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A Project Report [21ECP76] on

"ECO-PRINT SUSTAINABLE 3D PRINTING WITH E-WASTE AND RECYCLED POLYETHYLANE TEREPHTHALATE (PET)"

Submitted in the partial fulfillment of the requirement for the award of the degree

Bachelor of Engineering

In

Electronics & Communication Engineering

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CERTIFICATE

Certified that the Project work entitled **"ECO-PRINT SUSTAINABLE 3D PRINTING WITH E-WASTE AND RECYCLED POLYETHYLENE TEREPHTALATE(PET)"** is a bonafide work carried out by **KRUTHIKA (1EE21EC020), MADHUSHREE K (1EE21EC025), S HARINI (1EE21EC039), VINODH KUMAR J (1EE22EC058)** in partial fulfillment for the award Bachelor of Engineering in Electronics and Communication Engineering of the Visvesvaraya Technological University, Belagavi during the year 2024-25. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the report deposited in the department library. This Project Report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the Bachelor of Engineering Degree.

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ABSTRACT

This project presents an integrated system for recycling PET bottle waste into usable 3D printing filament through a custom-designed shredder and extrusion mechanism. The process includes cleaning, shredding, melting, and extruding PET to produce filament, which is then used to 3D print functional components such as keychains, mechanical parts, and structural prototypes. The system employs precise temperature control, material handling, and mechanical design to ensure uniform filament quality. SolidWorks simulations were used to analyze and compare the properties of PET and PLA, validating the recycled filament's suitability for additive manufacturing. Experimental trials showed successful extrusion and printing performance with acceptable layer adhesion and dimensional accuracy. Compared to commercial filaments, the approach achieved approximately 70–80% cost savings and significantly reduced plastic waste. This system offers a scalable and decentralized solution that not only supports environmental conservation but also empowers communities and educational institutions to engage in sustainable practices. Overall, the project demonstrates the feasibility and practicality of localized circular manufacturing using post-consumer PET waste.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Plastic pollution has emerged as one of the most critical environmental issues of the 21st century. Among the various forms of plastic waste, Polyethylene Terephthalate (PET) bottles are especially prevalent due to their widespread use in packaging beverages, water, and other consumer products. Although PET is valued for its strength, transparency, and resistance to chemicals, these very characteristics contribute to its persistence in the environment. Once discarded, PET bottles do not degrade easily, often remaining in landfills and natural ecosystems for hundreds of years. This growing accumulation of PET waste poses a serious threat to both terrestrial and marine ecosystems, leading to soil contamination, microplastic pollution, and harm to wildlife. Consequently, finding effective methods to recycle and repurpose PET waste has become a global priority.

Recycling PET bottles is an essential step toward reducing plastic pollution and promoting sustainable resource management. PET is one of the few plastics that can be efficiently recycled without significant loss of quality, making it a valuable resource even after its initial use. By recycling PET bottles, we can conserve non-renewable resources like petroleum, reduce greenhouse gas emissions associated with virgin plastic production, and limit the amount of plastic that ends up in landfills or oceans. A critical process in PET recycling is shredding—breaking down used bottles into small plastic flakes that can be further processed. This is where the PET bottle shredder comes into play, serving as a foundational technology in the recycling chain.

A PET bottle shredder is a mechanical device designed to cut PET bottles into small flakes using a system of rotating blades and motors. These flakes are easier to store, transport, clean, and process compared to whole bottles. Once shredded, the PET material can be melted, filtered, and extruded into new products. One particularly promising application of this recycled material is in the production of 3D printing filament. By converting PET flakes into filament, users can manufacture a wide range of items using 3D printing technology, from household tools and prototypes to educational models and functional parts. This process not only helps in managing plastic waste but also supports innovation, education, and economic development through low-cost, locally sourced material production.

The integration of PET shredding and filament production represents a powerful example of circular economy principles, where waste materials are not discarded but continuously reused to create new value. This approach helps in minimizing waste, reducing environmental footprint, and promoting resource efficiency. Moreover, the use of PET-based filament in 3D printing presents an environmentally friendly alternative to traditional materials like PLA and ABS, many of which are derived from fossil fuels and are not always recyclable. By utilizing recycled PET for 3D printing, the dependency on virgin materials is reduced, making manufacturing processes more sustainable and less harmful to the planet.

Beyond its environmental benefits, the development and deployment of PET bottle shredders offer significant educational, economic, and social opportunities. For students and engineering enthusiasts, working on shredder systems provides hands-on experience in mechanical design, electronics, programming, and environmental science. Building such machines fosters innovation, critical thinking, and technical skill development. In a broader context, PET shredders can support small-scale recycling initiatives in communities, especially in regions lacking centralized waste management infrastructure. Local entrepreneurs can utilize shredders to create affordable filament, generate income, and encourage community participation in recycling efforts. Thus, PET shredders not only address environmental issues but also contribute to socio-economic empowerment and skill-building.

However, the use of PET bottle shredders also presents certain challenges. These include high energy consumption, mechanical wear of blades over time, and the need to ensure consistent output quality during filament extrusion. Contamination of PET waste with food residue or other materials can also hinder the recycling process. Despite these challenges, ongoing research and technological improvements are addressing these limitations. The incorporation of smart features like automated sorting, temperature regulation, and real-time monitoring using sensors is making shredders more efficient and user-friendly. Future developments may even include solar-powered shredding units and community-scale recycling hubs that combine shredding and 3D printing capabilities.

In conclusion, the PET bottle shredder is a critical innovation in the fight against plastic pollution. By transforming waste into a valuable resource, it enables a practical, scalable, and environmentally responsible approach to recycling. More than just a machine, the shredder represents a mindset shift—from treating plastic as disposable to viewing it as a renewable resource that can fuel creativity and production. As awareness of sustainable practices continues to grow, the role of PET shredders in education, manufacturing, and environmental conservation will only become more significant. Their widespread adoption could mark a key step toward a cleaner, greener, and more circular economy.

As shown in fig. 1.1 deals with the sustainable approach to repurpose the PET waste bottles by transforming them into usable products through 3D printing. The process begins with the collection of discarded PET bottles, which are then refined into PET filament using a technique called pulltrusion. This filament serves as the essential material for 3D printing, enabling the creation of various models from previously discarded plastic. By integrating e-waste into the printing process, this method not only reduces environmental impact but also promotes innovation in recycling. The use of PET waste for filament production helps decrease plastic pollution while advancing the practical applications of 3D printing technology. This approach highlights a forward-thinking solution to sustainability, reinforcing the importance of repurposing materials for a cleaner, more resource-efficient future. Beyond its environmental benefits, this recycling approach also fosters innovation in material science and additive manufacturing. By refining the pulltrusion method, researchers and engineers can enhance the strength, flexibility, and usability of PET filament for diverse applications. This integration of sustainable practices into 3D printing not only mitigates plastic pollution but also opens avenues for cost-effective and eco-friendly production methods in various industries, from prototyping to consumer goods manufacturing.

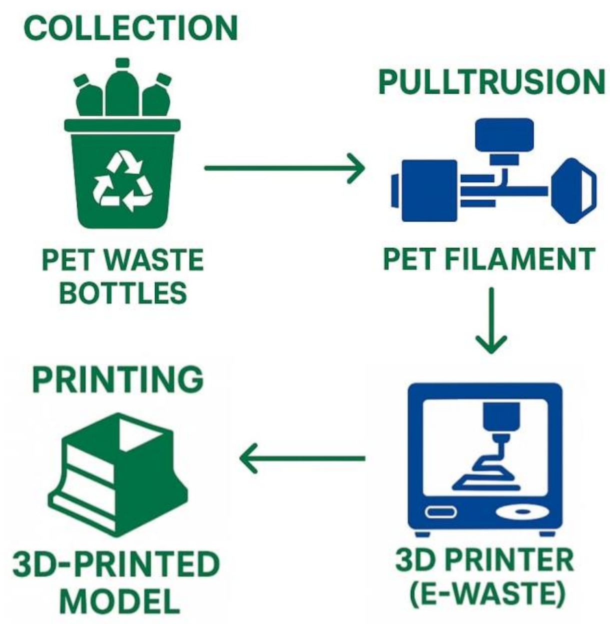

Fig. 1.1 Process Flow of PET Bottle Recycling into 3D Printing Filament

1.2 OBJECTIVES

- To design and develop a PET bottle shredder that efficiently converts used plastic bottles into small flakes suitable for recycling. The shredder will be compact, cost-effective, and easy to operate, making it ideal for small-scale or community-level use.
- To promote a waste-to-resource approach by transforming discarded single-use PET bottles into usable raw material for 3D printing. This initiative encourages the reuse of plastics and supports the development of a circular economy.

- To enhance the recycling process by improving the shredding, melting, and extrusion stages. The focus is on achieving better control over filament diameter, mechanical strength, and surface finish for consistent 3D printing performance.
- To contribute to environmental sustainability by reducing the volume of plastic waste entering landfills or water bodies. The project supports eco-conscious practices and promotes plastic recovery at the source.
- To simulate PET and PLA material properties using SolidWorks, enabling performance evaluation under different physical conditions. This helps refine the design and ensures reliability and efficiency in real-world applications.
- To empower communities and students by offering a hands-on educational tool that blends engineering, environmental science, and innovation. The project fosters awareness of plastic pollution and encourages creative solutions.

CHAPTER 2

LITERATURE SURVEY

Shinde, S,et al.[1] presents the design and fabrication of a PET bottle shredder machine aimed at addressing plastic waste management through mechanical innovation. The study highlights the environmental concerns arising from the improper disposal of polyethylene terephthalate (PET) bottles and proposes an efficient shredding mechanism as a solution. The machine is designed to reduce the volume of plastic waste by cutting bottles into small, manageable flakes. Emphasis is placed on the selection of suitable materials, blade configuration, and power transmission systems to ensure optimal performance. The authors also detail the fabrication process, including frame construction, motor selection, and safety features. The paper provides a comprehensive analysis of the shredding mechanism's efficiency, cost-effectiveness, and ease of operation. It underscores the role of such machines in promoting recycling practices and supporting sustainable waste management systems. Overall, the research contributes to environmental preservation by offering a practical and scalable solution for plastic waste reduction.

Tomy Muringayil Joseph,et al.[2] provides a comprehensive review of Polyethylene Terephthalate (PET) recycling technologies, highlighting the urgent need for effective strategies to manage the increasing volume of PET waste globally. The study outlines the chemical and physical properties of PET, which make it highly suitable for reuse, but also challenging to degrade naturally. It examines various recycling methods including mechanical recycling, chemical recycling (such as glycolysis, methanolysis, and hydrolysis), and emerging advanced technologies aimed at improving efficiency and sustainability. The authors explore the limitations of traditional mechanical recycling, such as degradation of polymer properties over time, and emphasize the potential of chemical recycling to convert PET into its original monomers, enabling the production of high-quality, virgin-equivalent plastics. Economic feasibility, environmental impact, and energy requirements of each method are thoroughly discussed. Additionally, the study addresses the role of policy regulations, public awareness, and technological innovation in enhancing PET recycling rates.The paper also emphasizes the importance of closed-loop recycling systems and circular economy models to minimize resource consumption and waste generation. With global plastic pollution reaching alarming levels, the authors advocate for the integration of PET recycling into industrial processes and municipal waste management strategies. Overall, the research highlights PET recycling as a critical step toward achieving environmental sustainability and reducing dependency on fossil-fuel-based raw materials.

