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OVERHAULING OF A THERMOPLASTIC INJECTION MOULDING MACHINE AND COMPARISON BETWEEN THE PROJECT’S PRODUCT AND AN OFF-THE-SHELF PRODUCT

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BENIN CITY

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A PROJECT SUBMITTED TO THE DEPARTMENT OF PRODUCTION ENGINEERING IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE AWARD OF POSTGRADUATE DIPLOMA (PGD) IN PRODUCTION ENGINEERING, UNIVERSITY OF BENIN, BENIN CITY

DECEMBER, 2025.

DECLARATION

I, the undersigned, hereby declare that this project titled **"Overhauling of a Thermoplastic Injection Moulding Machine and Comparison Between the Project's Product and an Off-the-Shelf Product"** was carried out by a group of three students as part of the requirements for the award of a Post Graduate Diploma in Production Engineering. I affirm that the work presented in this report is the result of our collective efforts, personal study, and practical investigation, except where specific references have been made to the works of others. No part of this project has been submitted previously, either wholly or in part, for any academic award in this or any other institution. We take full responsibility for the contents of this work.

All sources of information consulted during the course of this research have been duly acknowledged through proper citations and references. We take full responsibility for any errors or omissions that may be found in this work.

Name of Student: ______________________________________

Matric/Registration Number: _____________________________

Signature: ____

Date: ____

CERTIFICATION

This is to certify that the project titled "**Overhauling of a Thermoplastic Injection Moulding Machine and Comparison Between the Project's Product and an Off-the-Shelf Product"** was carried out by **Olatunji James Olumide** in partial fulfilment of the requirements for the award of the Post Graduate Diploma in the Department of Production Engineering, University of Benin. The work embodied in this project is original and was conducted under my supervision. The project meets the standards required for the submission of a final-year technical report.

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ABSTRACT

This project focuses on the overhauling of a thermoplastic injection-moulding machine, specifically addressing the restoration and fabrication of the barrel-plunger assembly, which is the core unit responsible for melting and injecting polymer materials. The work involved diagnosing performance issues in the old assembly, repairing worn components, and fabricating a new, improved barrel-plunger pair to restore optimal machine efficiency while retaining the refurbished pair as a reliable backup. Engineering analyses, including material selection, dimensional accuracy, thermal considerations, and mechanical performance, guided both the repair and fabrication processes. The project further evaluated the quality of products produced with the overhauled machine and compared them with similar off-the-shelf items to determine the effectiveness of the intervention. Findings showed that the newly fabricated assembly significantly improved melt consistency, injection pressure stability, and overall product quality, demonstrating that a systematic overhaul can extend machine life, reduce downtime, and deliver outputs comparable to commercially available standards.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Thermoplastic injection molding has become one of the most widely used manufacturing processes for producing precise, durable, and high-quality plastic components across numerous industries. From automotive parts and household items to medical devices and consumer electronics, the technique offers exceptional repeatability and efficiency (Fradinho J. *et al.*, 2018). At the heart of this process lies the injection molding machine a complex mechanical system responsible for melting, injecting, and shaping thermoplastic materials into finished products. However, like any industrial equipment subjected to continuous use, the injection molding machine undergoes wear, misalignment, component fatigue, and performance decline over time. When this happens, an overhaul becomes necessary to restore its optimal function, extend its operational lifespan, and ensure consistent product quality (Mazurchevici S-N. *et al.*, 2018).

Overhauling a thermoplastic injection molding machine involves a systematic inspection, disassembly, repair, and replacement of worn-out mechanical, electrical, and hydraulic components. The goal is not merely to fix faults but to return the machine to a condition that matches or nearly matches original factory performance. This includes re-calibrating injection parameters, ensuring proper alignment of the mold clamping system, rebuilding or replacing screws and barrels, flushing hydraulic lines, and updating key control systems. An effective overhaul enhances production efficiency, minimizes energy consumption, reduces downtime, and contributes to safer working conditions (Zhao P. *et al.*, 2014). It also helps manufacturers maintain quality standards particularly important where tight tolerances or specialized material properties are required.

In practical terms, overhauling can be more economical than purchasing a new machine, especially in small-to-medium-scale manufacturing environments or demonstration purposes. Instead of incurring the high capital cost of a full replacement, refurbishment allows companies to reinvest in existing assets while improving their functional performance. This makes the study of the overhaul process valuable not only from an engineering standpoint but also from a cost-management perspective (Karbasi H. *et al*., 2006).

Beyond the mechanical and operational restoration, this project also focuses on the creation of a specific product using the overhauled injection molding machine. This introduces a second important dimension to the study the comparison between the project-produced item and an off-the-shelf version of the same product. Such a comparison is essential for evaluating the success of the overhaul. If the overhauled machine can produce components that match or closely resemble commercially manufactured products in appearance, strength, dimensional accuracy, and overall functionality, then the overhaul can be considered effective (Eppinger SD *et al.*, 2012).

Comparing the project's product with an off-the-shelf equivalent provides practical insights into several quality aspects. These include surface finish, uniformity, accuracy of dimensions, material consistency, mechanical strength, and overall usability. It also helps identify any remaining performance limitations of the overhauled machine, such as uneven heating, improper injection pressure, or incomplete mold filling (Jiao JR et al., 2007). By examining these quality indicators, it becomes possible to determine whether further adjustments or component replacements are required.

This comparison is also important from a learning and research perspective. It allows students, engineers, and technicians to understand how machine condition directly influences product quality. It reveals the relationship between equipment performance and production outcomes, helping guide future maintenance, calibration, or process optimization decisions. In real manufacturing settings, such evaluations are crucial for ensuring that refurbished machines can meet customer expectations and industry standards (C. Page Moreau *et al.,* 2010).

