BANTING

FINAL YEAR PROJECT REPORT

IOT DEVELOPED INJECTION MOULDING LEARNING KIT

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This report is submitted to the department of the mechanical engineering as fulfilling part of the conditions of `The Award Diploma of Mechanical Engineering'.

DEPARTMENT OF MECHANICAL ENGINEERING

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Leading us ,

Mrs.MMANIYARASI MUNUSAMY

………………..

APPRECIATION

Dear supervisor Mrs.MMANIYARASI MUNUSAMY,

As we approach the completion of our final year project, we, the project team, would like to collectively express our sincere appreciation for the invaluable support and guidance we have received throughout this journey.

Primarily, we extend our deepest gratitude to Mrs MMANIYARASI MUNUSAMY your expert guidance, insightful feedback, and unwavering support have been pivotal to the success of our project. Your encouragement and direction have significantly enriched our learning experience, and for this, we are profoundly grateful.

We also want to express our heartfelt thanks to each other KUGAN A/L RAJA KUMAR, PRASHANTS RAM A/L SABAMOORTHY, MUHAMMAD HARIZ SYAHMI BIN ZULKPLI, and NURHAMIZAH AYUNI BINTI SUHAIME . Our combined efforts, dedication, and collaborative spirit have been the foundation of our achievements. Each member's unique strengths and perspectives have been crucial in overcoming challenges and driving the project forward.

A special acknowledgment goes to our mentors and advisors, Mrs.TAMILMOLI LOGANATHAN and Mr. THINAKARAN from IKTBN SEPANG. Your mentor ship and the resources you provided were instrumental in helping us bring our ideas to life. Your contributions have been crucial to the development and successful execution of our project.

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Lastly, we extend our heartfelt thanks to our families and friends for their constant encouragement and understanding during this demanding period. Your support has been a source of motivation and strength.

This project has been a remarkable journey of learning and growth for all of us. We are proud of what we have accomplished together, and we believe that the skills and knowledge gained will serve us well in our future endeavours.
Thank you once again to everyone involved. This achievement is a testament to our collective effort and dedication.

Warm regards,

KUGAN A/L RAJA KUMAR
Team Leader

On behalf of the project team:
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1.0 INTRODUCTION

Embarking on the journey of creating an IOT developed injection moulding learning kit discovers a captivating journey into the heart of manufacturing creativity. DIY enthusiasts, college students and small-scale creators, armed with a spirit of innovation for hands-on fabrication, are increasingly drawn to the transformative possibilities that injection moulding offers within the comfort of their workshops. The driving forces behind its surge in popularity, the challenges and opportunities it presents, and the mass ways it empowers individuals to become architects of their creations.

The roots of the IOT developed injection moulding learning kit movement trace back to the meeting point of technological advancements, open-source collaboration, and the basic human desire to create. Restricted to large-scale manufacturing, injection moulding was a well-guarded secret, its complexities hidden behind the walls of industrial facilities. However, the rise of the internet age, coupled with the rise of open-source communities, dismantled these barriers. Knowledge once held within the confines of industry giants began to seep into the public domain, democratizing information and sparking a renaissance in DIY manufacturing.

The injection moulding movement is fuelled by several splice forces. Foremost among them is the accessibility of information and resources. Online platforms, forums, and collaborative spaces have become digital forges where enthusiasts share knowledge, experiences, and blueprints for DIY injection moulding machines. Simultaneously, advancements in 3D printing technology have empowered creators to fabricate intricate moulds with relative ease, amplifying the possibilities for small-scale production.

Moreover, the movement gains momentum from a desire for customization and professionalization. Injection moulding allows creators, students, and enthusiast to craft reveal solutions tailored to their unique needs, from prototyping new inventions to replicating rare components. This quest for individualized production is a testament to the movement's ethos of self-reliance and creative expression.

As with any transformative movement, injection moulding is not without its challenges. Crafting a reliable and efficient injection moulding learning kit requires a delicate balance of engineering prowess and hands-on tinkering. Challenges such as material selection, temperature control, and mould design pose intricate puzzles that must solve to unlock the full potential of their desired aim.

Yet, within these challenges lie opportunities for innovation and learning. The iterative process of refining IOT developed injection moulding setups becomes a hands-on education in thermodynamics, material science, and mechanical engineering. Failures are not setbacks but steppingstones, fostering resilience and a deeper understanding of the intricacies involved.

Beyond the realm of hobbyists and entrepreneurs, the DIY injection moulding movement holds tremendous potential as an educational powerhouse. Students, both aspiring engineers and those venturing into the world of manufacturing, stand to gain invaluable insights and practical skills through hands-on engagement with injection moulding.

As educational institutions worldwide strive to prepare students for careers in STEM and TVET fields, the intersection of DIY culture and injection moulding offers a unique avenue for exploration. Imagine students stepping into a classroom equipped not only with textbooks and theories but with the opportunity to interact with a real manifestation of manufacturing principles. IOT developed injection moulding becomes an immersive educational tool, bringing to life the concepts of thermodynamics, material science, and mechanical engineering.

The process of designing, building, and operating a DIY injection moulding machine serves as an engineering adventure for students. It is a journey that demands critical thinking, problem-solving skills, and a deep understanding of the scientific principles governing the injection moulding process. The mistakes made, the hurdles faced, and the triumphs achieved in the DIY realm become valuable lessons, offering a practical context to theoretical knowledge.

1.2 PROJECT BACKGROUND

Injection moulding has firmly established itself as a cornerstone in modern manufacturing, renowned for its prowess in crafting intricate and precise components with remarkable repeatability. This method unfolds with the dance of thermoplastic resin, a symphony of heat and form within the confines of a heated barrel. The molten material, like a molten maestro, takes center stage as it is deftly injected into a meticulously designed mould cavity, where it undergoes a metamorphosis, solidifying into the desired product. As the cooled and hardened creation emerges, the mould graciously opens its embrace, allowing the finished product to be gracefully ejected into the world.

Despite its ubiquity across industries, the demand for injection moulding has evolved. There is a palpable yearning for machines that transcend the traditional complexities, machines that resonate with the spirit of simplicity and accessibility. Small-scale manufacturers, DIY enthusiasts, and educational institutions, often constrained by the intricacies and costs of conventional injection moulding equipment, are seeking a transformative solution. A call echoes for an injection moulding machine that is not just a tool for the manufacturing elite but a companion to innovators in varied settings.

In response to this call, the proposition of a user-friendly and affordable injection moulding machine emerges as a beacon of inclusivity. Such a machine has the potential to break down barriers, democratizing the manufacturing landscape and unlocking avenues for innovation across diverse sectors. Its simplicity becomes a bridge, connecting the realms of possibility for those who aspire to create but have been held back by the daunting complexity of traditional machinery.

Yet, beyond the realm of manufacturing, the impact of simplifying injection moulding extends into the domain of education. The educational landscape craves tools that can inspire and engage, tools that demystify the intricate dance of thermoplastics and moulds. An accessible injection moulding machine becomes not merely an apparatus but a key to unlocking the doors of curiosity, inviting students and enthusiasts into the fascinating world of manufacturing and engineering.

The educational benefits ripple through classrooms and workshops, offering a tangible and hands-on approach to learning. It becomes a canvas for teaching fundamental principles of design, material science, and practical problem-solving. As students engage with the machine, they not only grasp theoretical concepts but also develop a deep appreciation for the synergy between creativity and engineering. The injection moulding machine, in this context, becomes a mentor, guiding the next generation of innovators towards a future where skilled minds shape the world around them.

In summary, the evolution of injection moulding, from its intricate industrial dance to a simplified, accessible form, holds the promise of transforming not just manufacturing but education and innovation. The journey towards user-friendly and affordable injection moulding machines is a journey towards a more inclusive and empowered future, where the transformative magic of moulding is within reach for all those with a spark of creativity and a yearning to shape the world.

1.3 PROBLEM STATEMENT

Our Polytechnic offers manufacturing engineering course and there is a critical problem where currently lack of a functional and accessible injection moulding machine. We understand that a conventional injection moulding machine costs more than Rm 90,000 (ton) and creating a gap in practical education and inhibiting creative exploration. The subject code is DJJ 41032 & manufacturing workshop practice 1,where the students learn about plastic processing, injection moulding, and etc. If there are any hands-on practice related to injection moulding, its hindering students from engaging in hands on learning and prototyping which is what manufacturing engineering department specializes on. Our polytechnic will request guidance from another institute which has the desired facilities, which is an inconvenience for the lecturers and students. To address this challenge, there is a pressing need for the development of a cost efficient and user-friendly IoT developed injection moulding learning kit that can be easily used to know the working principles.

