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Research Article

Development of an Intelligent Mobile Metal Scrap Separating and Cleaning System Model

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Abstract

The development of an intelligent mobile metal scrap separating and cleaning system model is the focus of this work. Over the years, huge man power and other resources were required to run an industrial scrap metals separating process, and a great amount of process time was wasted in handling operations such as sorting, screening and cleaning of the scrap metals separately. The need to transfer the metal scrap from one point of operation to another makes human labour tedious and energy wastage. An already existing single unit scrap metal separating and single unit cleaning system are adapted in this design. These two different systems are adopted for a combine operation and a microcontroller introduced to give it a full automated system status. This designed device was developed using olidWorks CAD/CAM software, for the mechanical design; Proteus and Arduino IDE, for the schematic modelling and programming of the control system. The simulated model for both the solidWorks design and the Proteus design with the program code reveals the system simultaneous functionality as it is capable of sorting, screening and cleaning of the metals scrap. The virtual implementation of the developed model with its intelligent and mobile functionality has proven that the metal scrap separating and cleaning system can be put together for a self-driven, low energy consumption, less human effort, profit maximization and efficient time management system. Monitoring and control was made possible with Android Apps. Further research advancement can be made in converting the simulated model into a physical industrial machine.

Keywords: *Scraps, Cleaning system, Metal separator, Intelligent system, Model.*

1. Introduction

Recycling of metals from the scraps generated either from industrial operations or domestic activities has been a long-time viable business. Separating metals from other wastes after sorting requires proper screening and cleaning to make it fit for the recycling operations. Sorting, screening and cleaning are seemingly separate operations. These three operations has often been carried out separately leading to high man power demand, high energy consumption, process time wastage, poor handling operations, and low turnover. This necessitate the development of a self-driven, full-automated, intelligent and single unit system that guarantees low energy consumption, less man power and resources demand as well as profit optimization.

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Figure 1: Transportation of Sorted Scrap Metal for further process (Ohimain, 2013)

Despite the fact that Nigerian has a huge amount of iron ore deposits, gathering of the scraps metal has continuously played a major role in cushioning the effect of the shortage of raw material which renders some integrated steel plant redundant. The sorted metal from the municipal solid waste scattered around the gutters, drainage channels, rivers line, abandoned plots of land, market dumping ground and street has aid in the sustenance of the metal steel industrial production in the sense that , the metal scrap recycling business is reasonably rolling out raw materials for milling process (Ohimain, 2013).

Figure 2: Standalone Metal Scrap Sorting System (https://icasnetwork.com/3-tips-for-efficient-scrap-metal-recycling/)

Many at time eddy current separation techniques and other approaches are used in sorting scraps metals out of non-metal materials from where it was dumped as waste (Wang *et al*., 2013). The eddy current separation techniques and its allies are design to operate as a standalone system.

Figure 3: Standalone Metal Scrap Cleaning System (Bańkowski and Spadło, 2017)

(Parwate *et al*., 2020) developed a low sound/noise level tumbling machine for cleaning and smoothing of metals after manufacturing design to replace the conventional filing which the target is to give it a polished surface. The low noise tumbling machine was design to operate as a standalone system. This design considers the combination of the metal scrap separating system and metal cleaning system with a mobile ability and is termed "an intelligent mobile metal scrap separating and cleaning system model", were scrap metal are sorted, screen and clean within a single mobile unit.

A. Statement of the Problem

Inadequate utilization of resources and maximization of process time in separating and screening of metal scraps remains a challenge in the scrap metal processing industries. This is because the scrap metals are often sorted from the bulk by different machines, screened by different machines and cleaned by different machines thereby leading to excessive energy consumption. Also, huge manpower and other resources requirement incurred in the process of sorting, screening and cleaning would have been efficiently managed by one automated system with little or no human effort. More so, the inability to manage process time in running the sorting, screening and cleaning the scrap metals separately could be curtailed by the use of a single fully automated device for the simultaneous operations. The need to transfer the metal scrap from one point of operation to another makes human labour tedious and the process energy consuming.