Abeykoon, C, et al.[3] presents a study on the sustainable fabrication of 3D printing filament using recycled Polyethylene Terephthalate (PET) plastic, aiming to bridge the gap between plastic waste management and additive manufacturing. The research focuses on transforming post-consumer PET waste, particularly bottles, into high-quality filament suitable for 3D printing applications. This approach not only addresses the environmental issues associated with plastic pollution but also contributes to the development of cost-effective and sustainable raw materials for the growing 3D printing industry. The study details the entire process, including the collection, cleaning, shredding, extrusion, and spool winding of recycled PET into filament form. Key factors such as extrusion temperature, feed rate, and cooling methods are optimized to ensure the mechanical integrity and dimensional stability of the final filament. The authors also assess the thermal and mechanical properties of the recycled PET filament through various tests, demonstrating its suitability for producing durable and precise 3D printed objects. Additionally, the research highlights the challenges involved in processing recycled PET, such as moisture sensitivity and degradation during repeated heating cycles, and proposes solutions including proper drying techniques and controlled processing environments. The paper emphasizes the environmental and economic advantages of reusing PET waste in high-value applications, encouraging the adoption of circular economy practices. Overall, the study demonstrates a promising pathway toward sustainable manufacturing by integrating recycling with advanced fabrication technologies.

Patel.R,et al.[4] presents the design and development of a mini plastic shredder machine aimed at addressing small-scale plastic waste management in households, educational institutions, and local communities. The study responds to the growing concern over plastic pollution by proposing a compact, affordable, and easy-to-operate shredding solution that can process various types of plastic, including PET, HDPE, and LDPE materials. The design focuses on minimizing the machine's size while maintaining effective shredding capability. Key components include a mild steel frame, rotary and fixed blades for cutting, a geared motor for power transmission, and a hopper for feeding materials. The paper elaborates on material selection, stress analysis, and blade design to ensure durability and operational efficiency. Safety features such as a protective casing and user-friendly interface are integrated into the system. The fabrication process involves standard manufacturing techniques, making it suitable for localized production with low investment. The authors conduct performance testing, which confirms the machine’s ability to reduce plastic volume significantly, enabling easier recycling or repurposing. Emphasis is placed on the role of such mini shredders in promoting awareness, encouraging recycling habits, and contributing to a cleaner environment. Overall, the research offers a practical and scalable solution to tackle plastic waste at the grassroots level.

Gour, A,et al.[5] investigates the design and performance optimization of a semi-automatic PET bottle shredding machine aimed at promoting localized recycling solutions. The paper highlights the environmental impact of PET waste accumulation and the need for decentralized waste processing systems. Their research focuses on developing a machine that balances efficiency, safety, and cost for use in public places such as schools, offices, and railway stations.The machine is designed with a mild steel frame, high-speed rotary blades, a geared DC motor, and an automatic feed system to enhance productivity. The authors emphasize key design considerations such as torque requirements, blade angle, cutting speed, and energy consumption. The study also incorporates user safety measures, including overload protection and automatic shutdown features. Experimental analysis was conducted to test the machine’s efficiency across different sizes and densities of PET bottles. Results showed consistent shredding performance and significant reduction in waste volume. The paper suggests that such machines can significantly improve the plastic collection and recycling rate if strategically installed in urban areas. Overall, the study provides a viable, scalable model for addressing PET bottle waste through mechanical innovation and public engagement.

Kumar,et al. [6] presents the development of a low-cost plastic bottle shredding machine targeted for small-scale recycling units and educational institutions. The study addresses the urgent need for sustainable waste management solutions by introducing a machine that can efficiently process used PET bottles. Key design features include a rotating blade mechanism, belt-driven motor system, and a simple hopper feed setup to minimize complexity and maintenance. The authors highlight the importance of blade material selection, focusing on high-carbon steel for better wear resistance and cutting strength. The shredding mechanism is optimized for uniform flake size, which facilitates ease of storage and further recycling. Safety features such as guard enclosures and emergency switches are integrated to ensure safe operation. Experimental trials reveal consistent shredding capacity, minimal power consumption, and good performance even under continuous use. The paper suggests that this type of machine can play a crucial role in raising awareness about plastic recycling in rural and semi-urban regions. Overall, the study offers a technically sound and economically feasible solution for localized plastic waste management.

Verma T,et al. [7] explores the design and testing of a dual-shaft plastic shredding machine capable of handling PET bottles and other lightweight plastic materials. Their objective is to create a robust and reliable shredding system for medium-scale applications in industrial and community-level recycling facilities. The machine employs interlocking rotating blades powered by a high-torque AC motor for effective cutting and volume reduction. The research focuses on improving shredding efficiency through optimal shaft alignment, gear ratios, and blade geometry. The authors also analyse stress distribution using simulation software to ensure long-term durability and reduce maintenance requirements. The feeding mechanism is designed to prevent jamming and enhance throughput. Test results demonstrate efficient processing of up to 20 PET bottles per minute with uniform particle size and low noise output. The study also evaluates the recyclability of the shredded material and concludes that the machine effectively prepares waste for downstream processing. Overall, the research contributes to the development of high-performance shredders that can support industrial recycling operations and environmental sustainability goals.

Mehta,et al. [8] proposed an innovative design of a solar-powered PET bottle shredder machine intended for remote and off-grid locations. Recognizing the challenge of electricity access in rural areas, the study integrates renewable energy with mechanical waste processing to create a self-sufficient and eco-friendly solution. The system combines solar panels, a charge controller, battery storage, and a DC motor to drive the shredding mechanism. The machine features stainless steel blades and a lightweight aluminum frame to reduce corrosion and improve mobility. The research emphasizes energy efficiency, selecting components that allow for maximum shredding output with minimal solar power input. Field trials show the machine can operate continuously for several hours under direct sunlight, shredding up to 100 bottles per day.This approach not only aids in plastic waste reduction but also promotes the use of clean energy technologies in environmental management. The authors suggest that such machines can be effectively deployed in schools, villages, and remote tourist locations to raise awareness and encourage community-led recycling initiatives. Overall, the study presents a sustainable, portable, and energy-efficient model for decentralized plastic waste processing.

Sharma,et al. [9] introduced an innovative pedal-operated PET bottle shredder machine that focuses on sustainability and rural application, especially in areas with limited access to electricity. The shredder is based on a mechanical drivetrain using a chain and sprocket mechanism, which is directly connected to a shaft mounted with rotary blades. When the user pedals, the rotational energy is transferred to the blades, enabling the shredding of PET bottles without requiring any external power source. The design reflects principles of low-cost fabrication, ease of use, and zero emissions, making it ideal for decentralized recycling initiatives. To enhance the efficiency of human-powered input, the authors conducted gear ratio and torque analysis, ensuring minimal physical effort with maximum shredding capacity. The machine is made with a mild steel frame and high-carbon steel blades to ensure structural integrity and blade sharpness over long-term use. In practical testing, the shredder was able to process around 10–15 PET bottles in a single session, demonstrating its utility for daily waste management in small communities. The study concludes by emphasizing the machine's potential to promote environmental awareness and self-sufficiency among rural populations while fostering a culture of recycling at the grassroots level.

Bansal,et al. [10] proposed a fully automated PET bottle shredder integrated with Internet of Things (IoT) technology, aimed at enhancing efficiency in high-traffic public areas. The design is embedded with infrared sensors that automatically detect the insertion of bottles, triggering the shredding process without manual operation. The machine also includes a motorized conveyor belt for feeding bottles and a cloud-connected data system for remote monitoring of shredding activity. The machine is specifically tailored for locations such as railway stations, bus terminals, and shopping centers, where PET waste is frequently generated in large volumes. By incorporating real-time usage tracking, the system enables municipalities and facility managers to analyze data for maintenance scheduling and plastic collection planning. The shredding mechanism uses stainless steel blades powered by a DC gear motor, designed for durability and consistent performance under high load conditions. Performance tests revealed that the machine can shred up to 60 bottles per hour, with minimal human interaction. The paper emphasizes that automation in waste processing not only increases efficiency but also promotes behavioral change, encouraging users to dispose of plastic waste responsibly. The integration of smart features positions this shredder as a valuable component in smart city waste management systems.

Naik S,et al. [11] developed a compact PET bottle shredder designed for domestic and small-business use, addressing the lack of accessible and space-efficient machines for localized recycling. The machine features low-noise operation, a compact footprint, and an aesthetically neutral design, making it suitable for use in homes, schools, cafes, and small offices. The use of dual rotary blades, a low-speed, high-torque motor, and an acoustic insulation chamber ensures minimal sound and vibration, solving one of the major limitations of existing shredders in indoor settings.The study explores user comfort and safety, integrating automatic cut-off switches and a locking mechanism for the shredding chamber. Material choice, including ABS casing and aluminum housing for the motor, was carefully considered to reduce weight and improve portability. The machine successfully shredded bottles of varying thicknesses and volumes, from 500 mL to 2-liter PET containers.Testing showed stable performance with noise levels maintained below 50 dB, enhancing its acceptability in environments sensitive to sound disturbances. The authors conclude that this design offers a practical solution for initiating home-based recycling habits, ultimately contributing to broader environmental sustainability goals.

CHAPTER 3

METHODOLOGY

This study, 3D printer transforms digital designs into physical objects by coordinating software and hardware components. CAD software creates a 3D model, converted into G-code by Cura. This G-code guides the Arduino Mega 2560, connected to the RAMPS 1.4 board, which controls stepper motors and the hotend. Stepper motors and linear actuators position the print head for precise layer-by-layer construction, facilitated by the hotend's heating and extrusion. The process continues until the completion of the physical model, with the print head returning to its starting position.

As shown in the fig. 3.1, 3D Printer comprises of the following components:

- Design: A 3D digital model of the desired print is created using CAD software.
- File preparation: The computer-aided design (CAD) file is converted to a format that the 3D printer can translate.
- Material preparation: A spool feeds thermoplastic filament through an extruder.
- Heating and extrusion: The extruder heats, melts, and extrudes the plastic through a thin nozzle.
- Layer-by-layer deposition: The nozzle head moves in three degrees of freedom (DoF) to deposit the extruded polymer on the build plate as per the G-code instructions.
- Z-axis movement: After each new layer is deposited, a platform moves up and down vertically.