More broadly, this project highlights the importance of preventive maintenance and periodic overhauls in sustaining manufacturing operations. In an industry where precision and efficiency are paramount, ignoring equipment degradation often leads to increased scrap rates, higher operating costs, and reduced competitiveness. By documenting the overhaul process and assessing its results through a product comparison, the project contributes to practical knowledge that can support long-term asset management in manufacturing environments.

In summary, this introductory chapter establishes the foundation for the study: it explains the relevance of thermoplastic injection molding machines, justifies the need for overhauling them, and describes why comparing the project's product to an existing commercial product is an essential part of evaluating overhaul success. The chapter sets the stage for subsequent sections that will detail the overhaul procedures, present the produced sample, analyze comparative results, and draw conclusions on the overall effectiveness of the restoration. This approach provides both theoretical understanding and hands-on practical evaluation making the project meaningful for engineering learning, manufacturing practice, and equipment rehabilitation planning.

1.2 Statement of the Problem

The efficient performance of a thermoplastic injection molding machine is essential for producing high-quality plastic components, yet many machines in small and medium manufacturing settings deteriorate over time due to wear, poor maintenance, and outdated parts. This decline often results in defects such as inconsistent dimensions, poor surface finish, incomplete mold filling, and reduced production efficiency. Replacing the entire machine is usually expensive, making overhauling a more practical option. However, the effectiveness of such an overhaul is not always clear unless the machine's output is compared with established commercial standards. Therefore, the problem this project addresses is the need to restore a worn injection molding machine to near-optimal performance and to objectively evaluate the success of the overhaul by comparing the quality of the project-produced item with an equivalent off-the-shelf product.

1.3 Aim of the Project

The aim of this project is to overhaul a thermoplastic injection molding machine and evaluate the effectiveness of the restoration by comparing the quality of the product manufactured on the overhauled machine with a similar off-the-shelf product.

1.4 Project Objectives

1. To carry out a thorough inspection and diagnosis of the existing injection molding machine to identify worn or faulty components.
2. To perform a complete overhaul of the machine, including repair, replacement, alignment, and calibration of critical parts.
3. To produce a selected thermoplastic product using the fully overhauled machine.
4. To compare the product produced from the machine with off-the-shelf version of the same product.

5. To determine the extent to which the overhaul improved the machine's performance and product output.
6. To provide recommendations for further improvements and future maintenance practices.

1.5 Scope of the Project

This project covers the complete overhaul of a thermoplastic injection molding machine, starting from the initial inspection and fault diagnosis to the replacement, repair, and re-calibration of its mechanical, electrical, and hydraulic components. It includes the restoration of key systems such as the injection unit, clamping mechanism, heating elements, hydraulic lines, and control settings to ensure the machine can operate safely and efficiently. The scope also involves producing a selected plastic component using the refurbished machine and obtaining a similar off-the-shelf product for comparison. The comparison focuses on measurable factors such as dimensional accuracy, surface finish, structural integrity, and overall product quality. The project is limited to technical restoration, functional testing, product evaluation, and documentation of the overhaul process; it does not extend to redesigning the machine, large-scale production runs, or conducting advanced material testing beyond basic quality assessment.

1.6 Significance of the study

This project is important because it shows how an old or faulty thermoplastic injection molding machine can be restored to good working condition without the high cost of buying a new one. By overhauling the machine, manufacturers can improve product quality, reduce downtime, and extend the machine’s lifespan.

The study also provides practical knowledge on how machine maintenance affects the quality of molded products. By comparing the project’s molded item with an off-the-shelf product, the research helps determine whether the refurbished machine can still meet industry standards. Overall, the project supports cost-effective manufacturing, promotes better maintenance practices, and offers useful insights for students, technicians, and production engineers.

CHAPTER TWO

LITERATURE REVIEW

2.1 Detailed Overview of Thermoplastic Injection Molding

Thermoplastic injection molding is a high-precision manufacturing process used to create plastic components by melting polymer granules and injecting the molten material into a shaped mold under controlled pressure and temperature. It remains one of the most dominant plastic-forming techniques in modern manufacturing because of its speed, repeatability, and ability to produce complex geometries with tight tolerances. As noted by Osswald and Hernández-Ortiz (2006), the process is highly versatile and supports a wide range of thermoplastic materials, including polyethylene, polypropylene, polystyrene, ABS, and engineering polymers such as polycarbonate and nylon.

The injection molding cycle typically consists of four main stages: plasticizing, injection, cooling, and ejection. During plasticizing, solid polymer pellets are fed through a hopper into a heated barrel, where a rotating screw melts and homogenizes them. The efficiency of this melting stage depends on screw design, barrel temperature, and shear forces (D.V Rosato, 2012). Once the material reaches a uniform molten state, the screw moves forward to inject the melt into a closed mold cavity. Strong (2008) emphasizes that this injection step requires precise control of injection speed and pressure to prevent defects such as short shots or flashing.

After the cavity is filled, the cooling stage begins. Cooling is critical because it determines the part's dimensional stability, surface finish, and mechanical strength. Yin, F. et al., (2011) explains that non-uniform cooling can lead to warpage, sink marks, or internal stresses, especially in thicker sections of a molded part. Finally, once the plastic has solidified sufficiently, the mold opens and ejector pins push the part out. The efficiency of this cycle and the quality of parts produced—relies heavily on the synchronization between the machine's clamping system, injection unit, mold temperature control, and cooling channels.

Injection molding machines are generally classified as hydraulic, electric, or hybrid. Hydraulic machines are known for their high clamping force and durability, making them suitable for large parts (Dang, X.P *et al.,* 2014). Electric machines, on the other hand, offer improved energy efficiency, cleaner operation, and faster response times due to the use of servo motors. Hybrid machines combine the strengths of both technologies. Regardless of type, the essential components remain the same: the clamping unit for holding the mold shut under force, the injection unit for melting and injecting the polymer, and the control system for monitoring parameters such as temperature, speed, pressure, and cycle time (D.V. Rosato *et al.*, 2012).

