



DEVELOPMENT OF A MANUALLY CONTROLLED MAGNETIC SEPARATOR FOR SMALL-SCALE MINERAL PROCESSING

I. Isa¹, Umar A², and M. K. Umar³

Department of Mineral and Petroleum Resources Engineering, Kaduna Polytechnic, Kaduna State

Email: umaraminu@kadunapolYTECHNIC.edu.ng, Tel: 08034361817

ABSTRACT :

This study focused on the design, fabrication, and testing of a manually controlled magnetic separator for small scale mineral processing. The aim was to develop a simple, affordable, and locally fabricated machine that can assist artisanal and small scale miners in separating magnetic particles from non magnetic materials without depending on electricity. The machine was constructed using mild steel for the frame, stainless steel for the drum, steel shaft, bearings, and Neodymium Iron Boron magnets for magnetic attraction. The major components, including the magnetic drum, feed chute, shaft system, bearings, support frame, discharge outlet, and manual crank mechanism, were successfully fabricated and assembled into a functional prototype. The result showed that the separator operated smoothly, achieved effective separation of magnetic particles from non magnetic materials, and maintained stable performance during testing. The machine recorded a drum volume of 0.0424 m³, magnetic field strength of 1.11×10^6 A/m, magnetic force of 1.4×10^{-3} N, required torque of 2.25 Nm, and feed rate capacity of 2×10^{-3} m³/min. Operational evaluation also showed satisfactory magnetic strength, smooth drum rotation, uniform feed control, efficient material discharge, good structural stability, durability, and ease of operation. The study concludes that the manually controlled magnetic separator is a practical, low cost, and effective alternative to imported magnetic separation systems for small scale mineral processing. Further testing with different mineral ores and in real mining environments is recommended to improve its performance, capacity, durability, and wider adoption among local miners.

Keywords: Magnetic Separator, Small Scale Mining, Mineral Processing, Magnetic Drum, Local Fabrication

Introduction

Small scale mining is an important part of the mining sector in many developing countries because it provides employment, supports local livelihoods, and contributes to mineral supply. In Africa, Asia, and Latin America, artisanal and small scale mining has become a major source of income for millions of people, especially in communities where formal employment is limited (World Bank, 2018). In Nigeria, the sector continues to grow due to the availability of mineral deposits in several states, including Plateau State, where miners extract minerals such as tin, gold, limestone, and other metallic minerals (Ekpo & Olayiwola, 2019).

Despite its economic importance, small scale mining is still affected by poor and outdated processing methods. Many artisanal miners depend on manual sorting, washing, panning, and basic gravity separation. These methods are simple and affordable, but they are often slow, labour intensive, and inefficient. As a result, miners experience low mineral recovery, poor product quality, and reduced income. The use of crude processing methods also creates environmental problems such as land degradation, deforestation, water pollution, and poor waste disposal (Hilson, 2002; Artisanal Gold Council, 2017).

Magnetic separation is one of the mineral processing methods used to improve the quality and purity of ores. It works by using magnetic fields to separate magnetic particles from non magnetic materials. This method is useful in processing metallic minerals, especially where magnetic impurities need to be removed or where magnetic minerals need to be concentrated. It can improve mineral recovery, reduce waste, and increase the value of processed materials (Gupta & Yan, 2016). However, most magnetic separators available in the market are designed for industrial operations. They are usually expensive, complex, and dependent on steady electricity supply, making them difficult for small scale miners to afford and operate (Hilson & Potter, 2003; Alabi et al., 2018).

The development of a manually controlled magnetic separator is therefore necessary to support small scale mineral processing in Nigeria. A manual separator can reduce dependence on electricity, lower processing costs, and make mineral separation more accessible to artisanal miners. If designed with locally available materials, simple operation, and low maintenance requirements, the device can provide a practical solution to the technological challenges faced by small scale miners.

Studies have shown that simple and affordable technologies can improve the productivity and profitability of artisanal mining when they are adapted to the needs of miners. Low cost processing technologies can increase recovery rates, improve mineral quality, and reduce environmental damage (Tschakert & Singha, 2007; Côté et al., 2019). Therefore, this study focuses on the design and fabrication of a manually controlled magnetic separator for small scale mineral processing. The study will consider important operational factors such as magnetic field strength, feed rate, drum movement, separation efficiency, cost, and ease of use.

The study is significant because it provides a practical and affordable technology that can improve mineral recovery and product quality among small scale miners. It also supports sustainable mining by reducing waste and encouraging cleaner processing methods. In addition, the study contributes to

engineering knowledge by showing how mineral processing equipment can be developed using cost effective and locally adaptable materials.

