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Design, Fabrication, and Development of an Automated Seed-Sowing Machine

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Abstract: *Agriculture is a very important sector that has a direct contribution to the economy of both developed and developing nations of the world. Nigeria is a developing nation with great belief and anticipation that agriculture is a major sector that can bring the much-needed development of the country in no time. Automation of agro-technology involves the implementation of recent technologies to develop the crops that are being produced. The use of agro-technology helps to improve the throughput of the farm workers, improves the efficiency of the crops produced, and also helps in developing devices that are suitable for doing both manual and mechanical work in the fields. In this research work, an automatic seed-sowing machine was designed, fabricated, and developed using Arduino programming as the control. The machine comprises the following operating units; the chassis on which all other components are mounted, the power units comprising of two 9V batteries which serve as the prime mover, and the programmed Arduino chips for the automation of the machine. The Arduino programming supplies the mechanical parts with the necessary instructions and controls in order to perform the sowing operation. At the end of the test, the machine saves time, energy is more efficient, and has no seed wastage.*
Keywords: *Agro technology, Arduino programming, automation, control, efficiency, seed sowing machine.*

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I. INTRODUCTION

The world is currently moving toward automating every operation through the use of technology, and it is clear that individuals are becoming accustomed to doing so by using efficient methods to complete their tasks. One can observe how advances in seed-sowing methods and machinery have occurred over time Roshan et al. (2013). This is the real motivation behind this research work. Engineers have created hand-operated, partially automated, and fully operated seed-sowing equipment because proper seed-sowing is a crucial step in the agricultural process. Kalay Khan, et al., (2015). The largest industry in the world that is essential to a country's economic growth is agriculture. For each farmer, farming is a necessary but very laborious task. Because farming is so time-consuming when done on a large scale, more personnel are needed. Therefore, agricultural machinery was created to streamline human labor. From farm mechanization (Bankole et al. 2021) to automated farming (Leonard et al. 2022), to planting robots (Kee et al. (2016) & Xudong et al. (2021), a number of researchers have studied the development of planting methods. The automation of different processes involved in the seed sowing machine was also investigated, like solar-powered systems, utilization of seed metering systems, use of sensors with Arduino ARTMEGA, etc. Hogue et al. (2013). The goal of this research project is to design and construct a seed-sowing machine using Arduino programming, a relay, and a step-down module for the planting of maize seeds and beans. The machine that was constructed is highly practical,Adedeji et al, (2020*)*, and IoT technology, which is utilized to send commands to the machine, enables remote control from the user. This will result in a better and more consistent spacing of seeds while requiring less human labor and time to plant in the same area.

II. LITERATURE SURVEY

In order to give the seeds a suitable soil cover, Roshan et al. (2013) addressed spreading the seeds and composting them in a line at the correct depth. Ramesh et al. investigated various types of seeding hardware and highlighted advancements in seed-sowing equipment (2014). An autonomous sowing device was created by Kalash Singha et al. (2019) with the intention of boosting production, cutting down on seed waste, and speeding up the sowing process. A built and developed automatic seed-sowing machine uses solar-powered DC motors that are driven by an L298N driver circuit and an Arduino UNO R3 control kit. In order to find obstructions in the way and the ends of each row, an ultrasonic sensor is also attached. Kalay Khan et al, (2015)focused on the design and fabrication of a manually operated planter sowing for different crop seeds that are cheap, easily affordable by the farmers, easy to maintain, and less laborious to use. The multi-crop planter has the capability of delivering the seeds precisely with uniform depth in the furrow, and also with uniform spacing between the seeds. The seed planter consists of the main frame, adjustable handle, seed hopper, seed metering device, adjustable furrow opener, adjustable furrow closer, drive wheels, seed tube, and ball bearings. Most of these were fabricated from mild steel material, except for the metering mechanism which was made from good quality nylon, and the seed funnel tube was made from a rubber material. The seed metering device was designed to be interchangeable to allow for the different varieties and types of seeds.In order to increase planting efficiency and lessen the laboriousness associated with the manual planting method, Kyada et al. (2016) designed a manually controlled seed planter machine. It is also feasible to plant seeds of various sizes at various depths and distances between the seeds. Additionally, it improved the accuracy of seed planting and fertilizer placement, and it was made of durable and economical materials that were suitable for small-scale peasant farmers. Renitha et al. (2000)presented a study about the design and fabrication of an automatic seed-sowing and fertilizer-spraying machine. The basic requirements of a seed sowing machine are, it should be simple in design and construction and affordable for low-budget farmers. Easy to handle and repair by farmers. The main intention of this project is to reduce the cost of machines and get optimum yield. By utilizing a solar panel electric automatic system, Phaltane et al. (2009) developed a robot that is capable of automatic ploughing, seed dispensing, pesticide spraying, and leveling. The microcontroller, which controls every step of the operation, is the key element here. The robot starts by tilling the entire field, then moves on to ploughing while dispersing seeds side by side, leveling with water, and spraying pesticides. Bharat et al. (2016) worked on a Bluetooth-controlled seed-sowing process in agriculture. A mobile robot in this operation is controlled by a smartphone. The goal of this project is to create a mobile robot that will lower labor costs and improve seed-planting precision. Mahesh et al. (2019) presented a review that provides brief information about the various types of innovations done in seed sowing machines available for plantation. The seed-sowing machine is a key component of the agriculture field. The performance of seed-sowing devices has a remarkable influence on the cost and yield of agricultural products. Presently there are many approaches to detecting the performance of the seed-sowing device. Nagesh et al. (2017) developed an automatic seed-sowing machine that was used on farms by farmers and was user-friendly. The new proposed equipment has a number of advantages and can conduct several tasks simultaneously when compared to the conventional sowing method. Srilatha et al. (2006) designed and modeled an agricultural robot. reviews the success stories of robotic agriculture in different areas of agriculture. The work also throws light on the future scope of robotic agriculture, especially in developing countries. Annapurna et al. (2019) discussed an automated seed-sowing machine using atmega 2560. In this paper, they discussed the sowing techniques which are useful in farming. The ATMEGA2560 microcontroller board has 54 digital I/O ports (15 can use for PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a USB connection, and a 16 MHz crystal oscillator, a power jack, an ICSP header, and reset button

