International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 12 Issue: 12 | Dec 2025 www.irjet.net p-ISSN: 2395-0072

DESIGN AND FABRICATION OF PLASTIC WASTE BLOCK MAKING MACHINE WITH INTEGRATED THERMOELECTRIC HEAT RECOVERY POWER GENERATION SYSTEM

RAVICHANDRAN.P[1], RAMESH.A[2], AJAY.P[3], BALAMURUGAN.S[4], DANIEL.S[5]

[1] *Guide and Head of the department, Department of mechanical Engineering, Annai JKK Sampoorani Ammal Polytechnic College, Tamil nadu, India*
[2]*Lecturer, Department of mechanical Engineering, Annai JKK Sampoorani Ammal Polytechnic College, Tamil nadu, India*
[3-5]*Student, Department of mechanical Engineering, Annai JKK Sampoorani Ammal Polytechnic College, Tamil nadu, India*

Abstract- Plastic *waste accumulation has become a critical environmental challenge, demanding innovative and sustainable recycling technologies. This project focuses on the design and fabrication of a plastic waste block-making machine integrated with a thermoelectric heat recovery power generation system. The machine converts various types of waste plastics into useful construction materials such as blocks, tiles, and rods through controlled heating, melting, and compression. To enhance energy efficiency, a solar-assisted heating chamber is incorporated, where excess thermal energy is harvested using thermoelectric generators (TEGs). The recovered heat is converted into electrical power, which is used for charging batteries and supporting low-power lighting applications. The integration of recycling and renewable energy systems not only reduces plastic pollution but also minimizes energy consumption during the recycling process. This study demonstrates the feasibility of combining plastic recycling with sustainable power generation, offering an eco-friendly and cost-effective solution for small-scale and rural manufacturing environments.*

Key Words: *Plastic recycling, block-making machine, thermoelectric generator (TEG), heat recovery, solar heating system, renewable energy, sustainable manufacturing, waste-to-resource technology, eco-friendly construction materials.*

1. INTRODUCTION

Plastic waste generation has increased significantly over the past decades due to rapid industrial growth, consumer demand, and the widespread use of polymer-based products. Most plastic materials are non-biodegradable and remain in the environment for several hundreds of years, leading to severe land pollution, water contamination, and ecological imbalance. Conventional disposal methods such as land filling and incineration not only contribute to environmental degradation but also waste valuable resources that could otherwise be reused. Therefore, there is a growing need for sustainable methods to recycle and repurpose waste plastics into useful and durable products.

Recycling plastic into construction materials has emerged as an effective solution due to its ability to convert waste into high- strength, weather-resistant, and low-cost alternatives to conventional building materials. Plastic blocks, tiles, and rods produced through thermal processing have shown promising results in terms of mechanical strength and durability. However, the recycling process typically requires substantial thermal energy, which increases operational costs and limits its use in rural or small-scale industries.

To address this challenge, integrating energy recovery systems into the recycling process offers a more sustainable approach. Thermoelectric generators (TEGs), which convert heat directly into electrical energy, provide a reliable method for capturing waste heat generated during plastic melting. When combined with solar heating, TEG-based power generation systems can significantly reduce external energy requirements. This integration enables partial self-sustainability of the recycling unit while providing additional power for charging batteries and supporting low-power applications.

This project aims to design and fabricate a plastic waste block-making machine equipped with an integrated thermoelectric heat recovery power generation system. By combining plastic recycling with renewable energy harvesting, the proposed system offers an environmentally friendly, energy-efficient, and cost-effective solution suitable for decentralized and rural manufacturing environments.

2. LITERATURE REVIEW

The growing challenge of plastic waste management has led researchers to explore innovative recycling technologies and energy-efficient processing techniques. Several studies highlight the potential of converting waste plastics into construction materials due to their durability, lightweight properties, and resistance to corrosion. Researchers such as Kumar et al. (2019) demonstrated that recycled plastic blocks exhibit satisfactory compressive strength and can serve as a sustainable alternative to conventional masonry units.

Similarly, investigations by Adeyanju and Manohar (2020) reported that plastic–sand composite bricks provide improved water resistance and long-term durability compared to traditional clay bricks.

Multiple studies have explored plastic melting and extrusion systems to optimize the recycling process. Gupta and Bhatia (2021) analyzed the performance of low-cost melting chambers and found that temperature control is critical for achieving uniform melting and consistent product quality. Their findings emphasize the importance of proper heating mechanisms and controlled compression during the formation of tiles and blocks.