To differentiate our project and the conventional injection moulding machine, our project is developed to be operated by IoT integrated app and can easily maintained by the students. Since the era we are currently in the Fourth Industrial Revolution our group choose one of the 9 pillar which is Internet of Things (IoT) as our IR 4.0 pillar, since our projects control panel will be developed using Arduino to form an application type control panel. It didn’t end there since by undertaking this project, our aim is to empower our polytechnic with a tool that goes beyond more than a learning tool and becomes a catalyst for fostering on creative thinking. The solution that our group is seeking is not the just machine, it is a gateway to a more inclusive and innovative educational environment, where theoretical knowledge is pushed to another level and the practical application of engineering principles becomes an attainable reality.

1.4 OBJECTIVE

The main objective of this project is to develop a DIY injection moulding machine for usage in polytechnic for their teaching and learning purpose. The specific project objectives are as follow: -

i) Design a simple injection moulding machine suitable for small-scale applications, specifically for use with two-plate moulds.
ii) Employ the Pugh method to select the most appropriate design, taking into account several criteria.
iii) Develop an injection moulding machine based on the selected design.
iv) Implement remote operation of the injection moulding machine via applications and IoT integration.

1.5 PROJECT SCOPE

(Flow Rate, Size of the Mould, Max Temp, Min Temp, Motor Rpm)

The scope of this study encompasses several key parameters, including flow rate, mould size compatibility, maximum and minimum temperature requirements, and motor RPM. These factors are crucial for ensuring the functionality, efficiency, and versatility of the proposed injection moulding machine. By addressing these parameters, the resulting machine will be well-suited for a variety of small-scale applications, while also facilitating educational objectives related to injection moulding principles and practical implementation.

1.6 PROJECT EXPECTATIONS

The project expectations for an IoT-developed injection moulding learning kit encompass several key areas to ensure its success and effectiveness. The kit should feature a comprehensive curriculum that integrates both theoretical and practical aspects of injection moulding and IoT technology, facilitating hands-on learning and skill development in programming, sensor integration, and data analysis. Technically, it should include essential hardware such as sensors, micro controllers, and connectivity modules, alongside a user-friendly software platform for real-time monitoring and control. User experience is paramount, demanding ease of use, modularity, and interactive elements like real-time dashboards and data visualization. Educational outcomes should focus on measurable knowledge gain, practical skills, and fostering innovation through project-based learning. The kit must offer reliable and accurate performance, durable design for frequent use, and robust technical support. Scalability and flexibility are crucial, allowing customization for various educational levels and needs. Cost considerations include making the kit affordable and accessible, supported by comprehensive tutorials and resources. Safety and regulatory compliance are essential to ensure safe usage in educational settings. Continuous improvement through user feedback and iterative development is vital, along with clear success metrics and regular impact assessments to gauge the kit's effectiveness in enhancing learners' knowledge, skills, and engagement.

1.6 SUMMARY

This chapter highlights the production of an injection moulding learning kit, IoT-enabled, that is aimed to merge practical and theoretical knowledge that is received from injection moulding and IoT. The kit offers a thorough program design which does not only focus on hands on practice but also expertise in programmed sensor integration and data analysis(temperature). This is the technical part of the process, which include board-level components such as sensors, micro controllers, and connectivity modules, as well as the software platform for the real-time monitoring and control of the injection moulding process. Such emphasis on user experience guarantees the kit will be comprehensive, interactive, and user-friendly. Educational results will be tailored around observable gains in practical and cognitive skills as well as the development of a creative and curious mind through project-based learning models. The expectations are focus on reliability, precision and dependability by tech support to ensure they are robust. Such a kit is made to be durable and flexible, forming homogeneity with different educational levels and needs, and it is easy to reach and at low cost. The safety and regulatory criteria is followed in its entirety to guarantee its usage in educational institutions. Differentiation of our product will be triggered by feedback from users as well as the implementation of iterative development, clear performance indicators, and regular performance assessment to monitor the performance of our product in terms of increasing knowledge, skills, and engagement.

CHAPTER 2 : LITERATURE REVIEW

2.1 INTRODUCTION

Injection moulding is one of the most widely used manufacturing processes for producing plastic parts and components across various industries. These machines melt raw plastic materials, then inject the molten plastic under high pressure into mould cavities designed to shape the desired part geometry. The machine's main components include the injection unit for melting and delivering the plastic, the clamping unit for holding and closing the mould, and the control system for regulating the entire moulding cycle. Advancements like precise temperature control, advanced injection profiles, and accurate sensors have improved the quality, consistency, and efficiency of these machines in producing plastic components with accurate dimensions. The injection moulding kit originally meant for the students to learn the basics about the mechanism itself hands-on in the simpler form. The main problem which the unavailability of the conventional machine the institute has open the opportunity for us to developed this project. We apply IOT app based to this project to ease and make a safer operation for the user which will change the way people see about injection moulding.

2.2 REAL CASE

One of the courses in Polytechnic Banting which is manufacturing mechanical engineering students has 'plastic' as one of their syllabus, and unfortunately the existing injection moulding machine in our institute already broken. The cost to repair the machine is already over the budget and the previous solution to this problem was to visit other institute to learn about the injection moulding which troubling the students and lecturer to visit other institute. We as Polytechnic Banting students willingly to take this project so we can provide the knowledge to the other students even with the basic information. We handed out questions we made in google form to the students here to know how they feel about this issue and 41 students responded to them. We able to find out that 53.7% students here find it inconvenient to not have the machinery in the institute. Meanwhile, 97.6% of students agree that it will help them better to have the model in the workshop.

2.3 COLLECTOR IN THE MARKET

Injection moulding are important in industries of manufacturing providing efficiency, versatility and precision in producing wide selection of components globally. In Malaysia injection moulding plays an important role to an active economy with a strong manufacturing base to serve several key sectors which is automotive parts, electronics, packaging, construction and others. The research study includes profiles of leading companies operating in the Malaysia Plastic Injection Moulding Machine Market, such as

1. Advance Plus Moulds & Injections Sdn Bhd
2. Edverson Marketing
3. Glasfil Polymer Sdn. Bhd.
4. HICOM-Teck See (HTS)
5. SAVVY
6. MOLTEC PRECISION SDN. BHD

These are the major companies in the Malaysian market for plastic injection moulding machines, which are essential equipment for various manufacturing industries involving plastic products. The study's provide insights into their operations, market presence, product offerings, and strategies within the Malaysian plastic injection moulding machine sector.

2.4 LIMITATION

Injection moulding offers several advantages such as capable of making complex geometries, compatible with wide range of material and material reusability. However, despite its widespread use, injection moulding also has several inherent limitations that must be carefully considered.

Can't produce in mass production rate: Since the design we are using is smaller than the conventional one, it lack the output capabilities to produce large-batch production.

Lacks flexibility: Small batch production requires constant adjustment and a limited range of materials that can be used.

Injection pressure and speed: The limited power output of these smaller motors may affect the overall cycle time and production rate**.**

Long preparation time: For small production batches, the injection moulding takes some time needed for testing and adjusting the process before actual moulding can start.

Some delays may occur: A lot of calculation is needed to perfectly aligned all the components' movement while the machine is operating.

Can only use one type of material: thermoplastics are the only compatible material that can be used for this model.

2.5 SUMMARY

This literature review discusses the process of injection moulding, a widely used manufacturing machine to produce plastic parts. The lack the machinery of the injection moulding burden some of the students here. This issue provided insight of how the students here struggling to learn about their subject without the proper equipment in hand. We come up with various ideas to solve this problem. The solution is to make our own injection moulding kit, simpler, smaller and easier to learn. We are also able to find out that the users of the injection moulding are wide across the globe opening a new opportunity to us to offer them our ideas. However, despite the high usage rate injection moulding still possess some limitations, even so it is still a reliable source of making plastic parts compared to other technique. Hopefully this project will help the students to learn about injection moulding.

CHAPTER 3: METHODOLOGY

3.0 INTRODUCTION

Injection moulding is a widely used manufacturing process for producing parts by injecting molten material into a mould. It's commonly used for producing plastic parts, but it can also be used with metals and other materials. Here's an overview of the methodology of injection moulding:

- **Designing the Part:** The process starts with designing the part to be manufactured. The design should consider factors like material selection, part geometry, wall thickness, draft angles, and any functional or aesthetic requirements.