III. MATERIALS AND METHODS

Some good criteria for the selection of materials in engineering include; machinability, availability, and mechanical properties of the materials Leonard et al (2022).

3.1 Components of the Machine

The automatic seed-sowing machine consists of the following operating units:

a. The chassis on which all other component's parts are mounted is shown in figure 1 below. It is a skeleton of the fabricated machine. It givessupport toevery other part of the machine both in their construction and use. The chassis ismade from a 40 mm thickness pipe from a mild steel material with the following dimensions; 920mm x 610mm x 200mm and a weight of 25 kg.

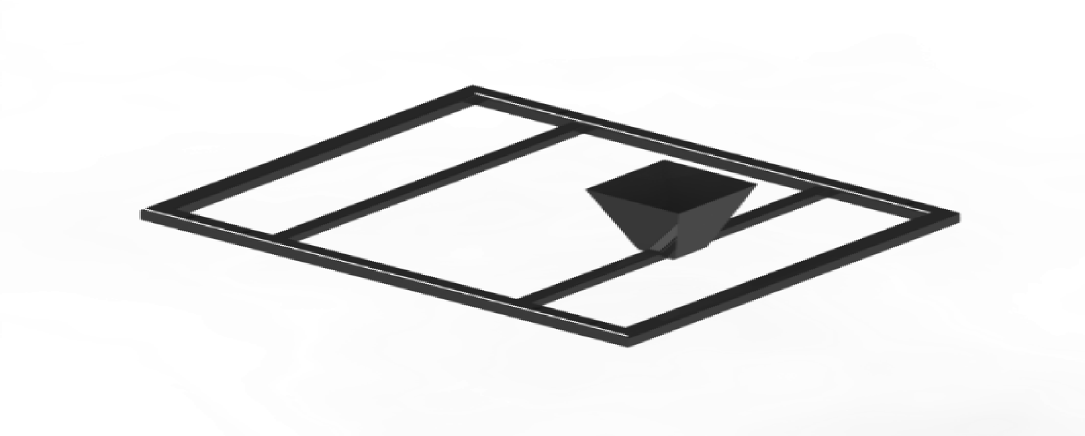


Fig. 1 **Designed chassis of the seed-sowing machine**

b. The power unit comprises two 9-Volts DC batteries. According to Ampere's Law, a wire which carries an electric current produces a magnetic field around it. Following this law, DC Motor creates mechanical work from electrical energy.

c. The automation unit and programming are basically an Arduino UNO R3: The Arduino UNO is a widely used open-source microcontroller board based on the AT mega 328 microcontrollers and developed by Arduino.

3.2 The Design Flow Chart of the Seed Sowing Machine

The flow chart shown in figure 2 below describes the working principle, the different units of the machine, and the sequence of operation during seed sowing operation.