In parallel, researchers have focused on improving the energy efficiency of recycling machinery. Heating processes remain the most energy-intensive stage in plastic reprocessing. To reduce dependence on external power sources, thermoelectric generator (TEG) technology has gained attention for waste heat recovery applications. Rowe (2018) highlighted the effectiveness of thermoelectric modules in converting temperature gradients into usable electrical power with high reliability and low maintenance. Studies by Patel and Suresh (2020) demonstrated that integrating TEGs with industrial heating systems can supplement power requirements for low-energy applications such as lighting and battery charging.

Solar-assisted heating has also been explored as a renewable alternative for plastic recycling operations. Bhattacharya and Singh (2019) reported that solar thermal collectors significantly reduce operational energy costs and enhance sustainability in small-scale recycling units. The combination of solar heating and thermoelectric power recovery has been studied by Li et al. (2021), who showed that hybrid systems can simultaneously provide thermal energy for processing and electrical power generation.

Overall, existing literature indicates strong potential for merging plastic recycling technologies with renewable energy-based heat recovery systems. However, limited research has focused on integrating these technologies into a compact, low-cost, and field-deployable machine. The present work addresses this gap by designing and fabricating a plastic waste block-making machine with an integrated thermoelectric heat recovery power generation system. This combination aims to enhance energy efficiency, reduce operational dependence on external power sources, and promote sustainable waste management practices.

3. MATERIALS

The design and fabrication of the plastic waste block-making machine with an integrated thermoelectric heat recovery system required a combination of mechanical, thermal, and electrical components. The major materials and components used in this study are listed below.

3.1 Plastic Processing Components

Waste Plastic (HDPE, LDPE, PP): Used as the primary raw material for producing blocks and tiles. These plastics were cleaned, shredded, and prepared for melting.
Shredding Unit: Mild steel blade assembly and housing for reducing the plastic size to uniform chips.
Melting Chamber: Fabricated using high-temperature-resistant mild steel capable of sustaining 200–300°C.
Heating Coil / Electric Heater: Chrome coil-based heating element used to melt the shredded plastic uniformly.
Compression and Molding Unit: Cast iron moulds and a mild steel frame designed to withstand high compressive forces during block formation.

3.2 Structural and Mechanical Components

Mild Steel Frame: Provides structural support for the machine and houses the melting and compression units.
Hydraulic or Screw Jack Mechanism: Used to apply compressive force for shaping molten plastic into blocks.
Insulation Materials (Glass Wool / Ceramic Wool): Installed around the melting chamber to minimize heat loss and improve energy efficiency.

3.3 Thermoelectric Power Generation Components

Thermoelectric Generator (TEG) Modules: Bi_2Te_3-based Paltrier modules capable of converting temperature difference into electrical power.
Heat Sink and Cooling System: Aluminum heat sinks with coolant circulation to maintain the required temperature gradient across TEG modules.
Solar Heating Plate: A flat-plate solar absorber used to assist in pre-heating the plastic and supplying additional thermal energy to the TEG system.
DC–DC Boost Converter: Used to regulate and stabilize the power output from the TEG modules.

3.4 Electrical and Control Components

Rechargeable Battery (12 V): Stores the electrical energy produced by the TEG system.
Charge Controller: Protects the battery from overcharging and voltage fluctuations.
Temperature Sensors (K-Type Thermocouple): Used to monitor the melting chamber and TEG surface temperature.

4. METHODOLOGY

The methodology adopted for the design and fabrication of the plastic waste block-making machine with an integrated thermoelectric heat recovery system is described as follows.

4.1. System Design and Structural Configuration

The machine was designed as a single-screw extrusion unit capable of melting and shaping mixed plastic waste into construction products. The major components include a motor-driven screw rod, a stainless-steel barrel fitted with electric heaters, a feed hopper, a nozzle with interchangeable moulds, and a thermoelectric generator (TEG) assembly mounted on the heated barrel. The structural frame was fabricated using mild steel to ensure strength, rigidity, and vibration resistance.

4.2. Screw and Barrel Fabrication

A single-flight screw was machined with three functional zones—feeding, compression, and metering—to ensure effective conveying, melting, and homogenization of waste plastics. The barrel was manufactured from high-temperature stainless steel to withstand continuous heating. Electric band heaters were installed along the barrel to create controlled temperature zones. Thermocouples were positioned near each heating zone for accurate temperature monitoring.

