



Sustainable Filament Fabrication: Transforming Waste Plastic into 3D Printing Filament

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Abstract :- In recent times, the issue of plastic recycling has become one of the leading issues of environmental protection and waste management. So, for that purpose our study is focused only on the recycling of plastic waste. While studying some review papers, we noticed that a high quantity of plastic waste is due to many types of failures which comes from the other resources like plastic bottles, etc., Firstly, we collected plastic waste from different Sources. After that our main aim is to convert plastic waste into a useful product. So, to make plastic waste as a useful product we made a filament extruder. A filament extruder is a machine that converts plastic waste into 3D printer filament with the extrusion on process. The 3D printing market is a well-growing sector. The process involves designing components in a CAD model, followed by 3D printing and assembly. The key elements of the filament fabrication machine include a bottle cutter, hot-end, reel, and controller. The cutter slices the bottle into a continuous strip, which is then softened and shaped by the hot-end into filament form. The reel stores the filament for 3D printing, and the controller manages the hot-end temperature and reel motor. Printable filaments can be made from a variety of thermoplastic materials, including those from recycling. The nozzle is modified to accommodate the filament diameter. The reel assembly involves adding threaded brass inserts, bearings, and a motor-driven pulley system. A customized PCB with a Pro Mini Arduino controls the entire system, with an OLED display providing real-time information. The PCB is housed in a 3D printed enclosure. The fabricated filament is tested by 3D printing benchmark objects, and adjustments to the flow rate and temperature settings are discussed. This paper focuses on a review of the available literature on the production of filaments for 3D printers from recycled polymers as the alternative to present approach of central selective collection of plastics. So, due to this Mechanical and thermal properties were improved by adding different fillers to the input raw material. In addition, commercially available filaments produced from recycled materials and devices which allow self-production of filaments to 3D printing from plastic waste were reviewed. The results indicate the feasibility of using the homemade filament for various projects.

Index Terms - Extruder, 3D printing, Filament, Recycling, Polymer, Plastic, Waste management.

I. INTRODUCTION

In nowadays, 3D printing is a highly common method for producing completely functional models and entire projects quickly through prototyping. Every project we work on at our university of technology uses 3D printing. Many of the pieces are tiny, but we need them to be strong, including motor mountings, clutches, and gears. Researchers are even looking for ways to make composite filaments by enhancing the mechanical qualities of prints. The opportunities that 3D printing offers us are priceless, extremely affordable, and expedient when it comes to turning a computer model into a tangible product. In addition, 3D printing enables us to create components that are not achievable with other techniques. Many materials and parts are thrown away as trash throughout the prototyping process as failed prints, badly made models etc.,

In late times, the issue of plastic recycling has become one of the top issues of environmental protection and waste management. Polymer materials have been found utilization in many areas of daily life and industry. Opportunities for recycling polymeric materials offer a second life guarantee option and allow efficient waste utilization to be wasted. This research focuses on a review available of research on the production of filaments for 3D printers which are recycled from polymers as the opportunity to present an approach to the central selective collection of plastics. Recycling consumer plastic products is also very help full to saving the environment and it will be also another source of 3D printer filament. That's why recycling of 3D parts and 3D printed wastes again for the rest of their life is a very important issue to be discussed. The objective of this research is to fabricate and Test filament extruders for optimal utilization of material. This research aims to find an optimized material with a combination of different materials and recycle the available waste from 3d Printing. Reusing waste plastic, especially PET bottles, to fabricate filament for 3D printing has been investigated in a number of research. One strategy is using combine material-extrusion additive manufacturing (MEX-AM) technique with recycled polyethylene terephthalate (rPET). The objective of this research is to assist the circular economy and sustainable materials concepts by investigating the possibility of upcycling recycled polyethylene terephthalate (rPET) into filaments for material-extrusion additive manufacturing (MEX-AM) technology. Uniform filaments with improved mechanical properties are created by mixing rPET with inexpensive additives like impact modifiers and chain extenders, providing flexibility in the creation of customized products. The practicality of using rPET-based filaments for MEX-AM is demonstrated by the notable gains in mechanical strength and melt flow index that are seen, even in the presence of minor printing errors.

1.1 Field of Invention

The process of turning waste plastic into 3D printer filament using sophisticated recycling techniques is known as sustainable filament manufacturing. This is developing new techniques in chemical engineering, material science, and recycling technology to produce high-quality filament with less of an adverse effect on the environment. Developing effective depolymerization techniques, streamlining extrusion procedures, and guaranteeing the caliber and uniformity of recycled filament are important areas of concentration. This project advances sustainable manufacturing techniques and the ideas of the circular economy by converting garbage into a useful resource.

1.2 Background of invention

The invention's origins are in tackling the two problems of growing plastic waste and the need for environmentally friendly production methods. With the use of 3D printing and recycling technology, the project hopes to turn waste plastic into useful filament for additive manufacturing. It aims to reduce environmental damage while encouraging innovation in the circular economy by turning trash into useful resources.

I. LITERATURE SURVEY

1. Title: Extrusion and Characterization of Recycled Polyethylene Terephthalate (rPET) Filaments Compounded with Chain Extender and Impact Modifiers for Material-Extrusion Additive Manufacturing.

Publication year: 2023

Authors: Ola Rashwan, Zachary Koroneos et.al.

Findings: The study calls attention to the necessity of further optimization of printing parameters in order to decrease faults and motivates researchers to investigate environmentally sustainable feedstock alternatives for additive manufacturing in order to promote environmental sustainability.

2. Title: 3Dprinting

Publication year: 2021

Authors: Oussai, Alaeddine.

Findings: The mechanical properties of 3D printed PET utilizing virgin and recycled materials are evaluated in the study, and similar findings are obtained. With its higher tensile strength and lower hardness, optimal printing with recycled PET is highlighted. The study highlights the need for better recycled filament technology to lower CO₂ emissions even if no appreciable variations were seen between pre- and post-recycling. Positive outcomes point to a potential for recycling trash from local 3D printing, with savings of USD \$3000 on an investment. Risks include mechanical quality degradation and nozzle blockages, even with advantages like lower CO₂ emissions and landfill use. It is advised to conduct more research on the recycling of filaments in addition to 3D printing, taking into account substitute plastics like ABS. This study encourages the development of 3D recycling technology for wider adoption at small business and community levels and emphasizes the significance of sustainable plastic recycling programs for environmental protection.

3. Title: The Effect of Printing Speed Variations on Dimensional Stability of 3D Printing Results Made from Waste Bottle Filament.

Publication year: 2023

Authors: Santosa Budiono, H., Hilmy, F., & Taufik.

Findings: Designing microbial cell factories as an alternative strategy to recycle PET into functionalized chemical building blocks for additive manufacturing has been proposed. The accumulation of plastic garbage is a serious global issue, and conventional disposal techniques like burning and landfilling worsen the effects on the environment. New methods of converting plastic trash into valuable items, like plasma- and microwave-assisted conversion, are encouraging. The pressing need for sustainable waste management, especially in emerging

nations, is examined in this paper. We can reduce pollution and generate income by repurposing plastic waste into fuels, building materials, and other useful items. But our incomplete knowledge of conversion mechanisms emphasizes the need for more investigation. Unchecked plastic garbage affects ecosystems and human health, so action must be taken immediately. To solve this urgent issue, sustainable practices must be given top priority by governments and regulatory agencies. By working together, we can make the transition to a circular economy model and make sure that plastic trash is produced, used, and disposed of responsibly, protecting the environment for coming generations.

