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An Attempt At Developing A 3D Printer PLA Filament Recycler

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Abstract

In the cutting edge world, getting an essential thing is very easy but getting an essential thing with good quality is too difficult. To survive in the world, first and foremost thing that every creature needs is pure water, food and healthy environment. But nowadays, all these necessary things are affected mainly by plastics. Water pollution is high due to dumping of waste materials and high usage of non-biodegradable waste and other factor. Environment is being polluted by burning plastics which leads to global warming (increase in Earth's temperature and ozone layer depletion.

Traditional methods are used in cleaning rivers, lakes and ponds. But to reduce the waste plastics and to recycle it into useful product a best method should be implemented. To solve this problem, this work attempts to create a 3D printer waste recycler that can be used to convert waste plastic material into useful products. So that this product will reduce the dumping of wastes as much as possible. Though this product is available in market, the cost of the product is high and also the strength of the material that is produced is less. Our main objective is to reduce the 3D printing waste generated by producing a product that is low in cost, environment friendly and people friendly.

Keywords—*3D printer, PLA Filament, Extruder, Temperature, Nozzle.*

I. INTRODUCTION

3D printing is a method to create 3D objects and it can be done with the help of CAD. It creates objects layer by layer by adding materials. Materials such as thermoplastics, metals, resins and ceramics used to print. 3D printer produces 3D models using many materials like Polyethylene Terephthalate (PET), polyamide (PA), Polylactic Acid (PLA) etc. During the making of these models certain amount of material gets wasted. The wasted plastic materials are made into filaments using sorting technique and be reused for other applications.

The product is designed to be lightweight, easy to work and clean. New filaments are made from many plastic wastes using crushers and extruders. This process reduces the wastage of plastics. As 3D printing filament can be costly an attempt at creating filaments using 3D printer filament recycler machine is tried, which ultimately reduces the cost of 3D printing. The machine helps to produce all kinds of 3D printing filaments with desired colors. Also helps in creativity and innovation of the product.

The filaments produced are used in various applications. In automotive sector, filaments are used in bodywork of car. Recycled filaments are used to produce toys like LEGO. In medical applications filaments such as PLA, PC are used to produce pharmaceutical products such as implants for drug delivery, tablets and specific dosage for patient etc. Filaments help in producing wires, holders and other common household products. In Fashion sector filaments are used to produce jewelries such as bracelets, rings, princess crown.

History of 3D printer filament recycler is as follows.1980s were the birth of 3D printing techniques. Kodama was the first to patent for rapid prototyping in 1981 and to describe layer by layer approach. First 3D printing filaments were used in 1981.Charles Hull was the first person to patent a file in Stereo lithography (SLA) and produced SLA -1 ad their commercial product in 1988. First Fused Deposit Modeling was invented in 1988 in which plastic filaments are melted and applied in layers.1990s are considered as the period of emergence of 3D printers manufactures. In 1990 first EOS stereos system was introduced.

In 1992 FDM patent was issued to StrataSys. In 1995 Z Corporation produced Z402 which is used to produce 3D models using starch.2000s gains media visibility for 3D printing. In 2000 first working 3D printing kidney was created. A self-replicating 3D printer was produced in 2004. In 2005 first HD 3D printer, Z510 was produced by Z Corporation. 3D printed Prosthetic leg was produced in 2008 for medical application. 2010s were the period of innovation in 3D printing. In 2010 Urbee, first 3D printed prototype was presented. Year 2012 saw the printing of the first prosthetic jaw. Daniel Kelly's lab produced 3D printed bone in 2016. In 2018 3D printed house was made which was 1022 square feet and it took just two days.

Problems in 3D printer filament recycler are lots of 3D printing wastes are being generated while creating any 3D printing material. To reuse those waste materials, 3D printer filament recycler is the best one. But this product is not widely used because the cost of the product is very high and the quality and strength of the material generated from existing 3D printer filament recycler is relatively low. The objectives of this machine are as follows. To reduce the cost of the machine, selection of components that are best and also cost efficient should be chosen, so that the product will be widely used. To increase the strength of the materials PLA pellets are added. To reduce the waste generated from 3D printer, recycling it into useful material that will help children to learn by

seeing the product (fruits, vegetables, alphabets) and to produce an environmental friendly product could also be made.