4.3. Integration of Thermoelectric Generators

Thermoelectric modules were installed on the external surface of the heated barrel to recover waste heat generated during plastic melting. A metal heat-spreader plate was mounted between the barrel and TEGs to improve thermal contact. The cold side of each TEG was equipped with fin-type heat sinks and forced-air cooling fans to maintain a sufficient temperature gradient. The electrical output from the TEG array was regulated using a DC charge controller and stored in a battery unit for powering auxiliary loads such as lighting and control electronics.

4.4. Electrical and Control System

A variable-speed motor was coupled to the screw rod through a rigid connecting rod. The motor was powered through a power supply unit integrated with overload protection. A control panel was developed using PID-based temperature controllers for each heating zone, enabling stable melting conditions. Safety features such as emergency stop, thermal cut-off, and grounding were incorporated to ensure safe operation.

4.5. Feeding, Melting, and Extrusion Process

Shredded plastic waste was fed through the hopper into the screw channel. As the screw rotated, frictional force and barrel heating gradually melted the plastic. The molten polymer was homogenized in the metering zone and extruded through the nozzle into moulds or forming trays. The extruded product was then cooled at ambient conditions or with forced air, depending on the required final dimensions and shape.

4.6. Operation of Heat Recovery and Power Generation

During operation, the heater-induced thermal energy created a temperature difference across the TEGs, enabling direct conversion of heat into electrical power. The generated power was stored in a rechargeable battery, allowing partial energy self-sufficiency of the system. Real-time temperature, voltage, and current values were monitored to evaluate TEG performance under different operating conditions.

4.7. Product Formation and Quality Assessment

The extruded plastics were shaped into blocks, tiles, or rods using removable moulds. After cooling and solidification, samples were collected for evaluation. Quality assessment included visual inspection for uniformity, measurement of dimensions and density, and preparation for subsequent mechanical testing such as compressive strength and water absorption tests.

4.8. Performance Evaluation

Machine performance was assessed based on production rate, stability of extrusion, melt uniformity, and TEG power output. Temperature distribution along the barrel, screw rotational speed, and energy consumption were recorded to evaluate the operational efficiency. The effectiveness of the heat recovery subsystem was analyzed by comparing heater energy input with electrical energy generated by the TEG modules.

5. BLOCK DIAGRAM

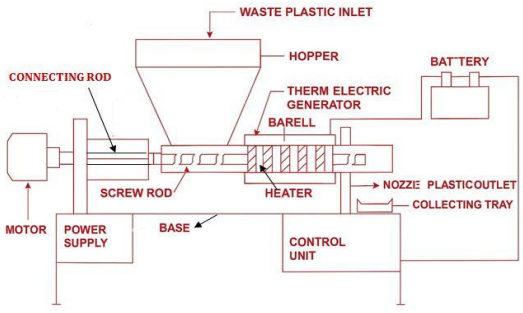

Fig -1 Block diagram

6. WORKING PRINCIPLE

The working principle of the plastic waste block-making machine with an integrated thermoelectric heat recovery system is based on the controlled melting, homogenization, and extrusion of plastic waste, combined with the conversion of waste heat into electrical energy.

Waste plastic materials are first introduced into the hopper, where they are fed into the rotating screw by gravity. As the screw turns, it conveys the plastic along the barrel through three functional zones—feeding, compression, and metering. Friction between the screw and the plastic, along with the applied heat from the electric heaters surrounding the barrel, raises the temperature of the material. This controlled heating melts the plastic uniformly without causing thermal degradation.

Once the plastic reaches a molten state, the screw's metering section ensures consistent pressure and flow toward the nozzle. The molten plastic is then forced through the nozzle into moulds or a collecting tray, where it cools and solidifies into blocks, tiles, or rods. Continuous rotation of the screw enables uninterrupted extrusion and product formation.

Simultaneously, the heat generated by the barrel during the melting process is partially recovered. Thermoelectric generator (TEG) modules mounted on the surface of the heated barrel experience a temperature difference between their hot and cold sides. This temperature gradient induces a direct conversion of heat into electrical energy based on the Seebeck effect. The generated electricity is routed through a charge controller and stored in a battery, providing power for auxiliary components such as lighting, cooling fans, or control electronics.

Thus, the machine operates on a dual-function principle: converting plastic waste into usable construction materials while recovering thermal energy to generate supplemental electrical power, improving overall energy efficiency and sustainability.

