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**DFA-BASED PRACTICES GUIDE FOR POLYMER INJECTION MOLD
ASSEMBLY DESIGN**

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Abstract. *The constant evolution of products has generated more complex design requirements, with more information and aggregated technologies, reduced life cycles, and an increase in market competitiveness, making it increasingly necessary to optimize the entire product design and manufacturing process. One of the aspects to be optimized, primarily, is the assembly of the product, where the project aims to decompose, reduce, standardize, and simplify the stages of assembly, reducing the amount of work, increasing the quality of the product, and, possibly, reducing the number of parts used and standardizing them. In this way, the Design for Manufacturing (DfA) represents the interaction of the product design with the components of the manufacturing system so that they are easy to manufacture. DfA can reduce the number of steps, costs, efforts, and production time, enabling increased quality. This work aims to demonstrate the principles, rules, and design guidelines for assembly applied to polymer injection molds since these tools are usually designed specifically for each part to be produced, generating excessive operations and assembly time. Although each injection mold is unique, there is a design uniformity of its components for most molds, which makes it possible to simplify and optimize assembly. In this work, a set of 12 guidelines based on the usual practices of DfA is presented. Their feasibility of application to the design of molds is evaluated and analyzed through a series of application case studies. These guidelines include solutions such as: minimizing the use of separate fasteners, using an efficient assembly sequence, and avoiding components with characteristics that make identification difficult. As a result, there are possibilities of obtaining simplified, reliable molds with lower costs, eliminating the need to create unnecessary drawings and specifications, reducing the search for suppliers and manufacturing of parts, and obtaining an injection mold with fewer parts that are easier and faster to assemble.*

Keywords: *Design for Assembly, DFA, Injection Mold, Manufacturing.*

1. INTRODUCTION

This work presents the principles, rules, and design recommendations for assembling injection molds. These tools are usually engineered to order, resulting in a wide range of manufacturing and assembly operations, leading to a high assembly planning time depending on the project. The concept of assembly encompasses all joining operations and additional procedures during and after the production of the part. The resources used, and the quality of the process depends on the type and number of operations and the execution of the assembly itself. The quantity and type of assembly operations are directly related to the structure in question, the configuration of the part, and the production method. Guidelines that aim to simplify, unify, automate, and ensure quality represent general criteria for assembly design. Such guidelines depend on the main characteristics of the form-function of the part and other factors, such as working principle, specifications, safety, ergonomics, production, control, transportation, use, maintenance, and recycling [1].

The assembly operations must be decomposed, reduced, standardized, and simplified to design a structure considering assembly. To do so, defining product configuration during the project conception is most appropriate. Design for Assembly (DFA) is related to understanding the interaction of all parts during product design so they are easy to assemble. DFA makes it possible to achieve an assembly with fewer steps and less cost [2].

Although each injection mold project can be considered unique, its structural elements and components do not vary considerably from mold to mold, offering the opportunity for simplification and optimization of assembly in its designs. DFA offers a systematic procedure for analyzing a proposed design from an assembly perspective, resulting in simpler, more reliable, and cheaper-to-assemble products. In addition, reducing the overall number of parts in the assembly process causes a general reduction in product costs, making drawings, specifications, and suppliers unnecessary and reducing inventory [2].

The assembly process embodies an important part of the manufacture of industrial products since it represents around 50 percent of the total manufacturing cost. Considering this, reducing the assembly costs significantly reduces the total product cost [3]. DFA aims to simplify the product to have the fewest parts, making assembly easier and faster. So,

products can be brought to the market more quickly, as they have few parts to design, acquire, inspect, and store, with a lower probability of delay [4]. For the product's end-user, there is the advantage of ensuring products that are available faster and tend to have more affordable prices. In addition, products that arrive on the market more quickly take longer to become obsolete, which is a major attraction for consumers [4].

It is possible to find in the literature current works that address the use of design for manufacturing in the general scope of the industry, as well as in more specific cases, such as architecture and civil construction [5], aerospace industry [6], intermediate goods industry [7], automotive industry [8], consumer goods industry [9] [10], among others. There are also works aimed at formalizing rules for design and manufacturing in a general context, such as creating an "optimal" assembly sequence [11]. However, the motivation behind this work is to develop a guide with general rules for the use of design for manufacturing specifically in the design of injection molds, as these techniques, when applied, bring advantages for both the producer and the consumer.