Brian Obudho [1], describes the reuse of 3D printed waste using 3D printer filament recycler and has explained the process involved in 3D printer filament recycler which includes smashing of 3D printed waste material, molten, cooled and coiled to a reel. Grinding plastics causes strain on motors and henceusage of industrial motors has been suggested. Several extruders available in the market like Filastruder Kit, Strooder, Filabot EX2 filament extruder, Noztek Pro and the type of materials it can extrude is also discussed. Harimalairajan.k, et al. [2], explained how to produce an extruder machine at low cost and has used recyclable plastics which are eco-friendly. In addition to that, it is suggested to add fillers while reinforcing the input raw materials in order to increase the strength of the extruded plastic. Leong Yong Lim [3], discussed the filament made from recycling plastic waste byproduct from the 3D printing process using extruder and transform it to thermoplastic 3D printer filaments again which leads to cost reduction in the process.

Ravichandran.P, et al. [4], explained how the materials wasted during the 3D printing process can be collected and reused. The study also explains how to overcome of the disadvantages that are currently in existing machines. Their study is to develop a 3D printer filament extruder at low cost with the help of ABS pellets to produce filament and has also discussed to use easily available materials to finish the entire product. The paper suggests to use ABS material as a raw material for this work. Vaibhav Vikram Tare, et al. [5], discussed the process of designing machine that helps to make filaments using PLA and also ABS and chose that as the main material.

Muhamad Aminur, et al. [6], explained the conversion of 3D printing waste materials into a filament with the help of extruder machine and formed the new filament from Acrylonitrile butadiene styrene waste material. Katarzyna Mikula, et al. [7], discussed the making of printable filaments from variety of thermoplastic material which includes materials from recycling and the basic concept is 6R. Aubrey L.Woern, et al. [8], described a recyclebot that can make a 3-D printing filament from a waster plastic material and explained the design, fabrication and working of Reparable Recycle bot and also discussed product cost, time taken to fabricate the filament from commercial pellets, diameter and also about temperatures and further research on novel application.

Joshua M.Pearce [9], used DRAW method and has explained from clean waste plastic till custom recycled plastic paper and also explained where DRAW method can be used and about recent researches on DRAW method. The main idea is about recycling plastics for environment benefits at low costs which helps to run a small business.Jukka Pakkanen, et al. [10], have presented about the recreating wastes from 3D printing for better use.. Zhiqiang Chen, et al. [11], has explained about digital light processing. The paper states that with the increasing use of DLP 3D printing, the thermosetting material recycling is efficiently performed and is also highly desired.

II. METHODOLOGY

Before starting any work, methods for proceeding about the work is framed, starting from project idea planning and confirmation, data collection and analysis, defining project requirements and buying components, product development and assembly, testing and rectifying and final prototype as shown in Fig 1.

A. Data Collection and Analysis

After project planning and confirmation of project, data collection was done. Searched many papers related to 3D printer filament recycler and framed literature survey which helped to collect ideas such as different techniques and components used for recycling filaments. As a part of data collection, Patent search was done.

B. Component Selection

After getting ideas on project techniques, proceeded with component selection. In this stage a block diagram that represents working of the recycler was framed.

C. Selection of Extruder

MK8 extruder J head with nozzle diameter of 0.4 mm is selected based on the requirements of this project, it has maximum operating temperature of hot end: 250 degrees. And uniform heating aluminium heater block.

D. Selection of Stepper motor

Nema17 4.2 kg-cm Single Shaft Stepper motor is selected based on the torque and less heat buildup it. This stepper motor is particularly chosen because position can be controlled very accurately. The Stepper Motor can provide torque of about 4.2 kg – cm of torque as the name itself indicates it for a current of about 1.2 A per phase.

E. Selection of Motor driver

To drive stepper motor, L298N drive module is used and it is the apt one to drive DC motor and stepper motor. It is chosen by considering cooling brushless motor where it can control 4 DC motors at a time.

F. Assembling

Initially, the frame is selected then motherboard (Arduino), and other components are programmed and fixed inside the main frame after finishing it, all components are given connections as per circuit diagram shown in fig 11 and are assembled. At last it is tested, error correction is done and fault is rectified.

G. Testing

In the testing phase, certain conditions are checked such as requirements, usability and customer acceptance and rectifying errors using alternate methods. Fig 1 shows the flowchart of methodology.