7. CONCLUSIONS

The present work demonstrates the successful design and fabrication of a **plastic waste block-making machine integrated with a thermoelectric heat recovery power generation system**. The developed setup efficiently converts low-value waste plastics into usable construction materials such as blocks, tiles, and rods, thereby offering a sustainable solution for waste reduction. The controlled heating chamber ensured uniform melting, while the mechanical compaction mechanism produced dimensionally stable and structurally consistent blocks.

A key contribution of this work is the incorporation of **thermoelectric generators (TEGs)** around the heating chamber, enabling the conversion of otherwise wasted thermal energy into electrical power. The recovered electricity was adequate for charging small batteries and powering low-voltage lighting, highlighting the potential for **energy self-sufficiency in small-scale recycling units**.

Overall, the system provides a cost-effective, eco-friendly, and technically viable approach for decentralized plastic recycling, while simultaneously recovering renewable energy from waste heat. Further research can focus on performance optimization, strength characterization of the produced blocks, and scaling the system for industrial applications.

REFERENCES

[1] Al-Salem, S. M., Lettieri, P., & Baeyens, J. (2009). *Recycling and recovery routes of plastic solid waste (PSW): A review*. Waste Management, 29(10), 2625–2643.

[2] Kumar, S., Panda, A. K., & Singh, R. K. (2011). *A review on tertiary recycling of plastics*. Waste Management, 31(12), 2525–2539.

[3] Hopewell, J., Dvorak, R., & Kosior, E. (2009). *Plastics recycling: Challenges and opportunities*. Philosophical Transactions of the Royal Society B, 364(1526), 2115–2126.

[4] Sharma, S., & Bansal, P. (2021). *Utilization of waste plastic in construction materials: A sustainable approach*. Construction and Building Materials, 273, 121–136.

[5] Reddy, A. R., & Reddy, K. H. (2014). *Performance of waste plastic as a binder in manufacturing eco-friendly construction blocks*. International Journal of Engineering Research & Technology, 3(8), 256–260.

[6] Rowe, D. M. (2012). *Thermoelectrics handbook: Macro to nano*. CRC Press.

[7] Snyder, G. J., & Toberer, E. S. (2008). *Complex thermoelectric materials*. Nature Materials, 7(2), 105–114.

[8] Champier, D. (2017). *Thermoelectric generators: A review of applications*. Energy Conversion and Management, 140, 167–181.

[9] Raut, S. P., Ralegaonkar, R. V., & Mandavgane, S. A. (2011). *Development of sustainable construction material using industrial and agricultural solid waste: A review*. Construction and Building Materials, 25(10), 4037–4042.

[10] Mohanty, A. K., Vivekanandhan, S., Pin, J. M., & Misra, M. (2018). *Composites from renewable and sustainable resources: Challenges and innovations*. Science, 362(6414), 536–542.

BIOGRAPHIES

Mr.P. Ravichandran B.E., is currently working as the Head of the Department of Mechanical Engineering at Annai JKK Sampoorani Ammal Polytechnic College, Tamil Nadu, India. His area of interest includes composite materials and their applications in engineering.

Mr.A.Ramesh M.E., is currently working as a Lecturer at Annai JKK Sampoorani Ammal Polytechnic College, Tamil Nadu, India. He has completed a Master of Engineering in Thermal Engineering. His research interests include heat transfer, renewable energy systems, and thermal analysis of engineering materials

Ajay.P is a Diploma student in Mechanical Engineering at Annai JKK Sampoorani Ammal Polytechnic College,, T.N. Palayam, Tamil Nadu. His current work involves the design and fabrication of a plastic waste block-making machine integrated with a thermoelectric heat recovery power generation system, reflecting his commitment to eco-friendly and innovative engineering solutions.

Balamurugan.S is a Diploma student in Mechanical Engineering at Annai JKK Sampoorani Ammal Polytechnic College,, T.N. Palayam, Tamil Nadu. His current work involves the design and fabrication of a plastic waste block-making machine integrated with a thermoelectric heat recovery power generation system, reflecting his commitment to eco-friendly and innovative engineering solutions.

Daniel.S is a Diploma student in Mechanical Engineering at Annai JKK Sampoorani Ammal Polytechnic College,, T.N. Palayam, Tamil Nadu. His current work involves the design and fabrication of a plastic waste block-making machine integrated with a thermoelectric heat recovery power generation system, reflecting his commitment to eco-friendly and innovative engineering solutions.