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Evaluation of the process parameters of 180 tons injection molding machine using GPPS and HDPE as thermoplastic materials in plastic production workshop of Sedi-Enugu Naseni

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Abstract
180 ton-capacity Injection molding machine in Scientific Equipment Development Institute SEDI Enugu, an arm of the National Agency for Science and Engineering Infrastructure (NASENI), Abuja, Nigeria was used to produce high quality plastic executive hangers, plastic agro products, plastic automobile spare parts, plastic plumbing valves, plastic science and laboratory equipment of high domestic and industrial value through a technology that can be used in Cottage and SME's in line with the current demand of the economic policies of the Federal Government of Nigeria. Engineers and scientists in the plastic workshop of SEDI Enugu analyzed and compared the processes parameters for general purpose polystyrene virgin material (GPPS G-126) and high density polyethylene recycled (HDPE). On the GPPS material, It was observed that the nuzzle heater temperature control was operated at 230 °C, barrel temperature 250 °C, injection time 0.370 seconds, cooling time 3.312 seconds, ejector time 0.140 seconds. On the HDPE, the nuzzle heater temperature control was operated at 190 °C, barrel temperature 180 °C, injection time 0.20 seconds, cooling time 0.15seconds, ejection time 0.11 seconds. The above operational standard was based on daily experimental approaches in the cost of production of the executive hangers using (GPPS G-126) and HDPE thermoplastic materials to determine the best quality product formation to satisfy the end users. The result shows that GPPS can withstand higher temperatures before softening or undergoing deformation and has an extended molecular configuration with a benzene ring. The absence of branches or side chains allows for closer packing of polymer chains, resulting in a more rigid and stable structure while that of HDPE is a polymer composed of ethylene monomers and has a linear structure with occasional branches, making it less densely packed compared to GPSS. The branching in HDPE imparts more flexibility to the polymer chains.

Keywords: Injection molding machine, process parameters, high density polyethylene, general purpose polystyrene, executive hanger, properties

Introduction
Plastic materials are among the most consumed today, due to their great molding versatility, lightness, and resistance to impact and bacteria (Dania *et al*., 2023, Imoh *et al*., 2023) [3, 6]. Polymer blends are formed via the combination (physical or mechanical) of two or more different polymers to obtain a new material with improved properties or to promote the recycling of post-consumer polymer blends, reducing production costs. They can be prepared by dissolving the polymers in the same solvent or by melting the mixture at a working temperature that does not cause degradation (Ajitha, 2020) [1]. Injection molding is a widely used manufacturing process for producing parts by injecting molten material into a mold. The injection molding machine is a crucial component in this process, as it facilitates the precise and efficient shaping of plastic or other materials into the desired form. Here, we will provide an overview of injection molding machines, their key components, and the basic steps involved in the injection molding process (Chanda, 2018; Park and Han, 2021) [2, 8]. The chiller uses a separate water loop to dissipate heat from the condenser coils. They are generally more efficient but require a water supply for cooling. The process relies on the principles of thermodynamics and phase change to transfer heat from the fluid that needs to be cooled to the refrigerant, which then releases the heat to the environment. The cooling process removes excess heat generated during plastic processing, allowing the material to solidify and maintain its desired shape. This is essential for achieving accurate dimensions and surface finish in the final plastic products.

1. Basic Operation

- **Injection Unit:** The machine's injection unit is responsible for melting and injecting the material into the mold. It consists of a hopper, barrel, and reciprocating screw that melts and pushes the material forward.
- **Clamping Unit:** This unit holds the mold in place and applies sufficient force to keep it closed during the injection and cooling phases. It includes the mold, clamping mechanism, and the hydraulic or mechanical system.

2. Injection Molding Process

- **Material Loading:** Raw material, usually in the form of pellets or granules, is loaded into the machine's hopper.
- **Melting:** The material is heated and melted in the barrel using the reciprocating screw.
- **Injection:** The molten material is injected into the mold cavity under high pressure.
- **Cooling:** The material solidifies within the mold, and the part is cooled to the point where it can be ejected without deformation (Divy *et al*., 2017) [4].

