DESIGN AND FABRICATION OF EXTRUSION MACHINE FOR RECYCLING PLASTICS

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ABSTRACT. The extruder is designed for producing filament that can be used for 3-D printers. The 3-D printer requires a filament having dimension ranging from 2-2.5mm. The quality expected is to obtain an extended filament having the specified dimensional range which can be fed into the 3D printer. Screw extrusion process is adopted to produce filament to fixes cross section. PET pellets were heated between 230̊ to 250̊ and pushed through a nozzle. The material experiences compressive and shear force. A continuous filament of diameter ranging from 2 to 2.5mm is obtained without any air bubbles and roughness.

I. INTRODUCTION.
Extrusion process produces thin filaments which is suitable for 3-D printing process. In the extrusion of PET plastic, raw PET material in the form of flakes is fed into the hopper mounted on the barrel of the extrusion machine. The PET flakes get transported by the action of gravity as it passes through the hopper. The flakes enter through the feed throat and come in contact with the screw. The screw rod is rotated using a motor at low rpm and the barrel chamber is heated by ceramic heater for a temperature range of 230 to 250̊C. The PET flakes as it passes through the screw rod gets heated and melted which then finally gets extruded from the nozzle designed for the size of the filament. Initially in most of the process, a heating profile is set for the barrel in which there are three heater zones which gradually increases the temperature from low to high. This allows the plastics pallets to melt gradually as they are pushed through the barrel and it will reduce the risk of overheating which may cause degradation in polymers.

The basic mechanism involved in this process is of a screw which transports the raw plastic pellets from a hopper through a heating metal pipe where the plastics are melted. The raw plastic pellets is fed into the screw from the hopper with the help of gravity. Then the molten plastic is forcefully passed into the pipe with the help of the nozzle at the end of the pipe to form the filament. Finally, the extruded plastics which is drawn from the nozzle to determine the final diameter of the filament which is drawn from the nozzle [2].
II. IMPLEMENTATION IN 3D PRINTER

3D printer utilizes the extruder to perform the type of additive manufacturing referred to as Fused Deposition Modeling. Fused Deposition Modeling also known as FDM begins with a software process that includes the processing of an STL (stereolithography file format). The STL file mathematically slices and orients the particular model for the physical build process. The part is then produced by extruding small beads of thermoplastic material to form layers as the material immediately hardens after extrusion from the J-Head hot end. There is typically a worm-drive or drive wheels (powered by the stepper motor) that feed the filament into the nozzle at a controlled rate. Inside the nozzle, the thermoplastic is then heated past its glass transition temperature by the heated resistor and thermistor, deposited by the extrusion head onto the build platform or base (FDM Technology: Stratasys). If required, support structures may also be generated. In this instance, the machine may dispense multiple materials to serve different purposes. It may dispense one material to build the model up and another material to serve as the support structure or base upon which the model is built. The movement of the nozzle can be in both horizontal and vertical directions which follows the tool path with the help of modelling software. In relevance to the 3D printer design, the extruder along with the motor is placed directly onto the z-axis and the stepper motor is plugged into an Arduino Mega 2560 microcontroller. The Arduino is then instructed by the user through the CAM program the appropriate dimensions and parameters upon which to build the model. The model is then built from the bottom up approach, which basically made one layer at a time.

III. LITERATURE REVIEW

1. Historical Development of Extruder

The extrude process means that the machine to push out the material through an opening which is the product as the extradite. The meaning of extruder is all about mixing. The inventor of this extruder machine was Charles Hancock and his co-workers in the year 1870s and developed in 1890s by applying the fundamental principle of extrusion in USA. In Europe the extrusion machine is developed by Francis Shaw and Paul Troester in 1900.

Extrusion technology was initially invented in the year 1870, this is done by setting up extruder system by the accurate temperatures in extrusion process. Due to this the plastic deformation also evolved and also side by side thermoplastic polymers evolution has also been developed. The main reason for the evolution of the extrusion machine is due to plastic which is having wide range of the polymers. From the year 1960 the evolution of the extrusion machine made successful in manufacturing part. The basic design of the extrusion machine does not change only the working and mechanical procedure during the productions. Initially, due to this machine the demand for the plastic product raised by the development of the extruder machine, the next type of extruder machine started after the generation of die making. Due to this most changes had to be done to the machine in order to obtain the required outputs. The compressions as well as the pressures of the machine were studied together. Nowadays the extruder machine had been changed in many ways, it is changed by the modern engineers in classical form to the modern form. The timing of the extruder screw was increased by co rotating to counter rotating principle. Every design were noted in order to make implementation. The produce pressure were analysed more in order to obtain better extrusion process.