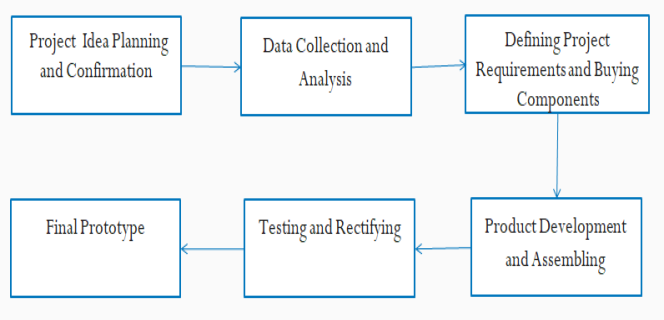

Fig 1 Methodology

III. COMPONENTS DESCRIPTION

A. Arduino UNO

Arduino Uno shown in Fig 2is used as the motherboard board of the project. It is operated 5V and uses ATmega328P as microcontroller. 14 I/O pins of digital are available and also analog pins of 6. Among the 14 pins PWM outputs will be given by 6 pins. Memory of Arduino Uno is divided into flash memory of 32 KB. Length is 68.6 mm and width is 53.4 mm. The board is used to interface with many sensors and is powered by USB cable or battery. In this project 2,3,4,5 digital PWM output pins and 5V pin is used as shown in fig 2.

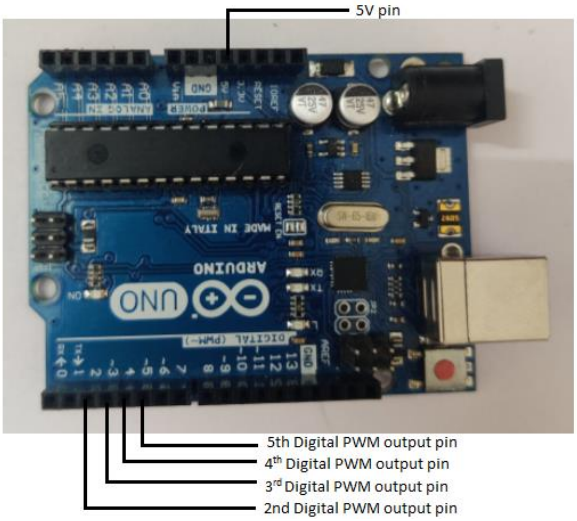

Fig 2 Arduino UNO

B. Polylactic Acid(PLA)filament

PLA filament ismost commonly used material in 3D printing. The material is easy to print and biodegradable. Filaments are available in 2 sizes i.e., 1.75mm and 3mm. Melting temperature of PLA varies from 130-180 °C. The material has high strength and stiffness during high temperatures. These are made from sugar so that it does not give the smell of plastics during heating. PLA is preferred than ABS due to rigidity and has a low melting temperature compared to other thermoplastics. The filaments are environment friendly and contain no harmful materials. These are used in medical field such as bones, food packaging, textiles and cosmetics etc.

C. Crusher

Crusher which is shown in Fig 3is used to crush the filament to thin sheet. The role of crusher in the project is used to crush the rolled filament that comes out from the roller into small pieces and send for the melting process.

Fig 3 Crusher

D. Extruder

Extruder which is shown in Fig 4 is a machine which forces the melted raw material to come out as filament with suitable diameter. Factors affecting the extrusion process are moisture, temperature, speed of extrusion, pressure etc. Extruder used is MK8 extruder J head with nozzle diameter of 0.4 mm. Material used is brass and axis speed is 40mm.The extruder is able to print only PLA and ABS of 1.75mm. Nozzle flow rate of this extruder is 24cc/h. The total weight is 510g. Fig 5 and 6 shows the fan and hot end inside extruder respectively.