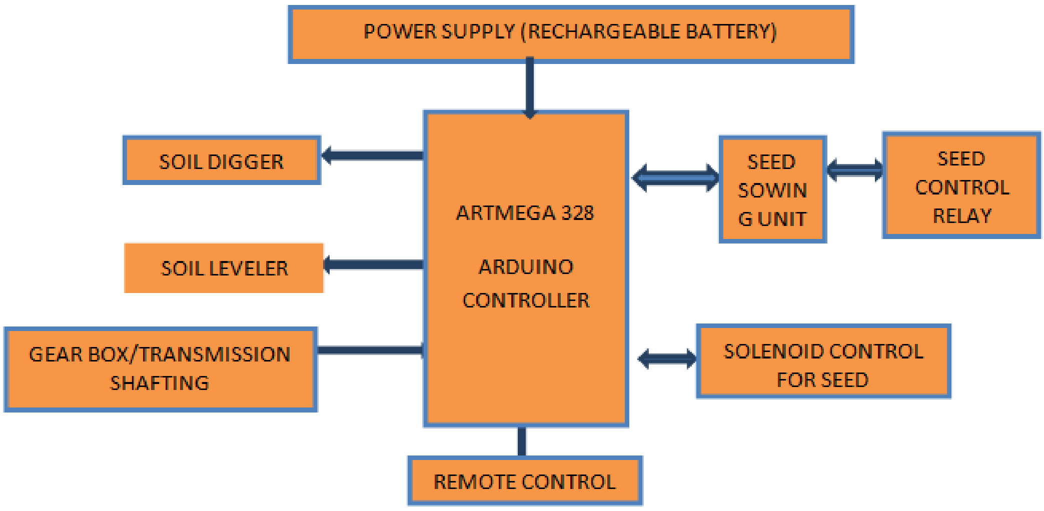


Fig. 2Block ***diagram of the design concept***

3.3 Components of seed sowing machine

3.3.1 Soil Digger

The soil digger is made from mild steel material due to the strength-to-weight ratio of this material to effectively dig the soil as the seeder machine moves on the farmland after the tillage operation. The digger is 300mm by 30mm in dimension and has a rake angle of $75^{o.}$ This rake ankle is responsible for the effective cutting of the soil before the seed is dropped.

3.3.2 Soil Leveler

The soil levelers help to level the ground or park the soil into the hole made during the digging operation. The leveler is 75mm in diameter. The soil leveler is attached to the chassis with the help of a hanger which is 50mm by 150mm in dimension.

3.3.3 Seed Hopper

The Seed Hopper consists of a seed drum made up of two frustums from a 16 gauge steel sheet. The small ends of frustums are connected with a square base of 25mm by 25mm while the upper part is 150mm by 150mm in dimension. The large ends of the frustums are connected to each other and three holes are created on the larger circumference of the hopper. Seeds are loaded in the frustums from the top while there is a smaller box grooved at an angle of repose responsible for dropping the seeds into the hole with the help of a solenoid control. Hopper will rotate about its central axis.

3.3.4 Reduction Gear and Electric Housing

The DC motor is the prime mover which provides the initial movement for the seed-sowing machine. An output gear of 8 teeth is meshed to a spur gear of 64 teeth thereby reducing the speed in the ratio 1:8.

3.3.5 Driver and Driven Shaft

These two sets of shafts are responsible for transmitting motion from the gearbox to the four
Wheels of the seed sowing machine.

3.4 ELECTRICAL, CONTROL COMPONENTS, AND PROGRAMMING

3.4.1 D C Motor

DC Motor creates mechanical work from electrical energy. It's a class of turning electrical machines changing over electrical machines that change over direct flow electrical vitality into mechanical vitality. As terminal voltage increments or diminishes, the speed of the associated/dc engine additionally expanded or diminishes. As shown in figure 3, a motor can convert electrical energy into mechanical energy in order to run.

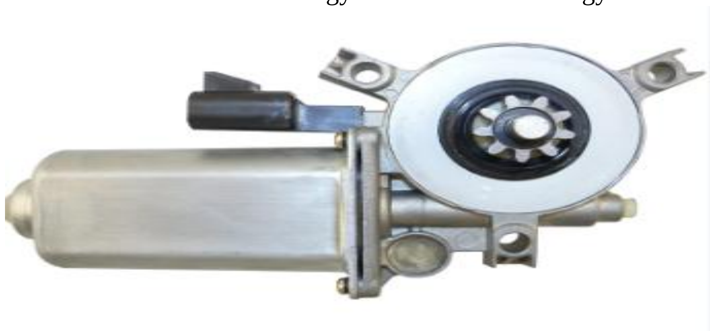


Fig. 3 DC Motor

3.4.2 Relay

A relay is an electrically operated switch. It consists of a set of input terminals for single or multiple control signals and a set of operating contact terminals.