Upon conducting a deeper literature review, only one article addressing design for assembly within the context of injection mold design [12] was found. However, in the mentioned work, DFA techniques are focused on reducing manufacturing costs through tolerance design, proposing an approach to eliminate tolerance stack-up through block assembly operations. While this work also discusses DFA in the context of injection mold design, it is focused on tolerance design, unlike the guide developed in this article, which aims to create a set of practices that can be utilized throughout the entire injection mold design process.

2. DESIGN FOR ASSEMBLY RULES

Frequently, the benefits of design for assembly fall on simplifying the product so that it has fewer parts and can be assembled more quickly and easily. This is because the highest cost for manufacturing a product depends on its total labor and overhead costs, so if there is a possibility of reducing these items, the benefits will be numerous. Thus, designing a product to facilitate its assembly is advantageous for any company: it facilitates services and recycling; simplifies disassembly for maintenance, repair, or dismantling operations; allows for early market launch by requiring fewer parts to design, acquire, inspect and stock, reducing the risk of delay; among many other benefits [4].

Based on all the advantages presented, it can be concluded that the best way to analyze a product or assembly is by analyzing the overall assembly, offering, in addition to benefits, the certainty of which parts will remain, their function, and how the overall configuration will be. From the analysis of which parts will be kept and their previous form, it is possible to simplify them [4].

Design for assembly should be considered during all phases of the design process, but especially in the early phases. The design team should seek a more simplified assembly when considering possible solutions. For this reason, the team needs a DFA tool to analyze the assembly difficulties of a product. Such a tool should provide solutions quickly, ensure integrity regarding its evaluation, allow comparison of alternative designs, identify possible assembly problems, and suggest alternative approaches, among other solutions, to simplify the product structure and reduce its manufacturing and assembly costs [13].

The assembly process is allocating and fixing one or more parts to others. These operations are usually performed manually, but automation has become popular, especially in the case of large production volumes. During the activities, accessories are usually used to keep parts together or to locate them relative to each other. A large part of the assembly takes place on individual workbenches, and a conveyor may assist in moving parts or assemblies between workstations. Assembly lines in mass production industries have a conveyor that moves an assembly through all the workstations, where certain parts are added at each one [4].

The design for assembly corresponds to the technical-scientific knowledge about one of the main stages of production: assembly, which represents 25 to 50% of the cost and 40 to 60% of the total production time. It can be considered as a philosophy, a process, and a tool for the project [2]:

- As a philosophy, it aims to examine the project from the initial stages, seeking to reduce product costs and improve the transition between its design and final assembly.
- As a process, it seeks to question and analyze the product structure, such as how the parts relate, their number, and the methods of safety and assembly, seeking to simplify or eliminate assembly.
- As a tool, it tries to obtain information to evaluate a project regarding assembly based on aspects such as the total number of parts, the difficulty of manipulation and insertion, and assembly time.

To the authors [2], from DFA there is a direction of the project for the product to have fewer parts and a more efficient union, improving its quality and obtaining several other advantages, such as simplification of assembly, reduction of handling operations, the possibility of standardization and modularization, fewer steps and adjustments, fewer points of attachment, among others. In addition, simplified projects present a greater reduction in the cost of parts than in assembly; indirect labor; equipment depreciation, inventories, and record maintenance; improvement of material flow, production, and space capacity.

In DFA, other aspects are considered: design for flexibility, functional rationalization, feeding processes, tightening and insertion, and structural relationships. Thus, the design team makes decisions that involve the product structure, the

number of parts, the geometry of the components, the methods of union, the assembly tolerances, the composition of surfaces, and the materials used [2].

An optimal assembly sequence is one that [3]:

- Satisfies the assembly constraints.
- Avoids the instability of the in-process assembly.
- Minimizes the assembly cost.

3. PRINCIPLES, RULES, AND DESIGN RECOMMENDATIONS FOR MANUFACTURING

When designing parts that will be assembled, it is necessary to visualize how they will be grouped, which requires considering alternatives that facilitate this process. The designer must understand which assembly method and tools will be used. Designers should consider assembly to minimize production costs as much as possible. Thus, it is preferable to use an assembly involving several parts rather than a complex single piece when the desired results or lower production costs are achieved. Assembly components should be designed to minimize the number of manufacturing and assembly operations.