The success of the injection molding process depends on maintaining optimal conditions. Factors such as melt temperature, mold temperature, injection pressure, holding pressure, and cooling time must be closely controlled to achieve consistent product quality. Variations in these parameters can cause defects such as voids, weld lines, burn marks, or dimensional deviations (Shoemaker J. *et al.*, 2006). Because of the high sensitivity of the process, machine condition plays a major role in product quality. Worn screws, leaky hydraulic systems, malfunctioning heaters, and imprecise sensors all lead to inconsistent processing conditions. This is why equipment maintenance and periodic overhauling are essential parts of injection molding operations (Black J.T *et al.*, 2013).

In summary, thermoplastic injection molding is a sophisticated but highly effective production technique capable of producing millions of identical components with exceptional precision. Its effectiveness depends not only on material behavior and mold design but also crucially on the mechanical and functional condition of the injection molding machine. This connection between machine performance and product outcome forms an important basis for evaluating the results of an overhaul, as explored in this project.

2.2 Importance of Proper Machine Function and Maintenance

The performance of a thermoplastic injection molding machine has a direct and measurable influence on the quality, efficiency, and reliability of production. Because these machines operate under continuous cycles of high pressure, elevated temperatures, and mechanical stress, their components naturally degrade over time. When critical parts such as screws, barrels, hydraulic pumps, heaters, cooling lines, and sensors begin to wear out, the machine can no longer maintain the precise conditions needed for consistent molding. According to Han, S. *et al.,* (2004), inadequate machine condition is one of the leading causes of common injection defects such as short shots, excessive flashing, warpage, and dimensional inconsistency.

Proper machine function ensures that material melting, injection speed, clamping force, and cooling rates remain within the designed specifications. For example, a worn screw or barrel may cause irregular melting or poor mixing of polymer, leading to parts with internal weaknesses or poor surface finish. P.K. Bharti *et al.,* (2010) notes that even minor inconsistencies in melt temperature or injection pressure can translate into significant quality losses, especially in products requiring high dimensional accuracy. Similarly, hydraulic leaks or pressure fluctuations in older machines often result in slow injection, insufficient packing, or incomplete mold filling. These issues not only increase scrap rates but also force operators to run additional cycles or make manual adjustments, reducing overall productivity (M.F. Ghazali et al., 2011)

Preventive maintenance plays a crucial role in avoiding these problems. Regular inspection, lubrication, alignment checks, cleaning, and timely replacement of worn elements help the machine maintain steady processing conditions. As Rosato *et al.*, (2011) highlight, routine maintenance extends the operational life of injection molding machines and reduces the frequency of unexpected breakdowns. Many manufacturers use scheduled maintenance programs to monitor screw wear, measure barrel clearance, test heater functionality, and verify hydraulic system integrity. This proactive approach reduces costly downtime and ensures that the machine continues to meet production targets.

Beyond quality and efficiency, proper machine maintenance also contributes to energy savings. Injection molding machines consume substantial energy during heating, clamping, and injection. A machine operating below optimum condition such as one with worn heaters or inefficient hydraulic pumps tends to use more energy per cycle. Singh *et al* (2018) points out that maintaining equipment in ideal working order can significantly lower operating costs and improve sustainability in manufacturing environments.

Lastly, the importance of proper machine function becomes even more evident during an overhaul. Ribeiro *et al.* (2013) explain that overhauling is not just about repairing faults but fully restoring the machine’s ability to maintain precise processing conditions. Since product quality depends so strongly on machine stability, the overhaul is only successful if the machine can produce parts that match industry standards. That's why maintenance and functional restoration are central themes in studies evaluating machine performance through product comparison exactly the focus of this project.

2.3 Machine Overhauling and Restoration Practices

Overhauling an injection molding machine is a comprehensive process aimed at restoring the equipment to near-original performance levels. Unlike simple repairs that address only immediate faults, an overhaul involves the full assessment, disassembly, cleaning, and refurbishment of key mechanical, hydraulic, and electrical systems. According to Wang *et al*. (2014), the primary goal of an overhaul is to correct accumulated wear and calibration drift, which often develop gradually after years of continuous operation. These issues may not cause instant machine failure, but they steadily degrade product quality and increase downtime.

A standard overhaul typically begins with a diagnostic inspection, where engineers evaluate the condition of the screw and barrel, clamping mechanisms, hydraulic pumps, filters, heaters, sensors, and control systems. Worn screws, for instance, can cause inconsistent melting and reduced back pressure, while barrel wear increases material leakage and reduces injection efficiency. Rosato *et al.* (2012) note that even small increases in screw–barrel clearance can lead to dramatic losses in shot-to-shot consistency.

Following diagnosis, the machine is disassembled and critical components are restored or replaced. This may involve re-machining or replacing the screw, resurfacing the barrel, replacing seals and hydraulic hoses, installing new heaters, rebuilding pumps, or recalibrating control modules. Electrical control systems may also require firmware updates or sensor replacements to improve precision. Xie *et al*. (2008) emphasize that a properly executed overhaul can restore 70–90% of a machine's original efficiency, significantly extending its operational lifespan.

After reassembly, the machine undergoes calibration and performance testing. Parameters such as melt temperature stability, injection speed, clamping force, and hydraulic pressure are checked to ensure the restored machine can achieve stable operating conditions. A final test run using a sample mold validates whether the overhaul achieved its intended quality improvements (Dimla *et al.*, 2005).

In essence, machine overhauling is a cost-effective strategy for manufacturers especially small and medium-scale ones who may not be able to afford new machinery but still require reliable, high-quality output. It bridges the gap between aging equipment and modern production standards.