B. Aim and Objectives

The principal objective in this work is to develop an intelligent mobile metal scrap separating and cleaning system model with the following specific objectives:

1) To design a self-driven smart mobile metal scrap separating system;
2) To develop and adapt a vibration cleaning process technique into an intelligent metal scrap cleaner for the designed device in (i.);
3) To design a control system algorithm for the designed device in (i.) and (ii.);
4) To formulate and implement a remote monitoring and control criteria for these self-driven devices;
5) To carry out virtual system performance and validation test for the complete system.

C. Significance of the Study

Efficient utilization of resources and maximization of process time is the prime advantage of incorporating these three-in-one systems into a single (mobile and self-driven) fully automated unit. These three-in-one systems are the metal scraps separating, screening and cleaning system. The scrap metals which were often sorted, cleaned and screened from the bulk by different machines can then be processed by a single system, thereby curtailing the excessive energy consumption with limited manpower involvement. This design guarantees the efficient management of the sorting, screening and cleaning process with the introduction of a fully automated single unit with little or no human effort and which can effectively reduce the huge manpower and other resources incurred in handling the operations separately as well as increasing the industries turnover. The mobility and self-driven capability, and ease of operation designed into the developed system eliminates the need for transferring the metal scrap from one point of operation to another by providing a three-in-one system instead of three separate systems.

2. Literature Review

The essence of separating metal scrap from solid industrial waste or disposal site is not just sorting it for environmental benefit and sustainability, but for the recycling propose (Dresden-Rossendorf, 2014). Recovering the metal scrap potential for reprocessing give raise to the new product while redeeming the environment from poor waste disposal (Ohimain, 2013). Several researches reviewed on scrap metals separation technology reveals that the eddy current method seems prominent among other approaches. The eddy current approach is capable of distinguishing nonmetals from metal for reuse (Wang *et al*., 2013).

Khaliq *et al*., 2014 explains that scrap metal could be separated from e-waste through the following ways: mechanical process; pyrometallurgical routes and hydrometallurgical process. In their research work, particular attention was given to the scrap emanating from electronic and industrial waste involving large household appliances, small household appliances, information technology and telecommunications equipment. Consumer equipment, lighting equipment, electrical and electronic tools (with the exceptions of large-scale stationary industrial tools), toys, leisure and sport equipment, medical devices (with the exception of all implanted and infected products), monitoring and control instruments and automatic dispensers among other metal-oriented devices, were also considered. The problem of scrap sorting, transportation cost, distance to discharge the metal elements, and cleaning of re-integrated process such as smelting and refining were challenging. From this assumption, the metal cleaning and screening system is required as a unit which this design proposed. Metal cleaning and screening system has tremendously contributed to the smooth scrap metal reprocessing concept after being sorted from the industrial waste or municipal disposal.

Most recently, (Parwate *et al*., 2020) developed a low noise tumbling machine for manufacturing purposes. This low sound polishing system was proposed to manage the vibration/abrasive machine - operators' complaints. The design considers the visual observation approach to conclude that within the approximate 4 to 5 hours, the machining device would have removed corrosion from the metal without technically deforming the external shape of the scrap metals while producing a clean, smooth and polished surface. Also, the vibration in machining system continues in its role with metal cleaning as chemical-to-mechanical (vibro-abrasive) ways of dry-deburring and polishing a metal scrap (Młynarczyk, Bańkowski and Spadło, 2014); (Bańkowski and Spadło, 2017).

Bańkowski and Spadło, 2017 design confirmed that closed tumbler vibration machine is suitable for the final treatment for aluminum alloys by polishing the metal. The vast and broadened applications of vibratory machining in external surface cleaning, brightening, smoothing, sharpening, and abrasive burnishing operations has become a universal approach. It further elucidated that the tensile strength of the cleaned material is dependence of the duration of the vibratory machining. The application of the zeolite rock aids the smoothing of the external surfaces of the metal in tumbler machining.

