



DESIGN AND DEVELOPMENT OF A PROTOTYPE FOR SUSTAINABLE PLASTIC WASTE MANAGEMENT THROUGH INJECTION MOULDING

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ABSTRACT:

The increasing accumulation of plastic waste poses a major environmental challenge due to its non-biodegradable nature and improper disposal practices. This project focuses on the design and development of a prototype system for sustainable plastic waste management using injection moulding technology. The aim is to convert post-consumer plastic waste into reusable products, thereby reducing environmental pollution and promoting circular economy principles. The proposed system involves the collection, cleaning, shredding, and melting of waste plastics, followed by the fabrication of new components using an injection moulding process. The prototype is designed with energy efficiency and cost-effectiveness in mind, utilizing locally available materials and incorporating semi-automated control to enhance productivity and reduce human effort. Experimental trials were conducted using different types of thermoplastics, such as polyethylene (PE) and polypropylene (PP), to assess material behavior and mould quality. The results indicate that the prototype can effectively recycle plastic waste into durable products with acceptable mechanical properties. The project demonstrates that small-scale, sustainable plastic recycling through injection moulding is both technically feasible and environmentally beneficial, providing a potential solution for community-level plastic waste management.

1. INTRODUCTION:

Plastic materials have become an essential part of modern life due to their versatility, durability, lightweight nature, and low production cost. They are widely used in packaging, construction, automotive, healthcare, electronics, and consumer goods

industries. However, the rapid increase in plastic production and consumption has resulted in a significant rise in plastic waste generation. Since most plastics are non-biodegradable, improper disposal leads to severe environmental problems such as land pollution, water contamination, marine life destruction, and increased carbon emissions.

Globally, a large percentage of plastic waste is either landfilled, incinerated, or leaked into the environment, while only a small fraction is effectively recycled. Traditional recycling systems often require centralized infrastructure, high operational costs, and complex processing techniques. In many developing regions, inadequate waste segregation and limited recycling facilities further worsen the problem. Therefore, there is a growing need for innovative, affordable, and sustainable technologies that can transform plastic waste into valuable products. Injection moulding is one of the most widely used manufacturing processes for producing plastic components with high precision and repeatability. The process involves melting plastic material and injecting it into a mould cavity, where it cools and solidifies into the desired shape. By adapting injection moulding technology to process recycled plastic waste, it is possible to create useful products while reducing reliance on virgin plastic materials. This approach supports the principles of the circular economy by converting waste into reusable resources.

2. RESEARCH MOTIVE:

The rapid growth in plastic consumption across industries has led to an alarming increase in plastic waste, creating severe environmental, economic, and social challenges. Improper disposal of plastic waste contributes to land pollution, marine ecosystem damage, greenhouse gas emissions, and long-term ecological imbalance. Despite increasing awareness, many regions still lack efficient, affordable, and scalable recycling systems. Conventional plastic recycling methods often involve centralized facilities that require high capital investment, complex logistics, and significant energy consumption. In developing regions and small-scale communities, access to such infrastructure is limited, resulting in large volumes of plastic waste being landfilled or incinerated. There is therefore a pressing need for localized, cost-

effective, and sustainable solutions that can convert plastic waste into valuable products.

Injection moulding is one of the most widely used plastic manufacturing processes due to its efficiency, repeatability, and ability to produce high-quality components. Integrating recycled plastic materials into injection moulding systems presents an opportunity to transform waste into functional products while promoting circular economy principles. However, challenges such as material degradation, contamination, inconsistent feedstock quality, and process optimization must be addressed to ensure reliable performance.



