

Tool Design for Assembly and Disassembly of Mold for Injection Molding Maintenance and Service

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Abstract

The maintenance of injection molding dies is a critical process in ensuring the longevity and efficiency of the molding process. However, the current methods of assembling and disassembling molds, particularly in the maintenance department, pose significant challenges, including safety risks and inefficiencies. This study aims to design and analyze a specialized tool for the assembly and disassembly of injection molding dies, focusing on improving safety and efficiency. The tool is designed using SolidWorks software, and its structural integrity is evaluated using Finite Element Analysis (FEA). Three designs were conceptualized, inspired by hydraulic lifters and hydraulic engine cranes. The results indicate that Design 1, with stress levels ranging from 28.76 MPa to 38.36 MPa under varying loads, is the most stable and reliable, while Design 2 is unsuitable due to its high stress levels and deformation. Design 3 offers a balance between flexibility and rigidity, making it suitable for specific applications. The study concludes that the developed tool can significantly enhance mold maintenance practices, ensuring safety and efficiency in the workplace.

1. Introduction

Injection molding is a widely used manufacturing process for producing plastic parts. The molds used in this process are subjected to high temperatures and pressures, necessitating regular maintenance to ensure consistent product quality and extend the mold's lifespan. However, the assembly and disassembly of molds during maintenance are often labor-intensive and pose significant safety risks, particularly when workers resort to manual handling due to a lack of adequate tools. Injection molding involves injecting molten plastic into a mold cavity, where it cools and solidifies to form the desired shape. The process is highly efficient for mass production but requires precise mold maintenance to ensure consistent quality [1]. Maintenance of injection molds involves regular cleaning, inspection, and repair. However, the disassembly and reassembly of molds are often hindered by the lack of appropriate tools, leading to delays and safety risks. Workers frequently resort to manual handling, which can result in injuries such as back strain and slipped discs [2]. Hydraulic lifters and engine cranes are commonly used in industrial settings for lifting heavy loads. These tools

offer precision and stability, making them suitable for handling heavy molds. This study draws inspiration from these hydraulic systems to design a tool specifically for mold maintenance [3].

This study addresses the challenges faced by maintenance workers in the mold die maintenance department, where the limited availability of chain blocks forces workers to manually lift heavy molds, leading to potential injuries and long-term health issues. The primary objective of this research is to design a tool that facilitates the safe and efficient assembly and disassembly of molds, reducing the physical strain on workers and improving overall productivity.

2. Methodology

The project framework is structured around a clear and systematic methodology, represented by a flowchart to guide the research process, as shown in Figure 1. The design of the tool is inspired by hydraulic lifters and engine cranes, which are known for their ability to handle heavy loads with ease and precision. Using SolidWorks software, the tool is designed in three different versions, each tailored to address specific challenges faced during mold assembly and disassembly. Once the designs are finalized and to evaluate the tool's strength and reliability, Finite Element Analysis (FEA) is conducted. This simulation process helps identify potential failure points by analyzing how the tool behaves under different loads, ensuring it can withstand the stresses encountered during mold maintenance. The results from the FEA are used to refine the design, making it safer and more efficient for workers.

In addition to the technical design and testing, this project incorporates a survey to gather firsthand feedback from workers involved in mold assembly and disassembly. The survey, titled "Survey on Mold Maintenance for Injection Molding" aims to understand the challenges workers face, the tools they currently use, and their suggestions for improvement. By combining technical analysis with real-world worker experiences, this project ensures that the final tool design not only meets engineering standards but also addresses the practical needs of maintenance staff.