Their design considers the visual observation approach to conclude that within an approximated time of 4 to 5 hours, the machining device would have removed corrosion from the metal without technically deforming the external shape of the Scrap metals. Furthermore, investigations also show that the vibration smoothing conditions is being influenced by the geometrical structure of the machined surfaces (Bańkowski and Spadło, 2018); (Bańkowski and Spadło, 2017); (Kane, Mishra and Dutta, 2016).

This design adopts the metal scrap separating system and metal cleaning system as a separate system and combine it for a smart and mobile operations. This research proposed an intelligent mobile metal scrap separating and cleaning system model were scrap metal are sorted, screen and clean within a single mobile unit. This system is monitored and control using android application.

3. Methodology

A. Materials and Specifications

1) Transformer: 220vAc/12vDc
2) Fuse:10A
3) Switch: Push button and Starter type
4) Diode: Crystal Diode IN4007 and Light Emitting Diode
5) Voltage Regulator: LM 7805 and LM 7812
6) Microcontroller: Arduino Uno
7) Resistors: 10kΩ, 1kΩ and 22kΩ,
8) Capacitors: 1000μF 35V, 10μF, and 22pF,
9) Relays: Double pole 220Ac /12v Dc
10) Transistor: BC548
11) Motor: Stepper type, servo type and DC type
12) Inductor: Coil 22mHz
13) Mechanical Arms
14) Electromagnet (core and the Coil assembling)
15) Vibration system Elements: Springs, Mass and damper

16) Wooden blocks, Support and Base
17) Vibrational Tumbler Assembling
18) SolidWorks
19) Proteus: 8.0
20) Android IDE

B. Methods

The metal scrap separating and cleaning architecture in figure 1 shows the units that makes up the designed model. The power supply is designed to provide energy to the entire system; the metal scrap separating unit is designed with the incorporated electromagnet system and the electromechanical drive.

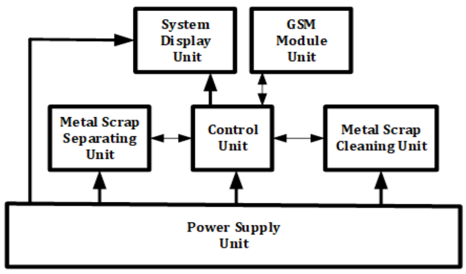


Figure 4: Intelligent mobile metal scrap separating and cleaning system model Architecture

The electromagnetic system creates the magnetic effect for the electric current to flows either to attract or release the sorted ferrous metal while the electromechanical drive provides the direction for the system to move the electromagnetic system from its initial position to select and collect the metal scrap. The metal scrap cleaning unit is designed to wash the scrap and release the dirty particle to one side, and pour the purify scrap to a collector for further processes. The control unit simultaneously provides an intelligent control algorithm for both the metal scrap separating and metal scrap cleaning unit, and presents the mobile system behaviour data in a human readable and interpretable format remotely with the aids of an android applications.

C. System Design and Implementation

The design of the intelligent mobile metal scrap separating and cleaning system model was divided into three parts which including: the electronic model design, the android model design and mechanical model design.