4. Title: 3D printing filament as a second life of waste plastics—A reviews." Environmental Science and Pollution Research

Publication year: 2021

Authors: Mikula, Katarzyna, et al.

Findings: The rise in plastic recycling is a response to urgent environmental issues since polymer materials remain toxic wastes after usage. In an effort to provide an alternative to centralized plastic collection techniques, this research investigates the possibility of recycled polymers for use as 3D printing filaments. The study highlights the importance of recycling in achieving a circular economy by analyzing the literature on recycled filament production and devices for creating filament at home. Because of the high expense of transportation, typical recycling processes produce low-value commodities; nevertheless, desktop 3D printing allows for the decentralized creation of complex plastic goods. This strategy not only lessens the impact on the environment but also promotes prospects for cost savings and customization. In addition, people have demonstrated the adaptability of 3D printing during the COVID-19 pandemic by creating visors and other necessary medical supplies. The increasing use of 3D printing has the potential to advance the concepts of sustainability and circular economy by allowing production to adjust to changing demands.

5. Title: Viability production of filaments for 3D printing using recycled polypropylene.

Publication year: 2023

Authors: Andre, Canal, Marques

Findings: The project aims to address the urgent problem of plastic waste through recycling, with an emphasis on plastic bottles and waste from 3D printing. Three varieties of filaments are produced from plastic waste that is gathered from different sources and processed using a filament extruder: Lime Green, Dark Green, and White. Tensile and ductility tests are performed on these filaments to evaluate their performance in comparison to filaments that are sold commercially. The Dark Green filament is remarkably five times more ductile than bought filaments, demonstrating a maximum Stress-Strain increase of 76%. In a similar vein, White and Lime Green filaments exhibit better mechanical qualities than their equivalents sold in stores. These experiments, carried out in university labs, demonstrate how recycled filaments can perform better than commercial alternatives, offering a viable path toward environmentally friendly 3D printing techniques.

6. Title: Recycling of plastic solid waste: A state of art review and future applications.

Publication year: 2016

Authors: Song, N., Hui, D., Song, R., Ahuja, I. P. S., Feo, L., & Fraternali, F.

Findings: In today's era, if we do additive manufacturing, then the best and better name that comes out is that of fused deposition modelling (FDM). This research explores the measurement of material waste in Fused Deposition Modeling (FDM) printers, with a focus on the influence of human error and printer dysfunctions on waste production. Information from an open shop that uses a lot of ABS material shows that about 34% of plastic is wasted, and that 19% of the material is used in failure prints. Significantly, calibration problems have been found to be a major cause to the 2.22 times higher material loss from failure builds than estimated from controlled process studies. Each of the nine failure categories is categorized in the report along with recommendations for reducing material waste. Moreover, it emphasizes the necessity of additional investigation into the connection between part orientation, failure rates, and energy usage of commercial FDM printers. Further research is suggested to fully solve material waste in FDM printing by comprehending how human and organizational behavior effect failure rates.

7. Title: Life Cycle Assessment of filament production in Distributed Plastic Recycling via Additive Manufacturing.

Publication year: 2023

Authors: Cristian, Cáceres., et.al.,

Findings: Using a life cycle assessment (LCA), the study compares the environmental effects of two scenarios of virgin plastic filament supply chains to Distributed Recycling via Additive Manufacturing (DRAM). The analysis, which is being done in Nancy, France, takes into account ion radiation, resource depletion, eutrophication potential, and climate change. Findings show that the environmental effects of DRAM production are significantly lower than those of virgin plastic production, with the exception of ion radiation emissions, which can be attributed to France's reliance on nuclear energy. The results demonstrate how DRAM can help with waste control initiatives and increase the longevity of plastic products. Sensitivity research indicates that DRAM can be applied in different energy scenarios and function in conjunction with centralized recycling networks to boost the rates of plastic recycling. Subsequent investigations need to enhance suppositions and incorporate intricacies of the recycling procedure, and worldwide evaluations can provide guidance on the best environments for DRAM integration.

8. Title: Material and energy loss due to human and machine error in commercial FDM printers.

Publication year: 2017

Authors: Song, Ruoyu, and Cassandra Telenko.

Findings: First, we needed some data to start this research, so to collect that data we chose someplace where 3D printing was done. All the people who used to work there, we told everyone that whatever waste will come out of the 3D printer due to different reasons, it has to be put in different dustbins. After that, we collect all waste and bring it in working place. After that, we characterizing those data well, the unsuccessful printers were divided into 9 types, and research was done on them. It was discovered that in open studios about 34% of the plastic is wasted. This analysis emphasizes how additive manufacturing—specifically, fused deposition modeling, or FDM—has the potential to completely transform manufacturing processes because of its low

cost, small size, and ease of maintenance. Life cycle assessment studies highlight the environmental benefits of FDM, including material efficiency and energy savings. Nonetheless, issues like waste of materials and energy resulting from printing faults and human error are addressed. The study offers suggestions for lessening environmental effects by highlighting the necessity of minimizing material waste and optimizing energy use in FDM procedures. The results emphasize how crucial it is to take operational parameters and real-world usage settings into account when assessing how environmentally friendly additive manufacturing technologies like FDM.

9. Title: additive manufacturing of up cycled commodity plastic through dynamic cross- linking.

Publication year: 2022

Authors: S. Kim, M.A. Rahman, M. Arifuzzaman, D.B. Gilmer, B. Li, J.K. Wilt, E. Lara-Curzio, T. Saito.

Findings: Plastics varied chemical structures make them a major waste management concern, which calls for better recycling techniques. Mechanical recycling is widely used, however because of its shortcomings in managing mixed plastic waste streams, research efforts have been directed towards the development of novel technologies such as selective deconstruction catalysts. Recycled plastics have lost some of their mechanical strength, which makes commercial recycling operations more difficult and require the blending of virgin polymers. Although there are obstacles to market acceptance and cost, chemical recycling offers viable options. Because actual waste streams have higher amounts of pollution, scaling up academic research for practical applications presents uncertainties. In an effort to improve recycling procedures and cut waste, academic research is also focused on creating sustainable polymer materials with dynamic functioning and depolymerization capabilities. But for integration into industrial processes to be successful, factors including material adoptability, scalability, and environmental effects must be taken into account.

10. Title: Dynamic mechanical analysis investigations of PLA-based renewable materials: how are they useful? Materials.

Publication year: 2020

Authors: M. Cristea, D. Ionita, M.M. Iftime

Findings: The paper focuses on poly(lactic acid) (PLA), a prominent renewable polymer, and how its complicated thermal and morphological properties can be understood by dynamic mechanical analysis (DMA). Secondary relaxations are observed in the glassy area of PLA, although overlapping processes such as enthalpic relaxation and crystallization pose difficulties in the glass transition. awareness PLA's behavior under various conditions and compositions requires an awareness of elastic modulus (E') fluctuations and crystallinity changes, which are both revealed by DMA. The determination of the glass transition temperature in PLA is complex, with unclear signs resulting from overlapping processes. Furthermore, PLA's characteristics are examined in relation to plasticizers and reinforcing agents, with a focus on how these affect T_g and $\tan \delta$ peak height. Examining PLA's cold crystallization and melting processes can provide light on the effects of plasticizers and molecular weight degradation. All things considered, the review provides insightful viewpoints and indices for understanding DMA experiments on PLA, which are crucial for researchers even with less DMA expertise.