Fig. 4 Relay

3.4.3 ARTMEGA 328 Arduino Controller

Arduino Uno is the heart of the system which is connected to all the sensors and other hardware assemblies required to achieve the desired work. The block diagram of Arduino UNO R3 is shown in figure 3. The Arduino UNO is a widely used open-source microcontroller board based on the AT mega 328 microcontrollers and developed by Arduino. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced with various expansion boards (shields) and other circuits. The board features 14 Digital pins and 6 Analog pins. It is programmable with the Arduino IDE (Integrated Development Environment) via a type B USB cable. It can be powered by a USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts. It is also similar to the Arduino Nano and Leonardo. Layout and production files for some versions of the hardware are also available. "Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, which now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards and the reference model for the Arduino platform. The ATmega328 on the Arduino Uno comes preprogrammed with a boot loader that allows uploading new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol. The Uno also differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter. It runs on Windows, Mac OS X, and Linux. Interrupts are used in programming to make the system more effective and respond to changes accordingly.

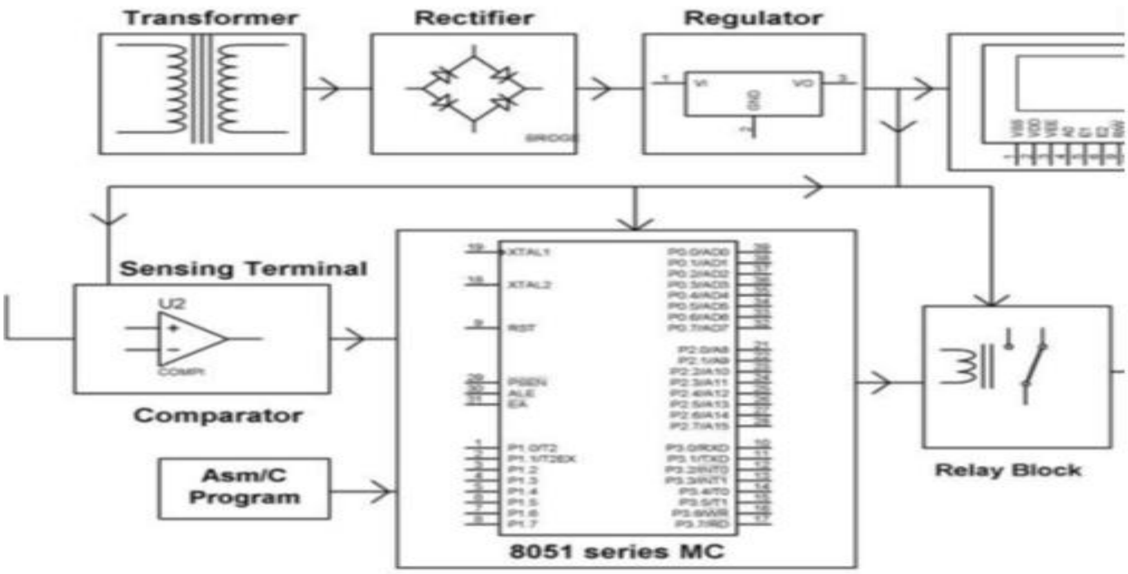


Fig. 5. Block Diagram of Arduino UNO ARTMEGA 328

3.4.4 Radio Frequency (RF) Module

An RF module (short for a radio-frequency module) is a small electronic device used to transmit and/or receive radio signals between two devices. In an embedded system it is often desirable to communicate with another device wirelessly. This module is employed to communicate wirelessly using radio frequency. We made use of this instead of other methods of communication systems due to its high wavelength.