D. Electronic model design

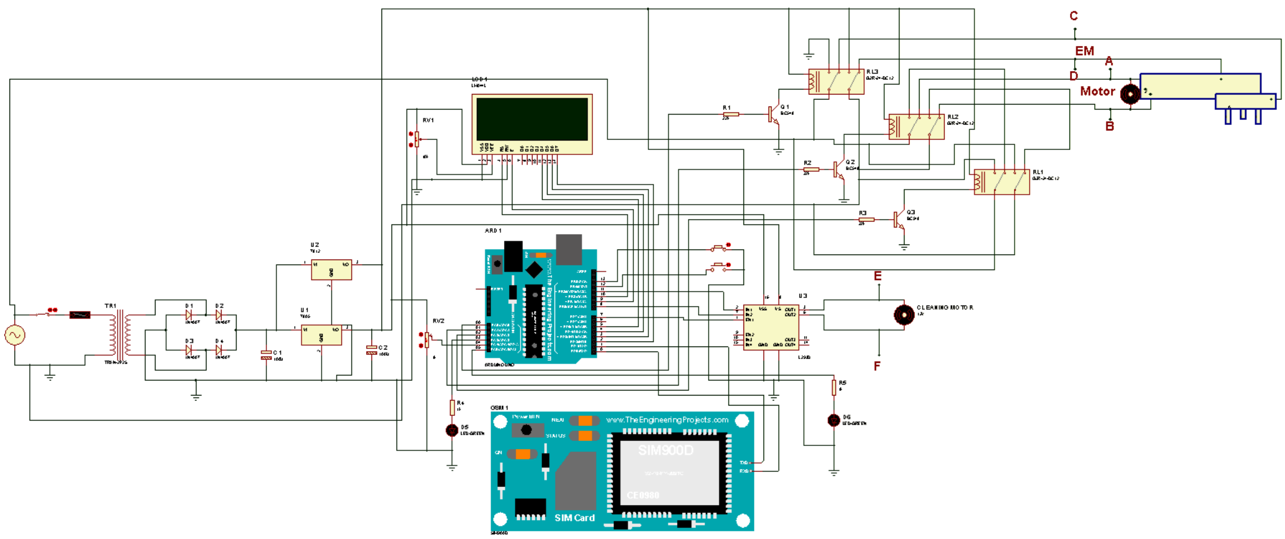


Figure 5: The intelligent mobile metal scrap separating and cleaning system model Circuit

E. Principle of operations

The regulated voltage of 5v and 12v were designed to power the microcontroller-based system alongside with other section in the system as designed. After the system initialization for the push button to be pressed intelligently, the metal scrap separating machine begins its operation with a light emitting diode lit and the transistor labeled BC548(Q1) is forward biase to actuate the double pole relay (RL1).The 220vAC is connected to the positive and negative terminal of the relay at the position A and B of the motor via the relay RL2. Then the relay RL2 is actuated to energize the electromagnet of the separator. The electromagnet being activated picks up the scrap metal and move the separator towards the metal cleaning system to drop the sorted metal. At the predesigned operational interval, the transistor BC548 (Q2) sent a low (0) input which deactivates the RL2 to cut off the power supply from the separator and subsequently stop the movement, and the transistor BC548 (Q3) sent a low (0) input signal, deactivating the relay RL3 to demagnetize the electromagnet in the terminal designated C & D. When the system is demagnetized, the scrap metal is drop into the metal cleaning machine were the scrap are cleaned, with the allotted cleaning time of 25minutes the dirty particles are separately poured into a collector for onward disposal after which the polished metal is poured out into a another collector for further processing. As the cleaning was going on, the transistor labeled BC548(Q1) is reverse biase to deactivate the double pole relay (RL1), this causes the polarity of the supply to change via the motor connected between terminal A & B. This reverse action then redirects the separator to the scrap site. At the scrap site, RL2 is deenergized while the RL3 is energized thereby prompting the electromagnet to magnetized and pick scrap metals, and after 10 seconds delay time, the reverse action again causes the separator to move to the scrap cleaning machine were the scrap are dumped for cleaning and screening. The system on receiving the metal scrap on the vibrational bowl (the tumbler), with its sensing and actuation capabilities, creates an applied force which cause the motor designated in terminal E & F to rotate.