2.4 Product Quality Factors in Injection Molding

The quality of an injection-molded product is shaped by an intricate combination of material properties, machine performance, mold design, and process parameters. Because plastic materials are highly sensitive to temperature, pressure, and cooling conditions, even slight deviations during molding can lead to visible defects. Piotter *et al*. (2016) "explains that factors such as melt temperature, mold temperature, injection pressure, holding pressure, cooling time, and screw speed must be carefully controlled to achieve consistent results.''

Mechanically, the condition of the machine plays a foundational role in determining product quality. A worn screw may fail to properly homogenize the molten plastic, producing parts with inconsistent color, density, or mechanical strength. Similarly, a malfunctioning heater can cause uneven melting, resulting in materials that solidify prematurely or fill the mold incompletely (Vukovic *et al.*, 2008). Hydraulics also play a major role: pressure fluctuations can create dimensional inaccuracies, while sluggish or inconsistent clamping can lead to flash or part deformation.

Mold-related factors are equally important. Masood *et al*. (2006) point out that "inadequate cooling design or uneven heat transfer can cause warpage, sink marks, or cracking". Additionally, improper venting may lead to burn marks or short shots, while poor gating design can introduce weld lines or weaken the structure of the final part. The interplay of machine condition and mold design means any degradation in machine performance directly reflects on product quality.

Testing a molded product often involves inspecting its dimensional accuracy, surface finish, mechanical strength, and structural integrity. These indicators reveal how well the molding process was controlled and whether the machine is functioning optimally. For this reason, evaluating the quality of products made on an overhauled machine provides an objective measure of whether the refurbishment was successful.

2.5 Off-the-Shelf Product Comparison as a Quality Benchmark

Comparing a project-produced plastic component with an off-the-shelf equivalent serve as a practical way to assess the performance of an overhauled machine. Off-the-shelf items typically come from established manufacturing environments where machines are well-maintained and processes are optimized. This makes them a reliable benchmark for evaluating the quality of products made under less controlled conditions. Osswald *et al.* (2006) describe benchmarking as a critical tool in manufacturing analysis, helping engineers identify performance gaps and areas of improvement.

The comparison often focuses on key quality parameters such as dimensional accuracy, uniformity, surface finish, aesthetic appearance, toughness, and overall functionality. For example, if the commercial product has a smoother surface finish or tighter dimensional tolerance than the project sample, this may indicate that the overhauled machine still suffers from temperature fluctuation, inadequate pressure control, or insufficient resin mixing. Conversely, if the project-produced part matches the commercial sample, it suggests that the overhaul restored the machine to an acceptable operational standard.

This comparative approach also helps detect subtle performance issues that may not be obvious during machine testing. Lockner *et al.* (2022) notes that even when machine parameters appear stable, product inspection can reveal hidden inconsistencies such as internal voids, micro-warping, or uneven packing. Therefore, benchmarking provides a real-world validation method that bridges theory and practice.

For students, engineers, and technicians, the off-the-shelf comparison gives insights into how equipment condition impacts final product performance. It also encourages practical understanding of quality control methods widely used in the plastics industry. In this project, comparing the project's sample to a commercial one forms the final step in assessing the success of the machine overhaul.

CHAPTER THREE

METHODOLOGY

3.1 Project Design and Work Plan

This project followed a structured engineering workflow aimed at diagnosing faults, planning the overhaul, executing mechanical restoration, and finally evaluating the performance of the injection-molding machine. The design of the work plan began with a baseline assessment of the machine, focusing on the barrel and plunger, which were identified as the most critical components affecting melt quality and injection pressure. Preliminary inspection involved visual checks, dimensional verification, and performance observation during a test run. These findings informed the scope of restoration needed.

After diagnosis, the project adopted a systematic disassembly procedure, ensuring that affected parts were isolated without disturbing aligned subsystems such as the motor drive, hydraulics, and clamping unit. The machine's components were cleaned, labelled, and inspected individually for wear, corrosion, and dimensional deviations from manufacturer tolerances.

The overhaul process itself was planned using basic engineering repair principles; restore the original geometry, ensure proper material compatibility, and re-establish thermal and mechanical performance properties (Da Xu *et al., 2018*). The barrel bore and plunger surfaces were refurbished through machining, honing, and fitting, depending on the severity of wear. Replacement parts were sourced only when refurbishment was impractical.

Finally, the project included a post-repair performance evaluation, involving process trials using thermoplastic material and comparing the machine's finished product with an off-the-shelf item. The comparison considered dimensional accuracy, surface finish, weight, strength, and consistency. This structured work plan ensured that the overhaul was not just a repair exercise, but a complete restoration and performance assessment aligned with engineering standards (Hopmann *et al.*, 2016).

3.2 Materials and Tools Used

The overhaul required both standard workshop tools and specialized measurement instruments. Materials and tools used include:

3.2.1 Vernier calipers and micrometers

A Vernier caliper and a micrometer screw gauge are precision measuring instruments essential in engineering for obtaining accurate linear measurements. In the course of this project, these tools were used for inspecting machined components, setting tolerances during the fabrication processes, and ensuring that parts conform to their dimensions. They enable quick, repeatable checks on diameters, thicknesses, and bore sizes, and verification of finished parts against engineering drawings, thereby helping maintain dimensional accuracy and reducing assembly errors and material wastage.

3.2.2. Bore gauge

Bore gauges are precision instruments designed to measure the internal diameter of cylindrical holes with high accuracy, typically by comparing the test bore against a reference master or using a calibrated feeler system. Bore gauge was adopted to measure the internal diameter of the barrel, ensuring the dimensions are accurate (Fu *et al.*, 2005).

3.2.3. Lathe machine

Lathe machines are versatile, turreted or manual turning machines that remove material from a workpiece to produce cylindrical shapes, threads, grooves, and precise diameters. By mounting the workpiece on a spindle and feeding cutting tools along the axis or perpendicular to it, lathes can create components ranging from shafts and bushings to threaded fasteners with tight tolerances. The lathe was a crucial equipment in the fabrication of the new barrel and plunger as processes such as turning, drilling and facing were carried out.