11. Title: The rise of 3-D printing: the advantages of additive manufacturing over traditional manufacturing.

Publication year: 2017

Authors: M. Attaran.

Findings: Although this technique has a lot of potential, issues including non-standard filament quality, problems getting a steady filament diameter, and contamination in the plastic waste stream need to be resolved. However, there could be a significant impact on the environment and the 3D printing industry from the manufacture of filament for 3D printing from waste plastic. The article describes how 3D printing, also known as additive manufacturing (AM), is changing conventional supply chain and manufacturing methods. Its advantages include improved flexibility, decreased waste, and better efficiency. AM is seen as a disruptive technology that has the power to completely transform a number of sectors, including the medical, aerospace, and automotive industries. Mass customisation, decentralized production, and quicker demand response are all made possible by it. As a supplement to conventional production techniques, additive manufacturing (AM) promises to lower the cost of mass customization and enable consumers to become micro-manufacturers. Similar to the effects of assembly lines in the past, technology is set to make production more efficient, localized, and globally connected. Manufacturing could be made more accessible in the future by 3D printers that are available at service locations like Kinko's or may even become standard in households.

12. Title: Drivers to Sustainable Plastic Solid Waste Recycling: A Review.

Publication year: 2017

Authors: Bupe G Mwanza, Charles Mbohwa.

Findings: Recycling is recognized as the most preferred option of waste management for reuse of the materials in order to manufacture new products. A survey of manufacturing enterprises in Kitwe, Zambia, revealed substantial difficulties that the plastic industry must overcome to achieve sustainable plastic waste recovery and recycling. These barriers include things like capacity and cost constraints, quality and demand challenges, market share dynamics, and environmental and legal constraints. Technology turns out to be the main barrier, with laws and environmental issues coming in second and third. These difficulties have an effect on sustainability's social, environmental, and economic facets. The study classifies barriers using a fishbone diagram and suggests actions like establishing domestic markets for recycled plastics, guaranteeing material applicability, replacing virgin materials, encouraging transactional cooperation, and enforcing laws to overcome these obstacles and advance sustainable recovery and recycling of plastic waste.

13. Title: A Framework for Material Selection in Multi-Generational Components: Sustainable Value Creation for a Circular Economy.

Publication year: 2016

Author: Jawahir, Bradley.

Findings: Population growth, intensive use of resources, and uncontrolled environmental pollution forced the implementation of another economic closed-loop system, based on the principles of 3Rs: Reduce, Reuse, and Recycle. The broader methodology includes additional three approaches: Recover, Redesign, and Remanufacture. This research study explores the possible synergy between 3D printing and recycling in sustainable production. By evaluating recycled materials' printability and performance, it reveals advantages including waste reduction

and resource efficiency. It draws attention to the benefits that 3D printing with recycled materials has for the environment through life cycle evaluation and sustainability analysis. The study concludes that increasing the use of recycled materials in 3D printing requires cooperation, innovation, and regulation. This research highlights the revolutionary impact of combining these technologies for a more sustainable future, with applications ranging from healthcare to prototyping.

14. Title: Polymer.

Publication year: 2009

Authors: M.L. Di Lorenzo, Eur. Polym. J., L. . Bouapao et al.,

Findings: This study clarifies the unrestrained spread of plastic trash, especially in food packaging, which is being fueled by consumer choices and the world's population expansion. It emphasizes how urgently packaging materials need to be reduced, reused, and recycled in order to lessen environmental contamination. To promote a circular economy, there is a requirement for a comprehensive approach to waste management that engages stakeholders from all sectors. It promotes group efforts to solve the plastic pollution challenge by highlighting the roles of corporations in invention, governments in legislation, academic institutions in research, and individuals in action. The emphasis on the continent of Africa's potential as a major user of plastics used in food packaging draws attention to how crucial it is to take proactive steps to address this urgent environmental issue.

15. Title: Prog. Polym. Sci.

Publication year: 2007

Authors: B. Gupta et al.,

Findings: This study looks into the pyrolysis of mixed plastic waste (MPW) and different plastic wastes, such as polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyethylene terephthalate (PET). We investigated the effects of operating temperatures between 450°C and 600°C on the yields of liquid products. The results show that although PET breakdown gives large solid residue and gas but no oil, HDPE degradation yields the maximum oil production with the least amount of solid residue. It is found that 500°C is the ideal temperature for recovering low-density pyrolytic oil. Different plastics degrade through different ways: PS undergoes side elimination or end chain scission, PE and PP suffer random chain scission, and mixed plastics exhibit a combination of these mechanisms. Overall, the study shows how pyrolysis can be used to control garbage and produce energy from plastic waste.

16. Title: Reverse logistics network for municipal solid waste management: The inclusion of waste pickers as a Brazilian legal requirement. Waste Management.

Publication year: 2015

Authors: L.G. Ferri, L.G. Chaves, M.G. Ribeiro.

Findings: This review of the literature looks at the factors that, in both established and developing economies, are driving sustainable development in post-consumer packaging plastic waste recycling systems. Key forces that present chances to lower oil consumption, carbon emissions, and waste disposal volumes are economic, environmental, and social reasons. Reusing plastic waste reduces the demand for new materials, which promotes sustainable manufacturing practices in addition to resource conservation. The research highlights how crucial empirical analysis is for estimating how these drivers affect the sustainability of the recycling system. Developing these drivers in various contexts is the main goal going ahead, with the goal of

achieving economic viability, environmental sustainability, and social benefits for communities resulting from plastic waste from post-consumer packaging.

17. Title: Waste reduction and recycling initiatives in Japanese cities: Lessons from Yokohama and Kamakura. *Waste Management & Research*.

Publication year: 2014

Authors: Y. Hotta, C. Aoki-Suzuki.

Findings: This study explores the essential elements that lead to the accomplishment of municipal recycling and waste reduction programs, with particular attention on Japan. It presents examples of how incinerators have acted as incentives rather than deterrents for garbage reduction, illuminating the complex interaction between these facilities and recycling initiatives. The study highlights the significance of making informed decisions about expensive waste treatment facilities and proposes that closing outdated incinerators can promote recycling. Capacity restrictions in the final treatment, backing from federal regulations, public involvement, and open communication from local authorities are important factors that contribute to the effectiveness of trash reduction and recycling. The results emphasize how important it is to prioritize trash reduction through source separation and support extensive municipal recycling programs in order to achieve successful results.

18. Title: The European plastic waste issue: trends and toppers in its sustainable re-use. In: *Proceedings of the 17th International Congress of Chemical and Process Engineering*.

Publication year: 2006

Authors: Dewil, R., Everaert, K., Baeyens, J.,

Findings: This study examines novel strategies for addressing the worldwide problem of disposing of plastic solid waste (PSW), with an emphasis on environmentally friendly procedures including improved mechanical recycling and heat treatments like pyrolysis and gasification. Gasification is a potential technique that produces a syngas rich in hydrogen and carbon monoxide when it is carried out at high temperatures in an oxygen-deficient environment. The use of gasification for PSW has not received as much research attention as it has for biomass and coal. Highlighting the results of laboratory and pilot-scale research, the study summarizes the body of literature currently available on PSW gasification. Recent developments show promise for efficient PSW recycling while fulfilling emission regulations, such as sequential gasification and combustion systems. But more research is needed to improve product performance and equipment design, which will open the door for gasification reactors to be widely used and applied on an industrial scale.