The most suitable assembly is the one that has the fewest parts and the cheapest type of fastening. Therefore, the assembly that presents the lowest cost is the one that minimizes the total cost of parts, the assembly process itself, finishing, and required labor. Following principles, rules, and design recommendations for manufacturing is necessary to assist designers during the project's early stages. Such principles correspond to systematic statements for good design practice, which stimulate creativity and indicate paths for more appropriate design for manufacturing. By correctly following these rules, obtaining a product with greater ease of manufacture will be possible.

The following principles are general and can be applied to several products, including injection molds.

3.1 Minimizing the number of parts

A product with high assembly efficiency has few components that are easily manipulated and connected [2]. The existence of fewer pieces reduces manufacturing effort and various other aspects, such as engineering time, number of drawings and parts, inventory documents, number of purchase and sale orders, accounting and calculation details, catalogs and services, inspection items, and types of inspection required, quantity and complexity of equipment, as well as facilitating production, assembly, and training processes. [2]

The impact of reducing the overall number of pieces is reflected in the assembly in a more expressive way than any other design change, making it a primary improvement [4]. This reduction can be achieved through alternatives such as:

- Combining parts to integrate several functions into one. For example, it's possible to incorporate a spring physical principle in a lever, eliminating the need for a separate spring.
- Using folds or crimped sections. Separated fasteners can be replaced by tabs that are bent over after the insertion.
- Using combined fasteners.
- Preferring self-tapping screws.
- Using casted labels. Instead of using fasteners on separated labels, they can be molded directly into the part.
- Replacing screws with pressure fittings, integral guides, or rivets.
- Increasing the size of the remaining pieces.

To carry out this process, it is necessary to examine each pair of adjacent components and verify if there is relative movement between them, so that there is a real need to separate them, if they are made of different materials, or if there are manufacturing, assembly, or maintenance constraints. If there is no relative movement between parts, the material of manufacture is the same, and there are no other restrictions, it is possible to transform a pair of components into a single one. Multifunctional parts, which are the combination of parts/functions, are an alternative that replaces sub-assemblies and eliminates several operations. [2]

Another viable alternative is standardizing and using common parts to facilitate design activities, minimize inventory, and standardize handling and assembly operations. The standardization of parts reduces inventory and costs, increasing reliability. In addition, the operator's work is reduced, and there is an opportunity for automation, considering the large production volumes and standardized operations. [2]

3.2 Minimizing the use of separate fastening elements

A fastening element is one more element to be stored, handled, and positioned. Moreover, they are expensive elements and can characterize potential stress concentrators. High-quality designs have few separate fastening elements, and the existing ones are standardized. It is necessary to reconsider the assembly of a design where more than $\frac{1}{3}$ of its elements represent fastening elements. [2]. When common mechanical fasteners are used, the cost increases following that order: snap-fit, plastic bending, riveting, and screw fastening, the latter being responsible for the highest cost increase in the

manual assembly process [5]. If the purpose of a part or assembly operation is just to connect other parts, the best alternative is to try to join both parts at the same point.

Screws, nuts, and washers take up much assembly time and have difficult operations to automate. The recommendation is to standardize these elements that are still used, which minimizes variety, and to seek the use of connectors such as quick couplings, snaps, and adhesives. When remaining in the design, fasteners should be standardized whenever possible (minimizing head types, body shapes, diameters, and lengths) and defining, in order of preference, the types and sizes to be used [2].

3.3 Designing the product with a base component

A proper assembly uses a solid base composed of guide surfaces or alignment elements on which the product will be structured, facilitating assemblies and subassemblies. In addition, the base should also have fastening elements, such as snaps, to keep the parts fitted together and positioned in the correct location [2]. Without a simple and unique base on which all other components and modules will be mounted, the assembly will require several sub-assembly operations, each with specific handling and composition types. In addition, without a base, the final assembly requires multiple repositioning and rearrangement operations [2]. Therefore, components should be grouped, where possible, into sub-assemblies, improving the assembly process planning [4].

With the existence of a base, it is possible to think of modular assembly, which has modules connected to the base element. Each module represents a standardized part whose design can be used in various products or even alone, as it has functionality. Modular assembly in a product family makes production standardization possible [2]. Products should be designed to be modular, making assembly easier, as designs with modules reduce the number of parts, assembly variations, and manufacturing processes. Through modularization, it is possible to reduce the total number of manufactured items and control items and improve quality. Modules make it possible to manufacture and assemble each in parallel, reducing the product's overall production time [4].