3. Types of Injection Molding Machines

- **Hydraulic Injection Molding Machines:** Use hydraulic systems for clamping and injection.
- **Electric Injection Molding Machines:** Employ electric motors for both clamping and injection, providing energy efficiency and precision.
- **Hybrid Injection Molding Machines:** Combine hydraulic and electric systems to optimize efficiency (Chanda, 2018) [2].

4. Key Components

- **Screw and Barrel:** Responsible for melting and injecting the material.
- **Mold:** Determines the shape and features of the final product.
- **Clamp:** Holds the mold in place during the injection process.
- **Hydraulic System:** Powers the machine's movements, such as the clamp and injection (Malloy, 2010) [7].

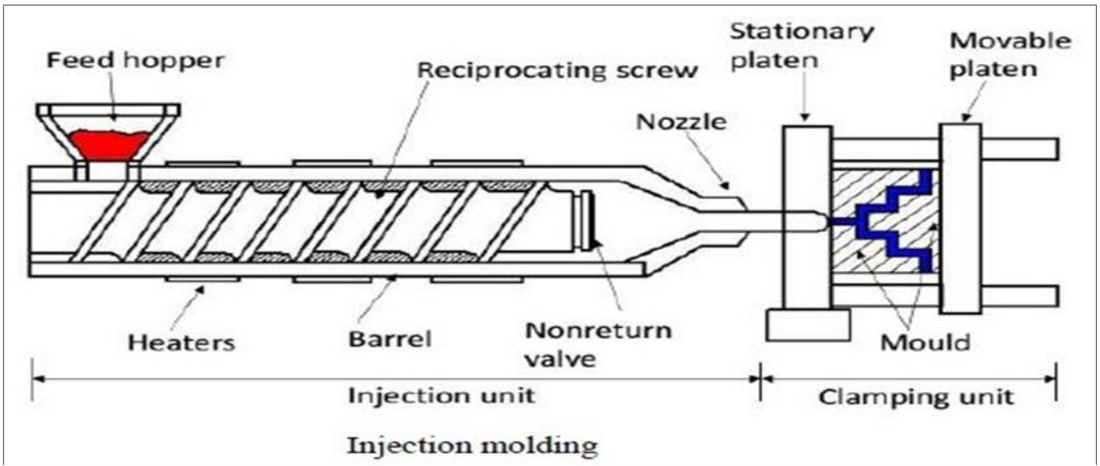

Fig 1: Parts of Injection molding machine

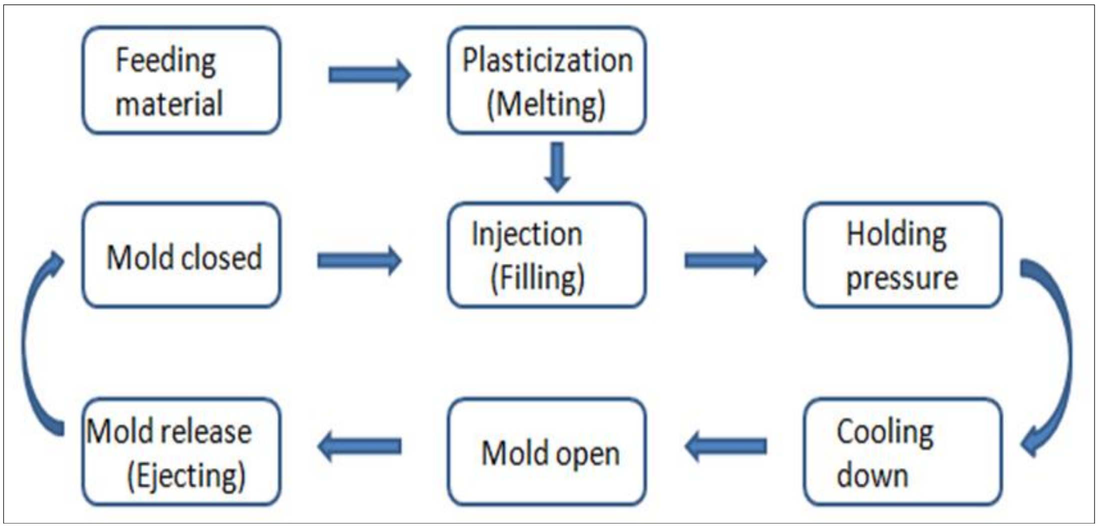

Fig 2: Injection process flow diagram

Methodology

General purpose polystyrene (GPPS G-126) and high density polyethylene recycled were procured by Scientific Equipment Development Institute, Akwaeke, Enugu. It is placed in the optimum operational standard by pelletizing and in most cases preheated in any case of moisture intermingling with the atmosphere to enable bonding and proper melt flow.

Material preparation (Mixing Ratio)

25 kg of GPPS G-126 material was completely poured into the hopper of the 180 tons injection machine at the