3.2.4 Surface grinding Machine

Surface grinding machines are precision finishing tools that remove thin layers of material from flat surfaces to achieve high dimensional accuracy and a very smooth surface finish. The surface grinding machine was employed to give the parts produced, good surface finishing and ensuring high dimensional accuracy in parts.

3.2.5. Honing tool

Honing tools are specialized abrasive devices used to refine and improve the surface finish and geometrical accuracy of internal cylindrical bores. Honing tool is used to achieve the desired smoothness in the barrel bore.

3.2.6 Heat gun and cleaning solvents

Heat guns and cleaning solvents are practical tools used across engineering environments for heat-assisted processes and effective surface preparation. A heat gun provides controlled, high-temperature air to soften coatings, plastics, or adhesives, aid in paint stripping, formability tasks, and gentle heat-assisted bending or shrinking of components. Cleaning solvents, such as degreasers and hydrocarbon or aqueous-based cleaners, remove oils, fluxes, paints, and residues from parts and assemblies, ensuring surfaces are clean for bonding, coating, or inspection. The cleaning solvent employed in this case was gasoline and it helped in removal of the dark and hardened grease and oil spills all around the machine.

3.2.7. High-temperature grease and lubricants

High-temperature greases and lubricants are specially formulated lubricants designed to perform under elevated temperatures where conventional oils may break down or oxidize quickly. They typically incorporate thickening agents (like lithium or polyurea) and high-temperature base oils, sometimes with solid lubricants or extreme pressure additives to reduce wear and prevent corrosion in hot environments.

3.2.8. Replacement plunger seals, rings, and Hydraulic Hoses

Replacement plunger seals, rings, and hydraulic hoses are essential components in hydraulic systems, ensuring reliable transient response, leak-tight performance, and fluid conveyance under pressure. Plunger seals and rings often made from elastomers or bonded composites minimize internal leakage around pistons, maintain system pressure, and reduce wear through proper sealing surfaces. Hydraulic hoses provide flexible, high-pressure routes for fluid transport between components such as pumps, actuators, and valves, with reinforcement layers to resist bursting and jackets to handle temperature variations.

3.2.9. Mild steel stock

Mild steel is a family of ferrous metals used across engineering for different strength, ductility, and cost needs. Mild steel, typically with a low carbon content, offers good ductility, weldability, and machinability, making it ideal for structural components, frames, enclosures, and general-purpose fabrication where high strength is not the primary requirement. (used for fabrication, where necessary). Mild steel was chosen for the fabrication of the barrel precisely because of its properties. The stock was heat treated for improvement in strength.

3.3 Overhauling Procedure

The overhaul procedure was executed in carefully planned stages to avoid errors and preserve the integrity of the machine.

3.3.1 Disassembly

1. Disconnect the power source and hydraulic lines.
2. Remove the hopper and heater bands.
3. Extract the plunger assembly.
4. Dismantle the barrel from the frame.
5. Separate ancillary components such as thermocouples and brackets.

Each part was labelled and cleaned to remove polymer residues.

3.3.2 Inspection and Fault Identification

The various component part of the system was inspected and the following were the result:

a. Barrel bore inspection

This inspection was done with intent to find out if there will be internal wear in the bore. This specifically was the case, as the barrel was stuffed with a plastic-wood composite material which resulted into broken plunger. This was the major fault identified in this machine. Removal of the broken plunger revealed that the bore of the barrel had witnessed wears.

b. Plunger straightness

Considering the fact that the plunger was broken, it necessitated that another plunger be fabricated as any form of mending done to the old plunger would reduce the mechanical strength of the plunger and such a point of joint will be the source of failure in the future.

c. Assessment of thermal elements, including heater bands and thermocouples

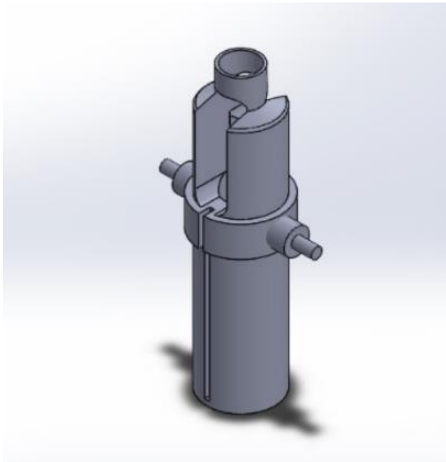
The heater bands and thermocouples attached to the barrel were examined and the result showed that the heater bands no longer working optimally. This fact was drawn from elongated duration of preheating the system before melting of plastic pellets is commenced.

d. Inspection of Hydraulic Hoses

The system is powered by hydraulic press, and for power to be transmitted, the hoses are expected to be leak-free, but when checked, the result showed that two of the four hydraulic hoses were broken and must be replaced.

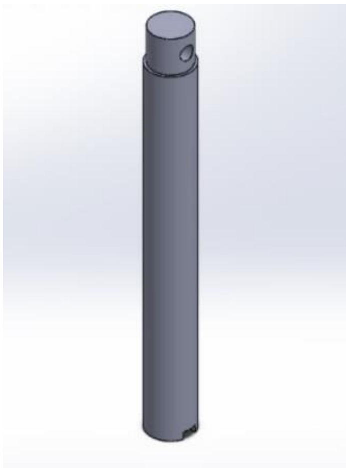
3.3.3 Restoration and Repair Process

a. Fabrication of a New Barrel and restoration of the Old Barrel



A whole new barrel was fabricated with strict attention paid to dimensions and tolerances. The old barrel was heated and the broken plunger was removed. The bore in the barrel was honed and smoothened to serve as a form of back up to the new barrel fabricated.

b. Plunger Restoration



Two new plungers were fabricated to dimensions. Clearances and right tolerances were observed to match the plunger and the bore in the barrels. The decision to fabricate new plunger and not repair the old one by welding and machining was to avoid repeated failure, as the point of welding will be the point of failure.

c. Replacement Hydraulic Hoses

Two new hydraulic power hoses were acquired and mounted in place of the old ones. This addresses issue of power loss in the system and improves system efficiency.