3.4 Do not reposition the base during assembly

Repositioning operations are often time-consuming and costly. By using a base on which all parts or modules will be inserted and standardized items that have the same insertion axis and reducing the number of separate fasteners, there is a reduction in the need to perform base repositioning operations, as well as a reduction in the total assembly time of the product.

3.5 Use an efficient assembly sequence

An efficient assembly sequence has the fewest possible steps, avoiding the risk of damaging parts and unstable and unsafe positions for the product, workers, and equipment [2]. In addition, when the parts have self-locating characteristics (e.g., Figure 1), the assembly becomes more efficient, as they can be placed in their specific positions without requiring adjustments, reducing the operator's work, simplifying the assembly, and enabling product development not to be hindered by adjustment operations [2].

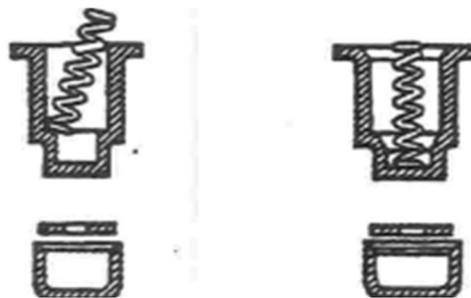


Figure 1. Example of self-location features [2]

The product should be designed with the fewest possible insertion directions, reducing reorientation operations during assembly, which is required when there are several processing surfaces (e.g., Figure 2 (a) three operation design and (b) one operation design). A recommended assembly is stacked and unidirectional, vertically from top to bottom. When it is necessary to rotate or support parts during assembly operations, the manufacturing time is longer [2].

Parts need to be designed to be stable during the assembly process, ensuring no need to waste time balancing sub-assemblies that fall or roll. To do this, the parts should be designed to be self-fixing or in a way that remains stable throughout assembly [2]. In addition to chamfers, it is possible to widen clearances and tolerances to facilitate insertion and add dimples and tab-in-slots without increasing the total cost of the part [2].

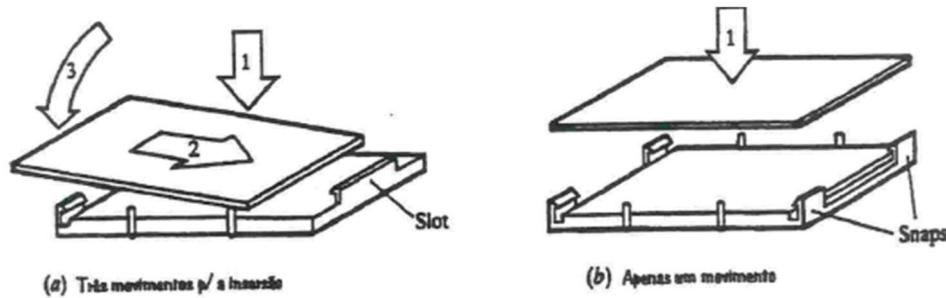


Figure 2. Example of unidirectional assembly [2]

The product must be designed so that the assembly of its subsequent parts or modules is located in the previously assembled parts or built in a unidirectional manner, enabling expansion, reducing the need for reorientation, allowing for semi-permanent assemblies, simplifying orientation, and reducing the need for adjustments [4].

Reducing the assembly levels simplifies specifications and documentation, facilitates the assembly process, and improves the factory layout. An assembly based on modules without adjustments reduces the final assembly, test procedures, handling, and the number of tools and facilities [4].

3.6 Avoid components with characteristics that complicate the assembly process

It is important to design parts in a way that reduces the effort required for assembly, as well as the ambiguity of orientations and manipulations. To achieve this, the parts must be designed to have their orientation within a project that incorporates symmetry, a low center of gravity, easily identifiable details (such as guide surfaces), and points that facilitate the activities of capturing and handling [2].

To reduce assembly time, parts must be designed to be easily manipulated. Factors such as geometry, stiffness, and weight directly influence the manipulation of parts. For this reason, parts should have regular shapes and be designed to avoid soft, fragile, sharp, and heavy materials or components [2].