Fig. 6 RF Module

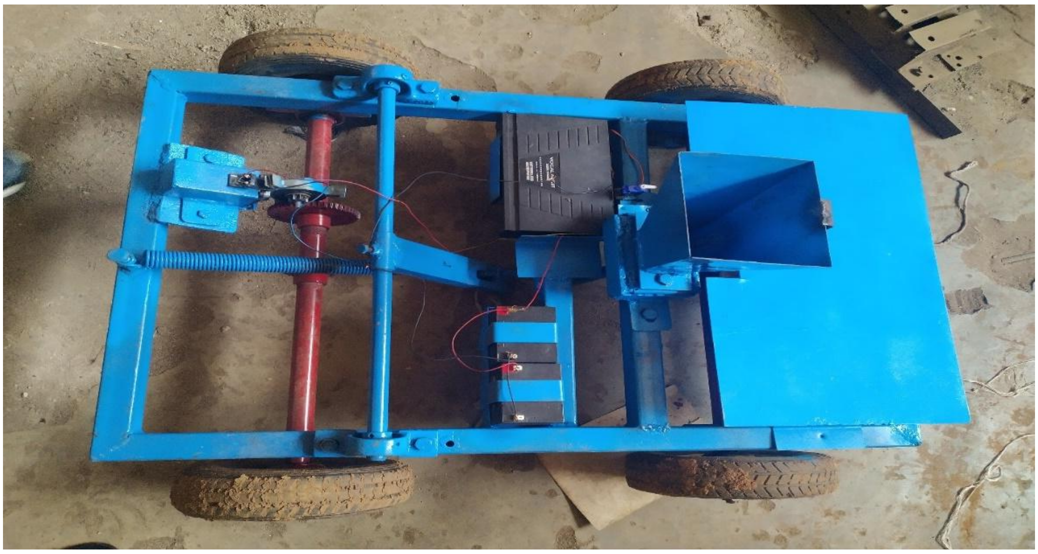


Fig. 7.Pictorial view of the seed-sowing machine

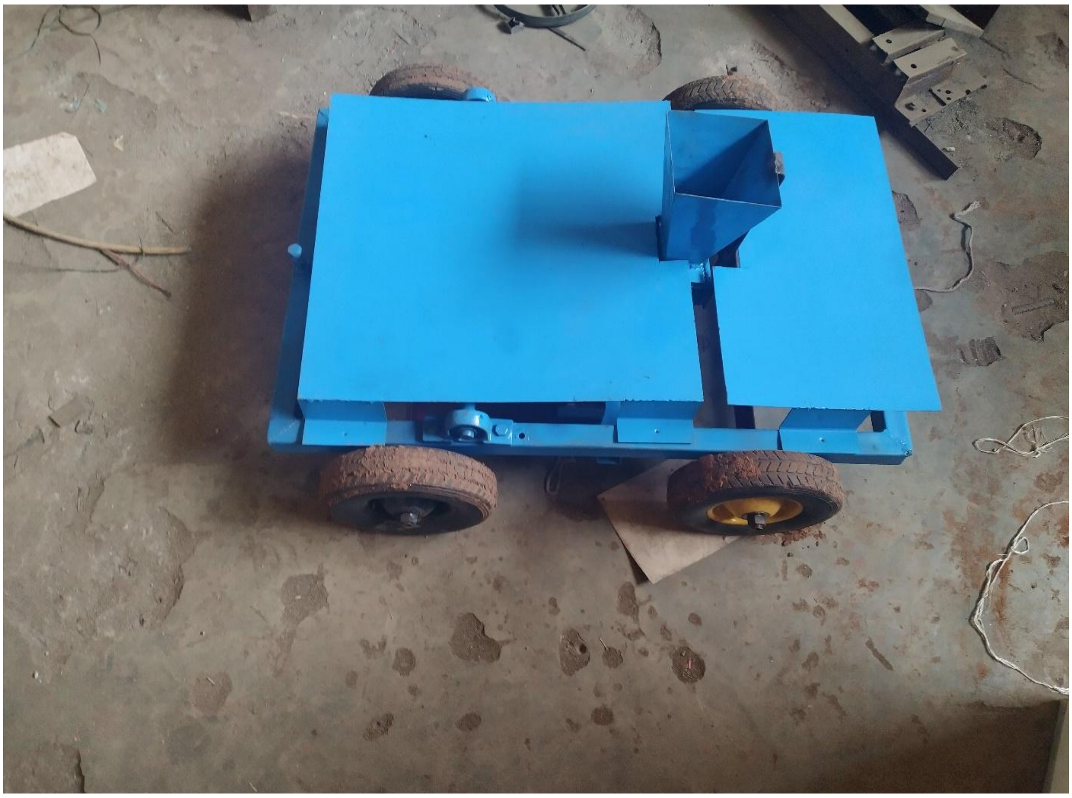


Fig. 8.Pictorial view of the seed-sowing machine