appropriate heating temperature of 230 °C and barrel zone temperature of 250 °C were recorded. The injection screw rotates to melt the GPPS pellets in the barrel, and the material was in molten form, the screw L:D ratio is 17:1 with maximum screw speed of 145 rpm with injected stroke of 230 mm pushes it towards the nuzzle and injected into the two cavity mold under high pressure of 122 Mpa. The injection time of the process was recorded at 03.70 seconds, cooling time of 33.12 and ejector time of 01.40seconds. The GPPS has solidified, the mold opens separating the two halves of the mold while the ejector pins or plates push the molded part out of the mold. Finally the part produced passed quality control check and was packaged for shipment or further processing.
In the preparation of the high density polyethylene the same method was carried out only that the process parameters of the nozzle's heating temperature was recorded at 180 °C-190 °C. The injection time 0.25 seconds, cooling time of 15seconds and ejector time of 01.40 seconds was recorded respectively to evaluate their process parameters.

Results and Discussion

Table 1: Operating temperatures of GPPS

Nuzzle heater control (°C)	Barrel °C	Barrel °C	Barrel °C
230	250	250	250

Table 2: Production Time (s)

Injection time (s)	Cooling time (s)	Ejector time (s)
0.370	3.312	0.140

Table 3: Operating temperatures of HDPE

Nuzzle heater control (°C)	Barrel °C	Barrel °C	Barrel °C
190	180	180	180

Table 4: Production Time (s)