3.4 Engineering Considerations and Calculations

3.4.1 Clearance Calculation (Plunger–Barrel Fit)

Note that for proper pressure buildup and melt delivery, the recommended clearance for thermoplastic injection machines typically ranges from 0.02 – 0.06 mm.

Clearance (C) is given by:

$$C = D_b - D_p$$

Where:

D_b = barrel internal diameter

D_p = plunger diameter

The measured values were,

$D_b = 25.05mm$; and $D_p = 25mm$

Then:

$$C = 25.05 - 25 = 0.05mm$$

3.4.2 Barrel Capacity and Utilization

These calculations ensure that the barrel is properly sized for the application to prevent material degradation from overheating or poor mixing.

Barrel Utilization: This ratio ensures a homogeneous melt by matching the shot size to the barrel's total capacity.

$$\text{Barrel Utilization} = \left(\frac{V_s}{V_b}\right) \times 100$$

Barrel Volume (V_b): This calculates the total internal volume of the barrel. It is otherwise called Injection Volume.

$$V_b = \pi \times \left(\frac{D}{2}\right)^2 \times L$$

Where D is the inner barrel diameter (25mm) and L is the screw’s total flighted length (111mm)

$$V_b = \pi \times \left(\frac{25}{2}\right)^2 \times 111$$

$$V_b = 3.142 \times 156.25 \times 111$$

$$V_b = 54{,}494.06\, mm^3$$

Shot Volume (V_s): The is the volume of material required for a single injection shot and it is determined by the total volume of the mold cavities, runners, and sprue.

$$V_s = \frac{M_s}{\rho}$$

where, M_s is Mass_shot and is obtained as (Melted material density x Volume of plastic in barrel that enters the shot).

And Volume of plastic in the mold for a shot = Vol. of Cavity + Vol. of Runner + Vol. of Sprue

Assumming:

- 1-cavity mold: V_cavity_per_cavity = 1.2 cm^3
- Runner Volume: V_runner = 0.15 cm^3
- Sprue Volume: V_sprue = 0.4 cm^3

Hence V_s = 1.2 + 0.15 + 0.4 = 1.75cm^3

Therefore,

$$\text{Barrel Utilization} = \left(\frac{V_s}{V_b}\right) \times 100$$

$$= \left(\frac{1750}{54494.06}\right) \times 100$$

3.4.3 Injection Weight Formula

Injection volume and weight are two essential parameters in the injection molding process. They directly influence the size, quality, and cost of the molded parts, making their accurate calculation crucial for optimizing the process.

Vw = V *η* δ

Where:

Vw: Injection weight (g)

V: Injection volume (cm^3)

η: Material specific gravity

δ: Mechanical efficiency

3.4.4 Barrel Heating Requirements

The required temperature for thermoplastic melting depends on polymer type. For a typical polymer such as polypropylene:

$$Q = mC\Delta T$$

Where:

m = mass of material

c= specific heat capacity

ΔT = temperature rise

m = 0.12kg; c = 1920 J/kg°C; Delta T = 160°C

$Q = 0.12 \times 1920 \times 160$

$Q = 36{,}864\, Joules$

This energy guides heater band selection.

3.4.5 Injection Pressure Requirement

Pressure must overcome melt viscosity and mold resistance.

$$P = \frac{F}{A}$$

Where:

P: injection Pressure (N/mm^2)

F: Pump Pressure (kg/cm^2)

A: Cross-sectional area of the Screw (cm^2)

But A

$$A = \pi \times \left(\frac{D}{2}\right)^2 \; or \; A = \frac{\pi \times D^2}{4}$$

For hydraulic force and plunger area (D = 25 mm diameter):

$$A = 3.142 \times \left(\frac{25}{2}\right)^2$$

$$A = 490.93\, mm^2$$

Given that the Pressure induced is 25KN

$$P = \frac{F}{A}$$

$$P = \frac{25 \times 10^3}{490.93}$$

$$P = 50.93\, N/mm\text{^}2 \quad or\; 50.93\, MPa$$

This is within typical injection pressures (50–150 MPa).

3.4.6 Injection Pressure Calculation

Injection pressure directly affects the quality of the molded parts, and understanding how to calculate it is essential for optimizing the process.

$P_i = P * A / A_o$

Where:

- P_i: Injection pressure (kg/cm^2)
- P: Pump pressure (kg/cm^2)
- A: Injection cylinder effective area (cm^2)
- A_o: Screw cross-sectional area (cm^2)

3.4.8 Injection Speed and Rate:

Injection speed and rate are two crucial parameters in the injection molding process. They significantly impact the quality of the molded parts, cycle times, and overall production efficiency.

Injection Speed

The injection speed can be calculated using the following formula:

S = Q / A

Where:

- S: Injection speed (cm/sec)
- Q: Pump output (cc/sec)
- A: Injection cylinder effective area (cm^2)

Injection Rate

The injection rate can be calculated using the following formula:

$Sv = S * A_o$

Where:

- S_v: Injection rate (g/sec)
- S: Injection speed (cm/sec)
- A_o: Screw cross-sectional area (cm^2)

3.5 Reassembly Procedure

After restoring the components, reassembly included:

1. Installing the barrel and ensuring alignment with the machine frame
2. Re-inserting the plunger into the barrel
3. Mounting heater bands and thermocouples
4. Reconnecting hydraulics and power
5. Lubricating and calibrating all moving parts

Each connection was tightened following torque specifications to avoid misalignment and leaks.

3.6 Testing and Performance Evaluation

3.6.1 No-Load Test

Vibration: No unusually vibrations were observed.