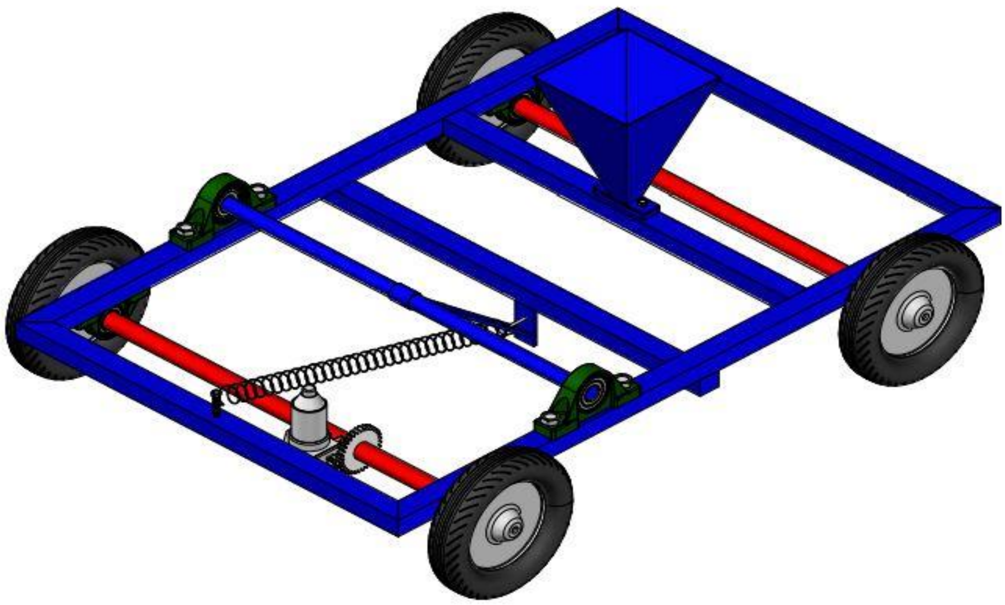


Fig 9. Isometric view of the seed-sowing machine

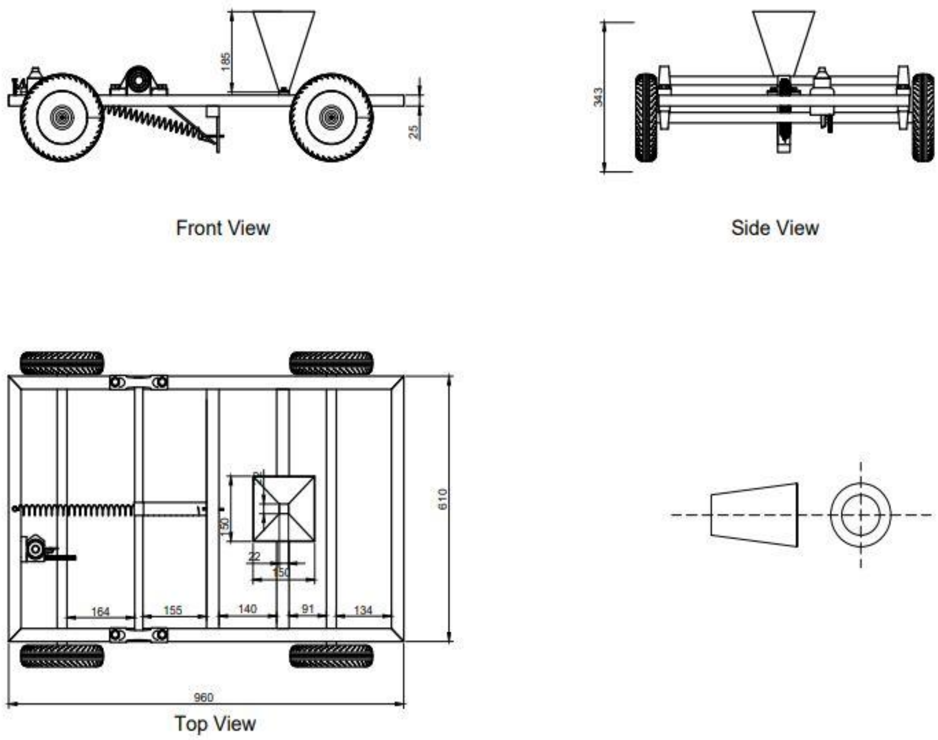
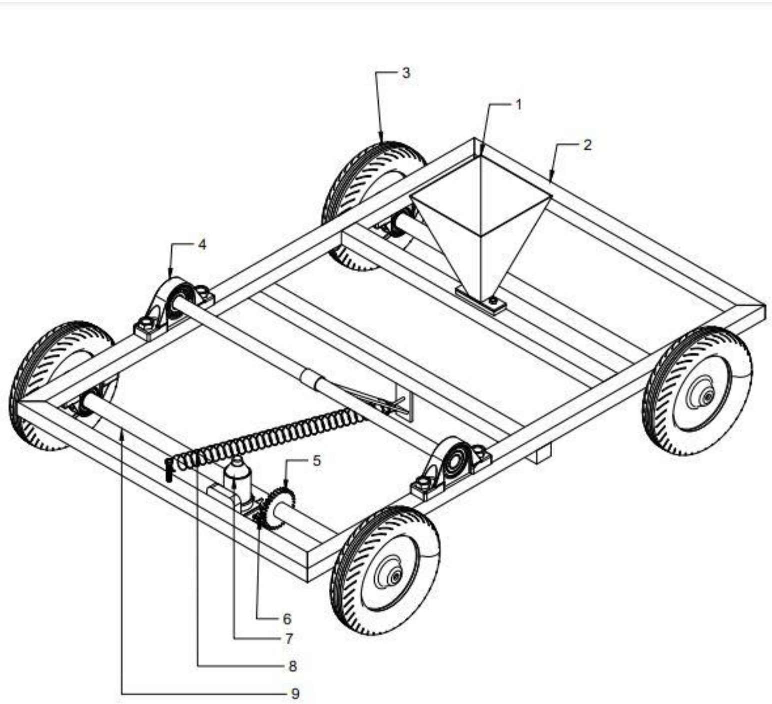