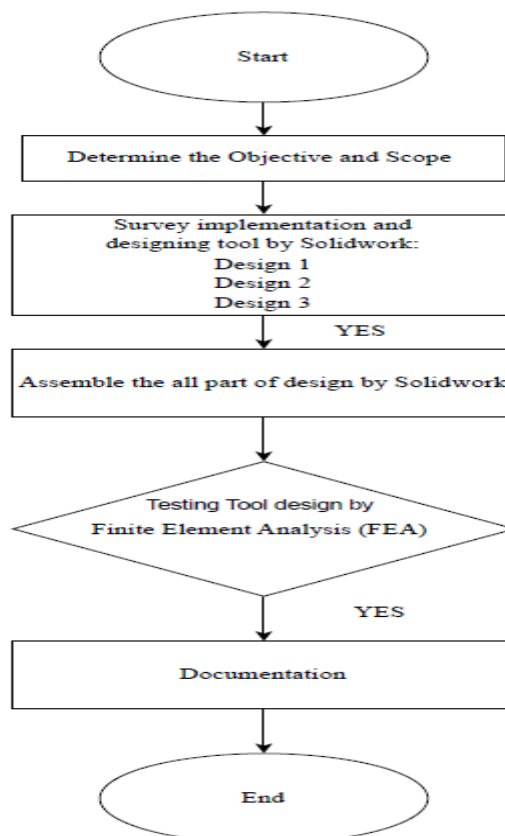
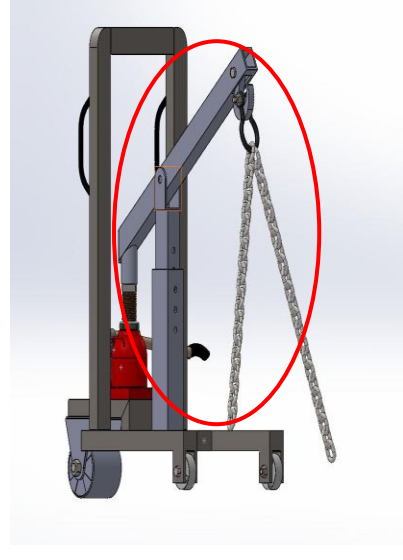
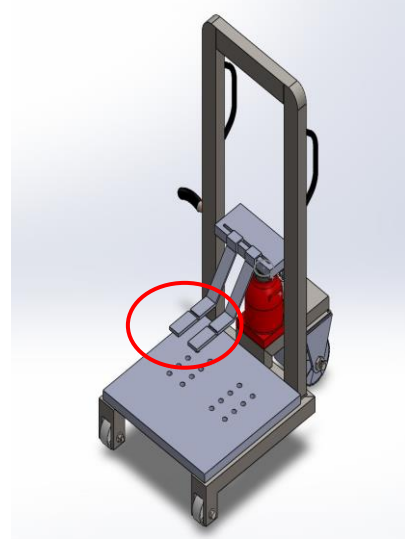
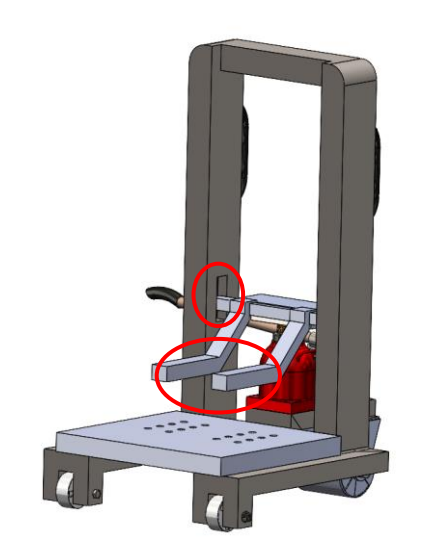


Fig. 1: Flowchart of Methodology

2.1 Design Concept

Three designs were conceptualized using SolidWorks software, inspired by hydraulic lifters and engine cranes. The designs were evaluated based on their structural integrity, ease of use, and safety features. Table 1 below shows the design stage of tool.

Table 1: Type of Design Tools

Design 1	Design 2	Design 3
		
<p>Inspired by a hydraulic engine crane, this design features a stable base, an extendable arm, and a hydraulic lifting system. The design aims to provide smooth and controlled movements, making it suitable for handling heavy molds.</p>	<p>Based on a hydraulic lifter, this design uses a hydraulic system to lift molds vertically. The design is small and works well in tight spaces. The blade has slots that make it easy to attach eye bolts, allowing molds to be lifted easily.</p>	<p>A simplified version of Design 2, this design focuses on the blade component. The slot from design 2 was removed, and the blade was made thicker. A new slot was added on the sides of the body to strengthen it for lifting and lowering the mold, making it easier to produce and maintain.</p>

2.2 Finite Element Analysis (FEA)

Finite Element Analysis (FEA) was used to evaluate the structural integrity of the tool designs. The analysis involved applying varying loads (500 N, 1000 N, 1500 N, and 2000 N) based on the actual weight of molds used in production, representing light to medium loads. The process started by selecting suitable materials and setting key properties like stiffness and strength. The design shapes were simplified to speed up the calculations. The mesh was carefully adjusted, with finer parts placed where stress was expected to be higher. Supports and fixtures were added to mimic real-world conditions, and loads were applied correctly. The goal was to identify the design that could withstand the applied loads without failure [4].