From the vibration of the tumbler, the metal scrap rub and grind against each other thereby effecting the cleaning process. Within the smart system preset time (5 seconds), the system produces the desired surface finished and polished metal pieces. The screening process is effected by the system by first exiting the dirty medium from the tumbler and afterward exiting the cleaned and polished metal to a collector. Whenever the rotor of the motor in terminal E & F is energized, it turns the tumbler in anticlockwise direction, this will in turn pulled the tumbler down and simultaneously push another part up. As the sensor detects a lighter-weight of the tumbler, exit cover for clean metal closes; the sensor deactivates the cleaning device motor and the cleaning process stops. The scrap separator is intelligently actuated as the screened session prepares to end, and reload itself against another round of operation. The liquid crystal display gives the operational sequence as in figure 6 where the metal scrap is separated, screened and the metal scrap cleaned. It also shows the intermittent activities within the system while the SIM900 module relates the system behavior with the aid of an android apps for remote monitoring and control. The process repeats itself smartly under the microcontroller mediated action until the scrap in the experimented site is completely sorted, cleaned and screened, the system smartly activates the stop bottom to a depressed mode.

F. Flow Chart

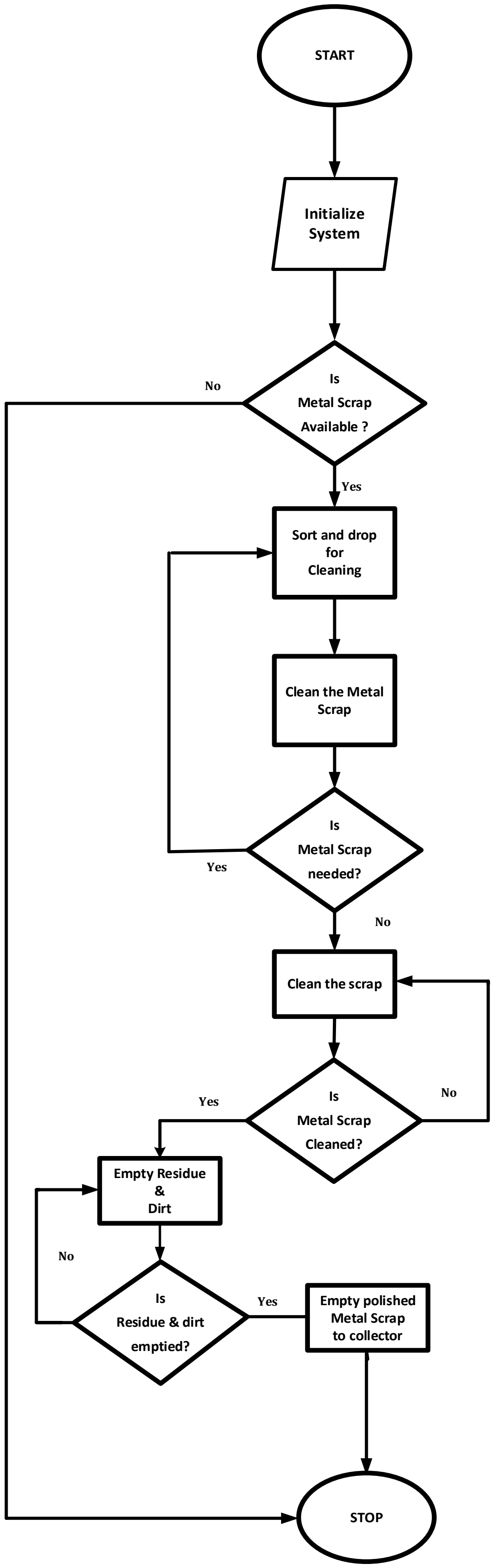


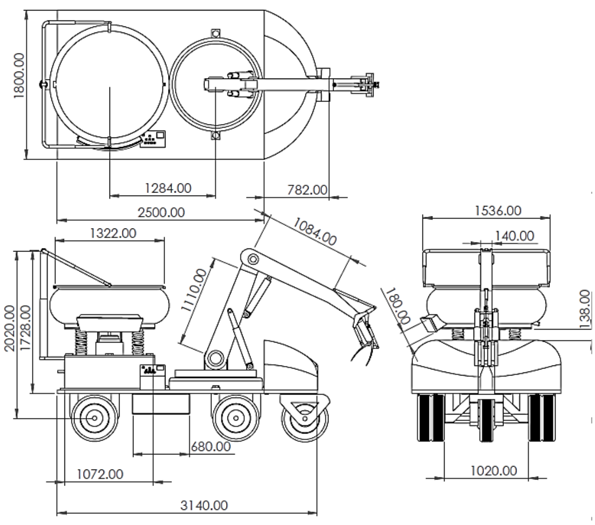
Figure 6: Flow chart for the intelligent mobile metal scrap separating and cleaning system

Android model design

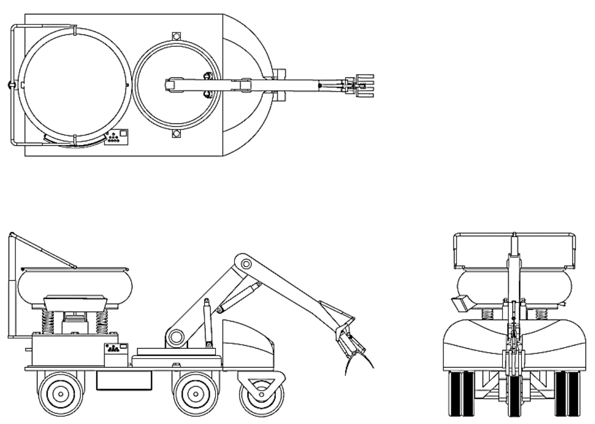
The intelligent mobile metal scrap separating and cleaning system android design was developed using Hypertext Mark-up Language (HTML), Cascading Style Sheets (CSS) and JavaScript with the aids of sublime text editor, the conversion of the scripts to the android was made possible with Cordova. The database was developed using Mango DB whereas the GitHub enabled the code hosting.

Mechanical model design

The conceptual design of the mechanical model is as presented in the projected views in figure 7. Figure 7 (a) shows the projected view with dimensions while figure 7 (b) presents the projected view without dimensions, for clarity.



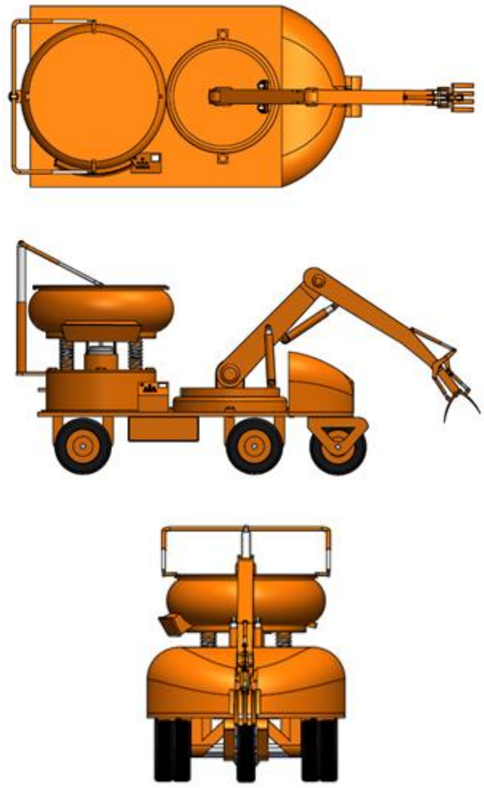
(a)