Reducing the weight of a part also reduces the time required for its manipulation and insertion. Thus, the mass of a part should be sufficient to meet its functions and requirements, such as strength or rigidity. It is necessary to ensure that the parts can withstand all the forces in the machining and assembly processes. In addition, to improve the assembly of the product, other measures can be adopted, such as [2,5]:

- Designs that do not restrict assembly operations.
- Symmetric parts, reducing orientation.
- Completely asymmetric parts, so inserting the wrong one is impossible.
- Considering individual packaging of parts.
- Using oval holes that avoid adjustments.
- Taking advantage of the elastic properties of plastics.
- Maximizing the available space for component access.
- Avoiding parts that require two or more hands to be manipulated.
- Avoiding parts that can stick or be slippery, delicate, flexible, too small or large, sharp, etc.
- Reducing the number of flexible or interconnecting parts, considering that flexible or fragile parts (such as belts, gaskets, pipes, cables, or wire ties) complicate manipulation and assembly processes.

3.7 Design components for a specific type of capture, manipulation, and insertion

During the design phase, it is necessary to consider the assembly method for each product part. Therefore, a design that presents little or no resistance during insertion and provides chamfers as a guide when inserting two coupled pieces is preferable (e.g., Figure 3-a). In addition, the design of generous clearances is important, but care must be taken to ensure that the clearances generated prevent parts from becoming stuck [5]. It is also preferable to use a design where there is no possibility of assembling the component incorrectly (e.g., Figure 3-b) through shapes or items that indicate the correct part positioning during assembly [4].

3.8 Design all symmetric components clearly symmetric

Symmetry is one of the main factors influencing the time required to pick up and orient a part. Assembly always involves at least two parts: one that needs to be inserted and one into which the other will be inserted. Orientation involves aligning the inserted part relative to the receptacle. It can be divided into two operations: aligning the part's axis with the insertion axis and rotating the part around the axis. A rotational design around its insertion axis and symmetrical from end to end is always more suitable [5].

Aiming for a design for easy assembly through simple movements and reducing the number of assembly axes is necessary. The existence of complex orientations and assembly movements in different directions makes the process more time-consuming and difficult for the operator. The design should make possible an assembly that starts from a base component, with a large mass and a low center of gravity, through which the parts will be inserted at the top and positioned using gravity. This way, it will be possible to reduce assembly time and the need for reorienting the assembly, temporary joints, and complex fixings [2].

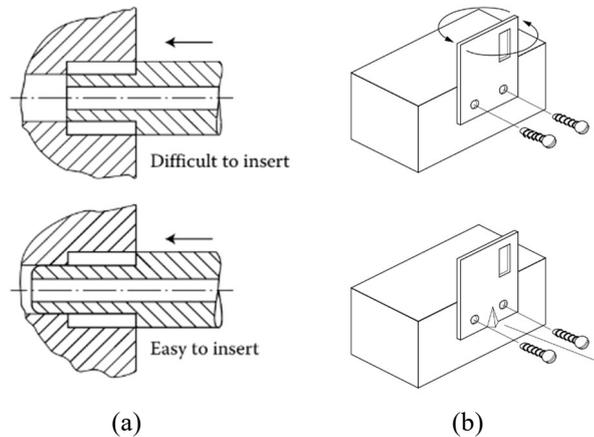


Figure 3. Examples of features that prevent assembly errors [4].

Whenever possible, the design should have the fewest possible insertion directions, thus reducing the need to reorient the part or even the operator during assembly, which is necessary whenever there are several processing surfaces. From this, a stacked and unidirectional assembly, preferably vertical and from top to bottom, makes assembly easier and more effective [2].

3.9 Design components without the possibility of symmetry clearly anti-symmetric

In cases where it is impossible to design symmetrical components, it is most appropriate to design them in a clearly anti-symmetric way (e.g., Figure 4) to avoid confusion or incorrect assemblies [5].

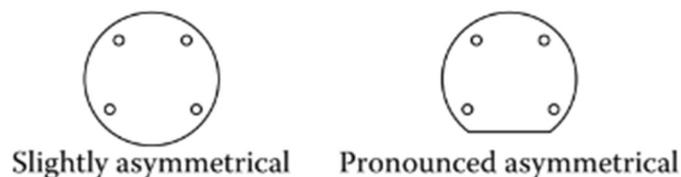


Figure 4. Clearly asymmetric designs [5]

3.10 Design components so that the assembly of joints occurs in a straight line and all in the same direction

Design components so that joints are assembled in a straight line and all in the same direction (e.g., Figure 5). Give preference using a pyramid assembly, which allows the assembly to progress around the same reference axis [5].