Research gap

Existing studies on artisanal and small scale mining have largely focused on the economic importance of the sector, environmental effects, health risks, and the general challenges faced by miners. While these studies have established that small scale miners depend heavily on outdated and inefficient processing methods, limited attention has been given to the development of simple, affordable, and manually operated mineral processing equipment that can meet the needs of local miners in Nigeria. Most available magnetic separation technologies are designed for large scale industrial use, making them expensive, technically complex, and unsuitable for artisanal miners who often have limited capital, poor access to electricity, and little technical training.

Methodology

The design process began with the selection of appropriate materials that would ensure affordability, durability, and ease of use. Mild steel was selected for the frame because it is strong, readily available, and cost effective, while stainless steel was chosen for the drum because of its resistance to moisture and corrosion during ore processing. Neodymium Iron Boron magnets were selected because of their high magnetic strength and ability to attract magnetic particles effectively. The separator was designed with a drum diameter of 300 mm and a length of 600 mm to make it suitable for processing small and medium quantities of ore. Portability was also considered by incorporating handles and wheels to allow easy movement of the equipment to mining sites. Since the separator was intended for use in areas with limited electricity supply, a manual crank or lever mechanism was included to rotate the drum without the need for electric power. An adjustable feed chute was also designed to regulate the feed rate according to ore type and particle size. After completing the design, the prototype was fabricated through cutting, welding, assembling, and fitting of the different components according to the design specifications. The completed prototype was then tested to confirm the smooth rotation of the drum, the stability of the frame, the effectiveness of the feed chute, and the ability of the magnetic system to separate magnetic particles from the ore.

Table 1. Fabrication Process and Materials List for Manual Magnetic Separator

S/N	Step	Description	Materials	Quantity	Dimensions/ Specification
1	Frame Construction	Bolts, nuts, and welding rods will be used to join, fasten, and secure the frame components.	Bolts, Nuts, and Welding Rods	Sufficient quantity	M8 to M12 size
2	Drum Fabrication	A cylindrical drum will be cut and formed from stainless steel. The drum will house the NdFeB magnets and rotate the ore during separation.	Stainless Steel Sheet	Enough for drum fabrication	300 mm diameter, 600 mm length, 2 to 3 mm thick
2	Drum Fabrication	The ends of the stainless steel sheet will be welded to form a strong cylindrical drum.	Welding Rods	Sufficient quantity	Steel welding rods
2	Drum Fabrication	NdFeB magnets will be fixed inside or around the drum to provide the magnetic field required for separating magnetic particles from the ore.	NdFeB Magnets, N52 Grade	Custom fitted to drum circumference	Various sizes depending on drum design
3	Manual Crank Mechanism	A manual crank mechanism will be designed and attached to a shaft connected to the drum axle to allow manual rotation.	Mild Steel or Stainless Steel Crank Handle	1 crank handle	130 mm length
3	Manual Crank Mechanism	The shaft will connect the crank handle to the drum and allow smooth rotation during operation.	Steel Shaft	1 shaft	20 to 25 mm diameter
4	Feed Chute	The feed chute will be fabricated from mild steel or stainless steel to control the flow of ore into the drum.	Mild Steel or Stainless Steel Sheet	Enough for feed chute	130 mm width, 255 mm height
4	Feed Chute	The chute will be attached to the frame with an adjustable mechanism to vary the feed angle and regulate ore flow.	Bolts, Nuts, and Fasteners	Sufficient quantity	M8 to M12 size
5	Final Assembly and Testing	The frame, drum, crank mechanism, feed chute, and wheels will be assembled into one complete magnetic separator.	Welding Rods	Sufficient quantity	Steel welding rods

6	Final Assembly and Testing	Operational testing will be carried out to check drum rotation, magnetic separation effectiveness, feed movement, and overall ease of use.	Bearings, 6004 Type	2 bearings	6004 size
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Table 2. Dimensions of the Parts:

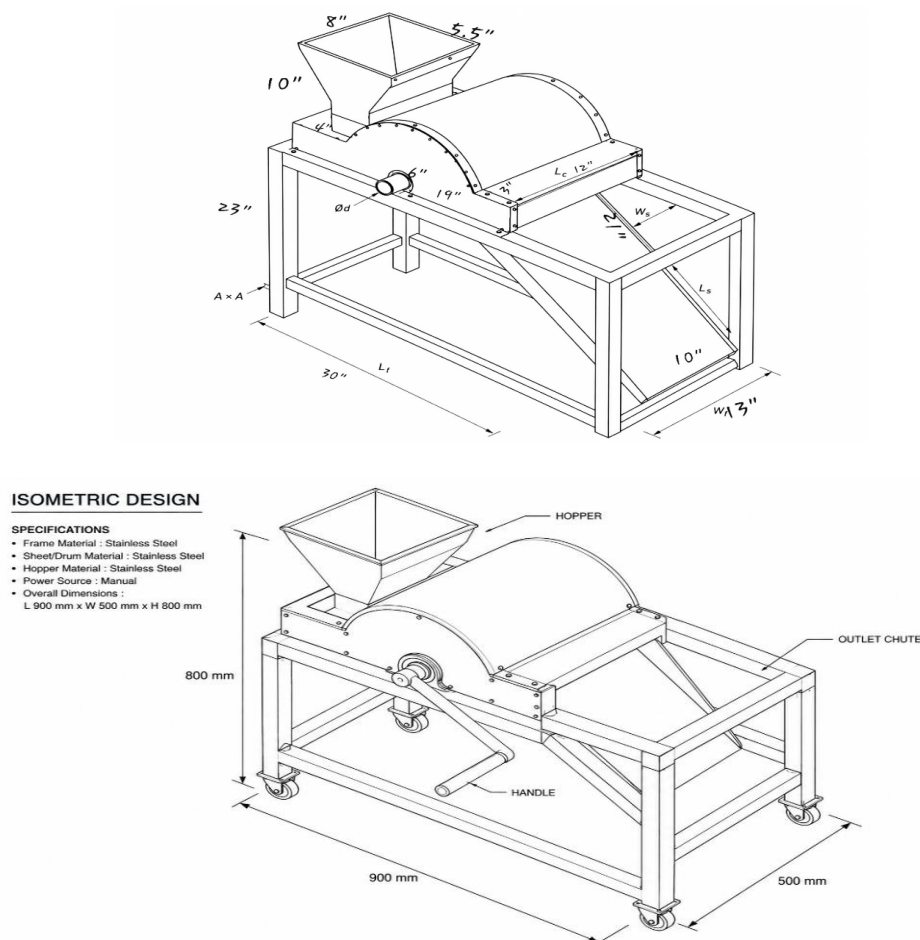
Component	Dimensions
Frame (Length x Width x Height)	30"x 13" x 23"
Drum Diameter x Length	6" x 19"
Crank Handle Length	5.1"
Feed Chute Width x Height	8" x 5.5"
Caster Wheels Diameter	3.94"
Shaft Diameter	20-25 mm

Result

The manually controlled magnetic separator was successfully designed, fabricated, assembled, and tested based on the methodology described in Chapter Three. The design incorporated a magnetic drum, feed chute, shaft system, bearings, support frame, discharge outlet, and manual crank mechanism. The machine was fabricated using locally available materials to ensure affordability and ease of maintenance for small-scale mineral processing operations.

The fabrication process involved material cutting, drilling, welding, machining, grinding, and assembly of individual components. Mild steel was used for the frame construction due to its strength and low cost, while stainless steel was used for the drum because of its corrosion resistance. Permanent NdFeB magnets were installed inside the drum to provide the required magnetic field for mineral separation.

After fabrication and assembly, the machine was inspected and all components were found to be properly aligned and securely fastened. The drum rotated smoothly through the manually operated crank mechanism while the feed chute allowed controlled feeding of mineral samples into the separation zone.