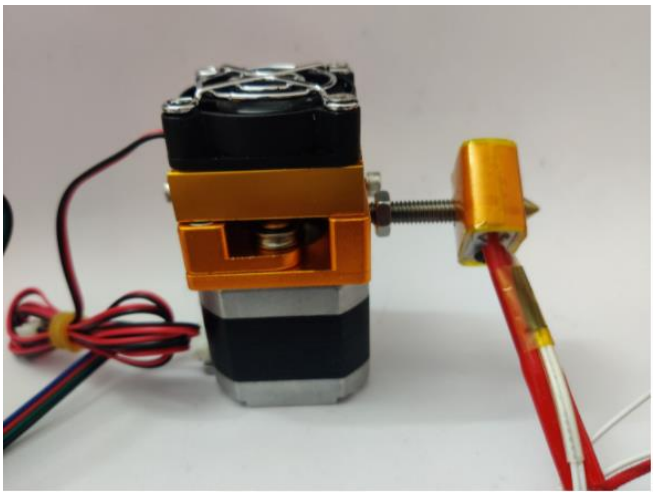

Fig 4Extruder

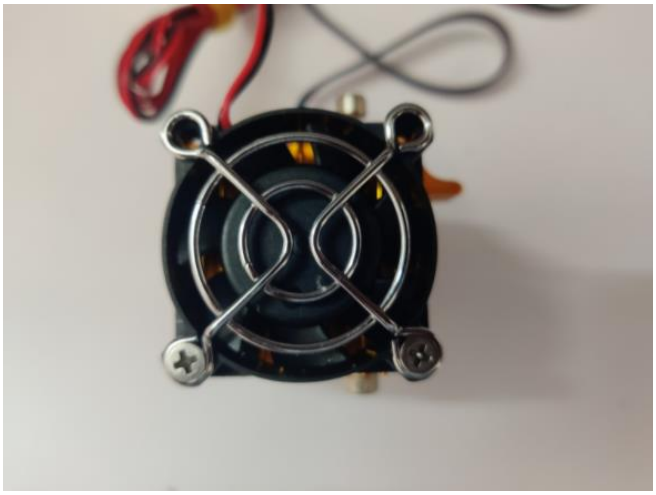

Fig 5 Fan inside extruder

Fig 6 Hot end of extruder

E. Cooling fan

Cooling fan used is Brushless DC fan with 3 inches as shown in Fig 7. Cooling fan blades are made up of plastic and dual ball bearing is used. Rated voltage of this fan is 12V.Length, width and height of fan are 8cm, 8cm and 2.5cm respectively. The length of wire used in fan is 40cm.Air is used a cooling method and power connector type is 2 pin. The weight of the fan is 60.8 g and can produce 2.1 W. This DC cooling fan spins at 2600 rpm and produces noise level of 30.7 dbA. These cooling fans are commonly used in Servers, Computers and other applications which require moderate air flow.

F. Motor driver

Motor driver used for the project is L298 based module as shown in Fig 8. For driving DC motors and also stepper motor it is best to choose drivers which deliver high power. 5V regulator is supplied and 4 DC motors can be controlled. A circuit called H - Bridge is used to drive current and controlling can be done by Pulse width Modulation. Lifetime of the motor can be increased by using PWM for controlling.

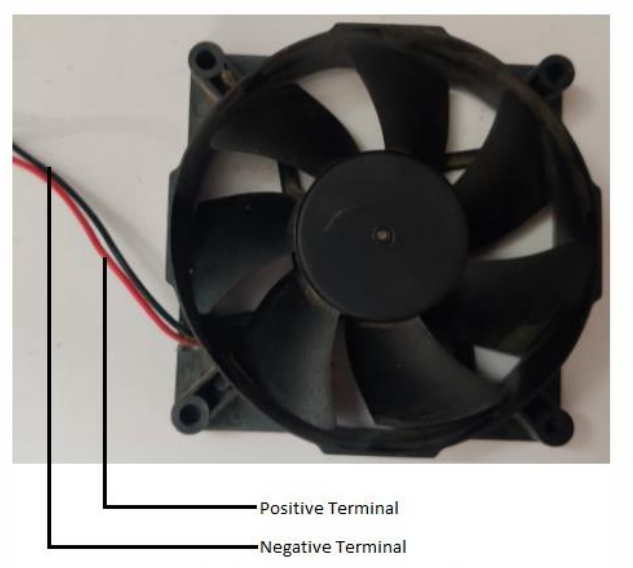

Fig 7 Cooling fan

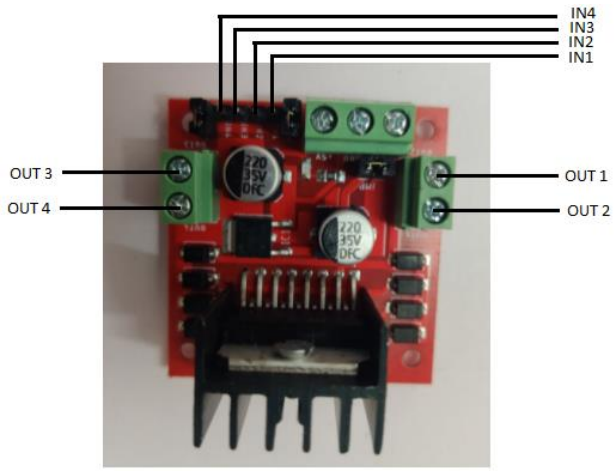

Fig 8 Motor driver

G. Stepper motor

Stepper motor used in the project is Nema 17 that provide torque of about 4.2 kg - cm at 1.7 A current phase and the stepper motor has single shaft. It is chosen because this motor is best at controlling precision position. For providing movement and to hold it in particular position stepper motor driver is used along with this. Excellent response is provided for the respective pulses by motor driver. It is the best choice for areas which require low speed and high precision.