- **Designing the Mould**: Once the part design is finalized, the mould design begins. The mould typically consists of two halves: the cavity side and the core side. These halves are precision-machined to form the desired part shape.

- **Material Selection**: The material for injection moulding is usually in the form of pellets or granules. The material choice depends on factors such as the part's properties, required strength, flexibility, colour, and surface finish.

- **Melting and Injection**: The selected material is fed into the injection moulding machine's hopper, where it's heated and melted. The molten material is then injected into the mould cavity. This will fill the mould completely and ensures that the final part has no voids or defects.

- **Ejection**: Once the part has sufficiently cooled and solidified, the mould opens, and the part is ejected from the mould cavity. Ejection mechanisms such as pins, ejector plates, or air blasts are used to remove the part from the mould without damaging it.

- **Trimming and Finishing**: In some cases, the ejected part may have excess material or flash around the edges. This excess material is trimmed off, and any secondary operations, such as machining or assembly, may be performed to achieve the final part specifications.

- **Quality Control**: Throughout the process, quality control measures are implemented to ensure that the parts meet the required specifications. This may involve inspecting the parts for dimensional accuracy, surface finish, and other critical attributes.

- **Iterative Improvement**: Injection moulding often involves iterative improvements in the process to optimize part quality, cycle time, and cost-effectiveness. This may include adjusting processing parameters, modifying the mould design, or refining material selection.

- **Regrinding and Recycling:** Any excess material or scrap generated during the injection moulding process can be reground and recycled, reducing waste and improving sustainability.

Overall, injection moulding is a versatile and efficient manufacturing process suitable for high-volume production of complex parts with tight tolerances and consistent quality.

3.1 DESIGN PROCESS

Designing for injection moulding involves several key steps to ensure the manufacturability, functionality, and cost-effectiveness of the final product. Here's an overview of the design process for injection moulding:

- **Define Requirements:** Understand the functional requirements of the part, including its intended use, mechanical properties, dimensional tolerances, and aesthetic considerations. Define any specific material requirements or regulatory standards that need to be met.

- **Conceptual Design:** Generate conceptual designs based on the identified requirements. Consider various factors such as part geometry, draft angles, wall thickness, ribs, fillets, and features like undercuts or threads. Iterate on different design concepts to explore trade-offs and find the optimal solution.

- **Design for Manufacturability:** Evaluate the manufacturability of the design by considering how it will be moulded. Ensure that the design is suitable for injection moulding by minimizing complexity, avoiding sharp corners, providing adequate draft angles for easy ejection, and designing uniform wall thickness to prevent warping or sink marks.

- **Material Selection:** Choose the proper material for the intended application based on mechanical properties, chemical resistance, environmental factors, and cost considerations. Consider the material's flow characteristics, shrinkage rates, and compatibility with the injection moulding process.

- **CAD Modeling**: Create a detailed 3D CAD model of the part using software tools like Autodesk Inventor. Pay attention to the design details and incorporate features such as fillets, chamfer, and surface textures as needed.

- **Mould Design**: Develop the mould design based on the part geometry and material requirements. Determine the number of cavities, gating system, parting line location, ejector system, and any additional features required for the mould.

- **Analysis**: Perform mould flow analysis and data tabulation to predict how the material will flow during the injection moulding process. Identify potential defects such as air traps, weld lines, or sink marks and optimize the design and processing parameters accordingly.

- **Design Review:** Conduct a design review with cross-functional teams including engineers, and manufacturing experts to evaluate the design from different perspectives and address any concerns or recommendations.

- **Injection Moulding Process Validation:** Set up the injection moulding machine and conduct trials to validate the manufacturing process. Fine-tune the processing parameters such as temperature, pressure, injection speed, to achieve the desired part quality.

- **Quality Control:** Implement quality control measures to monitor. Perform dimensional inspections, visual inspections, and functional tests to ensure that the parts meet the required specifications.

3.2 CRITERIA FOR SELECTION

1. **Machine Specifications**

- Clamping Force: Ensure the machine has sufficient clamping force for the types of moulds and materials you intend to use.
- Injection Capacity: Check the shot size or maximum volume of material the machine can inject per cycle, matching it with your production requirements.
- Mould Size Compatibility: Ensure the machine can accommodate the size and dimensions of the moulds you plan to use.

2. **Material Compatibility**

- Types of Plastics: Verify that the machine can process the types of plastics or other materials you intend to use, including thermoplastics, thermosets, or elastomers.
- Temperature and Pressure Range: Ensure the machine can achieve the necessary temperatures and pressures required for your materials.

3. **Control System**

- User Interface: Look for a machine with a user-friendly interface for easy operation and adjustments.
- Precision and Repeatability: The control system should allow for precise control over injection parameters to ensure consistent product quality.

4. **Build Quality and Durability**

- Materials and Construction: The machine should be constructed from high-quality, durable materials to withstand regular use.
- Maintenance Requirements: Consider the ease of maintenance and availability of spare parts.

5. **Safety Features**

- Safety Guards and Interlocks: Ensure the machine has appropriate safety guards and interlocks to prevent accidents.
- Emergency Stop: A readily accessible emergency stop button is essential for user safety.

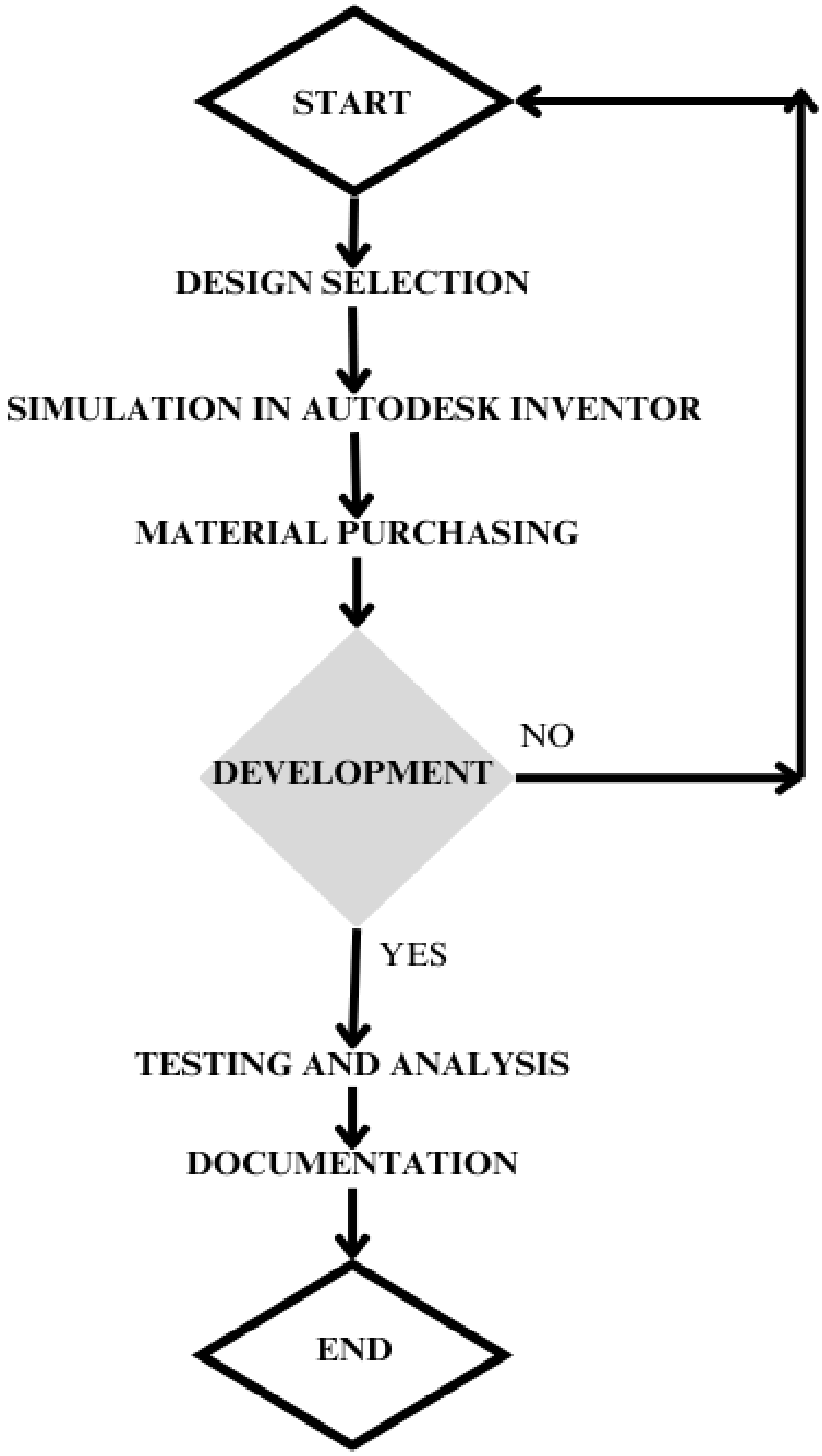
6**. Cost and Budget**

- Initial Cost: Evaluate the initial purchase price in relation to your budget.
- Operating Costs: Consider the ongoing costs of operating the machine, including energy consumption, maintenance, and materials.