19. Title: Analysis of household waste composition and factors driving waste increases, WRAP for strategy unit.

Publication year: 2002

Authors: Parfitt, J.,

Findings: This study offers a thorough analysis of current developments in the recycling and recovery of plastic solid waste (PSW), with an emphasis on polyolefinic sources. It goes into detail about the procedures and technology used in each of the four therapy pathways—primary, secondary, tertiary, and quaternary. Secondary procedures minimize waste size for reusability, while primary recycling is frequent in processing lines. While tertiary techniques such as thermochemical treatments show potential, more work is needed to get desired product results. Despite investigation, petrochemical factories do not integrate energy recovery. Research and attention should be directed towards tertiary and quaternary therapies, even in the face of established primary and secondary schemes. Recycling programs help the eco-image of trash management, although issues with polymer types, conditions, and energy use still exist. With the recovery of important petrochemicals and energy production, tertiary treatment appears as a viable solution. For sustainable waste management, recycling and energy recovery must be integrated into production plants. To increase the effectiveness of cutting-edge recycling technologies, more investigation and development are necessary.

20. Title: Biodegradation of polyurethane: a review International Biodeterioration and Biodegradation.

Publication year: 2002

Authors: G.T. Howard

Findings: Years of research, study and testing have resulted in a number of treatment, recycling and recovery methods for PSW that can be economically and environmentally viable. This paper offers an in-depth examination of the ways in which plastic trash affects ecosystems, delving into biotechnological solutions, mechanisms of degradation, and the necessity of moving toward a circular economy. It highlights the pressing need to use efficient waste management techniques to address the risks that plastic accumulation poses to the environment and public health. Together with biotic degradation made possible by microbial enzymes, abiotic degradation mechanisms also present viable alternatives. The plastic waste situation may be lessened with the help of biotechnological techniques such as gene editing and anaerobic biotechnology. Nonetheless, obstacles persist in creating environmentally sustainable and commercially feasible deterioration processes. The review emphasizes how crucial it is to coordinate efforts to manage plastic trash with sustainable development objectives, placing a strong emphasis on recycling programs, tougher laws, and education in order to achieve sustainability over the long run.

II. REQUIREMENTS

Components list and design specifications

Below are the explanations of the main components and their respective functions.

1. Aluminium strip cutter

The component number 1, Bottles of plastic are chopped into strips with a plastic strip cutter. A cutting mechanism and a frame make up the plastic strip cutter. In order to cut the plastic into strips of uniform width and length, a blade is used in the cutting mechanism, which is supported steadily by the frame. A specific width slit mechanism is incorporated into the cutter to guarantee uniformity. Cut into strips of the same width, the plastic can then be worked upon further to form a 3D filament.

2. Heating block

In Fig. 1, component number 2 is for the purpose of accommodating the recycled PET plastic strips, a copper heating block has undergone particular changes. To make it easier for the plastic strips to run smoothly through the extruder, the heater block's inlet threads have been removed and the opening enlarged. A taper has been added to the heater block along with the removal of the threads and expansion of the opening. In order to ensure a seamless and continuous extrusion operation, the tapered design aids in successfully guiding the plastic strips through the extruder.



Fig.1. Heater

3. Nozzle

The extruder uses nozzles with a diameter of 1.75 mm. This nozzle size guarantees uniform material extrusion and is appropriate for the extrusion of PET plastic.



Fig.2. Nozzle

4. Stepper Motor

After heating the PET bottle, 1.75mm diameter of filament is produced. Now stepper motor is used to rotate the reel in a series of small angular steps, instead of continuously.



Fig.3. Stepper Motor

5. Reel holder

It is one of the major components it holds the filament extruder in a specific manner which have connection with the motor.



Fig.4. Reel holder

6. Motor holder

It holds the motor which will be supporting the motor and gives the thrust force for the reel holder by transmitting power from the holder to the reel holder.



Fig.5. Motor holder

7. UNO board

A UNO board can be effectively employed in a filament extruder setup, particularly when recycling plastic bottles. The Uno board, serving as a microcontroller, manages and regulates various aspects of the extrusion process. It can control the temperature of the extrusion barrel, monitor the speed of the filament extrusion, and ensure consistent diameter and quality of the filament produced.

8. Thermal radiator

Thermal radiators play a vital role in maintaining optimal temperatures within a filament extruder setup utilizing plastic bottles. These radiators dissipate excess heat generated during the extrusion process, preventing overheating of critical components such as the extrusion barrel and motor.

9. Display

These displays can show vital information such as temperature readings, extrusion speed, filament diameter, and other relevant parameters. Operators can monitor these metrics to ensure the extrusion process is running smoothly and make necessary adjustments as needed.

10. Base

Generally the base is used to hold the bottle, aluminium strip cutter, and reel throughout the process.

IV.MECHANISM

The process entails gathering and classifying different kinds of plastic trash, after which they go through an extrusion and depolymerization procedure to produce filament. Sophisticated chemical and mechanical engineering methods guarantee the uniformity and quality of the filament while reducing pollutants and energy usage. To comply with industry requirements for 3D printing materials, quality control procedures are put in place at every stage of the process. The project lessens dependency on virgin polymers and promotes sustainable manufacturing processes by converting waste into useful filament.

4.1 DISPENSING MECHANISM:

Sorted plastic trash is sent into a regulated depolymerization chamber as part of the dispensing mechanism, where it is broken down chemically or thermally. After that, the material is extruded via fine-tuned nozzles to create filament with a constant diameter. For consistent filament production, automated sensors keep an eye on the feed rate and temperature and make necessary adjustments. The filament is then prepared for use in 3D printing applications by being spooled or trimmed to length for packaging. This effective method maximizes filament quality while reducing energy and material waste.

V. METHODOLOGY

To create a sustainable fabrication of 3D printing filament from recycled PET plastic, a step-by-step methodology is followed, which is illustrated in Fig. 10. This methodology is an essential step towards achieving sustainable 3D printing practices by reducing plastic waste and promoting the use of eco-friendly materials. Step by Step methodology that is followed for production of the recycled PET filament is elaborated in detail starting from material selection to extruding the filament.