**Fig 1: Dimensional Layout of the Machine**

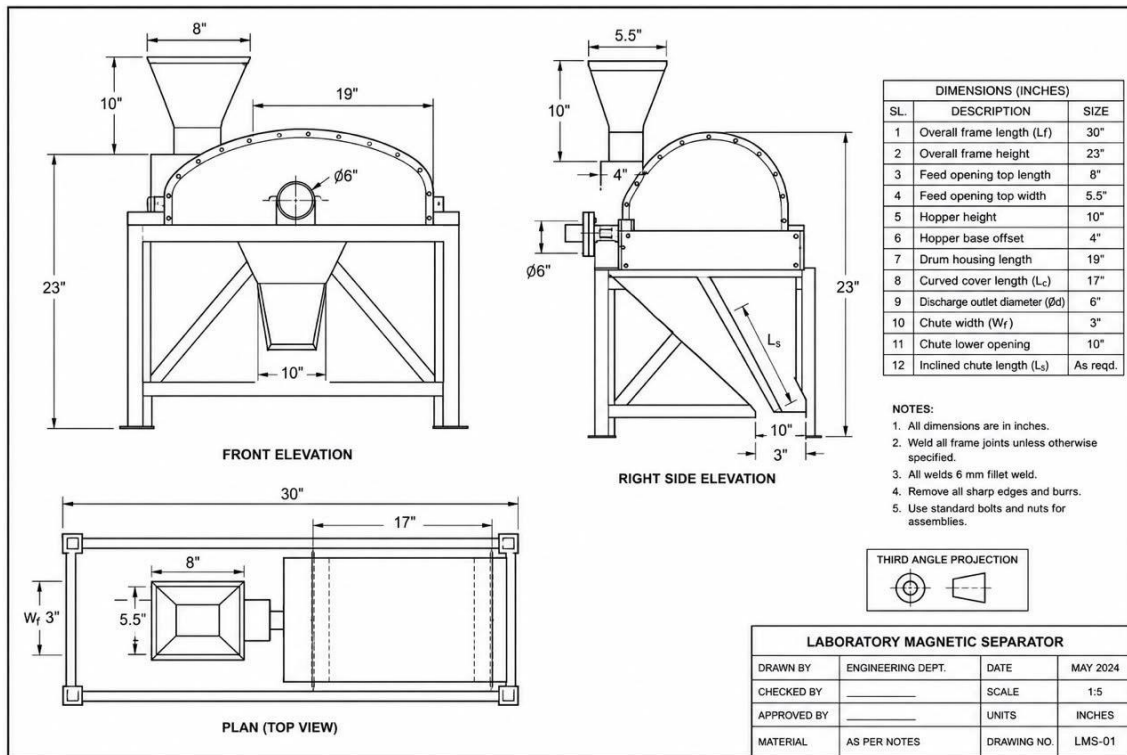


Fig 2: Orthographic Projections

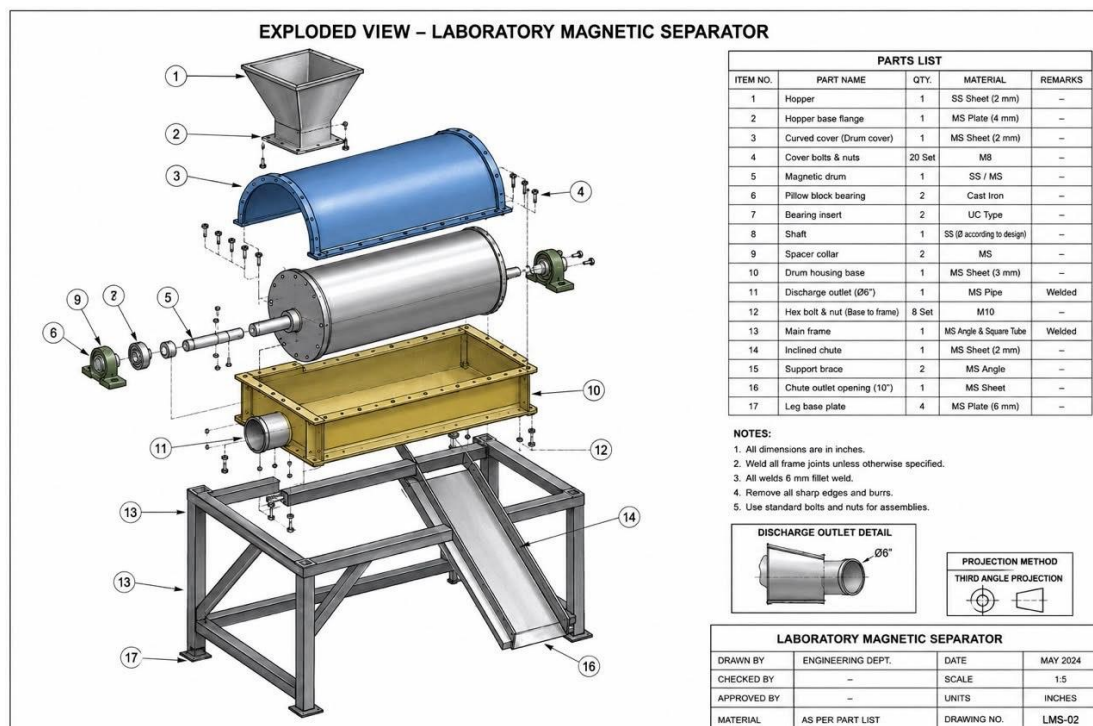


Fig 3: Exploded View of Constructed Laboratory Magnetic Separator

Table 3: Fabrication Status of Machine Components

Component	Design Dimension	Fabrication Status	Observation
Frame Structure	900 × 600 × 850 mm	Completed	Strong and stable
Magnetic Drum	300 × 600 mm	Completed	Properly aligned