7. **Production Requirements**

- Cycle Time: Assess whether the machine's cycle time meets your production speed requirements.
- Production Volume: Ensure the machine can handle the volume of parts you need to produce, whether it's for prototyping, small-scale production, or educational purposes.

3.3 FLOW CHART



3.4 LIST OF MATERIALS

COMPONENTS	QUANTITY	PRICE PER UNIT	PHOTO
Heating Band	4	17	
Coupling Jaw	3	11.90	
Motor 12v 180rpm	1	23.80	

Motor 12v 100rpm (Bi)	2	38.59	
Auger Bit	1	16.90	
Thermocouple Type K	1	4.40	
Emergency Button	1	5.90	

PDI	1	28.77	
Threaded Rod	1	25	
Pillow Block	2	20.50	
Solid State Relay (Ssr)	1	16.50	

3.4 REQUIRED CALCULATIONS

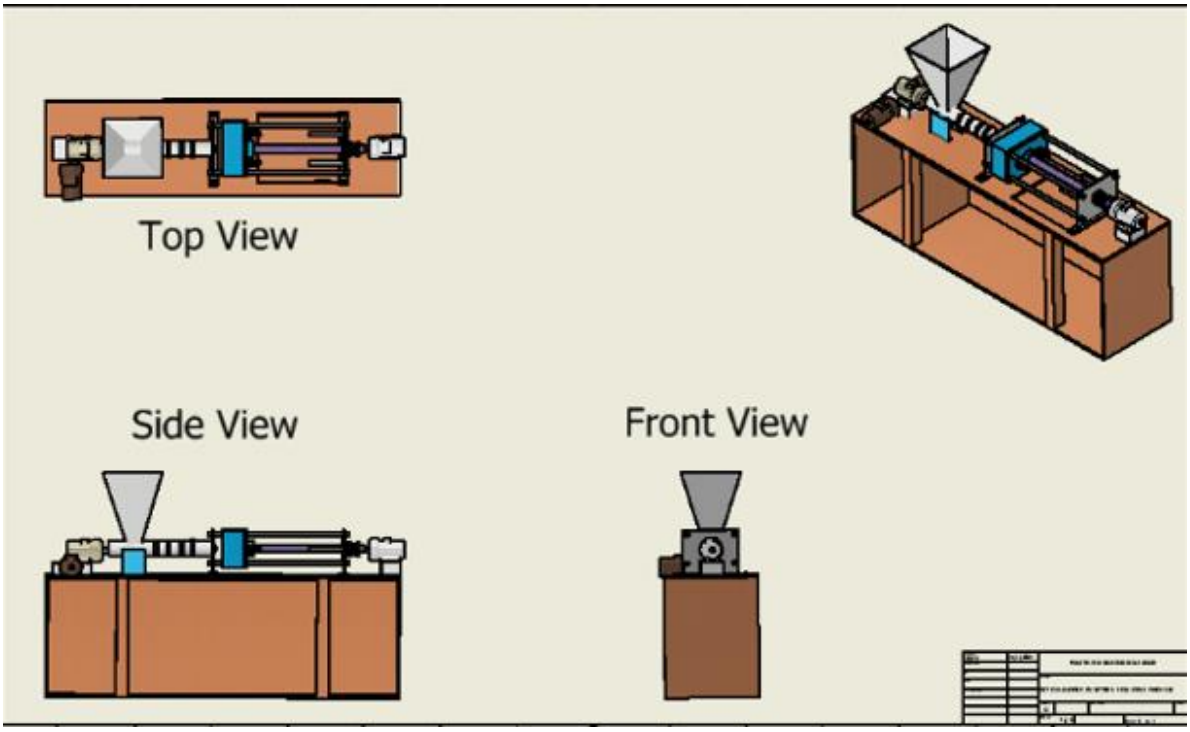
i. PRODUCT SHOT WEIGHT: (Product weight x no. of cavity) + Runner weight

ii. SHOT WEIGHT UTILIZATION: product shot weight/machine shot capacity x 100

iii. Formula for Cycle time = clamping time + injection time + cooling time + ejection time

iv. Machine shot capacity = Maximum barrel volume × Material density

3.5 FINAL DESIGN



CHAPTER 4: RESULT AND ANALYSIS DATA

4.0 INTRODUCTION

The primary findings that were acquired during this investigation were given in this part. Data collection methods, instruments, demographic and sample methods, and research design were all covered in the preceding chapter. This chapter presents the findings from the Polytechnic Banting Selangor students that participated in the survey. This outcome was acquired using Google Forms, which were disseminated over a WhatsApp link. The analysis that will ascertain the degree to which the objectives of the study were met will be covered by the researcher in this chapter. The respondent's comments will then be analysed using frequency and percentage, and they will be shown as tables and bar graphs.

4.1 DATA ANALYSIS AND STATISTICS

Surveys were used to collect the data presented in this chapter. To make inferences based on the stated goals, the data experiments are carefully assessed. We collected the data from Polytechnic Banting Selangor manufacturing students using a "Google Form," and approximately forty-five students participated in the survey.

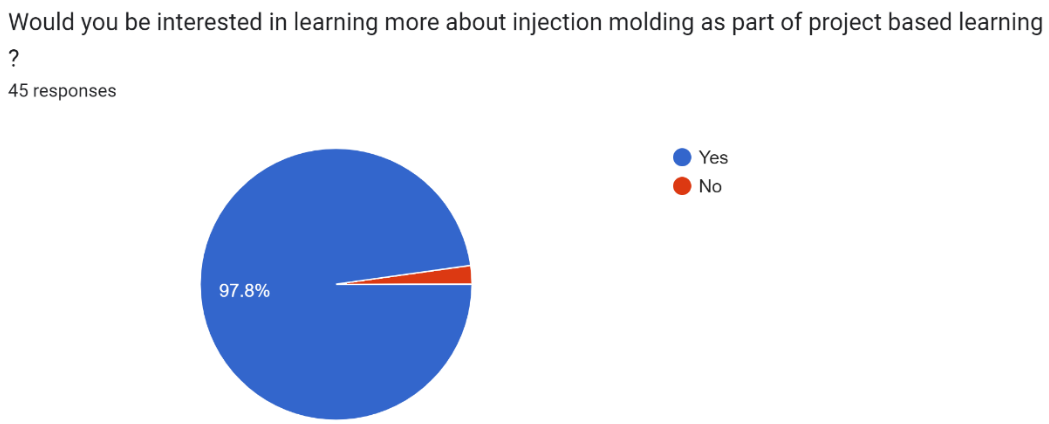


Figure 4.1 Pie chart Question 1

From the pie chart above show us that the overwhelming majority 97.8% of students expressed a strong interest in learning more about injection moulding while only a small fraction 2.2% of students indicated that they were not interested. This highlights the demand and enthusiasm among the student body for hands-on, project-based learning tools related to manufacturing processes, specifically injection moulding since our polytechnic doesn't have one.

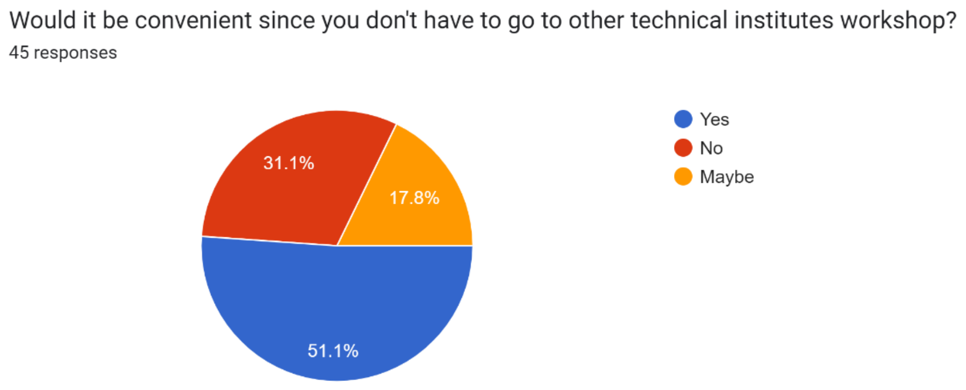


Figure 4.2 Pie chart Question 2

Following our analysis, 31.1% of respondents found it convenient to go to other technical institutes workshop, while 17.8% were uncertain. However, a significant 51.1% believe our product's availability at our own institute would offer greater convenience, allowing students to save time and expedite project completion.