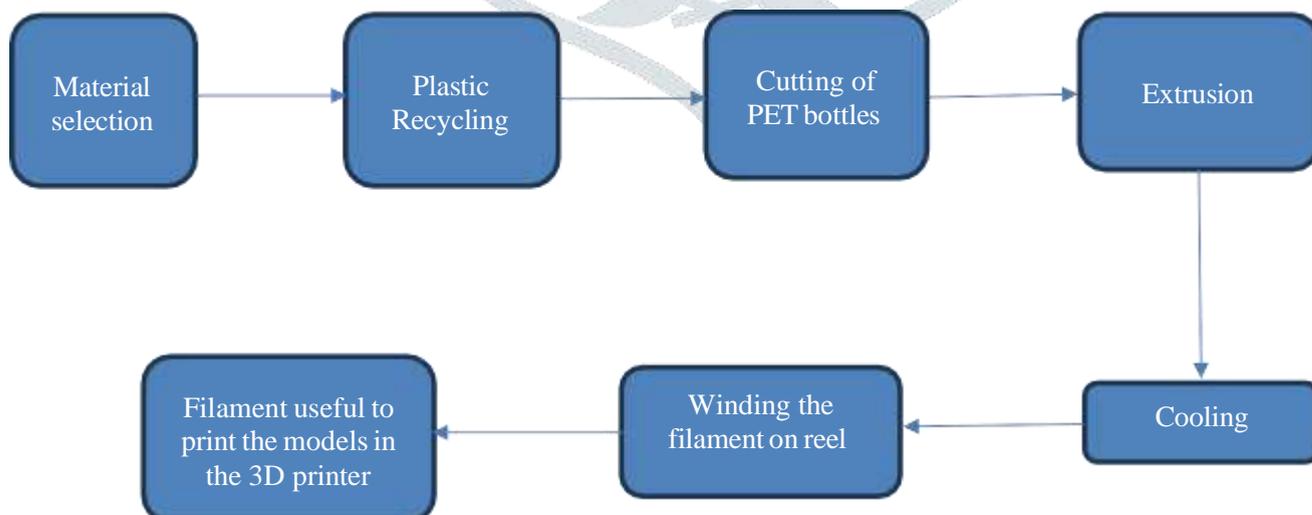


Fig. 10. Design of Methodology

5.1 Material selection:

As demonstrated in fig.10. that the initial stage of the methodology is material selection. This includes identifying plastic waste available for 3D printing filament, which necessitates selecting certain types of plastic to serve as a source material for 3D printing. Plastic waste is classified into various types, such as thermoplastics and thermosetting plastics, based on their characteristics. For this study, we chose waste plastic bottles made from PET plastic because most of the available waste is made up of PET plastic as shown in fig11.



Fig.11. Waste plastic bottles of PET plastic

5.2 Recycling of plastic

Recycling the plastic bottles comes after the first material selection process is finished. The process of recycling begins with giving the bottles a thorough wash and drying to get rid of any remaining contaminants, as shown in Fig. 12. Following cleaning, the bottles are heated to remove any abnormalities and increase their pliability, which will make cutting them into strips easier. This phase is crucial because it allows the bottles to be reshaped and sized in preparation for the following procedure. By cutting the bottles into strips, this enables the plastic to be easily fed into the extruder. This step is crucial for the overall success of the process, as it ensures that the recycled plastic can be efficiently used to create 3D printing filament.



Fig. 12. Waste plastic bottles of PET plastic.

5.3 Cutting PET bottles

Once the plastic bottles are cleaned and heated, they are sorted and cut into continuous strips using the plastic strip cutter shown in Fig. 13. The width of the strip is shown in Fig. 13. These strips of plastic are commonly referred to as “Pre- filament.” The purpose of cutting the plastic bottles into strips is to facilitate the subsequent steps in the process, which are extrusion and winding the filament on a reel. The plastic strips, as illustrated in Fig. 13, are cut using a specially designed plastic strip cutter which ensures that the plastic strips are of a consistent width. This consistency is essential to ensure that the strips can be easily fed into the extruder machine.



Fig. 13. Plastic strip.



Fig. 14. 3D design of PET strip cutter.

5.4 Extrusion

The subsequent stages involved in converting plastic bottles into filament for 3D printing. As illustrated in Fig. 14, the plastic strips are fed into an extruder machine after being trimmed to the appropriate width. The plastic strips are heated by the extruder, which then melts them into a uniform molten state. It has a heating element that has a temperature range of 0 to 400 °C. After that, the melted plastic is forced through a nozzle or die opening to create a long, continuous filament. The nozzle has a diameter of 1.75 mm. To guarantee that it solidifies and keeps its shape after extrusion, the filament is cooled. The equipment passes the filament across it, rapidly and effectively cooling it. It is essential because it keeps the filament from warping or losing its shape when it is being wound. Ultimately, a reel is used to wind the filament. Layer by layer, the filament is carefully wound onto the reel as it is rotating at a steady speed. By using this method, the filament is twisted firmly and uniformly, eliminating any tangles or knots that can lower the quality of the material. The reel can be used for 3D printing as soon as it is loaded with filament. High-quality, uniformly sized filament that may be used for a variety of 3D printing tasks is the outcome.

5.5 Experimental setup:

It shows the machine's experimental setup for creating 3D filament. Aluminium is used as the base material in the fabrication of the machine. By melting and forming plastic strips into the desired 3D filament, the extruder machine is an essential part of the creation process. The temperature range of 200–220 °C is achieved by heating the plastic strips in the extruder, which is controlled by a UNO Board controller. Through a carefully regulated heating procedure, the plastic melts and turns into a molten liquid, which may subsequently be forced through a nozzle aperture to produce the required diameter of the 3D filament. It is crucial to cool the filament after extrusion in order to guarantee that it maintains the correct size and shape. The natural cooling process occurs at room temperature. The plastic melts and is helped to solidify by this cooling process, which keeps the material's size and shape from changing during the extrusion process. In order to guarantee the consistency of the 3D printing filament produced, the extrusion and cooling processes are essential.

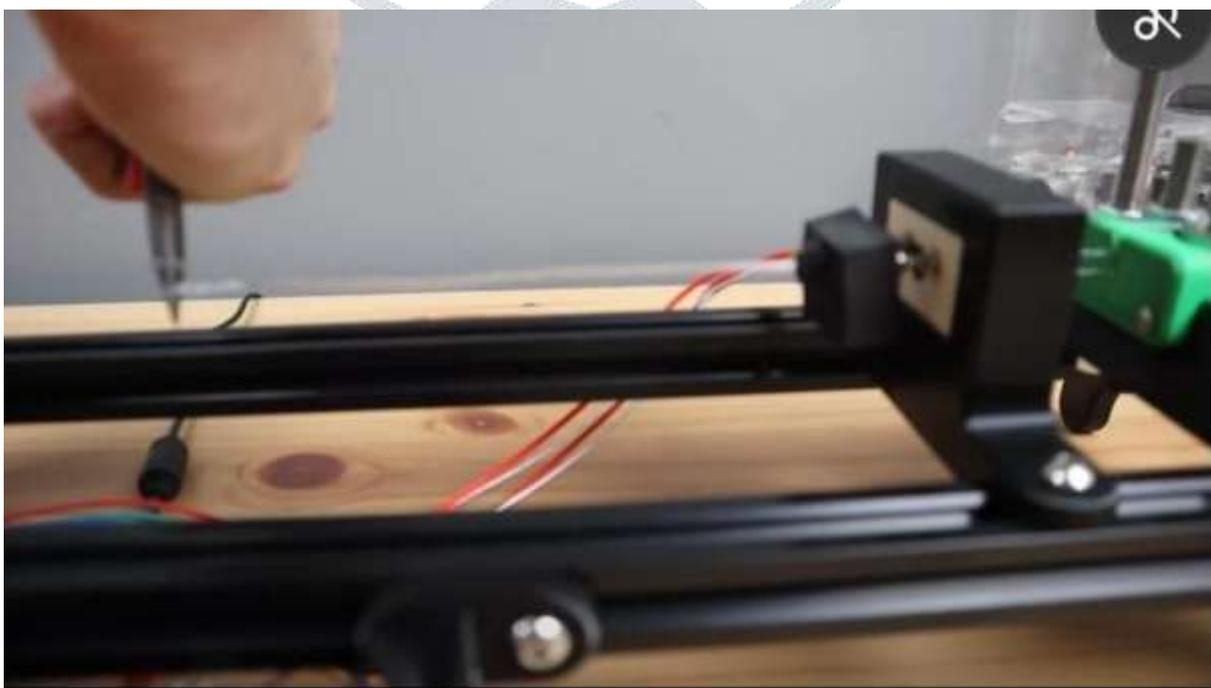


Fig.15. Extrusion of PET filament.