2.2 Survey on Mold Assembly and Disassembly: Worker Experiences and Recommendations

Mold assembly and disassembly are key parts of maintaining molds used in injection molding. However, this process can be tough for workers, especially when handling heavy molds. Often, there

are not enough tools like chain blocks to help separate mold parts safely. Because of this, workers sometimes have to lift molds by hand, which can slow down work and lead to injuries like back pain or hand strain. Over time, this can also cause serious health problems. This survey is designed to learn about experiences with mold assembly and disassembly and want to hear about the challenges faced and any ideas to make the process easier and safer. The feedback will help to create better tools and methods to improve the way molds are maintained.

3. Results and Discussion

The results of the FEA analysis are presented and discussed in this section. The stress and displacement levels for each design are compared, and the most suitable design is identified.

3.1 Stress Analysis

The stress analysis showed clear differences in how the three tool designs performed under different loads as shown in Figure 2. Design 1 had the best results, with stress levels ranging from 28.76 MPa to 38.36 MPa across all tested loads (500 N, 1000 N, 1500 N, and 2000 N). These values are much lower than the material's yield strength of 206.81 MPa, meaning Design 1 is strong and safe to use for mold maintenance. It can handle heavy loads without breaking, making it a reliable choice [5]. On the other hand, Design 2 did not perform well. Even under a light load of 500 N, it had a stress level of 738.09 MPa, which is much higher than the material's limit. This means Design 2 would likely fail under normal use, making it unsafe and impractical for mold maintenance tasks. Its high stress levels suggest it has structural weaknesses that could lead to tool failure, putting workers and molds at risk [6].

Design 3 performed better than Design 2 but not as well as Design 1. Its stress levels ranged from 30.30 MPa to 121.18 MPa under the tested loads. While these values are still within the safe range, they are higher than Design 1, meaning Design 3 is less durable under heavy or prolonged use. However, Design 3 could still be useful in situations where some flexibility is needed, such as when working with misaligned molds [7]. The stress analysis results are summarized in Table 2, which compares the stress levels of all three designs under different loads. This table clearly shows that Design 1 is the best option, as it consistently handles stress well and is safe for mold maintenance tasks. Design 2 is not suitable due to its high stress levels, and Design 3, while usable, is not as strong as Design 1.

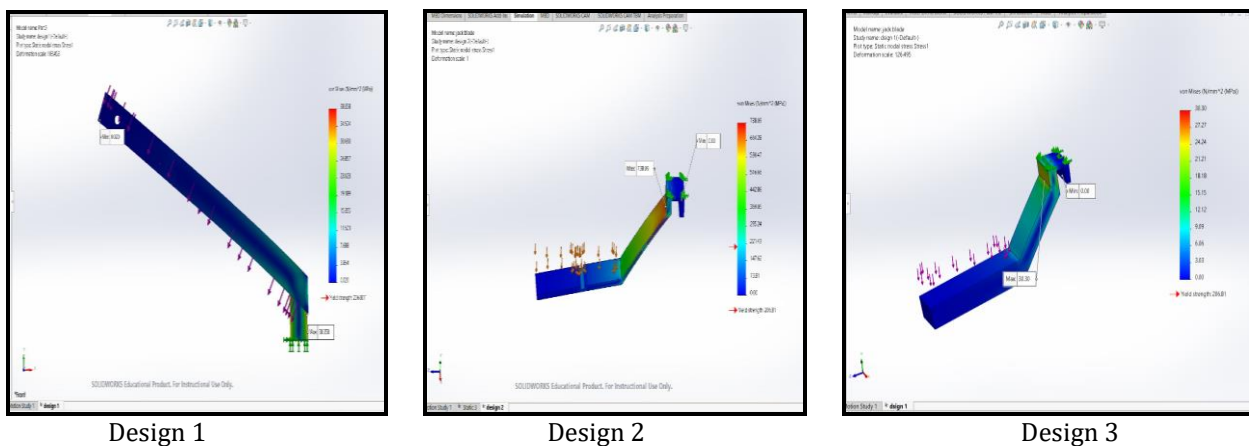


Fig. 2: The FEA of Stress for Design1, Design 2, and Design 3

Table 2: Stress Analysis

Load (N)	Stress (MPa) Design 1	Stress (MPa) Design 2	Stress (MPa) Design 3
500	28.77	738.09	30.30
1000	28.77	-	60.59
1500	28.76	-	90.89
2000	38.36	-	121.18

3.2 Displacement Analysis

The displacement analysis showed how the three tool designs performed under different loads, focusing on how much they bent or moved as shown in Figure 3. Design 1 had the best results, with a constant displacement of 0.64 mm across all loads (500 N, 1000 N, 1500 N, and 2000 N). This means Design 1 is very stiff and does not bend much under pressure, making it stable and reliable for mold maintenance tasks. Its low displacement ensures it can handle heavy molds safely and accurately [8]. On the other hand, Design 2 performed poorly. It had a displacement of 39.26 mm under all loads, which is very high. This means Design 2 is too flexible and bends too much, making it unsuitable for handling heavy molds. Such high displacement could cause misalignment during mold assembly or disassembly, increasing the risk of damaging the molds or injuring workers. As a result, Design 2 is not practical for mold maintenance [9].