Recently, the extrusion machines are fully automated and there are huge development in extrusion system. This extrusion machine have high demand in pipes to the objects that printed in 3D printer by using the extrusion process by using the latest new technology. The generation of this machine is done in two branches, the first branch has high efficiency and second has the finished product which is to be modified. But more than this wide range of extrusion technologies which is in hold and in development which is still running to produce eco-friendly polymers such as PLA [1].

2. Extrusion process

The process of the extrusion is mainly classified into five main parts:

1. Feeding
2. Melt
3. Melt conveying
4. Mixing
5. Filament forming
The extruding assembly generally consists of screw, barrel, heat control unit and the die during the extrusion process. The working of the extrusion machine is due to the gravitational force the plastic is fed into the extruder in the form drops into the rotational screw of extruder. Then the screw starts to rotate in order to that the friction is generated in order to generate heat and the plastic materials start to melt. In order to melt extra materials additional heating barrels are attached in the extruder. The electric heat control acts as shielding effect which does not allow heat to go out where the molten plastic is injected to the die. It also acts as thermal energy to the process.

Then the melted plastics is passed through the small hole in order to remove the impurities and then passes through the die to the final product. Extrusion process is mainly for large scale industries. In this manufacturing process it is very important to keep right operating control inputs and temperature measurements for required polymer and resin. If we followed the instructions then only we are able to get final products. During this extrusion process, there might be many errors in the product, for example if the temperature is not maintained properly the final product which will get is not as good as it should be.

2.1. Hopper
This is the part which is present at the starting stage were the plastic is fed into the system which works by gravity where granules reaches the hopper. The hopper is generally conical in shape so that the raw materials can move easily. Most hoppers are joined with help of nut and bolt so that it can be removed for different shape and size of material.

2.2. Screw
The screw assumes an imperative function in expelling. The screw is expected to push the material which is feed to the framework from the container. The pivoting screw pushes the granules in to the barrel. The screw is the basic part to improve the ill-advised plan if the screw may result hazards and inappropriate item result. The speed of the screw can be resolved from the control unit.

2.3. Barrel
The granules are warmed through the five channels of warming utilizing PTC or fired radiators in barrel. The granules are from strong state to fluid state combining. This is otherwise called warming and blending zone. The contact power among screw and granules makes it simple to liquefy on the grounds that the barrel temperatures get sufficiently high to soften the plastic. The liquid material through the barrel gets into the openings of kick the bucket where the state of item is given.

2.4. Nozzle
The extruder contains mainly a breaker plate which is used to brake the materials which is directly connected to the nozzle. Usually, the gear pumps are generally placed between the nozzle in order to maintain a uniform pressure which results in producing uniform dimensions of cross section. So it acts as an seal between the nozzle and the extruder and it contains a hole where the plastics is forcefully sent through it after rotating movement process. It also reduces the impurities while passing through the nozzle. We can change the nozzle according to the required size of the filament. Therefore, the nozzle is a key unit in this process.

3. Control unit
The control unit is the gadget wherein every gadget is associated with work. The simple or computerized control unit can control the creation esteem. The speed and the warmth in the barrel can be effectively kept up by the assistance of this control unit. Basically it is the arrangement of electronic associated together to make expelling simple. The creation esteem and the force taken by the engine are additionally commonly found in presentation board of control unit [1].

4. VISCOSITY IN EXTRUSION
Thickness is the amount that portrays a liquid's protection from stream. Liquids oppose the general movement of drenched items through them just as to the movement of layers with varying speeds inside
them. Officially, thickness is the proportion of the shearing pressure \( (\frac{f}{A}) \) to the speed angle \( (\frac{\Delta vx}{\Delta z} \text{ or } \frac{dvx}{dz}) \) in a liquid.

Polymer consistency is significant in expulsion to comprehend the handling window, the job temperature plays in thickness, and the significance of shear rate during preparing. The thickness versus shear rate bend shows enormous contrasts with temperature changes and just little contrasts with shear rate changes. To bring down thickness during expulsion, it is more successful to diminish the liquefy temperature. Going to a higher shear screw in one or the other single or twin-screw expulsion doesn't significantly change the gum consistency. Higher shear rate actuates shear warming, which brings down the polymer thickness and can prompt gum corruption. Some gum frameworks show both solid temperature and solid shear reliance. In these frameworks, while both temperature and shear effectsly affect thickness, changes in shear rate influence consistency more than changes in temperature [1].

