steel rod	Strong, cheap.
Belt	Polymer and thread	Strong and reliable.
Electromagnet	Copper wire	Strong and affordable.
Pulley	16.51 cm metal	Strong and affordable.

Table 3: Project Costing

Materials	Rate (₦)	Quantity	Cost (₦)
1.5 mm metal plate	23000 / length	2	46,000
5.08 angle steel bars	1000/ length	3	30,000
0.5 mm thick rubber belt	5000	1	5000
12.85 cm hollow steel pipe	1000	1	1000
Bi-polar electromagnet	30,000	1	30,000
0.5 Hp electric motor	15,000	1	15000
18 mm steel rod	7000	1	7,000
Bolts and nuts	250	12	3000
Bearing pillow	3750	4	15,000
100 mm large v-pulley	3000	1	3000
60 mm small v-pulley	2000	1	2000
V- belt	1000	1	1000
Electric cable and fittings	5200	1 set	5500
100mm round bar magnets	3500	4	14000
Welding electrode (Oerlikon)	4500 per pack	1 pack	4500
Grinding stone	1500	1	1,500
Cutting disc	1500	3	4,500
Glossy paint	5,500	1 gal	5,500
Consultations, Logistics, Miscellaneous			30,500
		Total	**224,000**

Table 4: Parts and Function.

Parts	Functions
Hopper	This is for uniform distribution of the burden material.
Rotary drums/ Prime mover	The conveyor belt is mounted on the prime mover. The separator consists of two prime movers. This is used for rotation.
Belt	The prime mover conveys the materials through magnetic flux.
Frame	This is the framework on which the structure is mounted.
Electric motor	The electric motor drives the prime mover alongside with the conveyor belt.
Electric cable	It connects the electric motor to the power source.
V-belt	It connects the electric motor with one of the prime movers.
Electromagnet	This is a device that uses electrical current to induce a magnetic field.
Containers	The separated materials are discharged into the troughs (one for non-magnetic and the other magnetic materials).

2.18 Operation of the Electromagnet

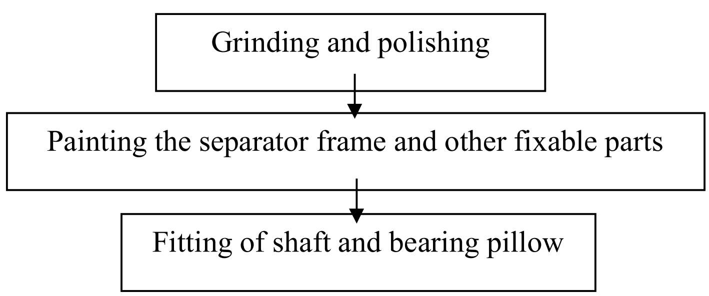
One electromagnet is used in this work; it is connected to the power source and picks up the magnetic materials from the bulk material charged into machine through the hopper on the conveyor belt. The non-magnetic materials are discharged off the belt, the electromagnet is disconnected from the power source; hence the magnetic materials fall off the electromagnet and discharged from the belt. The separation operates in a batch process.

2.19 V-belt selection

The V-belts are mostly used for transmitting motion from one pulley to another and when the two pulleys are very near to each other. They are made of fabric and cords moulded rubber. The wedging action of the V-belt in the groove of the pulley results in higher frictional force that disallowed the slip of the driving belt from the pulleys. Ax-type belt is used.

2.20 Finishing Process

This process involved as follows:



The electric motor was appropriately positioned and fastened with bolts and nuts. The large pulley was fixed to the drum nearest to the electric motor. The fitting of the V-belt on the pulleys (large and small) was done and it was ensured that the pulleys are held firmly to the shaft.

3.0 Result and Discussion

3.1 Testing Running of the machine

The electric motor was powered. The bulk mineral was fed through the hopper while the conveyor belt revolves. The conveyor belt moves the mineral through the magnetic field. Here, the non-magnetic minerals passed through the magnetic field while the magnetic minerals are attracted to the electromagnet. The electromagnet is disconnected from its power source; thereby losing its magnetism, and leaving the magnetic minerals fallen off by gravity onto the belt which are then discharged from the belt by a centrifugal force.

3.2 Results

Based on the design, fabrication and test running of the magnetic and electromagnetic separator, some modifications were done to achieve the following results:

The pictorial views of the complete fabrication are illustrated in Figure 5 (a-e). The belt conveyor initially transferred the minerals to be separated at higher speed than expected; hence the driving pulley and the belt were moderated.

The electromagnet picked up the minerals from the belt at relatively lower rate, thus the need to adjust the distance between the belt and the magnets. As the electric motor rotates the drums, the belt conveyor tends to twist; therefore the belt material was replaced with a stiffer rubber material.