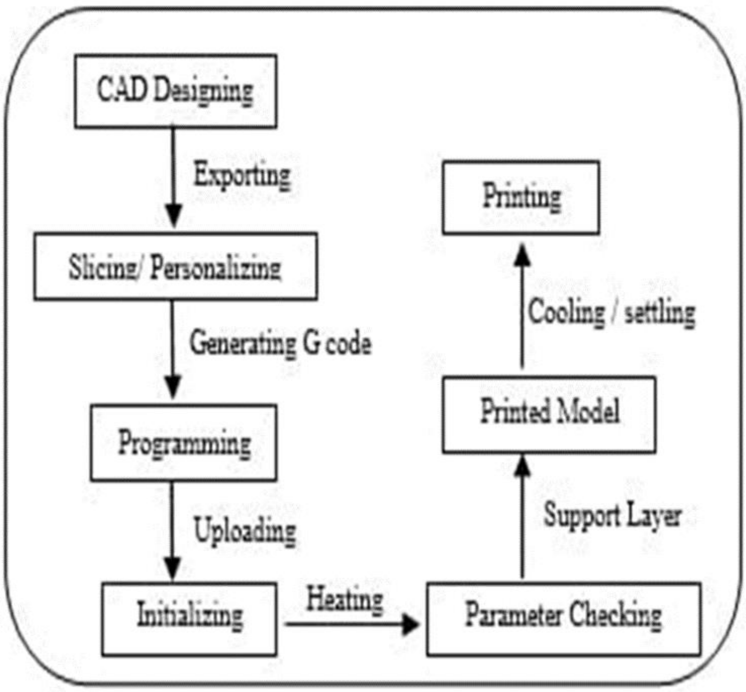

Fig 3.1: Block diagram of Eco-friendly 3D Printer

The PET Bottle Shredder is a critical component in the process of converting waste PET bottles into usable 3D printing filament. The shredder begins by slicing PET bottles into narrow, uniform strips using a PET strip cutter. These strips serve as the raw material for filament production. Once cut, the strips are fed into the hotend, where they are heated and melted to a semi-liquid state. A thermocouple integrated with the hotend continuously monitors the temperature to ensure optimal melting conditions are maintained, preventing material degradation. As the molten plastic exits the hotend, a cooling fan immediately solidifies the material into a filament strand. This rapid cooling is essential to retain the structural integrity and consistent diameter of the filament. Finally, the reeler motor, functioning as a spooling mechanism, pulls and winds the cooled filament onto a spool for storage and later use. This entire shredding and extrusion setup is enclosed within a single integrated system, making it efficient, portable, and suitable for small-scale recycling applications.

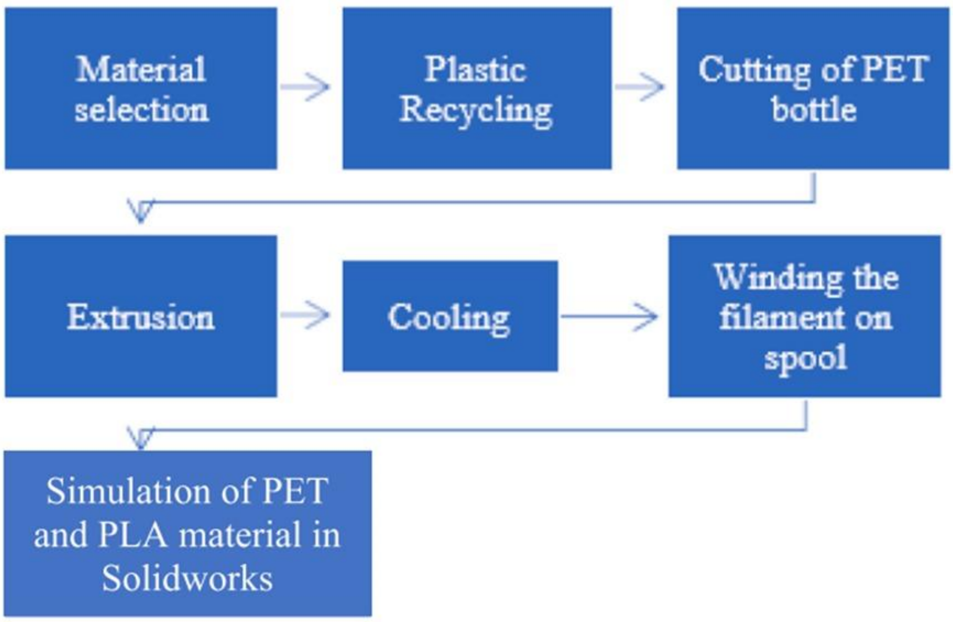

Fig 3.2 Block Diagram of PET Bottle Shredder

Fig. 3.2 provides a detailed block diagram of the PET bottle shredder system, outlining the sequential processes from material selection to filament spooling. Below is the explanation of the each component.

- **Material Selection:** The process begins by selecting appropriate plastic materials, specifically PET (Polyethylene Terephthalate) bottles, which are commonly used for packaging beverages and are ideal for recycling into filament due to their strength and melting properties.

- **Plastic Recycling:** The collected PET bottles are cleaned and prepared for recycling. Labels, caps, and other contaminants are removed to ensure the quality of the filament produced. This step is crucial for ensuring a consistent and pure raw material feedstock.
- **Cutting of PET Bottle:** The cleaned PET bottles are cut into strips using a mechanical cutting mechanism. These strips form the raw input for the extrusion process and must be uniform in size to ensure smooth feeding into the hotend.
- **Extrusion:** The PET strips are fed into an extruder where they are melted and pushed through a nozzle to form a continuous strand of filament. This process involves controlled heating and pressure to maintain the required diameter and material consistency.
- **Cooling:** As the molten plastic exits the nozzle, it is rapidly cooled using a fan or air channel to solidify it into a usable filament. Proper cooling is necessary to avoid warping and to maintain dimensional accuracy.
- **Winding the Filament on Spool:** Once cooled, the filament is pulled by a motorized reeling mechanism and neatly wound onto spools for storage and future use in 3D printing applications.
- **Simulation of PET and PLA Material in SolidWorks:** To validate the mechanical properties and behaviour of the materials, simulations are conducted using SolidWorks. This step helps in optimizing the design and performance of the filament and ensures its suitability for printing high-quality objects.

CHAPTER 4

IMPLEMENTATION

4.1HARDWARE COMPONENTS

4.1.1. **REX-C100 Digital thermostat**

Fig. 4.1 depicts the **REX-C100 Digital thermostat** is a temperature controller that utilizes PID (Proportional-Integral-Derivative) control to precisely monitor and regulate temperature levels. It maintains a user-defined setpoint by adjusting power output via a 12V solid-state relay (SSR). The controller supports a wide range of thermocouples and is capable of measuring temperatures from **0°C to 1300°C**, making it suitable for high-temperature environments.

Fig 4.1 REX-C100 Digital thermostat temperature controller

4.1.2 **DC Motor PWM Speed Control Switch Governor**

Fig. 4.2 shows the **DC Motor PWM Speed Control Switch Governor** is a crucial component in PET bottle shredders comprising of 12V-40V 10A is primarily responsible for regulating the speed of the DC motor that drives the cutting blades. This controller ensures efficient motor operation with variable speed control, allowing adjustments based on the material load and cutting requirements. It supports a wide input voltage range from 12V to 40V DC and can handle currents up to 10A, making it suitable for moderate to high-power shredding applications.

Fig. 4.2 DC Motor PWM Speed Control Switch Governor

4.1.3 **SSR-25DD Solid State Relay**

Fig. 4.3 depicts the **SSR-25DD Solid State Relay** which is designed to enable safe and accurate switching of electrical components in PET recycling machines, such as motors or heating elements. Unlike mechanical relays, it offers a fast response time and silent operation, which significantly reduces electrical noise and wear. This enhances the reliability and lifespan of the system. Operating with an input voltage range of 5V to 32V DC, it can control output voltages between 5V and 200V DC with a current rating of up to 25A. Its robustness and efficiency make it ideal for applications requiring frequent switching and precise control, contributing to smoother and more energy-efficient machine performance.

Fig 4.3 SSR-25DD Solid State Relay

4.1.4 **Square Gearbox DC motor Encoder Compatible**

Fig. 4.4 illustrates the **Square Gearbox DC motor Encoder Compatible** which is a 12V DC motor with a 10 RPM speed is specifically designed to deliver high torque at low speeds, making it well-suited for driving the cutting mechanism in a PET bottle shredder. The integrated gearbox amplifies the torque output, enabling the motor to powerfully slice through plastic bottles with ease. Furthermore, its encoder compatibility allows for precise control and feedback, which is essential for developing efficient and automated PET recycling systems. This precision ensures smoother operation, better safety, and improved energy efficiency in shredding processes.

Fig 4.4 Square Gearbox DC motor Encoder Compatible

4.1.5 **K type thermocouple temperature controller sensor probe**

Fig. 4.5 shows the **K type thermocouple temperature controller sensor probe** which plays a crucial role in the filament extrusion system by accurately measuring the temperature of the heating elements involved in melting shredded PET flakes. With a wide temperature range from 0°C to 1300°C, it is well-suited to handle the high temperatures required for plastic processing. Its 1-meter probe length provides flexibility in installation, allowing it to be positioned precisely where temperature monitoring is needed. By enabling precise temperature control, the sensor helps prevent overheating or inconsistent melting, ensuring that the extruded filament maintains high quality and uniformity, which is essential for reliable 3D printing.

Fig 4.5 K type thermocouple temperature controller sensor probe

4.1.6 **DC Switching Power Supply**

Fig. 4.6 is a **DC Switching Power Supply** which is responsible for converting standard AC mains electricity into a stable 12V DC output, which is essential for the reliable operation of various components in the PET recycling and filament extrusion system. With an output current rating of 10A and a total power capacity of 120 watts, it delivers sufficient energy to power the shredder's motor, speed controller, and heating elements used in melting PET flakes. Its stable and consistent DC output ensures that all connected devices operate efficiently and without interruption, contributing to the smooth and safe functioning of the entire recycling process.

Fig 4.6 DC Switching Power Supply

4.1.7 **Mk8 Extruder Hot End Kit**

Fig. 4.7 represents the **Mk8 Extruder Hot End Kit** that plays a critical role in the filament extrusion process by heating and melting the processed PET flakes, enabling the formation of a consistent and uniform filament suitable for 3D printing. It functions by pushing the molten plastic through a fine nozzle, ensuring smooth and continuous extrusion. Designed to operate at temperatures up to 260°C, the MK8 hot end ensures precise thermal control, which is essential for avoiding clogs and achieving high-quality filament. Its efficient heating mechanism helps maintain the necessary temperature throughout the extrusion, supporting reliable and accurate filament production.