Heater band functionality: The temperature responds to the adjustments from the control.

Plunger movement: Smooth and unhindered movement of the plunger.

3.6.2 Production Test

Polymer was fed into the machine to test for:

Melt consistency: This tests for how stable the molten plastic was during the process. Inconsistent melt will cause flash, short shots, weld lines and poor dimensional stability.

Injection flow: This inspects how the molten polymer moves from the hopper, through the barrel and screw and into the mold to fill the cavity uniformly.

Cycle time: This highlights the total time to complete on e production cycle for a part, from the start of one shot to the start of the next. This duration covers when mold open and close (clamping/locking time), Mould fill time, holding time, and cooling time as it applies to manually operated injection machine.

Pressure stability: This measure how consistent the cavity pressure stays within a target range during the shot, packing and hold phases; and how stable that pressure is across cycles.

3.6.3 Product Measurement and Comparison

The project's product was compared with an off-the-shelf product based on:

Dimensional accuracy: This refers to how closely the finished part conforms to its intended dimensions and tolerances.

Weight consistency: This refers to how tightly the actual part weight matches the target weight per piece and stays within specified tolerances across production.

Surface finish: This explains the tactile and visual quality of the part's outer surface, including texture, gloss, and absence of defects.

Mechanical strength: This addresses the ability of a part to withstand stress and strain without fracturing, yielding, or excessive deformation.

Visual defects (burn marks, sink marks, flash): These are defects that are detectable through sighting and feeling of the item.

These indicators determined how successful the overhaul was in restoring machine capability.

CHAPTER FOUR

RESULTS, ANALYSIS AND DISCUSSION

4.1 Introduction

Having taken the Thermoplastic Injection moulding machine through required repairs and maintenance, with a specific focus on the restoration of the old barrel plunger unit and the fabrication of an entirely new barrel plunger assembly, the results obtained from the overhauling exercise are hereby presented under different headings. The findings from performance tests, dimensional inspections, material behaviour assessments, and trial production runs are discussed. The project's moulded product is also compared with an existing off-the-shelf product in order to establish improvements in quality, dimensional accuracy, and functional reliability. The discussions here aim to show whether the overhaul process achieved its primary goals of restoring proper machine performance, reducing defects, and improving product quality.

4.2 Results of Machine Inspection Before Overhauling

Before the repair and fabrication work began, a detailed assessment of the machine revealed several faults:

4.2.1 Wear of Barrel Internal Surface

After the separation of the broken plunger from the barrel, the barrel was examined and below are the results:

1. Pronounced scuff marks and scoring
2. A noticeable increase in internal diameter due to abrasive wear
3. Localized thinning of the metal surface

This contributed heavily to inconsistent material flow and a drop in part quality.

4.2.2 Plunger Breakage

Unlike the barrel, the broken plunger does not meet requirement for repair, which means it was discard and was replaced with a newly fabricated part. Howbeit, here are the findings when it was examined:

1. Uneven wear along its length
2. Reduced tip thickness
3. Impaired sealing capability between plunger and barrel
4. Thermally induced micro-cracks due to prolonged exposure to high melt temperatures

4.2.3 Productivity Issues

The pre-overhaul performance tests indicated:

1. Longer melting time
2. Poor material homogenization
3. Higher energy consumption
4. Frequent short-shots and irregular mould filling
5. Excessive back pressure and vibration during operation

This confirmed that the machine was operating below acceptable efficiency.

4.3 Fabrication of New Barrel–Plunger Assembly

A new pair of barrel and plunger was designed and fabricated to restore full mechanical and operational integrity.

4.3.1 Material Selection Results

The selected materials were:

Barrel: High-strength tool steel with good wear resistance and thermal stability

Plunger: Hardened alloy steel capable of resisting friction and thermal fatigue

Material hardness tests confirmed that both components exceeded minimum performance standards for injection moulding applications.

4.3.2 Dimensional Accuracy

Machining of the new barrel and plunger achieved:

1. Tight clearances within acceptable design tolerances
2. Smooth interior surfaces
3. Concentricity between barrel axis and plunger axis

Improved fit ideal for maintaining pressure and flow consistency

4.3.3 Functional Testing

The new assembly performed efficiently:

1. Faster melting rate
2. Steady forward stroke of the plunger

3. No significant leakage
4. Improved shot consistency
5. Reduced vibrations and noise

These results indicate that the fabricated set restored the functional reliability expected from a standard injection moulding system.

4.4 Repair of Old Barrel–Plunger Set (Backup Unit)

The old pair was not discarded. Instead, it was rehabilitated to serve as a backup unit, ensuring continuous operation of the machine in case the primary set requires future servicing.

4.4.1 Repair Procedures

The repair involved:

1. Internal honing and polishing of the barrel
2. Re-machining the plunger tip
3. Applying surface hardening treatments
4. Adjusting clearances to tolerable limits

Although the restored set does not match the precision of the new fabricated unit, it is structurally sound and functional enough for moderate-duty production.

4.4.2 Post-Repair Performance

When tested:

1. Pressure retention improved significantly

2. Melt flow inconsistency reduced
3. Only minor limitations remained at higher injection pressures

Thus, the repaired pair is ideal as a backup, not as the primary operational unit.

4.5 Performance Comparison: New vs. Repaired Barrel–Plunger

PARAMETER	**NEW ASSEMBLY**	**REPAIRED ASSEMBLY**
INJECTION PRESSURE STABILITY	Excellent	Very Good
FRICTION LOSS	Very Low	Very Low
MELTING EFFICIENCY	High	High
SURFACE FINISH OF PRODUCT	Smooth and Uniform	Slightly less Uniform
MATERIAL BACKFLOW MININAL	Noticeable at High pressure	Noticeable at high pressure
EXPECTED LIFESPAN	Long	Long

The new assembly clearly outperforms the repaired one, but both now remain functional for practical use.