The V-belt transfers energy from the electric motor to the pulleys without slipping out of the pulley. Some part of the minerals flings pass the collection pans at higher speed, thus the size and positions of the containers were adjusted.

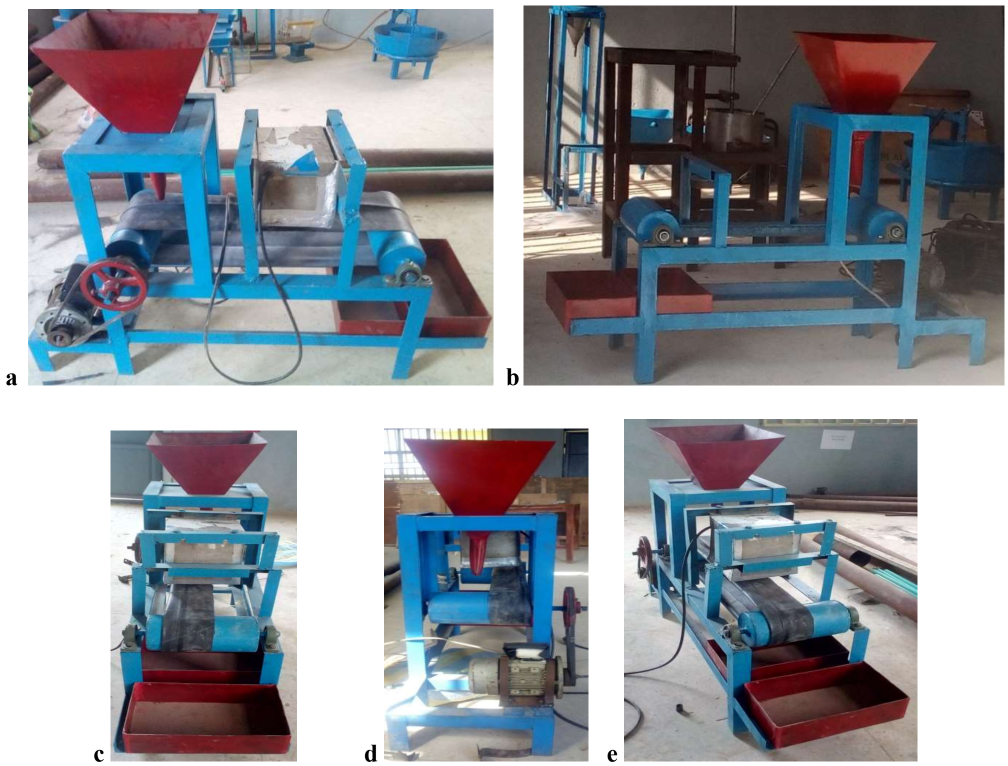


Figure 5: Pictorial views of left side (a), right side (b), front side (c), back side (d) and SE side (e), of the complete fabrication

4.0 Conclusion

The machine combines the applications of electromagnetism and simple magnetism in a single system to solve the challenges of separation of unwanted ferrous materials commonly found in non-ferrous casting industries; and extraneous iron ores during extraction process from the bulk minerals. Based on the result of test-run of the fabricated magnetic/electromagnetic separator, the machine effectively performed the purpose with which it was designed for. The cost of production of the machine is affordable and if adopted for utilization, it will reduce importation and serve as a means of saving the foreign exchange earnings of the nation. Therefore, it may be used in the mineral processing and foundry floors; the machine can be helpful in teaching students and for experimental purposes in mineral processing laboratories.

References

Adetunji O.R. and Quadri A.H. (2011), Design and fabrication of an improved cassava grater. The Pacific Journal of Science and Technology. Vol. 12 No.2, pp120-129

Ajibola O.O, Adebayo A.O, Akipeloye S,, Oladimeji V., Oyekanmi A., Ogungbe G., Omoyeni D.O, Borisade S.G, Oloruntoba D.T and Adewuyi B.O. (2021). Fabrication and performance evaluation of electroless-nickel deposition line for metal alloys and plastic substrates. FUW Trends in Science & Technology Journal, Vol. 6 No. 1 pp. 069 – 078

Ajibola O.O, Alamuoye O.F, Omoyeni D.O., Adebayo A.O., Borisade S.G., Olotu V., Adetoye O., Adebanji S. (2020) Design and fabrication of a multi-purpose homogenizer, NIPES Journal of Science and Technology Research 2(3) 2020 pp. 21-35

Allen, E. (1980). Magnetic materials. Bulletin 153. Edger Allen ltd, USA.

Burr A.H and Cheatham J.B (2002). Mechanical Analysis and Design (2nd Ed.).Prentice Hall, USA.

Cornish E.H. (1991). Materials and the Designer. Cambridge: Cambridge University Press.