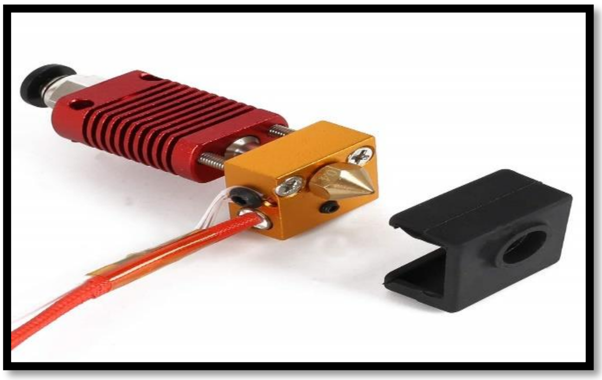

Fig 4.7 Mk8 Extruder Hot End Kit

4.1.8 **Arduino_Mega 2560**

Fig. 4.8 depicts the **Arduino_Mega 2560** which is the central microcontroller of our 3D printer. It is based on the ATmega2560 microcontroller and provides the necessary processing power to handle complex tasks. It features 54 digital I/O pins, 16 analog inputs, and 4 UARTs, making it versatile and capable of managing multiple components simultaneously. Its affordability and open-source nature make it an ideal choice for our project.

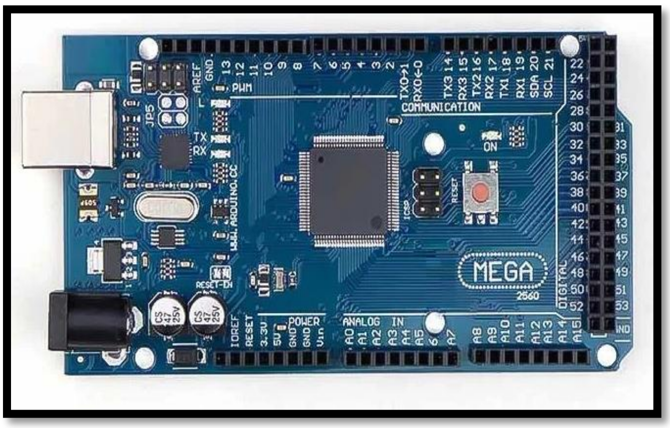

Fig 4.8 Arduino_Mega 2560

4.1.9 **RAMPS 1.4 Board**

Fig. 4.9 is a **RAMPS 1.4 Board** which is expanded as RepRap Arduino Mega Pololu Shield 1.4 board is designed to fit on top of the Arduino Mega 2560. It serves as an interface between the microcontroller and the printer's hardware components. It provides connections for stepper drivers, heaters, thermistors, and other peripherals. This board simplifies the wiring process and enhances the modarity of the system, making it easier to assemble the troubleshoot.

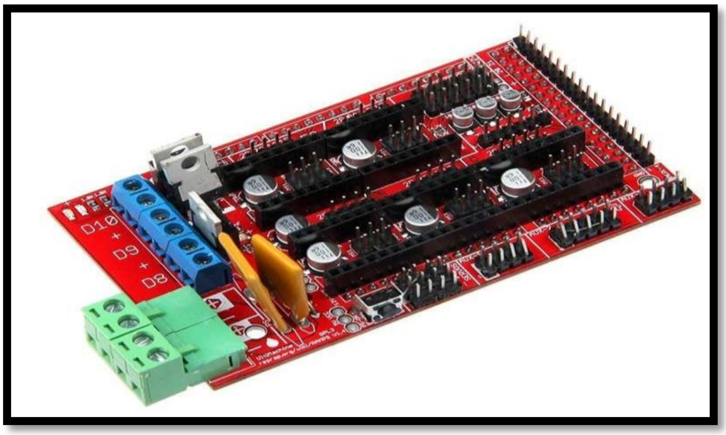

Fig 4.9 RAMPS 1.4 Board

4.1.10 **CD drives**

Fig. 4.10 represents the **CD drives,** particularly from old DVD-ROM or CD-ROM units, contain small stepper motors that can be reused in DIY 3D printers for tasks like controlling the X, Y, or Z axes in compact setups. These motors offer precise, incremental motion, which is ideal for applications requiring accurate positioning. Additionally, their compact form factor makes them suitable for space-constrained designs such as mini or delta-style 3D printers. Repurposing CD drive components also promotes electronic waste recycling, aligning with the sustainable goals of many hobbyist and educational projects. With proper driver circuitry and calibration, these motors can achieve impressive resolution and reliability despite their origin from consumer-grade devices.

Fig 4.10 CD Drives

4.1.11 **Endstops**

Fig. 4.11 represents the **Endstops** which are the switches placed at the ends of the printer's axes. They serve as reference points for the printer, allowing it to determine the limits of its movement and home its position accurately.

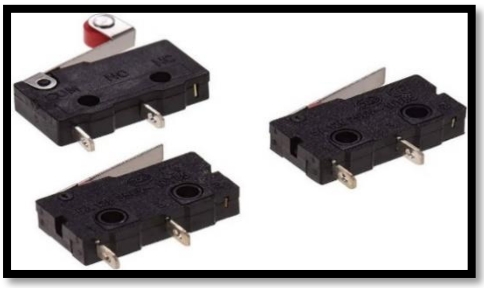

Fig 4.11 Endstops

4.1.12 **Nema 17**

Fig. 4.12 represents the **Nema 17** which refers to a standardized frame size established by the National Electrical Manufacturers Association. It is a type of hybrid stepping motor with specific dimensions and characteristics. Used to control the movement of the extruder motor and XY-axis, which ensures precise filament deposition and smooth motion for detailed prints.

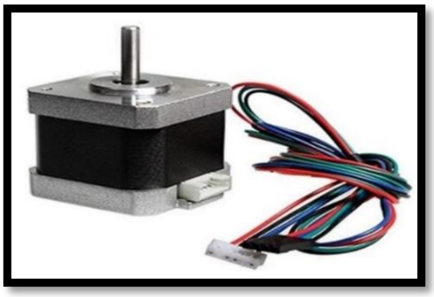

Fig 4.12 NEMA 17

4.1.13 **Creality Extruder Set**

Fig. 4.13 is the **Creality Extruder Set** which is a set of components & parts that are used in the extrusion process of 3D printers. It is designed to improve the printer's performance by ensuring a smooth filament extrusion process.

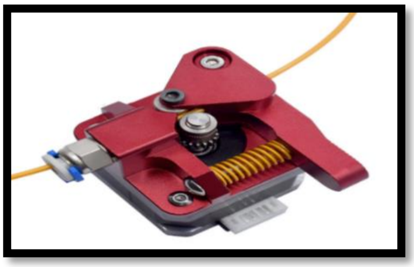

Fig 4.13 Creality Extruder Set

4.2 SOFTWARE REQUIREMENTS

4.2.1 **Marlin Firmware**

As shown in fig. 4.14, **the Marlin firmware** provides the core control logic for the 3D printer, managing movements, temperature regulation, and other essential hardware interactions**.** Marlin is based on previous firmware called sprinter marlin is made up of bunch of different files, which control the function of the printer such as moving stepper motor, reading from SD card and about pins for the hardware that simply tells marlin what's connected to what on our mainboard.

Fig 4.14 Marlin Firmware

4.2.2 **CAD and 3D Modelling**

CAD modeling enables designers to visualize, simulate, and refine their creations before any physical material is used, reducing prototyping costs and time. These digital models can be adjusted for dimensions, tolerances, and features to meet functional or aesthetic requirements. Once finalized, the 3D model is exported in a format like STL or OBJ, which can then be processed by slicing software. The accuracy of the CAD model directly affects the quality and functionality of the final printed object. Additionally, CAD software often includes libraries, parametric tools, and simulation features that enhance design flexibility and precision. Fig. 4.15 illustrates the CAD modeling environment used to design printable 3D models, serving as the foundational step in the digital fabrication workflow.

Fig 4.15 CAD and 3D Modelling

4.2.3 **Cura**

Cura is a 3D printing software that is used to prepare 3D models for printing. It is produced by Ultimaker and is simple to use but also has advanced features for more experienced users. Cura supports STL, 3MF, and OBJ 3D file formats and also has a function that will import and convert 2D images to 3D extruded models. It allows you to open and place multiple models on the print bed and has over 400 expert settings for advanced users. It is available for Windows, Mac, and Linux and is free to download from the Ultimaker website. As seen in fig. 4.16, Cura is used to slice 3D models into layers and generate G-code, which instructs the 3D printer on how to build the object layer by layer.

Fig 4.16 Cura

4.2.4 **Pronterface**

Pronterface is a powerful 3D printing host software suite that allows you to interact with your 3D printer and manage the printing process. It provides both a graphical user interface (GUI) and an interactive command-line interface for controlling your printer, slicing objects, and running prints. Whether you prefer a visual interface or command-line control, Pronterface has you covered. Fig. 4.17 shows the Pronterface interface, which provides users with real-time control over the 3D printer, including commands, temperature monitoring, and manual axis movement.

Fig 4.17 Pronterface

4.3 Circuit Diagram

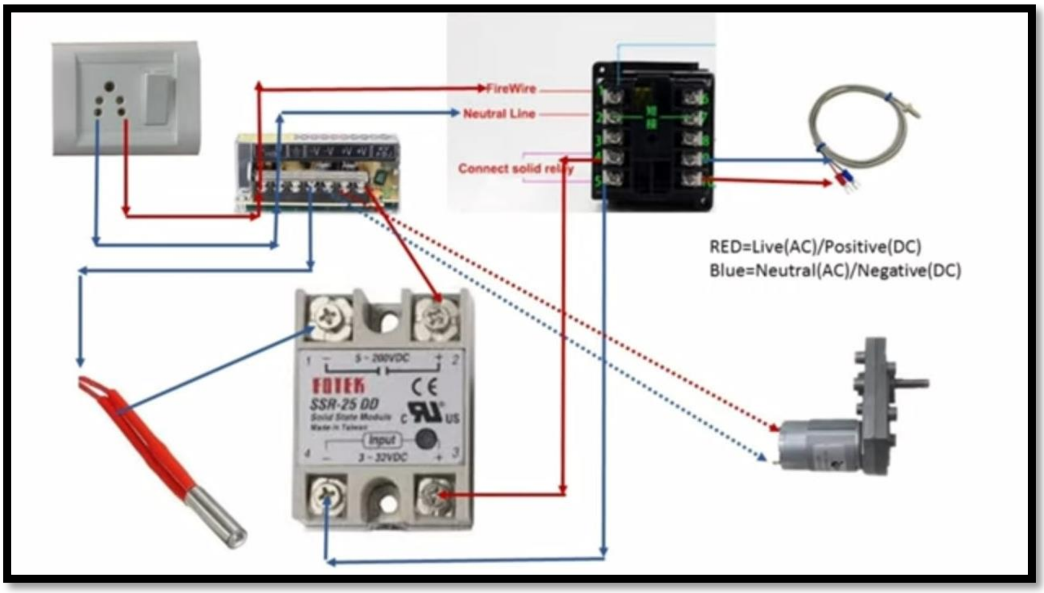

Fig 4.18 Circuit Connections

Fig. 4.18 illustrates the wiring connections of the PET shredder and extrusion system, highlighting key electrical components and their interconnections for safe and reliable operation. The components involved are:

- Rex C100 (REX100) Temperature Controller – controls heating based on temperature input.
- Solid State Relay (SSR-25 DD) – switches power to the heater.
- Thermocouple (K-type) – measures temperature.
- Heater or Heating Element – heats the PET plastic.
- Motor – likely used for feeding or extruding the filament.
- Power Supply – AC mains input.