IV. WORKING

Semi assembly of 3D printer filament recycler is shown in Fig 9 and 10. First step is to collect PLA waste materials and raw materials. After the collected materials are cleaned and purified to remove dust or other contaminants present in it. The washed PLA materials are dried for 2-4 hours at 104°F. The number of hours and temperature depend on the material. Next the cleaned materials are crushed. While crushing the materials become small pieces. Further the crushed materials are moved to extrusion process. In extrusion the crushed pellets are made into filament by melting the

pellets. During extrusion, pellets are fed into nozzle and temperature should be maintained because overheating leads to wastage of material. Temperature should be monitored and maintained between 50°Cto 60°C.The extruded material is pulled out and cooled using two cooling fans. Cooling of extruded material is important and should be done early as to maintain the quality of material.Finally the cooled filaments are rolled in a roller. After that the filaments can be used for 3D printing process.

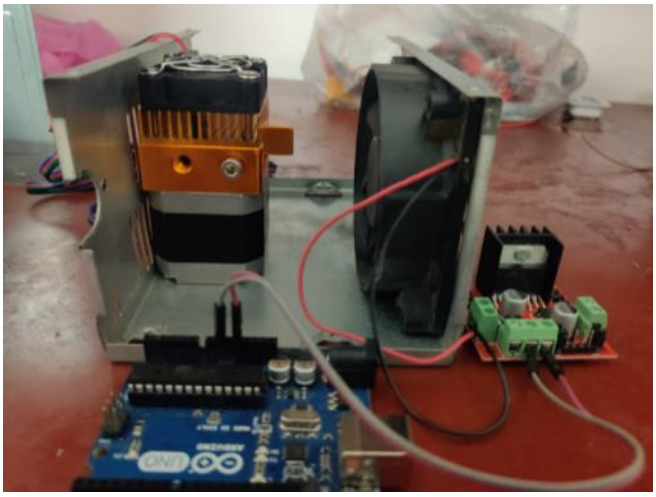

Fig 9 Front View of Partially Assembled Product

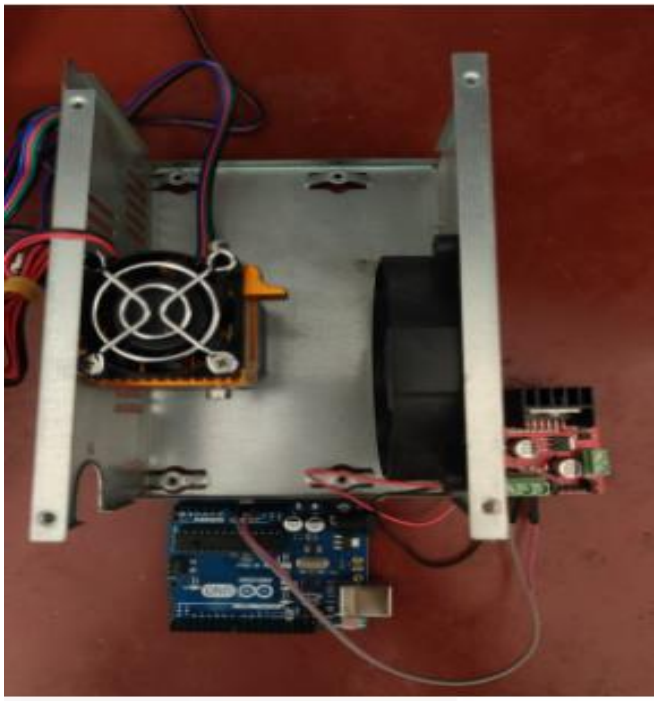

Fig 10 Top View of Partially Assembled Product

V. SOFTWARE ARCHITECTURE

Circuit design of connections is done using Fritzing software as shown in fig 11.The components used in circuit design are ArduinoUNO,L289N motor driver, two fans and a 9V battery. The positive and negative line of battery is given to 12V and GND terminal of motor driver. Red wire represents positive line and black wire represents negative line. Positive terminal of fan 1is given to out 1 terminal of motor driver and negative terminal of fan1 is connected to out 2 of motor driver. Likewise positive and negative terminal of fan 2 is connected to out 3 and out 4 of motor driver respectively. 5V pin of Arduino is connected to 5V pin of motor driver which is shown in red wire. 5,4,3,2 digital PWM output pins of Arduino UNO is connected to IN4,IN3,IN2,IN1 pins of L298N motor driver. This connection is given in blue color wire.