3. EXPERIMENTAL DETAIL:

The experimental procedure began with the collection of post-consumer plastic waste materials such as High-Density Polyethylene (HDPE) and Polypropylene (PP) from local households and commercial sources. The collected plastics were carefully segregated according to their resin type to prevent contamination and ensure uniform melting characteristics. After segregation, the materials were thoroughly washed with water and mild detergent to remove dirt, oil, and foreign particles. The cleaned plastics were then dried completely to eliminate moisture, as the presence of moisture can cause defects such as bubbles and voids during moulding. The dried plastics were shredded into small, uniform flakes of approximately 5–10 mm size to

facilitate smooth feeding and consistent melting inside the barrel. The shredded plastic flakes were fed into the hopper of the developed injection moulding prototype. The heating barrel was equipped with electric band heaters and a temperature control system to maintain the required melting temperature, typically ranging between 180°C and 250°C depending on the type of plastic used. Once the material reached a molten state, a plunger or screw mechanism was used to inject the molten plastic into a closed metal mould cavity under controlled pressure. The mould was held under pressure for a specific holding time to ensure complete filling and proper shaping of the product. After injection, the mould was allowed to cool either naturally or through an air-cooling arrangement before the finished product was ejected.

secure clamping were also included. The final assembled prototype was tested to verify its performance, durability, and suitability for small-scale sustainable plastic recycling applications.



3.1 Design and Fabrication details

The design and fabrication of the prototype for sustainable plastic waste management through injection moulding focused on developing a compact, economical, and efficient system capable of converting recycled plastic into useful products. The machine was designed with a sturdy mild steel frame to support the heating barrel, injection unit, hopper, and clamping system. A steel barrel fitted with electric band heaters and a temperature control system was used to melt the shredded plastic waste at controlled temperatures. A manually operated plunger mechanism was incorporated to inject the molten plastic into a precisely fabricated metal mould cavity under adequate pressure. The mould was designed to ensure proper material flow, cooling, and easy product removal. During fabrication, machining, welding, drilling, and assembly processes were carried out carefully to ensure proper alignment and smooth operation of all components. Safety features such as thermal insulation, proper electrical grounding, and

4. PRINCIPLE:

The prototype for sustainable plastic waste management through injection moulding works on the basic principle of **melting, shaping, and solidifying plastic materials**. The process begins with the collection of post-consumer plastic waste, which is cleaned, sorted, and shredded into small pieces to ensure uniform melting. The shredded plastic is then fed into a **heated barrel**, where it is gradually melted using electric heaters while being agitated or pushed forward by a plunger or screw mechanism to maintain consistent flow. Once the plastic reaches a molten state, it is **injected under pressure** into a pre-designed mould cavity. The pressure ensures that the molten plastic fills all corners of the mould, creating a uniform and accurate shape. The mould is then cooled either naturally or through a cooling system, allowing the plastic to solidify and retain the desired shape. After solidification, the mould is opened and the finished product is ejected. The principle combines **thermodynamics (heating and melting), fluid mechanics (flow of molten plastic), and solidification (cooling and shaping)** to transform plastic waste into usable products. By repeating this cycle, the prototype demonstrates an effective way to **recycle plastic, reduce environmental pollution, and promote sustainable manufacturing practices**.

5. CONTROL SYSTEM:

Temperature Controller: A PID temperature controller is connected to a thermocouple embedded in the heating barrel. It continuously monitors the barrel temperature and adjusts the electric band heaters to maintain the plastic at the required melting point, preventing overheating or degradation of the material.

Heating System: Electric band heaters around the barrel are powered through the temperature controller. The controller ensures uniform heat distribution and maintains a stable temperature for smooth melting of the plastic.

Plunger/Injection Control: The plunger mechanism can be operated manually or semi-automatically. In advanced versions, a simple relay or timer system controls the plunger stroke duration to ensure consistent injection pressure and volume for each cycle.

6. CONCLUSION:

The design and development of the prototype for sustainable plastic waste management through injection moulding successfully demonstrates an effective method to recycle post-consumer plastic into useful products. The project integrates plastic shredding, melting, and moulding into a compact system that is safe, cost-effective, and suitable for small-scale applications. Through proper design of the barrel, heating system, plunger mechanism, and mould, the prototype can process recycled plastics such as HDPE and PP, producing products with good surface finish and dimensional accuracy.

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