Fig. 4.18 illustrates the wiring summary of the PET bottle shredder's heating and control system, detailing the following connections:

- Thermocouple: Connected to terminals 9 & 10 on the REX100.
- SSR Input Side (3 & 4): Connected to REX100 terminals (likely 4 & 5) for triggering.
- SSR Output Side (1 & 2): Connected inline with the heater and power source.
- Heater/Motor Power: SSR switches AC/DC to heater or motor as required.
- Main Power Line: Connected to REX100 and SSR output.

4.4 FLOW CHART

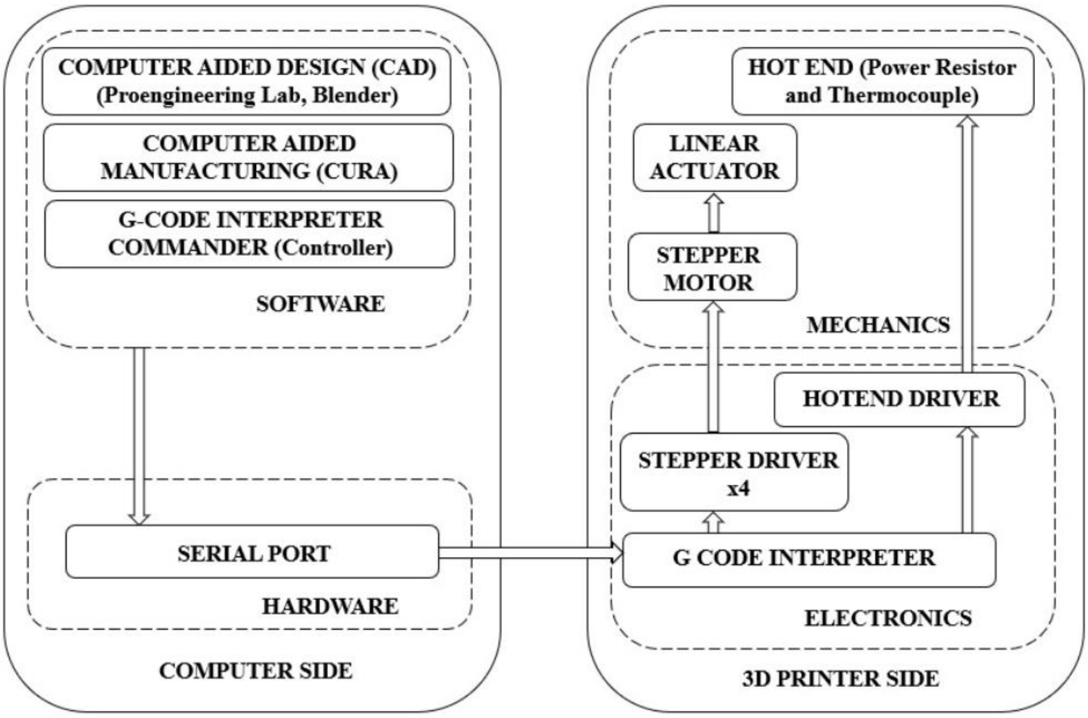

Fig 4.19 Flow chart of 3D Printer

Fig. 4.19 outlines the step-by-step process flow of 3D printing using recycled PET filament, from CAD modeling to final object fabrication. CAD software creates the 3D model. The steps involved are:

- Cura slices the model into layers.
- G-code is generated from the sliced layers.
- The G-code file is sent to the 3D printer.
- The printer follows G-code instructions to build the object.
- The Arduino Mega Processes G-code and controls printer components.
- The RAMPS 1.6 board simplifies wiring and connects various components.
- Stepper motor drivers regulate motor movement along X, Y, and Z axes.
- Stepper motors drive the printer's movement in precise steps.
- The hotend driver manages heating for filament extrusion.

- Thermocouples provide real-time temperature data for precise control.
- The printing process begins with G-code interpretation by the Arduino.
- Stepper motors position the print head and build platform.
- The hotend melts filament for layer-by-layer deposition.
- Continuous adjustment based on G-code ensures accurate printing.
- The final product is completed layer by layer.

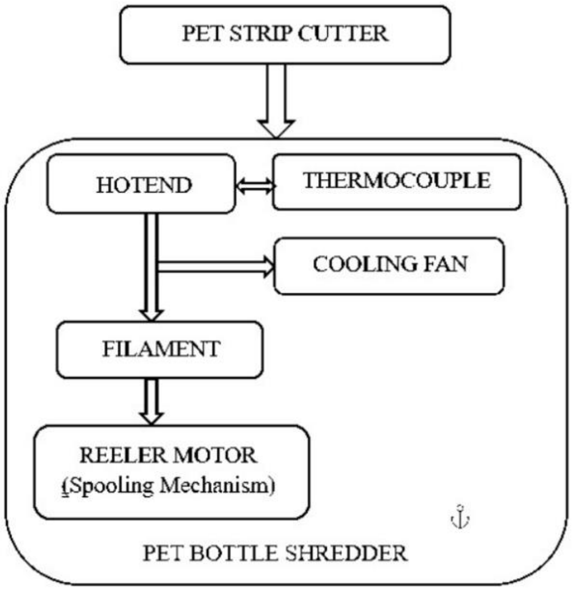

Fig 4.20 Flow chart of PET Bottle Shredder

As shown in Fig. 4.20, the PET bottle shredder process involves collection, cleaning, shredding, heating, extrusion, and filament testing for a complete recycling loop and are describes as:

1. Collection and Cleaning: Used PET bottles are collected and thoroughly cleaned to remove any labels, caps, and residues that could affect the extrusion process.

2. Shredding Process: The cleaned bottles are inserted into the shredding chamber, where a 12V DC gear motor with high torque drives the blades to cut the bottles into small, uniform flakes.

3. Temperature Monitoring: A REX-C100 digital thermostat, paired with a K-type thermocouple, is used to monitor and maintain the required temperature during the filament extrusion process.

4. Heating and Melting: The shredded PET flakes are transferred into a heated chamber equipped with an MK8 Extruder Hot End Kit, which melts the plastic at temperatures up to 260°C.

5. Controlled Power Supply: A 12V DC switching power supply provides stable voltage and current to all components, including the motor, heating system, and controllers.

6. Motor and Heat Regulation: A PWM speed controller adjusts the motor speed, while a solid-state relay (SSR-25DD) ensures smooth switching of the heating elements, maintaining safety and efficiency.

7. Filament Extrusion: The molten PET is pushed through a nozzle, forming a consistent filament strand that can be cooled and wound for later use in 3D printers.

8. Testing and Output: The produced filament is tested by printing standard test cubes using a 3D printer. The result is compared with PLA filament, and the output quality is evaluated.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Working Model 3D Printer

The combination of the PET bottle shredder and 3D printer proved to be an effective approach for converting plastic waste into usable 3D printed products. PET bottles were successfully shredded into uniform flakes, which were either used directly or prepared for filament extrusion. In cases where recycled PET filament was utilized, the 3D printer was able to fabricate small-scale prototypes such as keychains, containers, and mechanical components with satisfactory strength and surface finish. The integration demonstrated a significant reduction in material costs when compared to commercially available filament and contributed positively to environmental sustainability by recycling plastic waste that would otherwise contribute to pollution. Overall, the system showcased the feasibility and practicality of localized, eco-friendly manufacturing by turning discarded PET bottles into valuable functional objects through additive manufacturing.

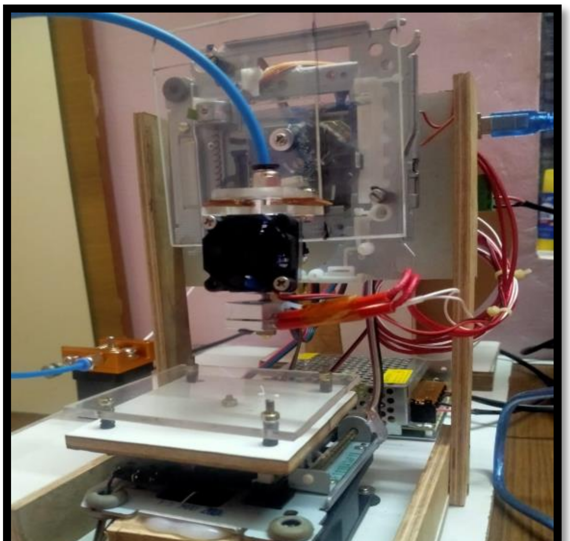

Fig 5.1 3D printer

As shown in the fig. 5.1 The PET filament obtained from the shredded PET bottles was processed and fed into the 3D printer to fabricate the desired components, demonstrating a complete recycling and reuse cycle. The 3D printer employed in the fabrication of various structural and functional components of the PET bottle shredder machine. This printer played a crucial role in transforming the CAD models into tangible prototypes, allowing for rapid iteration and real-world testing. The material used—recycled PET filament—was selected for its environmental benefits, along with good mechanical properties and printability. The use of 3D printing not only reduced fabrication time and cost but also allowed for easy customization and redesign if needed. During the initial printing phase, minor issues such as poor bed adhesion and stringing were encountered, but these were resolved through calibration of the bed, adjustment of retraction settings, and environmental control. Overall, the application of 3D printing significantly enhanced the design process and contributed to the functional realization of the PET bottle shredder.

5.2 Working Model of PET Bottle Shredder

Fig 5.2 PET bottle Shredder

As shown in the fig. 5.2 showcases the PET filament extrusion system developed as an integral part of the recycling process. This system converts shredded PET bottle flakes into continuous filament suitable for use in 3D printing applications. The setup consists of a filament spool holder for collecting the extruded filament, a cooling fan for solidifying the hot plastic immediately after extrusion, and a heating block controlled by a digital temperature controller to maintain the ideal melting temperature for PET (typically between 230–250°C). A motorized feeding mechanism, regulated by a speed controller, ensures uniform extrusion and diameter consistency. The yellow printed parts seen in the image are 3D-printed fixtures designed to hold and guide the components. This self-built extruder not only reduces the cost of filament production but also demonstrates the practical application of circular economy principles by transforming waste PET into useful raw material for 3D printing. The filament produced was later used in printing components of the PET bottle shredder itself, thereby closing the material loop.