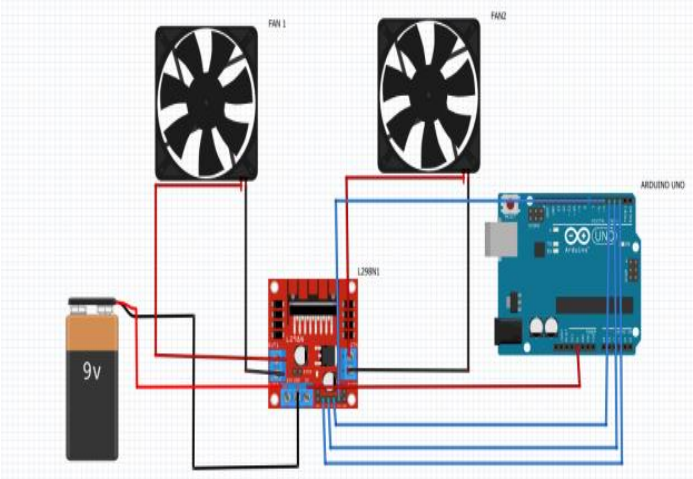

Fig 11 Circuit diagram

Coding to control motor is done using Arduino Integrated Development Environment software as shown in fig 12. First selecting and naming the two terminals of first motor as motor1pin1 and motor1pin2.Then assigning the two terminals of the first motor motor1pin1 and motor1pin2 to the 2 and 3 pins of the Arduino respectively. Similarly selecting and naming the two terminals of second motor as motor2pin1 and motor2pin2. Then assigning the two terminals of the second motor motor2pin1 and motor2pin2 to the 4 and 5 pins of the Arduino respectively.

Pin Mode in this section and the loop function can also be set in the Arduino code structure. Inside the pinMode () function, specific pins have been used to configure. As per the requirements, assigning the pins motor1pin1, motor1pin2, motor2pin1 and motor2pin2 all as outputs because the two motor should act as an output source.

Finally the project and code requires a loop to be included since it is an uninterrupted task. Arduino uses another function, called the loop() function. Within loop () function the first 5 lines represent the two motor to run forward with a delay of 1000 milliseconds. In this part the first motor 1st pin is high and the first motor 2nd pin is low whereas the second motor 1st pin is high and the second motor 2nd pin is low. In continuation to this loop part the next 5 lines represent the same two motor to run backwards with a delay of 1000 milliseconds. In this part the first motor 1st pin is low and the first motor 2nd pin is high whereas the second motor 1st pin is low and the second motor 2nd pin is high. With this loop() function out coding part comes to an end and this code make our function of our extruder to work smoothly and without error.

```
int motor1pin1 = 2;
int motor1pin2 = 3;

int motor2pin1 = 4;
int motor2pin2 = 5;

void setup() {
  pinMode(motor1pin1, OUTPUT);
  pinMode(motor1pin2, OUTPUT);
  pinMode(motor2pin1, OUTPUT);
  pinMode(motor2pin2, OUTPUT);
}

void loop() {
  digitalWrite(motor1pin1, HIGH);
  digitalWrite(motor1pin2, LOW);

  digitalWrite(motor2pin1, HIGH);
  digitalWrite(motor2pin2, LOW);
  delay(1000);

  digitalWrite(motor1pin1, LOW);
  digitalWrite(motor1pin2, HIGH);

  digitalWrite(motor2pin1, LOW);
  digitalWrite(motor2pin2, HIGH);
  delay(1000);
}
```

```
Done compiling.
```

Fig 12 Code

VI. CONCLUSION

This work has various advantages such as selection of strong but lightweight parts which helps reduce the weight of the final product. It can be used to recreate the products from plastic waste at faster rate and can be accessed by any local service provider and anyone can operate it easily and is also cost effective. Usage of combined scrap gives different color. It will reduce the waste plastic which is dumped in river, lakes, sewage and also burning of plastic which will in turn affect the environment leading to global warming and ozone layer depletion. Regenerating 3D material wastes into PLA filaments can be successfully done.

High quality melting equipment aids to get précise material and using automation monitoring and controlling can be done through a mobile phone. By sorting the materials, same colored filaments can be obtained. That is, separation of waste based on color and melting helps to retain a single color filament.

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