Fig.16. Experimental model of machine

IV. FUTURE SCOPE

Integration of Advanced Technologies

- Subsequent studies can concentrate on improving and streamlining the recycling procedures needed to turn plastic bottles into premium filament. In order to enhance the Caliber and uniformity of the final filament, this involves investigating cutting-edge methods for separating, purifying, and processing waste plastic.
- It may be possible to create novel composite materials by combining recycled plastic bottle filament with natural Fibers or other sustainable resources like biopolymers. This could increase the number of applications for sustainable 3D printing by producing filaments with improved mechanical, biodegradable, or aesthetic qualities.
- Comprehensive lifecycle evaluations (LCAs) and environmental impact analyses of the procedures used to fabricate sustainable filaments can offer important insights into how sustainable they are overall. Subsequent investigations may concentrate on calculating the advantages for the environment, energy conservation, and decrease in carbon emissions linked to the utilization of recycled plastic bottles as filament feedstock in contrast to traditional production techniques.

In general, there is a great deal of room for future research on the production of sustainable filaments from plastic bottles. This includes market development, policy advocacy, technological innovation, quality assurance, and environmental analysis. Researchers, business partners, and legislators may help improve sustainable 3D printing methods and the shift to a circular economy by tackling these issues and opportunities.

V. CONCLUSIONS

Sustainable filament fabrication utilizing plastic bottles offers several key benefits and conclusions:

- **Environmental Impact Reduction:** This procedure lessens the quantity of plastic trash that ends up in landfills and the ocean by converting plastic bottles into filament for 3D printing. Reusing resources is one way it promotes a circular economy.
- **Efficiency in Resource Use:** By using plastic bottles as a feedstock for filament manufacture, natural resources that would have been utilized to produce new plastic materials are conserved. As a result, there is less of a need for the creation of virgin plastic, which lowers energy use and greenhouse gas emissions.
- **Economic Opportunities:** In areas with inadequate recycling infrastructure, sustainable filament production has the potential to generate new business opportunities. Because it creates jobs in production, processing, and collection, it can boost regional economies.
- **Innovation and Technology Development:** The exploration of sustainable filament production procedures through research and development leads to the advancement of recycling technologies and materials for 3D printing. This promotes the development of more environmentally friendly practices in a variety of businesses.
- **Community Involvement and Education:** Projects centered on environmentally friendly filament production increase knowledge about plastic pollution and the value of recycling. They urge people to take up more sustainable habits and support community involvement in environmental stewardship.
- **Regulatory Compliance:** Adopting sustainable filament manufacture is in line with stricter environmental laws that encourage recycling and reduce plastic waste. Businesses can show their dedication to environmental sustainability and corporate social responsibility by implementing these strategies.

In summary, the creation of sustainable filaments from recycled plastic bottles offers a viable solution to the problem of plastic pollution while fostering resource efficiency, economic growth, creativity, and community involvement. This technique helps to provide a more circular and sustainable approach to the usage of plastic in industrial processes by utilizing technology and teamwork.

VI. RESULT AND ANALYSIS

6.1 Code for heating the plastic strip in the heater

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
//complete code without selection annaay
#define SCREEN_WIDTH 20
#define SCREEN_HEIGHT 4

LiquidCrystal_I2C lcd(0x27, SCREEN_WIDTH, SCREEN_HEIGHT);

#define initialTemp 220
#define minTemp 190
#define maxTemp 230
```

```
#define initialSpeed 22
#define minSpeed 1
#define maxSpeed 28
#define initialMot 1
#define minMot 0
#define maxMot 2

int encLowLim = minTemp;
int encHighLim = maxTemp;
int encIncrement = 1;
int encCurrent = initialTemp;
int dataInputNo = 0;

static int pinA = A2; // Change pinA to A2 (A3 on Nano)
static int pinB = A3; // Change pinB to A3 (A4 on Nano)
volatile int encoderPos = initialTemp;
volatile int prevEncoderPos = initialTemp;

byte oldButtonState = HIGH;
const unsigned long debounceTime = 10;
unsigned long buttonPressTime;
boolean pressed = false;

const int temperaturePin = A0; // Change temperaturePin to A0 (A3 on Nano)
const int pwmPin = 9;
const int enablePin = 8;
const int motDirPin = 6;
const int motStepPin = 7;
const int encButton = 4;

int loopTime = 500;
unsigned long currentTime = 0;
double Kp = 80.0;
double Ki = 35.0;
double Kd = 80.0;

double setpoint = initialTemp;
double input, output;
double prevInput = 0;
double integral = 0;
double derivative = 0;

int motSpeed = initialSpeed;
int motDir = initialMot;
int motMaxDelay = 100;
int motDelayTime = 500;
```

```
// Thermistor parameters
```

```
const float R0 = 10000.0; // Resistance at nominal temperature (25°C)  
const float T0 = 25.0; // Nominal temperature (°C)  
const float beta = 3950.0; // Beta value of the thermistor  
const float Rref = 10000.0; // Reference resistance
```

```
void setup()
```

```
{ Serial.begin(9600);
```

```
  lcd.init();
```

```
  lcd.backlight();
```

```
  pinMode(pwmPin, OUTPUT);
```

```
  pinMode(pinA, INPUT_PULLUP);
```

```
  pinMode(pinB, INPUT_PULLUP);
```

```
  attachInterrupt(digitalPinToInterrupt(pinA), rotaryInterrupt, CHANGE);
```

```
  attachInterrupt(digitalPinToInterrupt(pinB), rotaryInterrupt, CHANGE);
```

```
  pinMode(encButton, INPUT_PULLUP);
```

```
  pinMode(enablePin, INPUT);
```

```
  pinMode(motDirPin, OUTPUT);
```

```
  pinMode(motStepPin, OUTPUT);
```

```
  digitalWrite(motDirPin, HIGH);
```

```
  Serial.println("Setup complete");
```

```
}
```

```
void loop()
```

```
{ currentTime =
```

```
  millis();
```

```
  float temp = readTemperature(); // Read temperature using the thermistor function
```

```
  // PID calculation
```

```
  input = temp;
```

```
  double error = setpoint - input;
```

```
  integral += (error * loopTime);
```

```
  derivative = (input - prevInput) / loopTime;
```

```
  output = Kp * error + Ki * integral + Kd * derivative;
```

```
  output = constrain(output, 0, 255); // Limit output to the range of PWM
```

```
  analogWrite(pwmPin, output);
```

```
  Serial.print("Temperature: ");
```

```
  Serial.print(temp);
```

```
  Serial.print(" \u00B0C");
```

```
  Serial.print("\tPWM Output: ");
```

```

Serial.print(output);
Serial.print("\tEncoder: ");
Serial.println(encCurrent);

updateDataDisplay();

while (millis() < currentTime + loopTime)
{
  byte buttonState =
  digitalRead(encButton); if (buttonState !=
  oldButtonState) {
    if (millis() - buttonPressTime >= debounceTime)
    {
      buttonPressTime = millis();
      oldButtonState = buttonState;
      if (buttonState == LOW) {
        pressed = true;
      } else {
        if (pressed == true)
        {
          pressed = false;
          if (dataInputNo == 0)
          {
            dataInputNo = 1;
            encCurrent = motSpeed;
            encLowLim = minSpeed;
            encHighLim = maxSpeed;
          } else if (dataInputNo == 1)
          {
            dataInputNo = 2;
            encCurrent = motDir;
            encLowLim = minMot;
            encHighLim = maxMot;
          } else {
            dataInputNo = 0;
            encCurrent = setpoint;
            encLowLim = minTemp;
            encHighLim = maxTemp;
          }
        }
      }
    }
  }
}