Injection time (s)	Cooling time (s)	Ejector time (s)
0.20	0.15	0.11

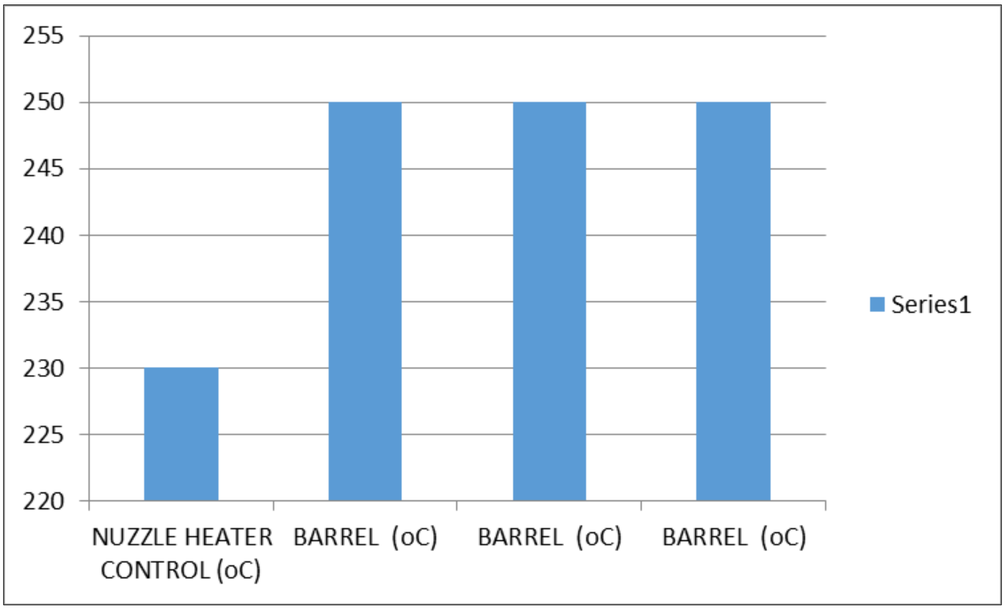

Fig 3: Bar chart representation of the operating temperature for (GPPS)

The above graph indicates that the temperature of the polymer GPPS begins to soften and eventually melt into its molten state from the origin.

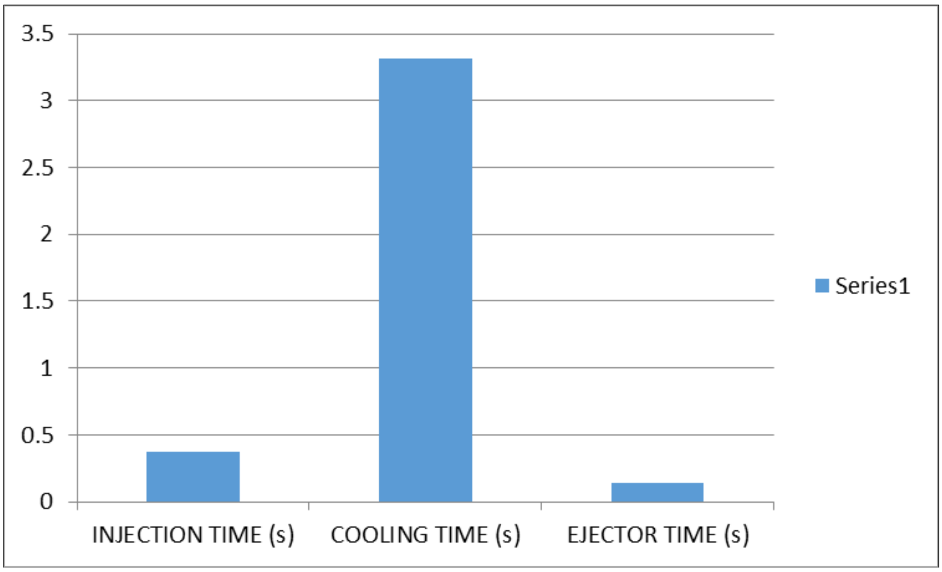

Fig 4: Bar chart representation of production time for GPPS

This shows that there is more precise control time over the filling of the mold cavity, which contributes to the production of high-quality and accurately dimensioned parts which might minimize part distortion, especially for thin-walled or complex geometries, by reducing the time for material shrinkage and cooling.