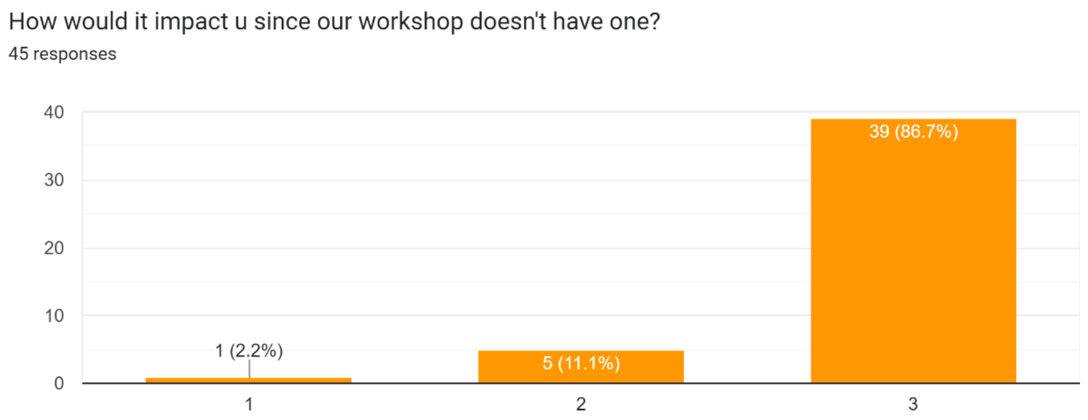


Figure 4.3 Bar Chart Question 3

The chart presents the impact on students due to the absence of an injection moulding machine in the workshop at Polytechnic Banting Selangor. A vast majority, 86.7% indicated a significant impact, expressing that the lack of this essential equipment hampers their ability to efficiently learn and complete related projects. Only 11.1% felt a moderate impact, while a mere 2.2% believed the absence of the machine had little effect.

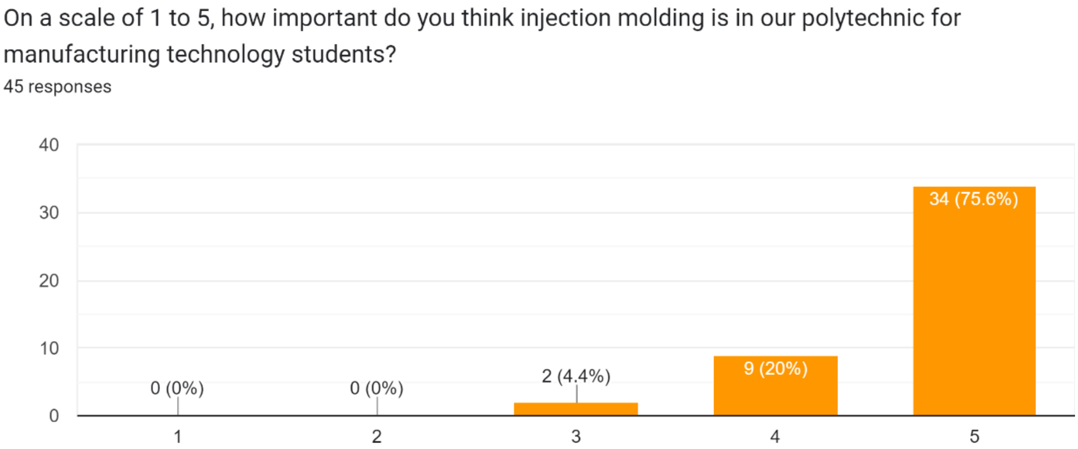


Figure 4.4 Bar Chart Question 4

The chart illustrates the perceived importance of injection moulding for Manufacturing Engineering Department students at Polytechnic Banting Selangor on a scale of 1 to 5. An overwhelming 75.6% (34 respondents) rated injection moulding as highly important, giving it a score of 5. Another 20% (9 respondents) rated it a 4, indicating that nearly all students see injection moulding as crucial for their studies. Only 4.4% (2 respondents) provided a neutral score of 3, with no one rating it below 3.

4.2.1 RESULT AND ANALYSIS OF MOTOR RPM AND TORQUE

In the operation of the IoT-enabled injection moulding learning kit, detailed monitoring of motor RPM and torque across each phase of the moulding cycle provided key insights into performance optimization. During the injection phase, the motor achieved RPM levels between 30 and 150, a range intentionally set to enable rapid filling of the mould cavity with molten plastic. This high-speed injection minimized cycle time by quickly delivering material into the mould, although it required higher energy input due to increased power demand. In contrast, during the holding and cooling phases, the motor RPM was lowered to a range of 20 to 60 RPM to stabilize pressure and reduce energy consumption, maintaining material integrity and allowing the plastic to solidify under consistent conditions.

Torque readings, which varied between 10 Nm and 50 Nm, reached their peak during the initial injection phase. This high torque was essential for overcoming the resistance as molten plastic encountered the mould cavity walls, ensuring the material fully filled the cavity without voids. High torque also played a crucial role in maintaining pressure during the holding phase, reducing the likelihood of defects like short shots and sink marks. The steadiness of torque during these later phases was especially important, as it helped to preserve the moulded part's dimensional accuracy by preventing any material backflow or pressure fluctuations.

Analysing these results highlights the importance of balancing motor speed and torque with each phase of the moulding cycle. High RPM and torque during the injection phase improved efficiency by reducing cycle time, but this came with increased energy consumption. This trade-off demonstrated the need for phase-specific adjustments to optimize both productivity and energy usage. By fine-tuning the RPM and torque according to cycle requirements, the system not only achieved a more efficient operation but also ensured consistent part quality and reduced mechanical strain on components. Future refinements in these parameters could yield even greater performance benefits, particularly when adapting to different materials and part geometries, allowing for tailored control settings that enhance both energy efficiency and product quality.

4.2.2 RESULT AND ANALYSIS OF NUMBER OF HEATING ELEMENTS

For the IoT-enabled injection moulding learning kit, three heating elements, each rated at 300 watts, were used to achieve and maintain the target temperature for the moulding process. Each heating element has a maximum temperature capacity of 300°C, with dimensions of 30 mm in diameter and 50 mm in length. The total heating capacity provided by these elements is 900 watts, which was sufficient to uniformly heat the mould to the desired processing temperature range within a reasonable time frame.

The use of three 300-watt heating elements allowed for effective thermal distribution across the mould, providing enough power to reach and maintain the maximum temperature of 300°C. By distributing heat through multiple elements rather than a single, high-power unit, the system achieved more uniform temperature control, minimizing hot spots that could lead to uneven melting and product defects. Additionally, this configuration offered flexibility in controlling temperature, as each element could be independently adjusted or turned off if lower heat levels were required, reducing energy consumption in certain processes.

The 900-watt total power was well-suited to the mould's dimensions and thermal mass, ensuring a balance between heating efficiency and energy use. However, further analysis suggested that using more heating elements with lower individual wattages could improve temperature stability and further reduce localized overheating risks. Additionally, the compact size (30 mm in diameter and 50 mm in length) allowed each element to be positioned precisely, contributing to optimal heat penetration. Fine-tuning the number, power rating, or positioning of heating elements could further enhance energy efficiency, especially if the system were to scale for larger moulds or varied material properties. This configuration provides a practical baseline for achieving required temperatures, with potential for optimization based on specific application needs.

4.2.3 RESULT AND ANALYSIS OF TYPES OF RESIN USED

In the IoT-enabled injection moulding learning kit project, two types of resins were tested: HD Virgin (High-Density Polypropylene) and LLDPE (Linear Low-Density Polyethylene). Through a series of tests on mould filling, part quality, and consistency, it was observed that LLDPE performed better than HD Virgin Polypropylene in terms of flexibility, process stability, and final product quality. Consequently, LLDPE was identified as the most suitable resin for this application.