As the melted PET is pushed through the extrusion nozzle, it passes by a **cooling system**, which in this setup includes a high-speed axial fan. This fan rapidly cools the extruded filament to solidify it and prevent deformation. The solid filament is then wound onto a spool mounted at the opposite end of the machine. This **filament winding mechanism** ensures smooth collection of the extruded material and helps in maintaining consistent filament diameter. A significant challenge encountered during development was maintaining a consistent extrusion speed to produce filament of uniform thickness. This was addressed by implementing a **DC motor with a variable speed controller**, allowing precise control over filament feed rate. Additionally, a nozzle cleaning and calibration routine was established to prevent clogging and ensure smooth flow of material. PET waste was not only shredded but also reprocessed and reused as filament to fabricate functional components of the PET bottle shredder itself using 3D printing. This subsystem reinforces the project's emphasis on environmental responsibility, low-cost fabrication, and innovative use of additive manufacturing technologies in waste management.

5.3 3D Printed cubes using PET Filament

Fig 5.3 3D printed cubes using PET filament

Fig. 4.3 represents the final output of the entire PET recycling and 3D printing process—test cubes printed using the filament derived from shredded PET bottles. These cubes, designed as calibration and quality verification models, serve to evaluate the feasibility of using recycled PET filament in additive manufacturing. The successful formation of these structures confirms that the PET filament extruded using the in-house setup possesses sufficient thermal and mechanical properties for 3D printing. Despite minor imperfections such as surface roughness and slight warping on edges—common in recycled filament prints—the models exhibit good layer adhesion, consistent extrusion, and dimensional integrity. The layered infill pattern visible on the broken pieces provides insight into the internal structure and the printing quality. These results validate the effectiveness of the filament production process and demonstrate the potential for creating practical, low-cost components directly from plastic waste. This milestone strongly supports the project's core objective of promoting sustainable, circular fabrication methods using locally sourced waste materials.

The printed cubes demonstrate that the recycled PET filament exhibits acceptable printability with standard 3D printing parameters. The geometry of the cubes was intentionally selected to assess critical aspects of the filament’s performance, such as dimensional accuracy, layer adhesion, infill consistency, and overall surface finish. While minor surface irregularities and stringing were observed—likely due to slight variations in filament diameter and moisture content—these imperfections were well within the tolerable range for recycled material. The successful formation of solid, stable, and clearly defined 3D printed parts confirms that the recycled PET filament is viable for fabricating functional prototypes or components, especially in low-load applications. The test cubes highlight the environmental impact and innovation embedded in this project: transforming post-consumer waste into a valuable manufacturing resource. The project not only achieved its technical objectives but also aligned with broader goals of sustainability, circular economy, and low-cost production. These results underscore the practical feasibility of implementing decentralized recycling and fabrication systems, especially in resource-constrained environments such as educational institutions or rural communities.

5.2 Discussions

The integration of the PET bottle shredder and 3D printer into a single system offers a practical and innovative solution to address the growing issue of plastic waste. Through this project, we were able to demonstrate the feasibility of converting post-consumer PET waste into usable 3D printed objects, effectively closing the loop on plastic use by enabling local recycling and manufacturing. The performance of the PET bottle shredder was consistent, producing adequately sized flakes that could be processed further. However, to ensure the quality and functionality of the printed outputs, additional steps such as washing, drying, and possibly filtering the shredded material were necessary. These steps are crucial in maintaining filament quality, as moisture and contamination can significantly degrade print performance and cause extruder issues.

The 3D printing phase using recycled material yielded promising results, although print quality varied based on material preparation and printer calibration. Objects printed using recycled PET showed reasonable layer adhesion and mechanical strength, indicating that PET bottles can indeed serve as a viable alternative source of filament, particularly for prototyping and low-load applications. However, achieving consistent filament diameter during extrusion remains a technical challenge that directly affects print reliability. One major limitation encountered during the project was the absence of an integrated filament extruder. While the shredded PET could be theoretically processed into filament, actual extrusion requires specialized machinery that can maintain uniformity in filament diameter and quality. Including a filament extruder in future iterations of this system would create a fully closed-loop recycling process. Additionally, the system's impact extends beyond engineering and sustainability—it holds educational and social value. It can be used to demonstrate real-world recycling processes in academic settings and empower communities to manage their own plastic waste more effectively.

This approach also aligns with the principles of a circular economy, encouraging local production, reducing environmental impact, and promoting innovation. In summary, while the project successfully illustrated the concept and initial implementation of a combined PET bottle shredder and 3D printer system, it also highlighted certain practical challenges such as the need for pre-processing PET waste and maintaining filament consistency. Addressing these challenges in future work could enhance the efficiency and reliability of such systems, potentially making them a scalable solution for sustainable manufacturing.

CHAPTER 6

ADVANTAGES, DISADVANTAGES AND APPLICATIONS

6.1 Advantages

- **Environmental Protection:** Recycling PET bottles into 3D printer filament plays a significant role in reducing plastic waste, which is one of the leading contributors to environmental pollution. By converting used PET bottles into a valuable resource, the system supports waste diversion from landfills and oceans. This not only helps protect ecosystems and wildlife but also reduces the carbon footprint associated with producing new plastic materials.
- **Cost-Effective Production:** Traditional 3D printing filament can be expensive, particularly for educational institutions, hobbyists, and small-scale manufacturers. By recycling PET waste into filament, the cost of materials is drastically reduced. This makes 3D printing more accessible and affordable for a wider range of users, particularly in resource-constrained environments.
- **Promotes Sustainability:** The project aligns with the principles of a circular economy by extending the life cycle of plastic materials. Instead of single-use consumption, waste PET is repurposed into high-value products, encouraging responsible use of resources and reducing the demand for virgin plastic production. This fosters a sustainable ecosystem that supports long-term environmental health.
- **Compact and Scalable Design:** The system is engineered to be both compact and modular, making it suitable for deployment in a variety of settings such as schools, universities, maker spaces, and small businesses. Its scalability allows users to start with basic configurations and expand the system as needed, enabling localized and decentralized production of filament.
- **Educational Value:** This solution offers rich educational opportunities by integrating concepts from environmental science, mechanical engineering, materials science, and digital fabrication. It provides a hands-on learning experience that fosters innovation, critical thinking, and practical skills. Educational institutions can use the system to teach students about sustainability, recycling processes, and additive manufacturing.

- **Customizable Output:** The filament extrusion system is designed to allow users to adjust variables such as filament diameter, color additives, and composition. This flexibility enables experimentation and customization for specific 3D printing needs, whether for structural components, prototyping, or artistic creations.
- **Energy Efficient Operation:** The components used in the recycling and extrusion process are optimized for low energy consumption. By leveraging controlled heating elements, energy-efficient motors, and smart electronics, the system minimizes power usage without compromising performance, making it suitable for continuous operation even in energy-sensitive environments.

6.2 Disadvantages

- **Material Limitation:** The system is primarily optimized for recycling PET (Polyethylene Terephthalate) plastics, commonly found in water and soda bottles. However, it is not compatible with many other plastic types like HDPE, PP, or PVC due to differences in melting points, thermal behavior, and chemical composition. Attempting to use incompatible plastics can result in poor-quality filament or damage to the equipment. This limitation narrows the scope of usable input materials and requires users to be selective about what waste can be processed.
- **Requires Technical Expertise:** Operating the filament recycling system requires a solid understanding of mechanical and thermal control systems. Proper calibration of temperature settings, motor speeds, and extrusion rates is critical to achieving consistent filament quality. Users must also be familiar with the basic principles of extrusion and material handling. For beginners or non-technical users, this could present a steep learning curve and necessitate initial training or supervision.
- **Initial Setup Cost:** While the long-term operation of the system is cost-effective, the initial setup requires investment in specialized components such as high-precision extruder kits, heating elements, thermocouples, gear motors, and control units. These components need to be durable and reliable to ensure safe and effective operation. For educational institutions or small labs with limited budgets, this upfront cost could be a barrier to adoption.
- **Safety Hazards:** The filament production process involves high temperatures, sharp cutting blades (for shredding PET), rotating machinery, and electrical components. Without proper safety protocols, these elements can pose risks such as burns, cuts, or electrical hazards. Protective gear, adequate ventilation, emergency shut-offs, and clear operational guidelines are essential to ensure user safety, especially in environments involving students or untrained personnel.

- **Maintenance Needs:** The system requires regular maintenance to operate efficiently. PET residue, dust, and impurities can accumulate inside the extruder or nozzle, leading to clogs and degraded filament quality. Routine cleaning, lubrication, and inspection of mechanical parts are essential to prolong the system's lifespan and ensure consistent output. Neglecting maintenance can result in increased downtime and equipment wear.
- **Slow Processing Speed:** Due to the system's compact and low-power design, the filament extrusion process is relatively slow compared to industrial-scale recycling systems. This makes it better suited for small-batch production, prototyping, or educational purposes rather than high-volume manufacturing. Attempting to scale the system for mass production may require significant redesign and additional investment.
- **Output Quality Depends on Input:** The quality and performance of the produced filament are heavily influenced by the cleanliness, consistency, and source of the input PET material. Contaminants like labels, glue residues, and food particles can interfere with melting and extrusion, resulting in filament that is brittle, uneven, or discolored. Pre-treatment of bottles (washing, drying, shredding) is crucial to maintain consistent filament quality.

6.3 Applications

- **Educational Institution:** This system provides an excellent platform for schools, colleges, and universities to engage students in hands-on, project-based learning. It integrates principles of environmental science, mechanical engineering, and digital fabrication. Students can explore the lifecycle of materials, understand the impact of plastic waste, and gain practical experience in sustainable technologies and 3D printing. It also opens opportunities for interdisciplinary collaboration between departments such as engineering, design, and environmental studies.
- **DIY & Makerspace:** For individual hobbyists, tinkerers, and makers, the system is a valuable addition to personal or community-based makerspaces. It enables users to create their own filament from household plastic waste, reducing dependence on commercial suppliers and encouraging experimentation. Makers can design, iterate, and fabricate unique creations while contributing to a more sustainable workflow.
- **Small-Scale Prototyping:** Startups, freelancers, and innovators can use recycled filament to produce prototypes and functional parts at a fraction of the cost of traditional filament. This democratizes access to rapid prototyping technologies, especially for low-budget or early-stage product development. The system is particularly useful for creating enclosures, fixtures, or mechanical parts using environmentally friendly materials.

- **Environmental Campaigns:** This system can serve as a powerful demonstration tool in environmental awareness programs, recycling drives, and sustainability events. By showcasing how plastic waste can be transformed into useful products, it reinforces the message of responsible consumption and recycling. Live demonstrations can engage audiences, especially students and youth, and encourage behavior change through tangible results.
- **Research & Development:** The setup supports a variety of R&D efforts focused on materials science, sustainable engineering, and green manufacturing. Researchers can use it to test different PET compositions, investigate the mechanical properties of recycled filament, or develop hybrid materials by adding fillers or reinforcements. The system enables low-cost, repeatable experiments ideal for academic and industrial research alike.
- **NGO and Community Projects:** Non-governmental organizations and community-driven initiatives focused on waste management and environmental education can integrate this technology into their programs. It offers a practical solution for managing local PET waste while simultaneously providing skill-building opportunities for community members. This can be particularly impactful in rural or underserved areas where plastic waste disposal is a major challenge.
- **Startup Innovation:** Eco-conscious startups can leverage this technology to build sustainable products and services. From creating custom 3D-printed goods to offering filament recycling services, the system enables innovative business models that align with green economy goals. It allows entrepreneurs to differentiate themselves with low-cost, eco-friendly production and local sourcing of raw materials.