}

if (dataInputNo == 0)
{
  setpoint =
  encCurrent;
} else if (dataInputNo == 1)
{
  motSpeed = encCurrent;
  motDelayTime = 100 * (1 + maxSpeed - motSpeed);
} else {
  motDir = encCurrent;
}

```

```

if (motDir == 0)
  { pinMode(enablePin,
    OUTPUT);
    digitalWrite(motDirPin, LOW);
    updateDataDisplay();
  } else if (motDir == 2)
  { pinMode(enablePin, OUTPUT);
    digitalWrite(motDirPin, HIGH);
    updateDataDisplay();
  } else {
    pinMode(enablePin, INPUT);
  }

while (motDir != 1)
  { runMotor();
    motDir = encCurrent;
  }
}

void rotaryInterrupt() {
  encoderPos = digitalRead(pinA);
  if ((prevEncoderPos == 0) && (encoderPos == 1))
    { if (digitalRead(pinB) == 1) {
      if (encCurrent < encHighLim)
        encCurrent = encCurrent + encIncrement;
      } else {
        if (encCurrent > encLowLim)
          encCurrent = encCurrent - encIncrement;
        }
    }
  prevEncoderPos = encoderPos;
  delay(1);
}

```

```

void updateDataDisplay()
  { lcd.clear();
  // Display temperature information on the first two lines

```

```

  lcd.setCursor(0, 0);
  lcd.print("Current Temp:");
  lcd.setCursor(0, 1);
  lcd.print("Set Temp: ");
  lcd.setCursor(14, 0);
  lcd.print(input);
  lcd.print("C");
  lcd.setCursor(10, 1);
  lcd.print(setpoint);

```

```

lcd.print("C");

// Display motor control information on the third and fourth lines
lcd.setCursor(0, 2);
lcd.print("Speed: ");
lcd.setCursor(7, 2);
lcd.print(motSpeed);
lcd.print("  ");
lcd.setCursor(0, 3);
lcd.print("Direction: ");
lcd.setCursor(11, 3);
if (motDir == 0)
  { lcd.print("CCW");
  } else if (motDir == 1)
  { lcd.print("Stop");
  } else {
  lcd.print("CW");
  }
}

void runMotor()
{ digitalWrite(motStepPin, HIGH);
  delayMicroseconds(motDelayTime);
  digitalWrite(motStepPin, LOW);
  if (millis() < currentTime + loopTime)
  { delayMicroseconds(motDelayTime);
  } else {
  currentTime = millis();
  float temperature = readTemperature(); // Read temperature using the thermistor function
  input = temperature;
  double error = setpoint - input;
  integral += (error * loopTime);
  derivative = (input - prevInput) / loopTime;
  output = Kp * error + Ki * integral + Kd * derivative;
  output = constrain(output, 0, 255); // Limit output to the range of PWM
  analogWrite(pwmPin, output);
  }
}

float readTemperature() {
  // Read the resistance of the thermistor
  int rawADC = analogRead(temperaturePin);

  float thermistorResistance = Rref * (1023.0 / rawADC - 1.0);

  // Calculate temperature using the Steinhart-Hart equation
  float steinhart;
  steinhart = thermistorResistance / R0; // (R/R0)

```

```
steinhart = log(steinhart);           // ln(R/Ro)
steinhart /= beta;                    // 1/B * ln(R/Ro)
steinhart += 1.0 / (T0 + 273.15);     // + (1/To)
steinhart = 1.0 / steinhart;         // Invert
steinhart -= 273.15;                 // Convert to Celsius