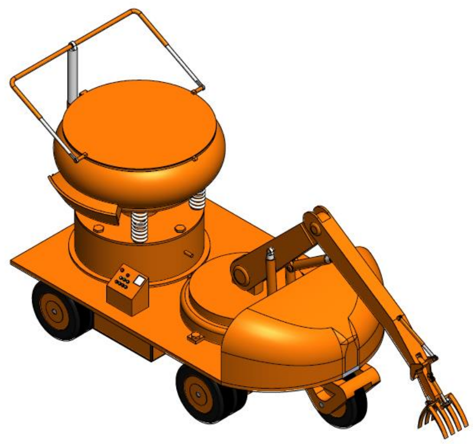
(b)

Figure 7: Mechanical design dimensions for the intelligent mobile metal scrap separating and cleaning system

Figure 7 gives the design specification for the intelligent mobile metal scrap separating and cleaning system development and outlined how the machine was design with its actuating devices such as hydraulic, pneumatic and electrical sensors.



(a)



(b)

Figure 8: Orthographic and Isometric view of the designed intelligent mobile metal scrap separating and cleaning system

Figure 8(a) shows the orthographic projection for the system with considerations to the plan, front and side view; while figure 8(b) shows the 3D model of the design intelligent mobile metal scrap separating and cleaning system was also presented.

Table 1: Design Part Labels

Designed Part Numbers	Part Name	QTY.
1	Excavator Drive System	1
2	Fork Arm Base	1
3	Fork Arm Link 1	1
4	Fork Arm Link2	1
5	Linkage Actuator Base	3
6	Linkage Actuator Male	3
7	Hook Head	1
8	Male Fork	1
9	Female Fork	1
10	Main Frame	1
11	Rear Axel	1
12	Tyre Shaft	2
13	Tyre	9
14	Front Tyre Guide	1
15	Front Tyre Suspension	1
16	Tumbler	1
17	DC Motor	1
18	Rotor Coil	1
19	Tumbler Plate	1
20	Spring	4
21	Tumbler plate 2	1
22	Tumbler Frame	1
23	Tumbler Cover	1
24	Tumbler Cover Actuator 1	1
25	Tumbler Cover Actuator 2	1
26	Tumbler Cover Actuator 3	2
27	Front Tyre Shaft	1
28	Separator Head Actuator Arm 1	1
29	Separator Head Actuator Arm 2	1
30	Separator Head Actuator 1	1
31	Separator Head Actuator 2	1
32	Circuit Box	1
33	Battery Box Cover	2
34	Front Tyre Motor	1
35	Front Bunnet	1
36	Linkage Hinge 1	1
37	Linkage Hinge 2	1
38	Cover Hinge	1
39	Sixty Bolt	4
40	Forty Six Bolt	4
41	Actuator Hinge 1	3
42	Actuator Hinge 2	1
43	Actuator Hinge 3	3
44	Separator Head Actuator 3	1
45	Separator Head Actuator 4	2
46	Separator Head Actuator 5	1
47	Exit Cover 2	1

Figure 9 and table 1 shows the part numbering and part list for the intelligent mobile metal scrap separating and cleaning system

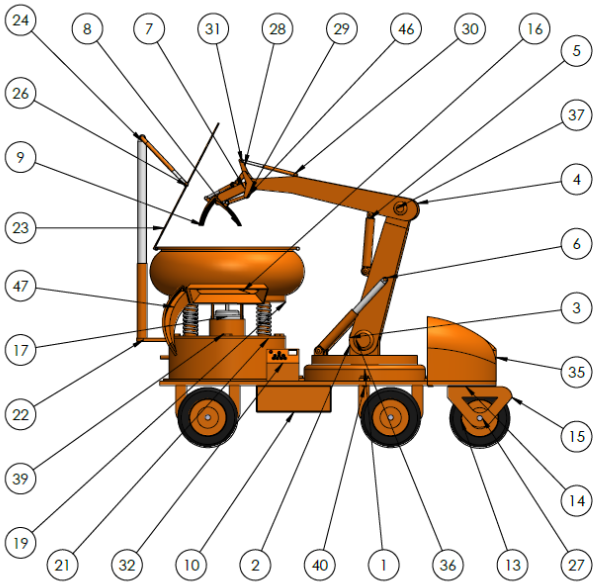


Figure 9: The design part label for an intelligent mobile metal scrap separating and cleaning system