The comparison of HD Virgin Polypropylene and LLDPE highlighted differences in their moulding characteristics and suitability for the learning kit. HD Virgin Polypropylene, due to its high density, exhibited higher rigidity and was less flexible, leading to increased brittleness in thin sections of the moulded parts. This rigidity also posed challenges in the mould filling stage, as the higher viscosity required higher pressure, increasing both energy consumption and cycle time.

In contrast, LLDPE demonstrated superior flexibility and a lower melting point, which improved flow during the injection process. LLDPE’s lower density and improved flowability allowed it to fill the mould cavities more easily and uniformly, even at lower pressure and temperature settings, reducing the likelihood of defects such as voids and short shots. These properties not only reduced the energy requirements but also allowed for faster cycle times, which can be beneficial for efficiency and cost savings in a production environment.

LLDPE's lower melting point and enhanced flowability contributed to its smooth mould-filling process, which reduced stress on both the mould and the machine. This characteristic is particularly advantageous in an educational setup where students and trainees may experiment with various settings. LLDPE's forgiving nature allows for minor adjustments in temperature and pressure without significantly impacting product quality, making it more suitable for hands-on learning and experimentation.

Another factor in favour of LLDPE is its lower risk of creating internal stresses in the final product. HD Polypropylene, while strong, often resulted in moulded parts with internal stress points due to its rigidity, which could lead to cracking or failure over time, especially in thinner sections. In contrast, LLDPE’s flexibility helps distribute mechanical stresses more evenly, producing parts that are more resistant to impact and wear. This durability is essential for producing resilient parts that can withstand handling, manipulation, or testing without deforming or breaking.

In conclusion, LLDPE emerged as the most suitable resin for the IoT-enabled injection moulding learning kit due to its flexibility, lower energy requirements, reduced cycle time, and high-quality finish. This choice not only enhances the learning experience by reducing the margin for errors but also offers insights into sustainable and efficient production practices.

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4.2.4 RESULT AND ANALYSIS OF MELTING TIME

The melting time for both LLDPE (Linear Low-Density Polyethylene) and HD Virgin (High-Density Polypropylene) was measured using three heating bands, each with a temperature setting based on the specific material type. For LLDPE, the heating bands were set at a target temperature of around 200°C, while for HD Virgin Polypropylene, the bands were set at 220°C, in line with the typical processing temperatures for each resin. The melting time was monitored from the moment the material was loaded into the mould until it reached the desired viscosity for injection.

- **LLDPE:** The melting time for LLDPE was approximately 3-4 minutes, which was quicker compared to HD Virgin Polypropylene.
- **HD Virgin Polypropylene:** The melting time for HD Virgin Polypropylene was observed to be around 5-6 minutes, taking longer due to the higher melting point and increased viscosity.

The differences in melting time between LLDPE and HD Virgin Polypropylene can be attributed to their respective thermal properties, which directly affect the heating process. LLDPE, with its lower melting point and enhanced flowability, required less time to reach the desired molten state. This characteristic made LLDPE more energy-efficient during the heating phase, as the material melted faster and required less heat input from the heating bands. The shorter melting time also contributed to a reduction in overall cycle time, improving process efficiency and throughput.

On the other hand, HD Virgin Polypropylene has a higher melting point and more rigid molecular structure, which meant it took longer to reach the required viscosity for injection. The higher viscosity of HD Virgin Polypropylene also resulted in higher resistance to flow, demanding more energy input and a longer period to achieve uniform melting across the material.

The use of three heating bands helped to distribute heat evenly across the material, preventing localized overheating or insufficient melting. Each heating band was strategically set to provide consistent temperature control, ensuring that both resins reached their optimal melting state without creating hot spots or inconsistent flow, which could lead to defects in the moulded parts.

The longer melting time for HD Virgin Polypropylene also suggests that it requires a more carefully controlled heating cycle to avoid energy waste or overheating, whereas LLDPE's faster melting rate indicates a more forgiving process that can be more easily adapted to different operational conditions.

Overall, the shorter melting time of LLDPE is a significant advantage for processes that prioritize speed and energy efficiency, while HD Virgin Polypropylene, although requiring more time and energy to melt, offers greater strength and rigidity for parts that require higher mechanical properties. Future work may involve refining the heating bands' temperature settings and profiles to further optimize the melting time and energy consumption for different materials, ensuring a balance between cycle time and product quality.

4.2.5 RESULT AND ANALYSIS OF CLAMPING UNIT

In the IoT-enabled injection moulding learning kit, a linear actuator was employed as the clamping unit, which provided the necessary force to hold the mould halves together during the injection process. The actuator used in the system has a speed of 70 mm/s, a stroke length of 100 mm, and a maximum load capacity of 150 N. The actuator was responsible for applying the clamping force to ensure that the mould remained tightly closed during injection, preventing mould separation and ensuring the moulded part's quality.

- **Speed:** The linear actuator moved at a speed of 70 mm/s, allowing for precise control over the clamping movement and minimizing cycle time.
- **Stroke:** The stroke length of 100 mm was sufficient to provide the necessary movement to fully engage the mould and ensure it remained closed during injection.
- **Maximum Load:** The actuator could exert a maximum force of 150 N, which was adequate to apply the necessary clamping force for smaller to medium-sized moulds used in this kit.

The linear actuator's speed of 70 mm/s allowed for quick, yet controlled, clamping actions. This speed is well-suited for educational or low-scale production environments, where cycle times are critical but precision is still necessary. The actuator’s speed enabled the mould halves to close efficiently, minimizing delays and optimizing cycle time while still allowing for accurate mould engagement.

The stroke length of 100 mm was adequate for most injection moulding scenarios within the learning kit’s scope, ensuring that the actuator could fully engage the mould and maintain proper closure throughout the injection process. While this stroke length may be limited for larger moulds, it was appropriate for the smaller moulds used in the kit, providing sufficient movement for proper clamping and material injection.

The maximum load capacity of 150 N provided a sufficient clamping force for the moulds tested in the kit. For smaller and medium-sized moulds, this load was effective in preventing mould separation during injection, ensuring consistent part quality. However, for larger moulds or materials requiring higher pressures, a more powerful actuator with a higher load capacity might be necessary. In this case, the linear actuator's 150 N capacity was an ideal match for the kit's scale and educational purpose, ensuring the clamping unit functioned reliably without overloading or underperforming.

In terms of energy efficiency, the linear actuator was able to provide the necessary force with a relatively low power input, making it suitable for an IoT-based system where monitoring and optimization of energy consumption are crucial. Additionally, the actuator’s performance could be further fine-tuned through the IoT-based control system, which could adjust speed and load requirements based on real-time data, further optimizing the clamping process and ensuring minimal energy consumption.

Overall, the linear actuator's specifications made it a suitable choice for the IoT-enabled injection moulding learning kit. Its speed, stroke length, and load capacity provided reliable and efficient clamping force, ensuring that the mould stayed securely closed during the injection phase. For future upgrades or scaling, the actuator's performance could be improved by incorporating higher-speed actuators or those capable of handling greater load capacities, especially when working with larger moulds or more demanding materials.

4.3 BODY AND FRAME FABRICATION

The body and frame of an injection moulding system serve as the foundational structure that supports all mechanical components and ensures stability during operation. In this final year project, the fabrication of the body and frame was designed to provide robust support while maintaining durability and efficiency in the moulding process. The materials selected for this fabrication are critical to achieving a balance between strength, weight, cost-effectiveness, and resistance to environmental factors.

Mild steel was chosen as the primary material for the frame due to its excellent mechanical properties, including high tensile strength, machinability, and ease of welding. Mild steel offers a solid, cost-effective option for creating a stable and durable frame that can withstand the forces generated during the injection moulding process. Additionally, galvanised iron pipes were selected for specific parts of the frame where increased resistance to corrosion is required. Galvanisation provides an added layer of protection against rust, ensuring the longevity of the frame when exposed to moisture or other harsh conditions.

The combination of mild steel and galvanised iron pipe offers a strong, durable structure that meets the physical demands of the system while ensuring a long lifespan with minimal maintenance. The frame's design was carefully considered to support the actuator, heating elements, and other components, providing a secure foundation for smooth operation.

4.3.1 BODY FABRICATION

In a dedicated effort the figure to ensure the successful and smooth advancement of the IoT Developed Injection Moulding Learning Kit's body fabrication process, a systematic introduction of well-thought-out processes has been undertaken, with the core objective of ensuring that each element of the body construction process operates in an organized and efficient manner, ultimately leading to the successful completion of the project. This comprehensive approach initiates from the project's inception, encompassing meticulous planning, thoughtful material selection, precise cutting and shaping operations, and, finally, the application of finishing touches.