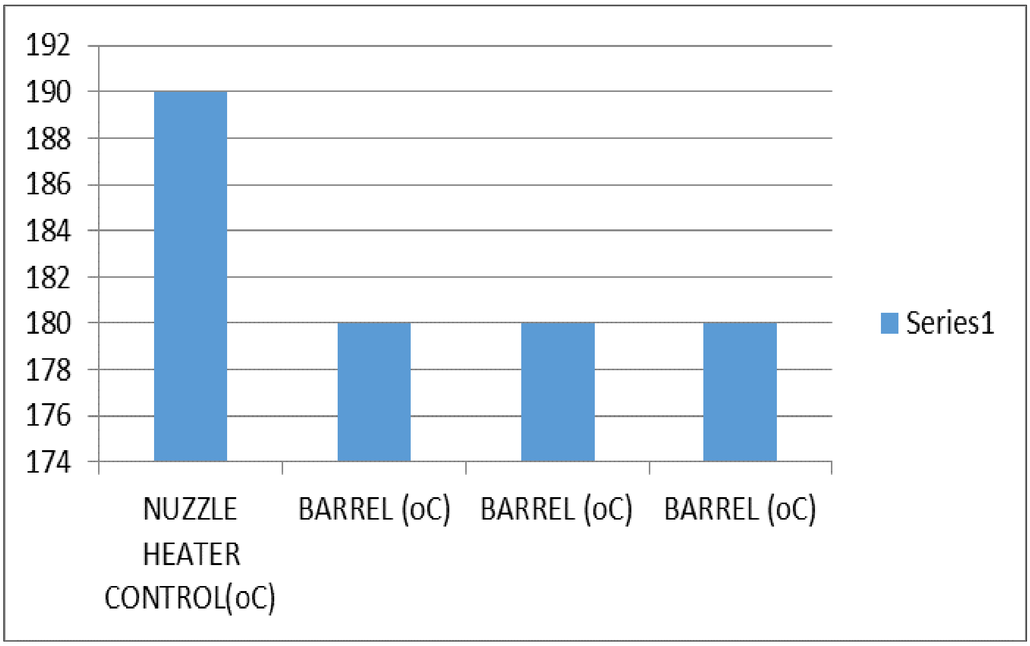

Fig 5: Bar chart representation for operating temperature (HDPE)

The above shows that the operating temperature of HDPE begins to increase by softening and loses its structural integrity and shaped into the desired form in the molten state

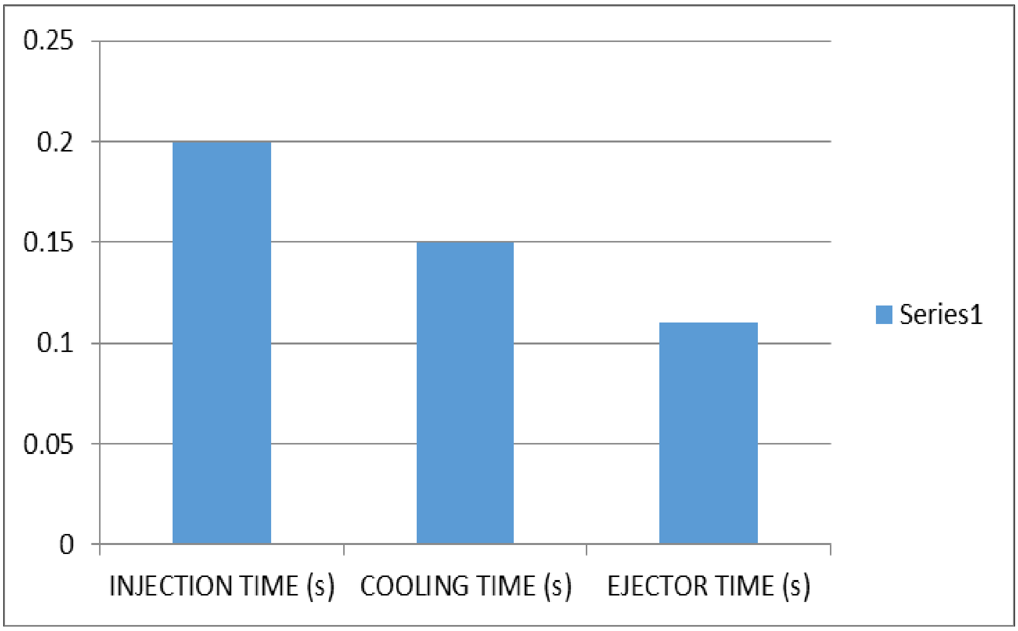

Fig 6: Bar chart representation of Production Time for (HDPE)

The above graph indicates that the production time of HDPE material cools rapidly, which can be advantageous for achieving faster production rates and reduced energy as the molding machine is operating for a shorter duration during each cycle.