4. Results Discussion and Analysis

A. Electronics Design Result

The result of the virtual simulation model for the intelligent mobile metal scrap separating and cleaning system is as shown on Figure 5. The controller which is the brain of the system coordinates the scrap separating process simultaneously with the metal scrap cleaning and screening system. This process was viewed remotely using the developed android application and it was validated as a smart, self-driven and a single unit system.

B. Android Application Result

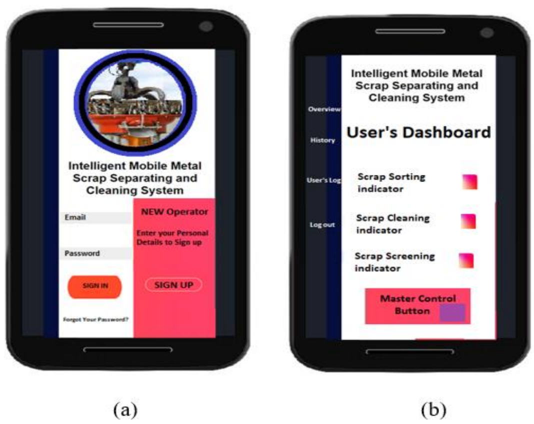


Figure 10: Intelligent mobile metal scrap separating and cleaning system Android design

Figure 10(a) shows the android signup/in interface for the intelligent mobile metal scrap separating and cleaning system whereas figure 10(b) shows the android graphical users interface design for the remote monitoring and control operations. The scrap sorting indicators shows the machine sorting operation status and the scrap cleaning status shows the machine cleaning operation status, while the scrap screening status shows the machine screening operation status. The dashboard comprises of the system overview platform, the historical documentary for the previous and recent operation. The users log platform documents the user detail on a real time basis and the logout pallet give the users environment to sign out after a particular operation. Master control button was designed for the emergency shutdown and use to direct the self-driven device to another scrap site in case the machine can no longer sensed the scrap within a particular area within a preset time interval of 10 seconds.

C. Electro-Mechanical model

Figure 11: The electro-mechanical system model for the intelligent mobile metal scrap separating and cleaning system

Figure 11 shows the complete four degree of freedom electro-mechanical system model for the intelligent mobile metal scrap separating and cleaning system. This generalizes model for the system was demonstrated and validated. It was revealed that the metal scrap separating system can be combined with the scrap cleaning system to produce an intelligent, vibrational and self-driven smart mobile system with embedded control system algorithm that facilitates its remote monitoring and control operations.

Conclusion

This proposed intelligent mobile metal scrap separating and cleaning system model was demonstrated virtually. An already existing scrap metal separator and cleaning system were adapted for combine operation. The formidable means of sorting, cleaning and transferring the metal scrap from one point of operation to another was developed which ease human labour and eliminate energy wastage that would have emanated from their separate operations.

This designed model was developed using solidWorks CAD/CAM software and Proteus. The programming code for the control action was developed with Arduino IDE.

The simulated model for both the solidWorks design and the Proteus design with the program code reveals the system simultaneous functionality as it is capable of sorting, screening and cleaning of scrap metals. With the superposition of these two different systems and subsequent introduction of the microcontroller, the system becomes intelligent, mobile and self-driven due to its controller-controlled algorithm. The development and virtual implementation of the proposed system prototype with its intelligent and mobile capability has proven that the metal scrap separating and cleaning system can be put together for a self-driven, low energy consumption, less human effort, profit maximization and efficient time management system model. The android apps for the monitoring and control of this self-driven system was validated as it conformed with the research design. Further research advancement can be made in converting the simulated model into a physical industrial machine.

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