4.3.2 FRAME FABRICATION

The design of the frame was meticulously planned to ensure that it provided adequate support to the entire system while maintaining ease of assembly and access for maintenance. Materials were selected based on their strength, durability, and resistance to wear and corrosion. Mild steel was chosen as the primary material due to its excellent mechanical properties, such as high tensile strength, toughness, and ability to be easily welded. Mild steel is cost-effective and ideal for the heavy-duty requirements of the frame. Galvanized iron pipes were used for certain sections of the frame where additional resistance to corrosion was required, such as parts exposed to moisture or heat, providing long-lasting protection against rust and environmental wear.

The fabrication process involved a series of steps, each executed with precision to ensure the accuracy and quality of the frame. The process began with cutting raw material into the desired shapes and sizes using saws or plasma cutters. Once the parts were cut to size, machining was performed to refine and finish each component. For example, milling was used to create flat surfaces, while turning was employed for cylindrical shapes. Threading was applied to sections where bolts and screws would be used to secure components, ensuring a tight fit and reliable assembly.

In some areas of the frame, grinding was used to smooth rough edges or surfaces, ensuring there were no sharp points that could pose safety risks or affect the machine's performance. After the individual parts were fabricated, welding was employed to join them together, forming a strong and stable structure. Sculpting was used for any custom shapes or modifications needed for unique design requirements.

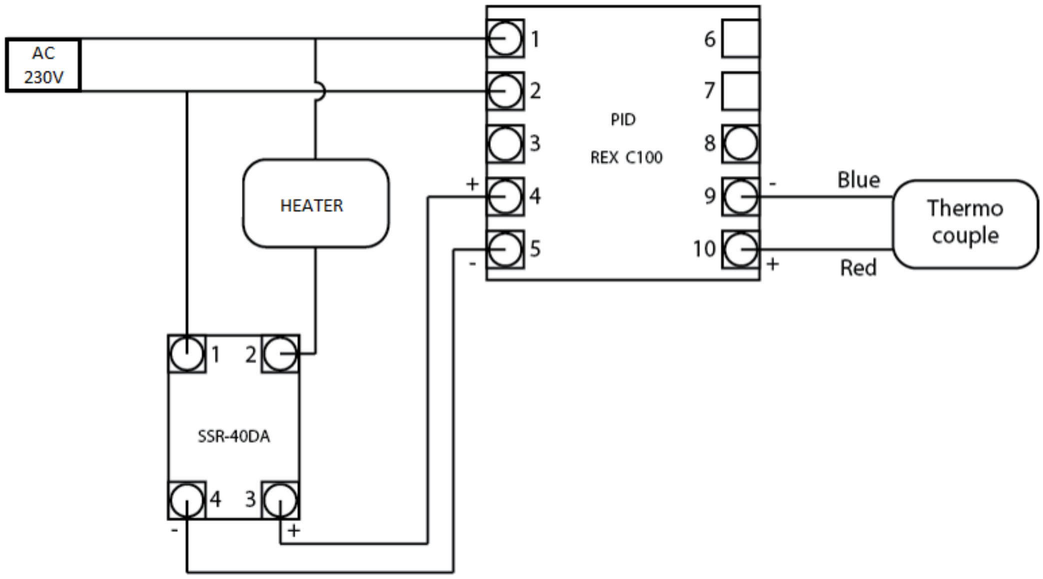
Once all parts were fabricated, the assembly process began. Each component was carefully placed and secured to form the final frame. Precision in alignment and fit was crucial to ensure that the frame was sturdy and stable during operation, as even small errors in assembly could affect the overall functionality of the moulding kit.

The assembled frame was then subjected to strict quality control measures. This included visual inspections, dimensional checks, and load tests to ensure that the frame met the required standards for strength and durability. The frame's ability to withstand mechanical stresses, vibrations, and thermal conditions was thoroughly tested to confirm its resilience under typical operational conditions. Any defects or weaknesses identified during this process were corrected to ensure the final product would perform reliably over its intended lifespan.

The final result was a robust, sturdy, and functional frame that supported the entire moulding system. Its design ensures that the components are securely mounted, reducing vibrations and movements during the moulding process. The mild steel provides a strong backbone for the frame, while the galvanized iron pipes add resistance to corrosion, making the frame ideal for long-term use in a variety of environments.

In conclusion, the fabrication of the body and frame of the IoT-developed Injection Moulding Learning Kit was a detailed and precise process, ensuring that the final frame is not only practical and sturdy but also long-lasting. The use of appropriate materials and manufacturing techniques contributed to the overall performance and reliability of the system, ensuring that the kit functions efficiently and effectively throughout its lifecycle.

4.4 WIRING DIAGRAM OF PID, THERMOCOUPLE K TYPE, SOLID STATE RELAY AND HEATING ELEMENTS



In the IoT-enabled injection moulding learning kit, the wiring diagram shows a well-coordinated setup for controlling the heater using a PID controller (REX C100), a solid-state relay (SSR-40DA), and a thermocouple. The system is powered by an AC 230V source, which supplies the necessary voltage to generate the heat required for the moulding process. One line from the AC power source connects directly to the heater, while the other line goes through the SSR before reaching the heater. This arrangement allows the SSR to act as a switch, controlling the power flow to the heater based on signals from the PID controller.

The heater itself is connected in series with the SSR and the AC power supply, receiving power when the SSR is activated. The SSR (Solid State Relay) is crucial for regulating the power supplied to the heater based on the PID controller's signals. Pins 1 and 2 of the SSR are connected to the AC power lines: Pin 1 connects to the incoming AC line, while Pin 2 links to the heater, enabling the SSR to control the heater by opening or closing the AC circuit. Pins 3 and 4 of the SSR are connected to the PID controller’s output terminals, with the positive terminal (+) of the PID controller connected to Pin 3 and the negative terminal (-) to Pin 4 of the SSR. When the PID controller sends a signal to these terminals, it activates the SSR, allowing AC current to flow through Pins 1 and 2 to power the heater.

The PID controller serves as the control centre of this temperature management system. It monitors the actual temperature feedback from the thermocouple and adjusts the heater’s power through the SSR to maintain the desired temperature. The PID’s Pins 4 and 5 connect to the SSR (Pins 3 and 4), which sends the control signals needed to regulate the heater based on the temperature feedback. The thermocouple, connected to Pins 9 and 10 on the PID controller, provides real-time temperature readings, with its blue wire connected to the negative terminal (Pin 9) and the red wire to the positive terminal (Pin 10). This temperature feedback allows the PID controller to monitor and adjust its output to keep the temperature stable at the desired setpoint.

The system works as follows: the PID controller reads the thermocouple's temperature data, compares it to the target temperature, and, if the temperature is below the setpoint, sends a signal to the SSR to complete the AC circuit, thus powering the heater. As the heater operates, the temperature rises until it reaches the desired level, at which point the PID controller reduces or stops the signal to the SSR, cutting off power to the heater. This cycle of continuous monitoring and adjustment ensures a stable and consistent temperature, which is essential for effective injection moulding.

Overall, this setup is essential for maintaining precise temperature control in the moulding process. The combination of the PID controller, SSR, and thermocouple creates a controlled environment where temperature can be monitored, logged, and adjusted in real time, enhancing both learning and practical application in the IoT-enabled injection moulding system. This reliable temperature regulation is critical in achieving consistent material flow, proper mould filling, and high-quality end products, making it an invaluable part of the learning kit.

4.5 LIMITATION AND SOLUTION

In the development of the IoT-enabled injection moulding learning kit, several limitations were identified that impacted its performance, efficiency, and overall feasibility. One major limitation was the requirement for additional heating in the core of the mold. The existing heating setup proved insufficient for evenly heating the entire mold, particularly in the core, which led to issues like inconsistent material flow and incomplete filling. This pointed to the need for a more advanced heating system capable of maintaining uniform temperature across the mold, especially in the core area, to ensure high-quality moulding results.

The design of the nozzle was also a challenge. The initial nozzle shape did not optimize the flow of molten material into the mold cavity, resulting in uneven filling and restricted flow. It became clear that adjustments to the nozzle's shape and size were needed to enhance flow dynamics and reduce backpressure, allowing for smoother and more efficient injection of plastic into the mold.