Design 3 showed better results than Design 2 but not as good as Design 1. Its displacement increased gradually from 0.31 mm at 500 N to 1.25 mm at 2000 N. While this means it has some flexibility, the displacement is still within acceptable limits. Design 3 could be useful for tasks where a bit of flexibility is needed, such as working with slightly misaligned molds. However, it is not as stiff as Design 1, so it may not be the best choice for very heavy or precise tasks [10]. The results of the displacement analysis are summarized in Table 3, which compares the displacement levels of all three designs under different loads. This table clearly shows that Design 1 is the best option because it stays stiff and stable under pressure. Design 2 is too flexible and not suitable for use, while Design 3 offers a middle ground but is not as strong as Design 1.

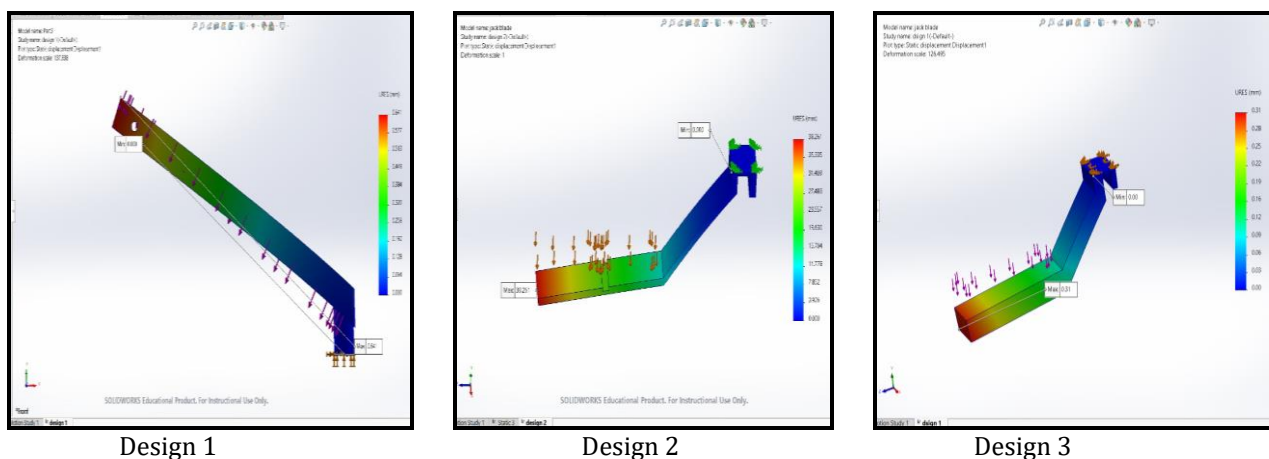


Fig. 3: The FEA of Displacements for Design1, Design 2, and Design 3

Table 3: Displacement Analysis

Load (N)	Displacement (mm) Design 1	Displacement (mm) Design 2	Displacement (mm) Design 3
500	0.64	39.26	0.31
1000	0.64	39.26	0.62
1500	0.64	39.26	0.93
2000	0.64	39.26	1.25

3.3 Survey Results: Mold Maintenance for Injection Molding

Table 4: Survey Result by Respondent

Category	Subcategory	Responses	Percentage
Gender	Male	7	100%
	Female	0	0%
Age	18-25	5	71.4%
	25-35	2	28.6%
	35-45	0	0%
	45-55	0	0%
Position	Technician	3	42.9%
	Maintenance	1	14.3%
	Operator	3	42.9%
Years of Experience	Less than 1 year	6	85.7%
	1-3 years	1	14.3%
	4-6 years	0	0%
	More than 6 years	0	0%
Type of Company/Industry	Automotive	4	57.1%
	Electronics	1	14.3%
	Consumer Products	1	14.3%
	Swasta (Private)	1	14.3%
Types of Molds Worked On	Plastic Injection Molding	7	100%
	Blow Molding	0	0%
	Rotational Molding	0	0%
Issues with Tools	Yes	5	71.4%
	No	2	28.6%
Encountered Stuck/Seized Components	Yes	7	100%
	No	0	0%
Average Time for Disassembly/Reassembly	Less than 1 hour	1	14.3%
	1-3 hours	1	14.3%
	4-6 hours	5	71.4%
	More than 6 hours	0	0%
Good Skill for Maintenance	Yes	2	28.6%