CHAPTER 7

CONCLUSION & FUTURE SCOPE

7.1 CONCLUSION

The PET bottle shredder project successfully demonstrated the potential of converting plastic waste into usable raw material for further applications such as 3D printing filament production. The system effectively reduced the volume of PET waste, contributing to environmental sustainability and promoting responsible plastic disposal. The project highlights the feasibility of small-scale plastic recycling as a step toward reducing the ecological impact of plastic pollution.

The performance of the shredder met expectations in terms of output quality, consistency of shredded material, and operational safety. The design was kept simple and robust to ensure easy maintenance and user-friendly operation. Testing showed that the shredder could handle moderate loads without overheating or mechanical failure, making it suitable for small-scale or educational use.

Overall, the project successfully demonstrated the feasibility of decentralized plastic recycling. It provides a practical example of how technology can be used to minimize plastic waste and support sustainable development. With further refinement and scaling, such a system could be a valuable asset for schools, makerspaces, and local recycling initiatives.

7.2 FUTURE SCOPE

- **Automation:** Introduce automatic feeding and shredding mechanisms using sensors and microcontrollers to reduce manual effort and improve efficiency.
- **Safety Features:** Add enhanced safety mechanisms such as auto shut-off when the lid is open, emergency stop buttons, and overload protection.
- **Integrated Washing & Drying:** Incorporate cleaning and drying units to ensure that the PET flakes are ready for extrusion without contamination.
- **Modular Design:** Develop a modular version of the shredder to allow easy upgrades or replacements of parts like blades, motors, and feeding systems.
- **Energy Optimization:** Optimize the motor and gear system for reduced power

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APPENDIX

- **Appendix A:**

First Prize in Srishti innovation and Exchange Competition:

In the Srishti Innovation and Exchange competition held on 24th - 26th of May 2024, our team was awarded the prestigious first prize in the field of Robotics by showcasing this Eco-Friendly 3D Printer. We received this award from ISRO Chairman Dr. S. Somanath who was the main guest for this competition.

SRISHTI
Innovation exchange
2024

CERTIFICATE OF ACHIEVEMENT

This is to certify that

Mr./ Ms. S. Harini

From East west college of engineering

has Participated in **SRISHTI 2024, State Level Project Exhibition and Competition** and secured **First / Second / Third / Consolation** Prize in **Srishti Avishkar - Pre Final Year Project Competition** held at Atria Institute of Technology, Hebbala, Bengaluru from May 24th- 26th 2024.

Dr. Satish H K
State President
ABVP, Karnataka South

Dr. Rajesha S
Principal
AIT, Bengaluru

Dr. T N Sreenivasa
Register (Evaluation)
VTU, Belagavi

VSS TRUST ATRIA INSTITUTE OF TECHNOLOGY ABVP YUVAKA SANGHA AICTE

SRISHTI
Innovation exchange
2024

CERTIFICATE OF ACHIEVEMENT

This is to certify that

Mr./ Ms. Kruthika

From East west college of engineering

has Participated in **SRISHTI 2024, State Level Project Exhibition and Competition** and secured **First / Second / Third / Consolation** Prize in **Srishti Avishkar - Pre Final Year Project Competition** held at Atria Institute of Technology, Hebbala, Bengaluru from May 24th- 26th 2024.

Dr. Satish H K	**Dr. Rajesha S**	**Dr. T N Sreenivasa**
State President	Principal	Register (Evaluation)
ABVP, Karnataka South	AIT, Bengaluru	VTU, Belagavi

VSS TRUST ATRIA ABVP YUVAKA SANGHA AICTE


SRISHTI
innovation exchange
2024
24 - 26 May, 2024
Atria Institute of Technology
Bengaluru
VSS TRUST
ATRIA
INSTITUTE OF TECHNOLOGY
ABVP
YUVAKA SANGHA

Eco Friendly 3D Printer

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Abstract*—This project aims to develop a 3D printer specifically designed for producing prototypes with a volume of 3 cubic centimeters or more. Our primary focus is on leveraging the latest technology and innovative methods to facilitate quick modifications and customizations of designs while minimizing material waste. The project will incorporate a blend of cutting-edge manufacturing techniques, precise engineering, and eco-friendly practices to ensure that the printer performs optimally and sustainably. A key highlight of our project is the commitment to environmental sustainability, particularly through the incorporation of e-waste recycling. The printer's design will prioritize the use of recyclable and biodegradable materials, as well as energy-efficient components, to significantly reduce the environmental impact of the manufacturing process and contribute to the development of greener production practices.By combining these elements, we intend to create a 3D printer that is not only highly efficient and accurate but also easy to use and adaptable to various industries and applications. The printer will address common challenges in the field of rapid prototyping, such as speed, precision, and resource efficiency. Our approach will involve the integration of advanced software and hardware solutions to streamline the design-to-production process, making it more accessible for users to implement changes and produce high-quality prototypes swiftly.Ultimately, this project seeks to revolutionize the way prototypes are made, offering a solution that combines speed, accuracy, and sustainability. We believe that our advanced 3D printer, with its emphasis on e-waste recycling, will inspire new ideas and innovative manufacturing techniques, paving the way for more sustainable and efficient production methods across various sectors. Through this endeavor, we hope to set new standards in the field of 3D printing and contribute to a more environmentally conscious future.

Keywords:* 3D printer, *Prototypes, Material waste, Precision, Cutting-edge manufacturing techniques, Eco-friendly practices, Environmental sustainability, E-waste recycling, Recyclable materials, Environmentally conscious future, Arduino mega, ramps 1.6, Energy-efficient components,Fused Deposition Modeling (FDM).

I. INTRODUCTION

3D printing technology, also known as additive manufacturing, has revolutionized the manufacturing landscape by enabling the creation of intricate objects layer by layer from digital designs. This advancement has unlocked new possibilities for rapid prototyping, customized production, and the fabrication of complex designs. However, despite its transformative potential, current 3D printers often encounter limitations in speed, customization, and material efficiency, particularly when tasked with producing small-volume prototypes.In response to these challenges, our project endeavors to design a specialized 3D printer optimized specifically for prototyping applications. Central to our approach is the integration of cutting-edge technologies and innovative methodologies aimed at enhancing the speed, customization capabilities, and material efficiency of the 3D printing process. By harnessing advancements in additive manufacturing, precision engineering, and sustainable practices, we aspire to develop a printer capable of meeting the rigorous demands of rapid prototyping while also minimizing its environmental impact.The successful achievement of our project's objectives holds the promise of significantly advancing 3D printing technology. Not only will it foster innovation, but it will also promote sustainability and efficiency in product development and manufacturing. Importantly, the impact of our endeavor extends beyond rapid prototyping, as the technology we develop can be adapted for broader manufacturing applications, thus contributing to more sustainable production practices across industries.

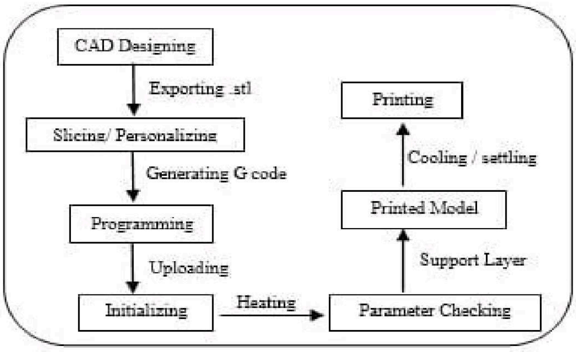

Fig. 1 . Process Diagram [1]

Moreover, our research underscores the importance of environmental sustainability in the development of this new 3D printer. We are dedicated to promoting eco-friendly practices by incorporating e-waste recycling and utilizing recyclable and biodegradable materials[2]. its overall environmental footprint and aiding in the advancement of greener production practices.In summary, our project represents a concerted effort to address the limitations of current 3D printing technology while also prioritizing environmental sustainability. Through the integration of advanced technologies and sustainable practices, we aim to pave the way for a future where 3D printing is both efficient and environmentally responsible.

II. LITERATURE SURVEY

Sadiq Ur Rehman. [1] Delta 3D Printer: Metal Printing July 2019, Block diagram for the working of proposed 3D printer

Sanket Barad. [2] The Fused Deposition Modeling (FDM) is an Additive manufacturing process that belongs to the material extrusion family.In FDM an object is built by selectively depositing melted material is extruded through a nozzle and deposed layer wise on a heated table. The material used are thermoplastic polymers and come in a filament form and it is Biodegradable.

Sadrina Sadrina. [3] The Arduino Mega 2560 is employed in the current machine, marking an improvement over the previous version. The main goal of the research is to develop a new 3D printer design that reduces production costs while enhancing design and performance compared to existing machines. The primary mainboard, which uses Arduino Mega and Ramps, is chosen because it is highly suitable for running programs and is very cost-effective.

III. SYSTEM DESCRIPTION

- **Hardware components**

1. Arduino Mega 2560 : The Arduino Mega 2560 is the central microcontroller of our 3D printer. It is based on the ATmega2560 microcontroller and provides the necessary processing power to handle complex tasks. It features 54 digital I/O pins, 16 analog inputs, and 4 UARTs, making it versatile and capable of managing multiple components simultaneously. Its affordability and open-source nature make it an ideal choice for our project.[3]

2. RAMPS 1.4 Board : The RAMPS (RepRap Arduino Mega Pololu Shield) 1.4 board is designed to fit on top of the Arduino Mega 2560. It serves as an interface between the microcontroller and the printer's hardware components. It provides connections for stepper drivers, heaters, thermistors, and other peripherals. This board simplifies the wiring process and enhances the modularity of the system, making it easier to assemble and troubleshoot.[4]

3. Stepper Motor Drivers : Stepper motor drivers, such as the A4988 or DRV8825, are connected to the RAMPS board and control the current supplied to the stepper motors. They enable smooth and precise motor operation, which is crucial for achieving high-quality prints.

4. Endstops : Endstops are switches placed at the ends of the printer's axes. They serve as reference points for the printer, allowing it to determine the limits of its movement and home its position accurately.[5]

5. Hot End : The hot end is the part of the extruder where the filament is melted and extruded onto the print bed. It includes a heating element, a thermistor for temperature sensing, and a nozzle. The hot end's temperature is carefully controlled to ensure optimal melting and deposition of the filament.

6. Stepper Motors from CD Drives : Repurposing CD drive components for 3D printers is a cost-effective and eco-friendly approach. Stepper motors from CD drives provide precise movement control for the printer's axes, while guide rails ensure smooth, accurate movements of the print head or platform. This reduces electronic waste and promotes sustainability. Using these readily available parts lowers production costs and encourages innovation. This practice highlights the potential of converting e-waste into valuable resources for technology development.