return steinhart;
```

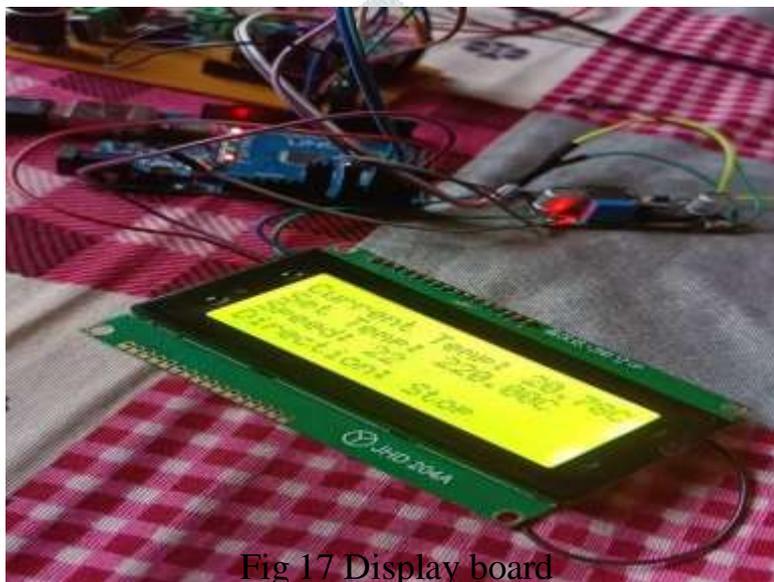


Fig 17 Display board

This code has been used for the project in order to get satisfactory results and we have changed them to our needs mainly this code has been used to give command to the Arduino Uno board to get other parts to get the work done properly and in this we have used the thermistor, stepper motor and a display which will be used to determine how much temperature is currently available and we can set the temperature as per we need and the motor is used to get the reel to rotate in stimulate and way of the filament. and the display is used to get the current information about the temperature and the motor running status etc....

The sustainable filament fabrication project aims to address plastic pollution and promote environmental sustainability by repurposing plastic bottles into filament for 3D printing. Plastic bottles, a common source of pollution, are collected and processed through recycling techniques to create high-quality filament suitable for additive manufacturing applications.

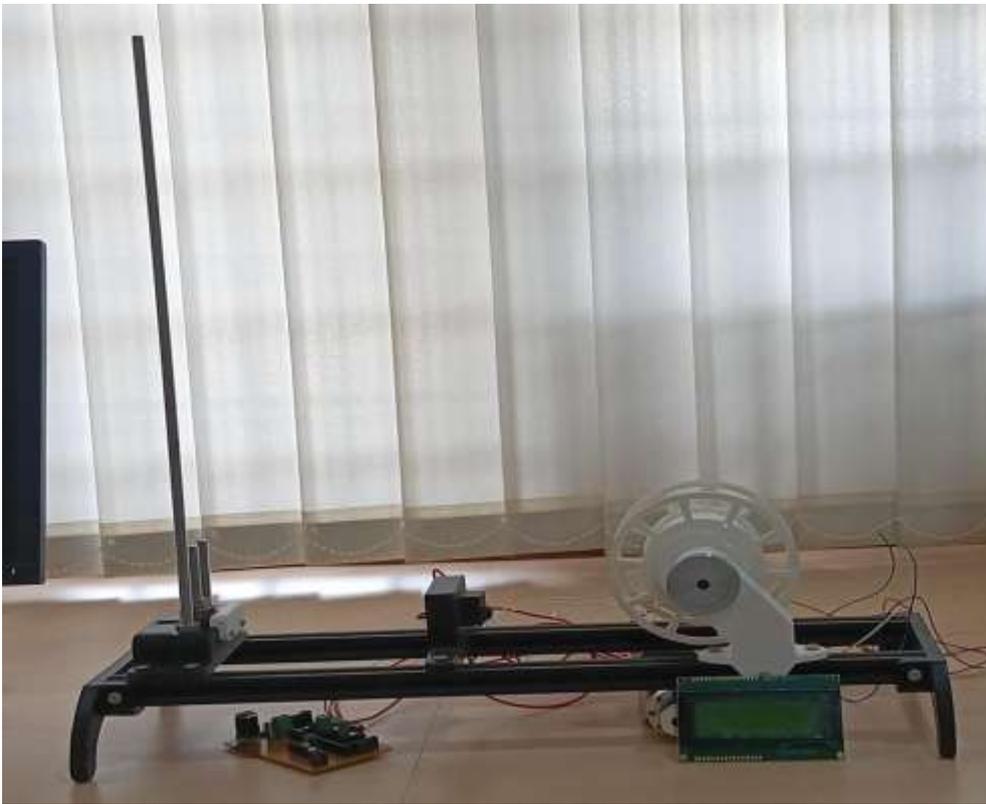


Fig 18 Model of the Filament extrusion using plastic bottles

6.2 Key Components:

- The initiative entails gathering and classifying plastic bottles from many sources, such as residences, commercial establishments, and recycling facilities. To guarantee a constant feedstock for filament production, these bottles are separated according to the kind and quality of polymer.
- After being gathered, the plastic bottles go through a rigorous cleaning and processing procedure to get rid of impurities including labels, tops, and residues. Filament extrusion uses the cleaned bottles as a raw material, which are shredded into small bits and melted down to make plastic pellets or granules.
- Filament Extrusion: To create continuous filament strands, the plastic pellets are placed into an extrusion machine, heated, and then extruded via a nozzle. The filament's diameter and other characteristics are carefully regulated to satisfy the requirements needed for 3D printing applications.
- Quality Assurance: Throughout the fabrication process, quality control mechanisms are put in place to guarantee the integrity and consistency of the recycled filament. Testing for mechanical qualities, dimensional accuracy, and equipment compatibility with 3D printing are all included in this.
- Market Integration: Through collaboration with 3D printer manufacturers, distributors, and end users, the project seeks to integrate sustainable filament into the market. Education and outreach initiatives are carried out to increase consumer and business adoption of recycled filament by bringing attention to its environmental benefits.

6.3 Benefits:

- Environmental Impact Reduction: By converting plastic bottles into filament, the concept helps divert garbage from landfills and oceans, minimizing the environmental footprint of plastic pollution.
- Resource conservation: Compared to traditional plastic production methods, using recycled plastic as a feedstock saves energy and preserves natural resources.
- Economic Opportunities: By promoting regional recycling businesses and offering a sustainable substitute for conventional filament materials, the project generates income.
- The initiative stimulates creativity in recycling technologies and collaboration amongst stakeholders in the 3D printing supply chain.

All things considered, the sustainable filament fabrication project is an all-encompassing strategy that tackles plastic waste in the additive manufacturing sector while encouraging creativity, growth, and environmental responsibility.

REFERENCES

- [1] Ola Rashwan, Zachary Koroneos et.al., (2023) "Extrusion and Characterization of Recycled Polyethylene Terephthalate (rPET) Filaments Compounded with Chain Extender and Impact Modifiers for Material-Extrusion Additive Manufacturing." doi: 10.21203/rs.3.rs-3073266/v1.
- [2] Oussai, Alaeddine 2021 "3Dprinting.com".
- [3] Santosa Budiono, H., Hilmy, F., & Taufik, I. (2023). The Effect of Printing Speed Variations on Dimensional Stability of 3D Printing Results Made from Waste Bottle Filament. *Jurnal E-Komtek*, 7(1), 187-194. <https://doi.org/10.37339/e-komtek.v7i1.1114>.
- [4] Mikula, Katarzyna, et al. "3D printing filament as a second life of waste plastics—A reviews." *Environmental Science and Pollution Research* 28.10 (2021): 12321-12333.
- [5] André, Canal, Marques. (2023). Viability production of filaments for 3D printing using recycled polypropylene. doi: 10.29183/2596-237x.ensus2023.v11.n2.p180-192.
- [6] Song, N., Hui, D., Songh, R., Ahuja, I. P. S., Feo, L., & Fraternali, F. (2016). Recycling of plastic solid waste: A state of art review and future applications. *Composites Part B: Engineering*, 115, 409-422.
- [7] Cristian, Cáceres., et.al., (2023). Life Cycle Assessment of filament production in Distributed Plastic Recycling via Additive Manufacturing Context. *Cleaner waste systems*, 5:100100-100100. doi: 10.1016/j.clwas.2023.100100.
- [8] Song, Ruoyu, and Cassandra Telenko. "Material and energy loss due to human and machine error in commercial FDM printers." *Journal of cleaner production* 148 (2017): 895-904.

- [9] S. Kim, M.A. Rahman, M. Arifuzzaman, D.B. Gilmer, B. Li, J.K. Wilt, E. Lara-Curzio, T. Saito, Closed-loop additive manufacturing of up cycled commodity plastic through dynamic cross-linking, *Sci. Adv.* 8 (22) (2022) 1–10.
- [10] M. Cristea, D. Ionita, M.M. Iftime, Dynamic mechanical analysis investigations of PLA-based renewable materials: how are they useful? *Materials (Basel)* 13 (22) (2020) 1–24.
- [11] M. Attaran, The rise of 3-D printing: the advantages of additive manufacturing over traditional manufacturing, *Bus. Horiz.* 60 (5) (2017) 677–688.
- [12] Bupe G Mwanza, Charles Mbohwa “Drivers to Sustainable Plastic Solid Waste Recycling: A Review”(2017).
- [13] Jawahir, Bradley “A Framework for Material Selection in Multi-Generational Components: Sustainable Value Creation for a Circular Economy”(2016).
- [14] M.L. Di Lorenzo, *Eur. Polym. J.* (2005), L. . Bouapao *et al.*, *Polymer* (2009).
- [15] B. Gupta *et al.*, *Prog. Polym. Sci.* (2007).
- [16] L.G. Ferri, L.G. Chaves, M.G. Ribeiro. Reverse logistics network for municipal solid waste management: The inclusion of waste pickers as a Brazilian legal requirement. *Waste Manage;* 2015; 40: 173–191
- [17] Y. Hotta, C. Aoki-Suzuki. Waste reduction and recycling initiatives in Japanese cities: Lessons from Yokohama and Kamakura. *Waste Management & Research;* 2014; 32(9): 857–866.
- [18] Dewil, R., Everaert, K., Baeyens, J., 2006. The European plastic waste issue: trends and toppers in its sustainable re-use. In: *Proceedings of the 17th International Congress of Chemical and Process Engineering*, 27–31 August, Prague, Czech Republic.
- [19] Parfitt, J., 2002. Analysis of household waste composition and factors driving waste increases, WRAP for strategy unit. Government Cabinet Office, London, UK.
- [20] G.T. Howard 2002. Biodegradation of polyurethane: a review *International Biodeterioration and Biodegradation*.