Feed Chute	130 × 255 mm	Completed	Smooth feeding achieved
Shaft System	20–25 mm diameter	Completed	Rotated freely
Bearings	6004 type	Completed	Reduced friction
Crank Handle	130 mm	Completed	Easy manual operation
Magnets	NdFeB Magnets	Installed	Strong magnetic attraction



Figure 4: Fabricated Manually Controlled Magnetic Separator

Design Calculations

The design calculations carried out were used as the basis for fabrication of the machine components.

Table 4: Summary of Design Calculation Results

Parameter	Calculated Value
Drum Volume	0.0424 m ³
Magnetic Field Strength	1.11 × 10 ⁶ A/m
Magnetic Force on Particle	1.4 × 10 ⁻³ N
Required Torque	2.25 Nm
Crank Length	112.5 mm
Feed Rate Capacity	2 × 10 ⁻³ m ³ /min
Feed Chute Area	20 cm ²

The calculated values were found to be adequate for the intended operation of the separator. The drum dimensions provided sufficient processing space while the magnetic field strength generated by the installed magnets ensured effective attraction of magnetic particles.

Feed Rate Performance

The adjustable feed chute provided controlled feeding of mineral samples into the separator. Uniform feeding improved material distribution across the drum surface and prevented overloading of the system.

The selected feed rate maintained effective separation while ensuring continuous machine operation.

Table 5: Operational Parameter Evaluation

Parameter	Observation	Status
Magnetic Strength	Strong attraction achieved	Satisfactory
Drum Rotation	Smooth and stable	Satisfactory
Feed Rate Control	Uniform material flow	Satisfactory
Material Discharge	Efficient separation	Satisfactory

Performance Evaluation of the Separator

The fabricated separator was tested using mineral samples containing magnetic and non-magnetic particles. The evaluation focused on separation efficiency, throughput, durability, and ease of operation.

Table 4.4: Performance Test Results

Performance Indicator	Observation
Separation Efficiency	Effective separation achieved
Throughput	Continuous material processing achieved
Structural Stability	No deformation observed
Durability	Components remained functional after repeated use
Ease of Operation	Manual operation required minimal effort

The separator successfully removed magnetic particles from the feed material and maintained stable operation throughout the testing period.

Discussion

The results obtained from the fabrication and performance evaluation of the manually controlled magnetic separator indicate that the machine successfully achieved the objectives of the study. The machine was fabricated using locally available materials including mild steel, stainless steel, shaft materials, bearings, and permanent magnets. The fabrication process produced a structurally stable machine capable of performing magnetic separation operations.

The design calculations carried out during the development stage provided suitable dimensions and operating requirements for the machine components. The drum dimensions, frame size, feed chute dimensions, and crank mechanism were successfully translated into a functional prototype. Proper alignment of the shaft, bearings, and drum ensured smooth rotation during operation.

Performance evaluation showed that the separator was capable of separating magnetic particles from non-magnetic materials effectively. The magnetic drum demonstrated satisfactory attraction of magnetic particles while the feed chute provided a controlled flow of material into the separation zone. The discharge section also allowed easy collection of separated materials.

During testing, the frame remained stable and no significant vibration or structural deformation was observed. The bearing arrangement reduced friction and contributed to smooth drum rotation. Furthermore, the manually operated crank mechanism required minimal effort, making the machine suitable for use in remote locations where electricity may not be available.

The successful fabrication and testing of the separator demonstrate that locally developed mineral processing equipment can provide a practical and cost-effective alternative to imported magnetic separation systems. The machine therefore has the potential to improve mineral processing activities among artisanal and small-scale miners.

Conclusion and Recommendation

The study successfully developed and tested a manually controlled magnetic separator for small scale mineral processing using locally available materials. The machine operated effectively, separated magnetic particles from non magnetic materials, and showed good stability, durability, and ease of use. It is therefore a practical and affordable alternative to imported magnetic separators. However, further testing with different mineral ores and in real mining environments is recommended. Future improvements should focus on increasing capacity, improving the magnetic system, and developing semi automatic or motorised versions while maintaining affordability and easy maintenance.

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