Fig. 10. Orthographic Projection of the seed-sowing machine



Part List		
Part No.	Part Name	Material
1	Hopper	Mild Steel
2	Chasis	Mild Steel
3	Tire	Standard
4	Pillow Bearing	Standard
5	Driven Gear	Alloy
6	Driven Gear	Alloy
7	Motor	Standard
8	Return Spring	Standard
9	Shaft	Mild Steel

Fig. 11 Detailed part list of the seed sowing machine

3.5 DESIGN CALCULATIONS

3.5.1 Power Calculation

Assume that the machine runs at the speed of 35Rpm. As per the requirements of the machine, the motor selected is 24V. Which is having speed of 35rpm. The motor is of DC geared motor. With current 1.8Amp.

P = V*I[Where, P = Power of motor (Watt) V = Voltage (Volt)] (1)

I = Current (Amp)

P = 24 * 1.8 = 43.2Watt

The power transmitted by the motor is equal to the power received by the shaft.

Since Power = $\frac{2\pi nT}{60}$ (2)

Where; n = Speed in RPM

T = Torque in N.mm

Since power = 21.6 watt, then;

$$21.6 = \frac{2\pi * 35 * T}{60}$$
$$T = 5.89 * 10^3 N.mm$$

Therefore, $R_S = 30mm$

Hence, Force in Shaft, $F = \frac{T}{R}$ (3)

F=$\frac{5.89*1000}{30}$

F= 192N

Then we select the standard diameter as D = 60mm

Velocity, V = $\frac{\boldsymbol{PZ_n}}{60*10^3}$ (4)

Where, p = pitch, Z = no of teeth, n = speed

$$V = \frac{15.875 * 12 * 35}{60 * 10^3}$$
$$V = 0.11m/s$$

3.5.2 Determination of Allowable Force and Pool

By using the diameter and velocity we can easily calculate the required pull and allowable pull.

P = $\frac{\boldsymbol{F*V}}{10^3 * K_l * K_S}$ (5)

Where, F = required force, p = power, v = velocity, K_l = Load factor, K_s = Service factor

$$21.6 = \frac{F * 0.11}{10^3 * 1.1 * 1}$$

Allowable pull; F= $216000N$

$F_a = \frac{F_u}{n_o}$ (6)

Where $F_u = Ultimate\ load\ , n_o = working\ factor\ of\ safety$

$$F_a = \frac{17900}{7} = 2257.14N$$

3.5.3 Design of shaft

Upward force = Downward force

$R_A + R_B = 192NR = \frac{F}{2}$. (7)

$R_A = 96N$ $R_B = 96N$ Shear force diagram

Also, $SF_A = 96N$ $SF_B = -96N$ $SF_C = 0N$ Bending moment diagram

$$BM_A = 0N.mm$$
$$BM_B = 192N * 228.6mm = 21945.3N.mm$$
$$BM_c = 0N.mm$$

Maximum bending moment in shaft$M_b = 21945.3N.mm$

The reaction of the forces R_a and R_b due to self-weight of the shaft and also the external load on the shaft assuming the diameter of the shaft is uniform and simply supported by A and B may be calculated as given by S.R Khurmin (2005)

Maximum twisting moment in shaft, $M_t = \frac{9550*1000*P}{n}$ where P= power and n= speed of shaft

$$M_t = \frac{9550 * 1000 * 21.6}{35} = 5.9 * 10^6 N.mm$$

Determination of the shaft diameter

$$D = \sqrt[3]{\left[\frac{16}{\pi\tau}\sqrt{\{(K_b * M_b)^2 + (K_t * M_t)^2\}}\right]} \quad (8)$$

Where, τ=permissible shear stress, M_b=Bending moment, M_t= Twisting moment

K_b= Shock factor, K_t= Endurance factor

Select the value of$K_b = 1.5$ and $K_t = 1$. The permissible shear stress for steel shaftis

$$\tau = 120N/mm^2$$

$$D = \sqrt[3]{\left[\frac{16}{\pi * 120}\sqrt{\{(1.5 * 21945.38)^2 + (1 * 5.9 * 10^6)^2\}}\right]}$$

$$D = 22mm$$

3.5.4 Design of Hopper

Length of the upper square dimensions

X=Length (l) = 150mm = 0.15m

Y=Width (w) = 150mm = 0.15m

Lower square dimensions

x= Length (L) = 25mm = 0.025m

y= Width(w) = 25mm = 0.025m

Height of the hopper

Height = H = 200mm = 0.2m

Using the relationship

Volume = $\frac{1}{3}H[\frac{X^2*Y-x^2-y}{X-x}]$ (9)

V = $\frac{1}{3} * 0.490\left[\frac{0.15^2*0.15-0.025^2-0.025}{0.15-0.025}\right]$

3.6 Fabrication Procedure

The fabrication of the seed sowing machine is done in parts and later assembled. The chassis is fabricated from mild steel square pipe of 40mm thickness. The hopper is fabricated from 16-gauge steel sheets and 12 mm steel rod. A soil digger with 300 mm by 30 mm and a rake angle of 75^0 . A welding machine, tri square, machine grinder, hack saw, vice, lathe machine was used during the fabrication.