Power and torque limitations in the current drive system posed further challenges. A timing belt system was identified as a potential improvement, as it could provide better power transfer efficiency and enhanced torque. By implementing a timing belt, the system would achieve more precise and synchronized motion, making it better equipped to handle the mechanical load required during injection. This adjustment would reduce slippage, improve durability, and ensure reliable performance throughout the moulding cycle.

Additionally, the motor used in the initial design lacked the power needed for the injection phase, where significant force is essential to fill the mold cavity properly. Upgrading to a higher-powered motor became necessary to improve the system's capability, enabling faster cycle times and ensuring consistent material flow. This modification would address the limitations in torque and speed, making the entire moulding process more efficient.

Cost was another significant limitation, as the addition of a core heating source, redesigned nozzle, timing belt system, and a more powerful motor would increase the project's expenses. Budget constraints restricted the scope of these enhancements, requiring careful consideration of which upgrades would offer the most value. Each potential improvement needed to be evaluated against its impact on the overall project budget, limiting the extent to which performance enhancements could be implemented without overshooting costs.

Finally, time constraints also emerged as a significant factor. Developing and testing each improvement required additional time, and balancing these refinements with the project's deadlines was challenging. Implementing and optimizing changes, particularly in design, testing, and adjustments, needed to be done within a limited timeframe, which constrained the depth and thoroughness of each modification.

In summary, these limitations including the need for core heating, nozzle redesign, enhanced drive system, motor upgrade, budget constraints, and time limitations highlighted areas for further development. Addressing these issues would lead to a more effective and reliable injection moulding learning kit, but they also underscored the trade-offs between performance improvements, cost, and project timelines.

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1 RECOMMENDATIONS FOR FUTURE UPGRADES

For future upgrades to the IoT-enabled injection moulding learning kit, several improvements could significantly enhance its safety, efficiency, and overall functionality. One key recommendation is the incorporation of an ejector pin mechanism in the clamping unit. This addition would allow for automatic removal of moulded parts from the cavity, eliminating the need for manual part removal, which can be time-consuming and may lead to damage of the mold or product. A well-designed ejector pin would ensure smooth and consistent part release, contributing to better cycle times and product quality.

Another suggested upgrade is the integration of a Programmable Logic Controller (PLC) to synchronize the system's sequence of operations. By controlling the timing and order of each phase such as injection, clamping, and ejection a PLC would enhance the precision and automation of the moulding process. This synchronization would improve the system's efficiency, reduce timing errors, and enable more complex moulding cycles, making the kit more versatile for various learning and operational scenarios.

In addition, the use of a fiber blanket as a heat insulator around the injection unit would address issues related to heat retention. By trapping heat, the fiber blanket would reduce energy loss and help maintain a stable temperature in the injection unit. This insulation would also decrease the power requirements for the heating elements, enhancing energy efficiency and extending the lifespan of heating components by reducing strain on them.

Finally, adding a safety cover around the machine would improve user protection during operation. A cover would shield users from hazards such as high temperatures, moving parts, and unexpected part ejections, which is particularly beneficial in an educational environment where users may lack extensive experience with such machinery. The safety cover would reduce the risk of accidents, making the learning kit safer for both students and instructors.

In summary, these recommended upgrades including the ejector pin, PLC synchronization, fiber blanket insulation, and safety cover would improve the learning kit's functionality, safety, and energy efficiency. Implementing these modifications would result in a more robust, user-friendly system that is well-suited for complex educational and practical applications in injection moulding.

5.2 DISSCUSION AND CONCLUSION

DISSCUSION

The development and testing of the IoT-enabled injection moulding learning kit have highlighted key areas of improvement, as well as insights into the system's current strengths and limitations. Throughout the project, a variety of components were optimized, including the motor RPM, torque, heating elements, and clamping unit, each playing a critical role in ensuring consistent, efficient moulding operations. Motor performance, for instance, was optimized by monitoring RPM and torque across different stages of the moulding cycle. Higher RPMs were necessary for efficient material injection, while lower RPMs and torque were maintained during the holding and cooling phases to ensure stability. However, limitations were observed in the system's power and heating distribution, indicating the need for a more robust motor and additional core heating.

Material selection was another important aspect, particularly in the use of high-density virgin polypropylene (HDPE) and linear low-density polyethylene (LLDPE). Testing both resins allowed for an informed comparison of their melting properties, mold flow, and overall compatibility with the injection moulding process. LLDPE emerged as the more suitable material due to its lower melting point and easier flow characteristics, which provided better consistency in moulding and reduced energy consumption. Nevertheless, the exploration of additional materials could further enhance the system's versatility.

The clamping unit's functionality and efficiency were also essential to the system's operation. Although the chosen linear actuator was effective in basic applications, higher power and torque requirements pointed to the need for a stronger actuator and possibly a timing belt system for increased torque transmission. Furthermore, the testing revealed the importance of precise heating control, as insufficient heat retention in the mold core led to incomplete mold fills. Introducing fiber blanket insulation would reduce heat loss, while adjusting heating elements or adding core heating could ensure a uniform temperature throughout the mold.

Future recommendations, such as incorporating a PLC for automated sequence control, are aimed at enhancing both precision and automation. A PLC would enable more synchronized operations, reducing the potential for timing issues and improving overall efficiency. Other recommendations, like the addition of an ejector pin system and a safety cover, address usability and safety. The ejector pin would simplify part removal, while the safety cover would reduce risks during operation, making the learning kit more suitable for educational environments. Together, these upgrades would make the system more versatile, robust, and user-friendly.

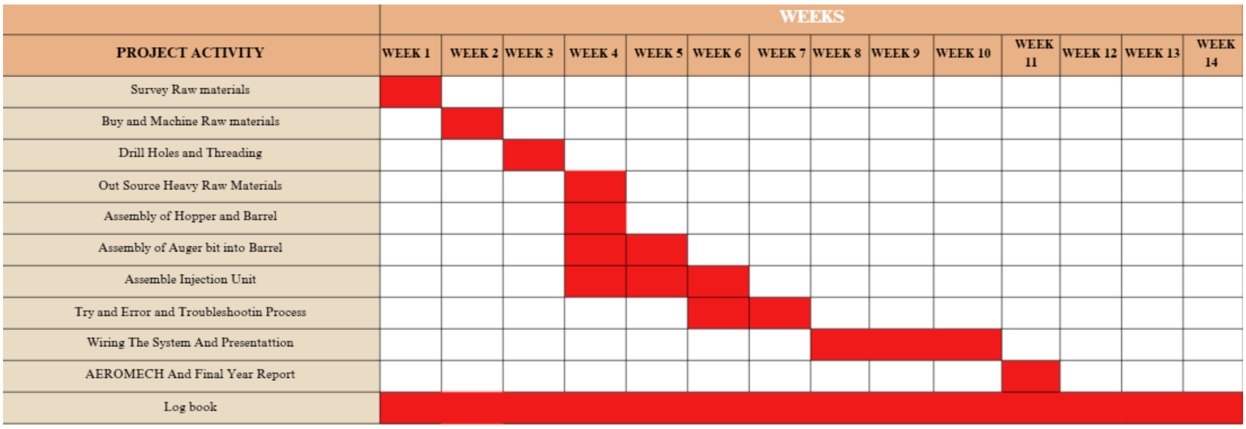
CONCLUSION

In conclusion, the IoT-enabled injection moulding learning kit has proven to be a valuable educational tool, providing hands-on experience with essential concepts in injection moulding, IoT integration, and system automation. The project successfully met many objectives, including effective temperature control, material testing, and basic automation of the injection moulding process. However, several limitations were identified, such as insufficient core heating, motor power limitations, and challenges in maintaining consistent material flow. These issues underscore the need for further enhancements, including a more powerful motor, a timing belt system, additional insulation, and an optimized heating system.

The insights gained from testing both HDPE and LLDPE highlighted LLDPE’s suitability due to its ease of moulding and energy efficiency. Future improvements could expand the kit’s material options, enhancing its educational value. Furthermore, integrating a PLC, ejector pin system, and safety cover would significantly improve safety, functionality, and usability. These recommendations not only address current limitations but also open avenues for advanced control and automation, positioning the learning kit as a more comprehensive and reliable teaching tool.

Overall, this project has laid a strong foundation for a versatile, efficient, and safe injection moulding learning kit. With targeted upgrades, the system has the potential to become an even more effective resource for students and professionals to learn the fundamentals of injection moulding technology, IoT applications, and industrial automation.

5.3 GANTT CHART



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