5. OBJECTIVES
The objective of this task is to plan and construct an expulsion machine that makes 3D printing fiber from PET bottle pellets. The application is for any business utilizing 3D imprinting in a non-industrial nation with the plan to make the 3D printing practical and efficient. The deliverable is an economical and tough machine that admissions polyethylene terephthalate (PET) plastic water bottle shreds, dissolves and blends them, and afterward expels them as homogeneous fiber. Although, PET plastic is hard to reuse, it was picked in light of the fact that it is the most ordinarily accessible waste plastic [3].

IV. METHODOLOGY
1. PROCEDURE OF EXPERIMENT
The development and activity of the plastic extruder is to a great extent dependent on existing plans utilized in both mechanical and diversion applications. The essential component is contained a screw that transports crude plastic pellets from a container through a warming zone in a metal line where the plastic is liquefied. The crude plastic pellets are gravity-taken care of from the container into the screw. Inside the line the liquid plastic is constrained through a spout toward the finish of the line to frame a fiber. The expelled plastic can be attracted from the spout to decide the last breadth of the fiber. The spout is molded to frame the expelled plastic into the ideal cross-segment. Single screw extruder is an extruder which have just one screw in the framework. It is regularly utilized for the straightforward and general materials. As of late, individuals have done heaps of exploration for more steady and stable expulsion. In extruder, material is blended inside the barrel till the length of the expulsion machine [2].

2. EXTRUSION
2.1 Install Extruder Nozzle
Install a bolt nozzle of diameter 2.5mm so that the filament is drawn easily.

2.2 Set Material Temperatures
Initially the temperature of the machine is very low. To melt the very high temperatures are required. So suitable temperature is needed to be maintained.

2.3 Feed Hopper
After the equipment in the machine gets heated up fill the hopper with raw materials. Always clean the hopper with the brush so that the controls and inside wall of the hopper will be clean. Do not fill the hopper fully as the screw starts to rotate there may be chance to overflow of the melted plastics.

2.4 Guide Filament
Tenderly guide the fiber into a characteristic twisting, either heading turns out great. To get a predictable fiber, try not to pull on the fiber. Contacting the fiber will cause irregularities in the fiber measurement. Contacting the fiber while its expelling presents curves and changes in the width.
The principle point of this cycle is to spool it without any problem. Initially toward the starting the beginning of twisting is hardest, yet whenever it is spiraled it turns out to be simple.

2.5 **Measure diameter**
After the filament gets hardened and made spool the measurement is done in the filament coil itself. The temperature also varies for different sizes of filament. If the size of filament is too large high temperature is required, if the size of filament is small low temperature is required.

3. EXTRUDER MACHINE
The extruder machine these days is generally cutting-edge. The extruder is characterized into different various sorts depending the quantity of screws. There are fundamentally 3 sort's extruders

- Single screw extruder
- Twin screw extruder
- Multi-screw extruder.

3.1 Single screw extruder
Single screw extruder is the extruder machine which consists of only one screw. This is used only for one type of materials which is to be melted. Generally, many research have been done on this extruder in order to obtain higher accuracy by mixing up of different materials.

3.2 Twin screw extruder
This type of extruder is mainly used in powder processing plant. The extruder is automatic since it can clean itself and mixes mainly based on the ratio. The twin screw extruder is mainly used in industry for the pelletization process. The performance obtained from this extruder is more qualitative.

3.3 Multi-screw extruder
This is the extruder is used in order to get more output. In this extruder it has more numbers of screw. In this type of extruder there is no problem in mixing process. The output obtained from this process is very good and strong.

3.4 Fiber and 3D printer
3D printer is machine which takes fiber with the assistance of combined together constrating to get the items. It prints the fibers in layer by layer structure. The size of printing layer thickness shifts from 0.01 mm to 0.04 mm. The thickness of the fiber goes from 1.75 mm to 3 mm. The 3D printer causes the fiber to dissolve at high temperature and the prints it to get required shape and size of the article. All together get more strength of the item it ought to have a layer thickness of 0.01 mm. There are different sorts of the printers however it utilizes fluid resin based and powder gum based rather than fiber. Some sort of help material can be effectively eliminated by dissolving it in dissolvable to acquire the eventual outcome.

3.5 Stereo-Lithography
3D printing is a laser type of the sintering. This is the stage where the melted pellets plastics is cured with the help of the laser beam. The photosensitive polymers are made set during this cycle. The obtained complex polymers are obtained of high accuracy.