Safety Importance	No	5	71.4%
	Yes	7	100%
Use of Spinal Support Device	No	0	0%
	Yes	3	42.9%
	No	4	57.1%

Table 4 shows a survey looked into mold maintenance needs and procedures in injection molding. Most respondents were male, aged 18-25 (71.4%), and 85.7% had less than a year of experience. Many worked as technicians or operators, mainly in the automotive industry (57.1%), followed by electronics and consumer products. The main problem in mold maintenance was the lack of reliable tools, with 71.4% reporting tool-related issues that made the work harder. Every respondent faced stuck or jammed mold parts, creating major challenges. Maintenance tasks like taking molds apart and putting them back together took 4-6 hours for 71.4% of participants, showing time inefficiencies.

Safety was a big concern for all (100%), though only 42.9% had access to spinal support devices. Most felt their skills were not good enough for proper maintenance, likely due to limited experience. Suggested improvements included easier-to-use tools (42.9%), lifting devices (14.3%), and magnifying glasses to inspect small parts (14.3%). These ideas showed a need for better tools and safer, faster maintenance processes.

3.4 Discussion

Based on the results, Design 1 is the best tool for mold maintenance tasks. It performs well because it has low stress levels, ranging from 28.76 MPa to 38.36 MPa under different loads, which are much lower than the material's limit of 206.81 MPa. This means Design 1 can handle heavy loads without breaking, making it safe and durable. It also has low displacement levels, staying at 0.64 mm across all loads, which shows it is very stiff and doesn't bend much under pressure. This stiffness is important because it keeps the tool stable and precise during mold assembly and disassembly, ensuring safety and efficiency [5, 8]. Design 3 is less stiff than Design 1 but could still be useful in some cases. Its displacement increases from 0.31 mm at 500 N to 1.25 mm at 2000 N, meaning it has some flexibility. This could be helpful for tasks like working with misaligned molds, where a bit of bending is needed. Its stress levels, ranging from 30.30 MPa to 121.18 MPa, are still safe, so it can be used for lighter tasks. However, it was not as strong or stable as Design 1, so it was not the best choice for heavy or precise work [7, 10].

On the other hand, Design 2 is not suitable for mold maintenance. It has very high stress levels, reaching 738.09 MPa under just 500 N, which is way above the material's limit. This means it could easily break under normal use. It also has a high displacement of 39.26 mm under all loads, meaning it bends too much. This makes it unstable and unsafe for handling heavy molds, as it could cause misalignment or accidents. Because of these issues, Design 2 is not a practical option for mold maintenance [6, 9].

4. Conclusion

This study successfully created a reliable tool for injection mold maintenance, with Design 1 proving to be the best option. Its strong performance, with low stress levels (between 28.76 MPa and 38.36 MPa) and very little bending (only 0.64 mm under all loads), shows it can handle heavy molds safely and effectively. Design 1 is a major improvement for mold maintenance because it reduces physical strain on workers, lowers the risk of injuries like back pain or hand strain, and increases productivity. By providing a stable and precise tool for mold assembly and disassembly, Design 1 solves many of the problems workers face, making their jobs safer and more efficient. In the future, there are opportunities to make the tool even better by using stronger, lighter materials and adding automation features. For example, lighter materials could make the tool easier to handle without losing strength, and automated lifting systems could reduce the need for manual effort and improve accuracy. These

improvements would make the tool more advanced and align with the growing trend of creating smarter, more worker-friendly solutions.

In summary, Design 1 is a big step forward in mold maintenance technology. It improves worker safety, reduces physical strain, and boosts productivity, making it a valuable tool for the industry. Future work on better materials and automation could make it even more effective, helping workers and making mold maintenance faster and easier.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Muhammad NurFaiz Supiyanto, Haffidzudin Hehsan; **data collection:** Muhammad NurFaiz Supiyanto; **analysis and interpretation of results:** Muhammad NurFaiz Supiyanto, Haffidzudin Hehsan; **draft manuscript preparation:** Muhammad NurFaiz Supiyanto, Haffidzudin Hehsan. All authors reviewed the results and approved the final version of the manuscript.*

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