3.7 Mode of Operation

This machine is capable of digging the ground, sow seeds with the help of automatic seed metering controlled by Arduino programming and then cover the hole after the seed is dropped into it. The two 9-volts rechargeable battery which are connected in series provides the necessary electrical power to start the machine when the on/off switch is depressed. The battery powers the DC motor which in turns drives the four wheels with the help of 64 teeth spur gear meshed with it. Instead of the on/off switch RF panel the machine can also be controlled with a remote control. As the machine moves along the farmland it stops after every one foot to dispense seeds into the hole. The seed dispensing is automatically controlled with the help of Arduino programmed, a relay and the solenoid control. A cam arrangement is attached to the driven shaft and the body of the hopper which provides the necessary vibration for proper seed dispense when the relays open the base of the hopper for metering of seeds into the hole.

Ones the seed is dispense, the soil leveler covers the hole by packing the dugout soil back to fill the hole and the operation continues in that sequence.

3.8 System Architecture

The system architecture is as follows;

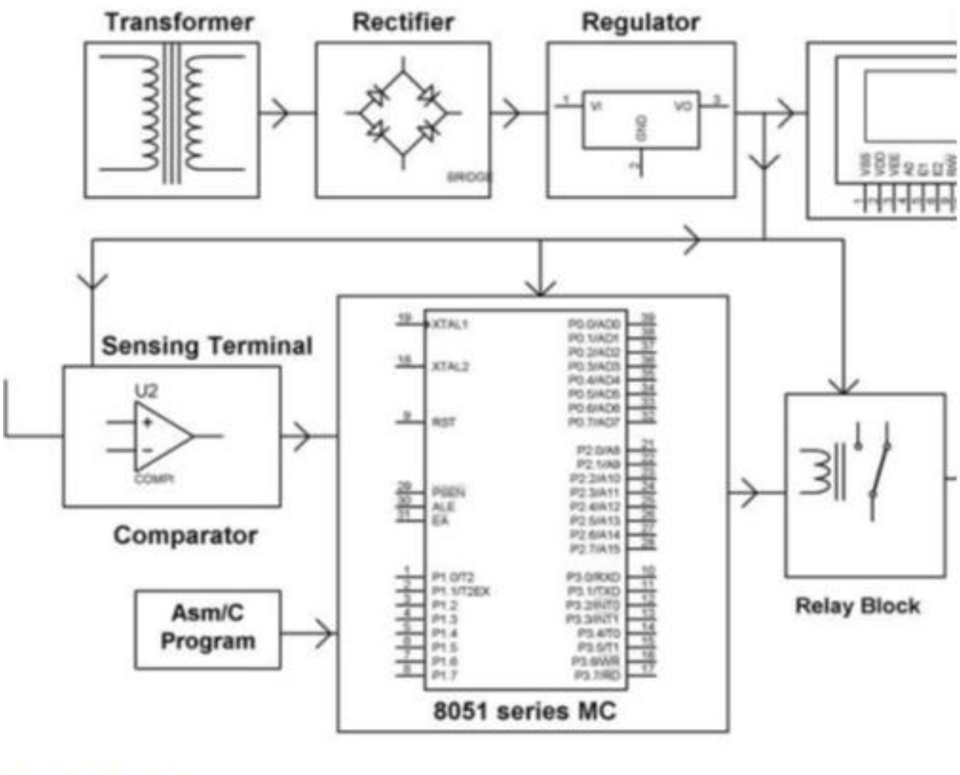


Fig. 3.6: Block diagram of the system architecture

IV. RESULTS

A seed sowing machine was designed and fabricated, the machine was tested and performance evaluation carried out. After building the device, both the arduino program and all the circuit designed work successfully. The controlled components and mechanical component parts worked synchronously. The machine drops 3 to 4 seeds at distance of 1 foot in 5 seconds. The machine operates at 76% efficiency.

V. CONCLUSION

The model design, fabrication and its automation have been achieved in order to overcome thedifficulties faced by farmers such as time wastage, laborious efforts and challenges of achieving regular distance between rows and consecutive seeds. It can definitely be useful on a large-scale basis due to its minimum requirement of man power and also the installation process being easier making it more compatible for everyone to use. It can be further concluded that;

(i) metering of the seed was accurate as per requirement.

(ii) There was no damage to the seed during metering.

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