3.6 Electrical Heaters
Electrical heaters are essentially utilized in this machine by supplanting other liquid warmers or steam warming frameworks. These are principally utilized since it proficient and cost diminishing. It isn’t costly to keep up correlation between warming framework. Electric radiators typically covers an enormous territory then other warming framework. It has become a specialist well-disposed loathing framework in expelling measure. The specific measure of current goes through the conductor which has certain obstruction, these opposition functions as hindrance in the stream and creates the warmth. These warmers are basically needed for liquefying of materials to took care of into next stage. In the extruder, on the off chance that the extruder machine is little and has less zones, at that point it have not many warmers and in the event that the machine is enormous and numerous zones, at that point it has more electric radiators.

3.7 PID Controller
PID is the gadget which gives the Information to SSR when to turn on and when to off. ID peruses the temperature of any framework with the assistance of indoor regulator. It capacities as the info board to the framework. Broadly useful of temperature regulators are utilized to control most common cycles in industry. Commonly, they arrive in a scope of DIN sizes, have different yields, and programmable yield capacities. These regulators can likewise perform PID control for incredible general control circumstances. They are generally positioned in the front board with the showcase for simple
administrator openness. These regulators have a pre-tune capacity to at first ascertain the PID temperature for a cycle, and a consistent tune capacity to continually refine the PID temperature. This takes into account quick arrangement, sparing time and diminishing waste.

3.8 Thermocouple
The main function of the thermocouple is used to measure the temperature. It acts like an sensors which are made from different materials and consist of two wires. When the current is passed to the wires it generates some voltage which determines the temperature of the system. These are mainly used since they are cheap and measures high temperature.

3.9 Motor
The most important motor used in this machine is DC motors. This motor can rotate both in clockwise as well as anticlockwise with the help of commands given to the motors. They can generate a torque up to three to five times in emergency situations. In this motor the energy is direct fed into the resistors so that it can work in various fields when required. The motor can work continuously without any brake and can come to state of rest without the help of switch. It mainly reduces the mechanical brake sizes.

V. DESIGN
1. BARREL

![3D model of Barrel](image1)

Figure.1.1: 3D model of Barrel

![Dimensions of Barrel](image2)

Figure.1.2: Dimensions of Barrel

2. HOPPER
Figure 2: 3D model and Dimensions of Hopper

Calculation Volume = \( \frac{\pi h}{3} (R^2 + Rr + r^2) \)

= \( \pi \times \frac{60}{3} (30^2 + 30 \times 10 + 10^2) \)

= 81681.40 m³

3. NOZZLE

Figure 3: 3D model and Dimensions of Nozzle

4. SCREW ROD
Figure 4: Dimensions of Screw Rod

5. SHREDDER BLADE

Figure 5: 3D model of Shredder Blade

6. SHREDDER CASING

Figure 6: 3D model of Shredder Casing
7. EXTUSION ASSEMBLY

![3D model of Extrusion Assembly](image)

Figure 7: 3D model of Extrusion Assembly

VI. CONCLUSION

The optimum output is obtained when the temperature ranges from 230-250°C. By decreasing the heat conduction we can increase the efficiency of the extruder machine. In order to remove the excess materials which is present in the pipe must be cleaned before the screw rod gets cool down else it may get hardened. The excess plastic which is left inside can also be removed by rotating the screw rod in a clockwise manner.

Extrusion process happens at high temperature to dissolve the plastics where the extrusion rate is set roughly. In the event that it doesn't arrive at the extrusion rate inexact worth the crude plastic won't completely liquefy and little strong pieces will cause unpleasantness and air pockets in the subsequent fiber. This issue can be overwhelmed by diminishing the engine speed to inexact temperature. This will empowers to warm the plastic totally and results in homogenous and smooth plastic fiber. The outcome acquired from the experimentation that the great nature of fiber is gotten with engine DC power supply set to 6V and the temperature abundance to 230°C, the liquefying purpose of the PLA pellets being used for try. The last measurement of the fiber drawn is dictated by both the size of the kick the bucket and the hot fiber which is drawn away from the source. For effective and powerful proceeded with activity of the extruder the container must be segregated from the warming zone so the crude pellets utilized at starting don't start to dissolve in the container and obstructs the delta port. With more prominent separation between the container and warming zone so a bigger volume of the plastics can be added so that the extruder can expel greater fiber without stress of the stopping up the delta of the warming line. Likewise, diminishing warmth conduction must between the warming line and the edge would improve the security of the extruder and furthermore builds proficiency with no force misfortune. To eliminate the abundance plastic which is available in the line must be cleaned before the warming line cools and again warmed the extruder to utilize once more [2].

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