David Michaud (1993). Electromagnetic separators for strongly magnetic minerals. Retrieved (February 6th, 2018) www.911Metallurgist.com

Eskibalci M.F., Ozkan S.G. (2012). An investigation of effect of microwave energy on electrostatic separation of colemanite and ulexite. Minerals Engineering 31 (2012) 90–97

Fan P., Fan M., Liu A. (2015). Using an axial electromagnetic field to improve the separation density of a dense medium cyclone. Minerals Engineering 72 (2015) 87–93

Gaudin A.M. (2016). Principles of Mineral Dressing, McGraw Hill Book Company, New York and London.

Gebi A.I., Yaro S.A., Abdulwahab M., Dodo M.R., Eyitayo S. M. (2016). Characterization of Kuluki wolframite ore deposit for its beneficiation. NIMACON 2016 Book of Proceedings Volume II, 2016, pp 98-100. https://www.researchgate.net/publication/344900807

Iwai B.T. (2012). Dynamic multifocal contact lens dual layer with core. Retrieved from https://daycounter.com.

John D.K. (1992). "Electromagnetics" (4th Ed.). McGraw-Hill Inc., New York.

Khurmi R.S. and Gupta J.K. (2005). A Textbook of Machine Design (1st Multi-colour Ed.). S. Chand and Company Ltd., New Delhi.

Li Y., Wang J., Wang X., Wang B., Luan Z. (2011). Feasibility study of iron mineral separation from red mud by high gradient superconducting magnetic separation. Physica C 471 (2011) 91–96

Liu B., Zhang L., Zhang Y., Han G., Zhang B. (2021). Innovative methodology for co-treatment of mill scale scrap and manganese ore via oxidization roasting-magnetic separation for preparation of ferrite materials. Ceramics International 47 (2021) 6139–6153

Michaud D. (1993). Electromagnetic separators for strongly magnetic minerals. Retrieved (February 6th, 2018) www.911Metallurgist.com

Olson A, Finio B, Daly T, (2018). The strength of an electromagnet. Science Buddies Staff. Retrieved from tps://www.electronics-tutorials.ws.

Omran M., Fabritius T., Elmahdy A. M., Abdel-Khalek N. A., El-Aref M., Elmanawi A. E. (2014). Effect of microwave pre-treatment on the magnetic properties of iron ore and its implications on magnetic separation. Separation and Purification Technology 136 (2014) 223–232

Papiewski, J. (2018). Advantages of an electromagnet over a permanent magnet. Leaf Group Education. USA

Shigley J.E. (2007). Mechanical Engineering Design (8th Ed.). Mc Graw-Hill Book company. New York.

Smith C. O. (1976), Introduction to Reliability in Design: In Materials Selection and Design, ASM Handbook (1997) Volume 20 pg 222-223.

Spaldin, N. A. (2011). Magnetic materials: fundamentals and applications (2nd Ed.). Cambridge University Press, New York.

Srinivas K. and Natarajan R. (2000). Studies on the recovery of tungsten from a composite wolframite. Retrieved from https://www.finelib.com_about_wolframite.

Styriakova I., Styriak I., Malachovsky P., Lovas M. (2006). Biological, chemical and electromagnetic treatment of three types of feldspar raw materials. Minerals Engineering 19 (2006) 348–354

Svoboda, J. (1987). Magnetic methods for the treatment of minerals. The University of California: Elsevier, New York.

Thomas D. G., Asuke F., Yaro S. A. and Adams S. M. (2019). Chemical, mineralogical and petrological characterization of Gyaza iron ore deposit, Katsina State, Nigeria. Nigerian Journal of Technology, Vol. 38, No. 3, July 2019, pp. 660 – 667

Tripathy S.K., Banerjee P.K., Suresh N. (2014). Separation analysis of dry high intensity induced roll magnetic separator for concentration of hematite fines. Powder Technology 264 (2014) 527–535

Walker M.S. and Devernoe A.L. (1991). Mineral separations using rotating magnetic fluids. International Journal of Mineral Processing, 31 (1991) 195-216

Watson J.H.P. (1994), Status of superconducting magnetic separation in the minerals industry. Minerals Engineering, Vol. 7, Nos 5/6, pp. 737-746, 1994

Wills, B.A., Finch, J., (2016). Wills' Mineral Processing Technology: An Introduction to the Practical Aspects of ore Treatment and Mineral Recovery. 8th Edition. Butterworth-Heinemann

Wołosiewicz-Głąb M., Ogonowski S., Foszcz D. (2016). Construction of the electromagnetic mill with the grinding system, classification of crushed minerals and the control system. IFAC-PapersOnLine 49-20 (2016) 067–071

Zhu H., Tang H., Cheng Y., Li Z., Tong L. (2021). Electrostatic separation technology for obtaining plant protein concentrates: A review. Trends in Food Science & Technology 113 (2021) 66–76