The result of Table 1 shows the data of the operational temperature of the GPSS that existed an Isotherm at 250 °C whereas the nozzle heater control temperature was set at 230 °C. Also in Table 2, where the production time for the GPSS was considered, the injection time was adjusted to 0.370s while the cooling time was set to 3.312s and the ejector time at 0.140s. However for the HDPE, the nozzle heater control temperature is set at 190 °C while the barrels are at isotherm at 180 °C. During production, the injection time was set at 0.2s, at a cooling time of 0.15s and the ejector time placed at 0.11s, no doubt this variation in the parameter between GPSS and HDPE were as a result of the tacticity and the bonding nature of the two polymeric materials as the bond mechanism affects their amenability to heat. Figures 3 and 6 shows that the GPSS material had a higher operational temperature ranges in the entire working days of the week of the machine as shown in the area chart which indicated that GPSS can withstand higher temperatures before softening or undergoing deformation. The results underscored the complex and extended molecular configuration in GPSS, which would require increased temperature to break compared to HDPE with a simple linear configuration (Imoh *et al*., 2023) [6]. The presence of pendant group (benzene ring) and the isotacticity of their arrangement gave GPSS a closer packing of polymer chains, resulting in a more rigid and stable structure than HDPE, with a simple linear arrangement and soft bonding system.

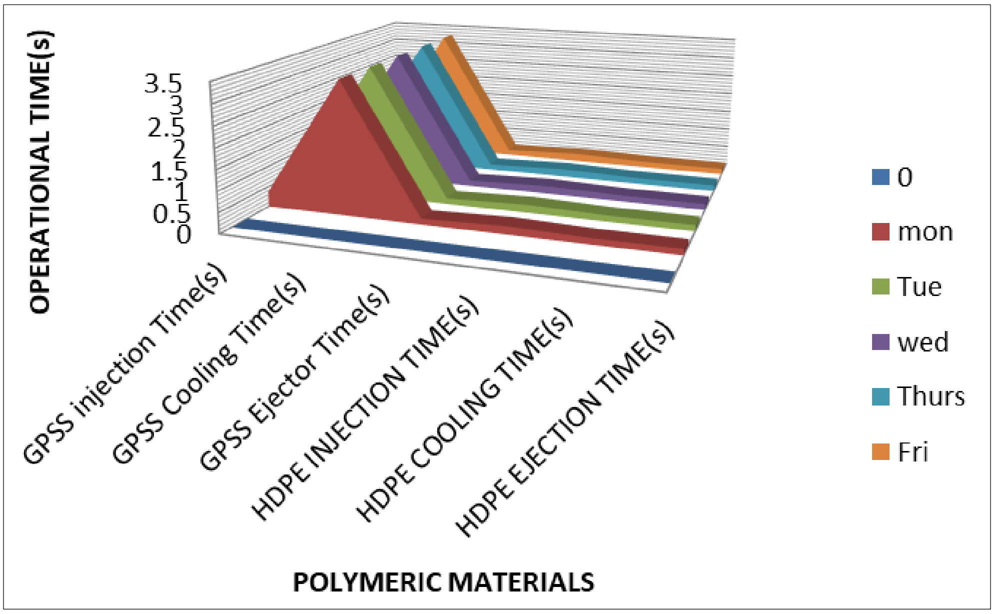

Fig 7: Pictorial representation of chart area for the operational time between GPPS and HDPE material as used in the 180 tons injection machine for each working days of the week.

Conclusion

The differences in chemical structure, melting temperature, glass transition temperature, and crystallinity contribute to the higher operating temperature of GPSS compared to HDPE. It's essential to note that the specific grades and formulations of these polymers can also influence their thermal properties.

Conflict of Interests

The authors' bear no conflict of interest in carrying out research on this work and its publication.

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