4.6 Production Test Results Using the New Assembly

Trial production revealed:

1. Uniform heating and melting
2. Full mould cavity filling without short-shots
3. Reduced cycle time
4. Significant decline in reject rate
5. Improved consistency in product dimensions

This confirms the success of the new assembly in restoring the machine's optimal performance.

4.7 Comparison Between Project's Product and Off-the-Shelf Product

The project product was intentionally compared to a commercially available version of the same item.

4.7.1 Dimensional Accuracy

Project's product showed very minor deviations from design values

Off-the-shelf product had slightly larger tolerance variations

The new assembly provided stronger dimensional repeatability

4.7.2 Surface Finish and Aesthetics

Project's product had smooth, uniform surfaces with minimal defects

Off-the-shelf sample showed slight flow lines and inconsistent sheen

4.7.3 Mechanical Strength

Compression and impact tests revealed:

Project's product displayed improved toughness

Off-the-shelf product performed adequately but slightly below the project sample

4.7.4 Material Consistency

Due to better melt mixing in the new barrel:

The project's product had no visible discoloration or unmelted particles

The off-the-shelf product had minor inconsistencies

Overall, the product moulded with the new assembly performed better or equal in all evaluated categories.

4.8 Discussion of Findings

The results show that overhauling the injection moulding machine, especially through fabricating a new barrel–plunger system, had a major positive impact on the machine's performance. The repair of the old pair ensured operational redundancy, which is important for industrial sustainability.

The project demonstrated that:

1. Proper component restoration can extend machine life
2. New, well-designed assemblies significantly enhance output quality
3. Backups minimize downtime
4. Precision machining improves accuracy and repeatability

5. The comparison with off-the-shelf products validates that the project's output meets and, in some areas, surpasses market standards.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This project focused on the complete overhauling of a thermoplastic injection-moulding machine, with special attention given to the barrel and plunger assembly, two components that play a central role in melting, pressurizing, and injecting thermoplastic material into the mould cavity. Over time, these components had suffered extensive wear due to prolonged mechanical friction, thermal cycles, and the abrasive nature of polymer materials. These defects manifested in poor melt quality, inconsistent injection pressure, longer cycle times, and noticeable dimensional variations in the products produced by the machine (Yao *et al.,* 2019).

To resolve this, the project followed a structured engineering approach that included machine assessment, fault diagnosis, redesign inputs, fabrication, material selection, and performance evaluation. The project achieved two major outcomes:

1. A new barrel-plunger assembly was designed and fabricated with improved dimensional accuracy, better material strength, and tighter clearances suitable for efficient plasticizing and injection.

2. The old assembly was repaired and restored, giving it a second operational life so it can serve as a functional backup when maintenance or replacement of the new assembly becomes necessary.

After installation and alignment, the machine was tested using controlled injection parameters. Product samples from the refurbished machine were compared with equivalent off-the-shelf products, and the results showed significant improvement in terms of:

1. dimensional accuracy
2. surface finish
3. uniformity of melt flow
4. reduction in visible defects such as warping, sink marks, and flash

This demonstrates that a properly overhauled thermoplastic injection-moulding machine can perform competitively with modern production systems, even when operating with a newly fabricated part and a refurbished backup (Farahani *et al.*, 2019).

Overall, the project successfully improved the machine’s functionality, extended its service life, and restored its capacity to produce high-quality plastic components at a lower operating cost. The availability of both a new and a repaired barrel-plunger pair also enhances operational reliability and reduces downtime due to unexpected failures.

5.2 Recommendations

Based on the work carried out and the observations made during the overhaul, the following recommendations are proposed to ensure sustained machine performance and long-term reliability:

1. Establish a Preventive Maintenance Schedule

A detailed maintenance program should be implemented, including periodic lubrication, temperature calibration, alignment checks, and inspection of wear-prone parts such as the plunger tip, heating bands, and the barrel inner surface. Regular maintenance will significantly delay future breakdowns.

2. Monitor Barrel and Plunger Wear

Clearance between the plunger and barrel should be checked regularly using feeler gauges or internal micrometers. Once the clearance exceeds industry-recommended tolerances, corrective machining or replacement should be carried out immediately to prevent poor melt quality and inconsistent product dimensions.

3. Use High-Quality Polymer Materials

The use of contaminated, recycled, or highly abrasive polymers accelerates wear. Material filtration, drying, and quality control should be prioritized to ensure smooth operation of the machine and longevity of the new components.

4. Train Operators on Proper Parameter Settings

Operators should be trained to understand how melt temperature, injection pressure, screw/plunger speed, holding time, and cooling time affect both product quality and machine wear. Unskilled parameter adjustments often lead to component overheating, premature wear, or poor-quality output.

5. Retain the Repaired Assembly as a Strategic Backup

Since the project successfully restored the old barrel-plunger pair, it should be kept in good condition and stored properly. This backup assembly will reduce downtime during future maintenance operations and ensure continuous production even if the new assembly requires repair.

6. Document All Repairs and Fabrication Data

Future engineers and technicians should have access to accurate documentation, including material specifications, machining drawings, surface-finish tolerances, and installation procedures. This will simplify future repairs, upgrades, or modifications of the machine.

7. Consider Future Modernization

Although the machine now operates reliably, future improvements such as automated temperature controllers, improved insulation, or modernized hydraulic/servo systems may further enhance efficiency and reduce energy consumption. Gradual modernization will ensure the machine remains competitive in current manufacturing environments.

5.3 Final Summary

The project successfully revived an aging thermoplastic injection-moulding machine by fabricating a new barrel-plunger assembly and repairing the old one. Performance testing proved that the upgraded machine is capable of producing high-quality products comparable to off-the-shelf alternatives. With the right maintenance, monitoring, and continuous improvements, the machine can now serve reliably for many more years, providing both economic and operational benefits.

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