7. PLA Filaments : PLA filament is a biodegradable, eco-friendly material made from renewable resources like cornstarch or sugarcane. It decomposes naturally, reducing environmental impact. Ideal for 3D printing, PLA offers ease of use, minimal warping, and a lower melting point, making it a sustainable choice for various applications.[6]

- **Software Components**

1. Marlin Firmware : Marlin is based on previous firmware called sprinter.marlin is made up of bunch of different files, which control the function of the printer such as moving stepper motor,reading from SD card and about pins for the hardware that simply tells marlin what's connected to what on our main board.

2. Cad & 3d Modelling : 3D modeling involves creating digital representations of three-dimensional objects using specialized software. These models serve as blueprints for physical objects, guiding the 3D printing process. CAD (Computer-Aided Design) software tools are commonly used for 3D modeling.

3. Cura or slicer : Cura is a 3D printing software that is used to prepare 3D models for printing. It is produced by Ultimaker and is simple to use but also has advanced features for more experienced users. Cura supports STL, 3MF, and OBJ 3D file formats and also has a function that will import and convert 2D images to 3D extruded models. It allows you to open and place multiple models on the print bed and has over 400 expert settings for advanced users. It is available for Windows, Mac, and Linux and is free to download from the Ultimaker website.

4. Pronterface : Pronterface is a powerful 3D printing host software suite that allows you to interact with your 3D printer and manage the printing process. It provides both a graphical user interface (GUI) and an interactive command-line interface for controlling your printer, slicing objects, and running prints. Whether you prefer a visual interface or command-line control, Pronterface has you covered.

- **Implementation**

Our 3D printer consists of several key components, each playing a crucial role in transforming a digital design into a physical object. The system starts with the software part, which includes CAD, Cura, and G-code. CAD (Computer-Aided Design) software is used to create the 3D model. This model is then imported into Cura, a slicing software that processes the model and converts it into layers, generating G-code. G-code is a language that provides detailed instructions for the 3D printer, including how to build the object layer by layer. This G-code file is sent to the 3D printer through a serial port, establishing communication between the software and hardware components.

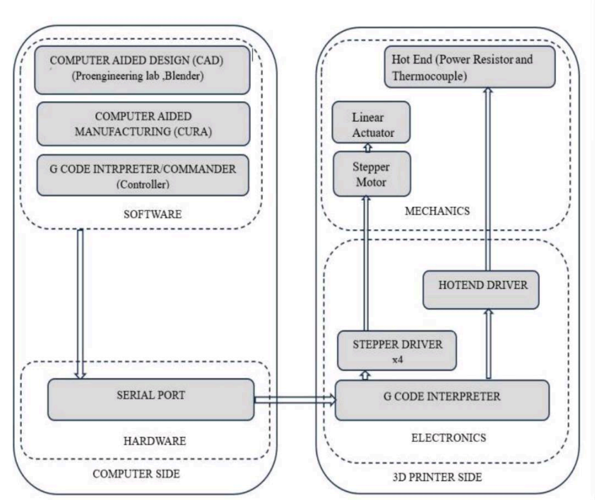

Fig. 2. Flow Chart

On the hardware side, the central microcontroller is the Arduino Mega 2560. This device is crucial as it processes the G-code instructions and controls various components of the printer. It is connected to the RAMPS 1.6 board, which serves as an interface for connecting stepper motor drivers, the hotend, thermocouples, and other components, simplifying wiring and making the system more manageable. The G-code interpreter on the Arduino reads the incoming commands and translates them into electrical signals that control the printer's hardware. The stepper motor drivers, such as A4988 or DRV8825, receive signals from the RAMPS board and control the stepper motors, regulating the current supplied to the motors to enable precise control of movement along the X, Y, and Z axes. Stepper motors are vital for driving the movement of the printer's axes and the extruder, operating in discrete steps to allow for precise positioning and controlled movements. These motors are connected to linear actuators, which convert the rotational motion of the stepper motors into linear movement, positioning the print head accurately to build the model layer by layer.The hotend driver manages the heating element of the hotend, ensuring the filament reaches the correct temperature for extrusion. The hotend itself is where the filament is melted and extruded onto the build platform. It includes a heating element and a nozzle that work together to deposit the filament accurately. To ensure the hotend maintains the correct temperature, a thermocouple provides real-time temperature data to the Arduino, enabling precise temperature control.The printing process begins when the G-code file is sent to the printer, and the Arduino Mega interprets the commands. The stepper motor drivers activate the motors, positioning the print head and the build platform according to the G-code instructions. The print head moves along the X and Y axes, while the build platform moves along the Z axis.

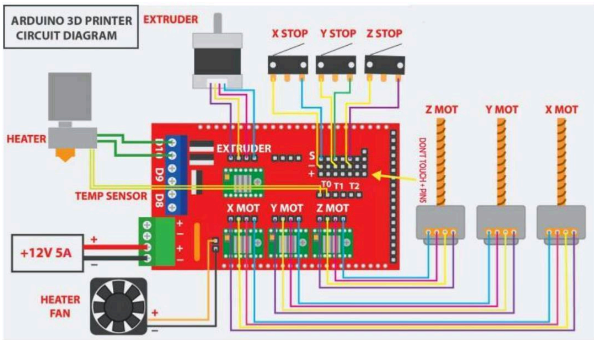

Fig. 3. Schematic Diagram

The hotend heats up to the specified temperature, and the extruder pushes the filament through the hotend nozzle, melting it and depositing it in thin layers. Throughout the printing process, the Arduino and RAMPS board continually adjust the motors and hotend based on the G-code. The thermocouple ensures the hotend maintains the correct temperature, while the stepper motors and linear actuators ensure precise movement and positioning. This layer-by-layer construction continues until the 3D model is complete. Once the printing is finished, the print head returns to its home position, and the final product can be removed from the build platform.

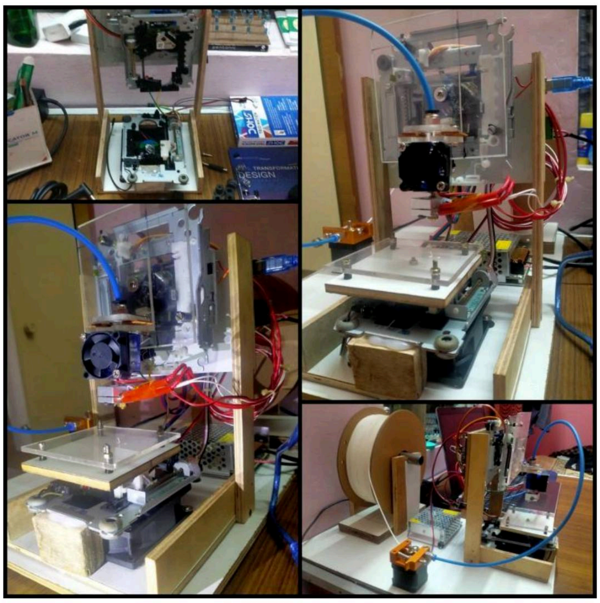

Fig. 4. Eco Friendly 3D Printer

In summary, our 3D printer transforms digital designs into physical objects by coordinating software and hardware components. CAD software creates a 3D model, converted into G-code by Cura. This G-code guides the Arduino Mega 2560, connected to the RAMPS 1.6 board, which controls stepper motors and the hotend. Stepper motors and linear actuators position the print head for precise layer-by-layer construction, facilitated by the hotend's heating and extrusion. The process continues until completion, with the print head returning to its starting position.

- **<u>Results</u>**

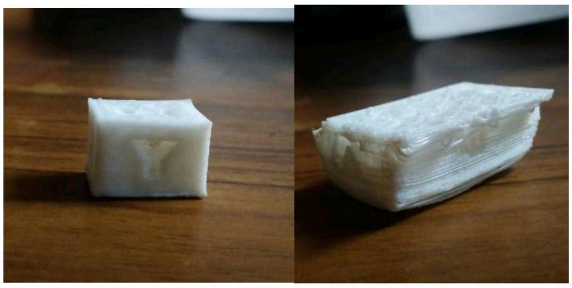

Fig. 5. Output Before Calibration

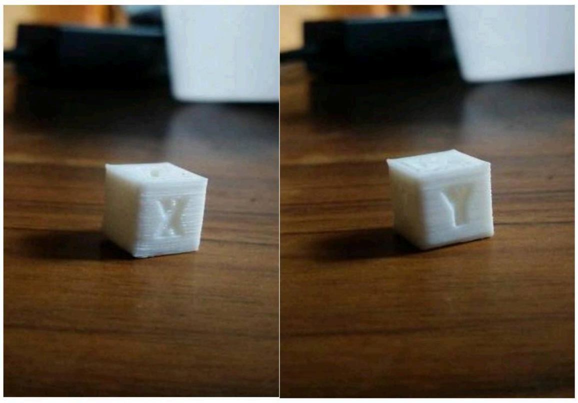

Fig. 6. Output After Calibration

Before Calibration: Fig.5

- Y-axis inconsistencies led to distorted shapes.
- Layer misalignments resulted in rough and uneven surfaces.

After Calibration: Fig.6

- Accurate Y-axis calibration produced consistent and symmetrical shapes.
- Enhanced layer alignment resulted in smoother surfaces and stronger prints.

IV. REAL TIME APPLICATIONS

a. Construction Sector : One of these innovations is the utilization of 3-dimensional printing technology. Civil engineers build structures using materials and techniques available in the times. 3D printing technology attracts attention since it is faster than traditional construction, less costly, less labor and less error margin in today.[7]

b. 3D Bioprinting of Tissues and Organs : Recent advances have enabled 3D printing of biocompatible materials, cells and supporting components into complex 3D functional living tissues. 3D bioprinting is being applied to regenerative medicine to address the need for tissues and organs suitable for transplantation.[8]

c. Marine Applications : The materials used in the production of these parts produced using 3D printers can be of various types. AM technologies have found an industry in which they can bring great innovations for development. As in other fields, the maritime sector is increasing the use of 3D printing technologies and renewing itself according to different needs.[9]

d. Aerospace Applications : Astonishingly 3D printing has excited the world of aerospace. This paper takes stock of the popular 3D printing processes in aerospace. Reasons for their popularity over the traditional manufacturing processes are dwelled upon..[10]

e. Self-design and Manufacturing: The material extrusion and the stereolithographic 3D printers, which were recently launched in a desktop size, herald a new time whereby common people will be able to own manufacturing means in their home. [11]

V. CONCLUSION

Our 3D printer project successfully integrates e-waste components like CD drive stepper motors and guide rails, promoting environmental sustainability. By using biodegradable PLA filament, we further reduce environmental impact. Cost-effective components like the Arduino Mega 2560 and RAMPS 1.6 board ensure affordability without compromising performance. Calibration improvements have significantly enhanced print accuracy and quality. Overall, this project demonstrates a sustainable, efficient, and cost-effective approach to 3D printing, highlighting the potential for eco-friendly innovation in manufacturing technology.

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