3.11 Make use of chamfers, undercuts, and flexibility to facilitate insertion and alignment

To make use of chamfers, undercuts, and flexibility to facilitate insertion and alignment, some rules are presented [5]:

- Design features to avoid jamming of parts.
- Avoid parts that can tangle during storage.
- Avoid parts that are sticky, slippery, delicate, flexible, too small or large, or that may pose a risk to the operator.
- Prefer a design that allows for part placement before it is released.

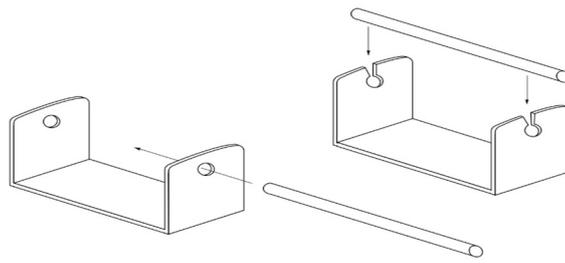


Figure 5. Stacked assembly using snap fitting [4]

During assembly, two common operations are inserting a pin or shaft into a hole and positioning a part with a hole onto a pin. In a pin with a chamfer, the diametrical clearance between the pin and the hole is provided by the quotient between the differences in diameter between the pin and the hole and the diameter of the hole. The manual insertion time for a pin into a hole with a small clearance depends on the type of engagement between both during the initial stages of insertion [5]. Some recommendations are provided [5]:

- Given a certain clearance, the difference in insertion time for two different chamfer designs is constant.
- A chamfer on the pin is more efficient in reducing insertion time than a chamfer on the hole.
- The maximum hole width that can efficiently reduce insertion time is approximately 10% of the hole diameter.
- For tapered chamfers, the most effective design features chamfers on both the hole and pin, with widths equal to 10% of the hole diameter and chamfer angles less than 45°.
- Manual insertion time is not sensitive to variations in chamfer angle between 10 and 50°.
- A rounded or curved chamfer, considering small clearances, may have more advantages than a tapered chamfer.

3.12 Maximizing component accessibility

The difficulty of accessing components during assembly makes the process much more time-consuming since it makes the necessary task more challenging for the operator. The easier the component is to access and manipulate, the greater the reduction in assembly time will be [5].

Several experiments were conducted to verify the time required to insert threaded fasteners of different types under varying conditions (Figure 6). Considering the time required to insert a machine screw and engage the threads in situations with various screw tip shapes and hole entry conditions when the assembler's vision is obstructed at different levels, it was concluded that when the distance from the obstructed surface to the center of the hole is greater than 16mm, the surface does not influence manipulation, with vision restriction being the only factor. Under these circumstances, the standard screw has the shortest insertion time when inserted into a countersunk hole. For standard screws in standard holes, an additional time of 2.5s is required. When the hole is located near a barrier that inhibits manipulation, an additional time ranging from 2 to 3s is necessary. Under these same conditions, without vision restriction, the difficulty of visualizing has little influence since access is obstructed, given that proximity to the obstructed surface allows touch to replace vision. However, when removing the obstruction to access, the difficulty of visualization has an additional time of 1.5s [5].

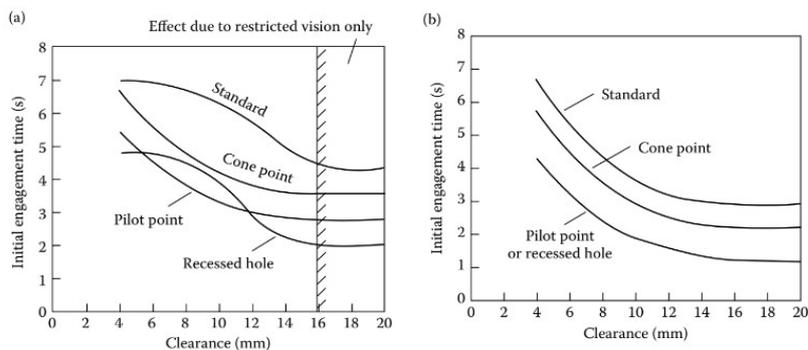


Figure 6. Comparison of screw insertion time with and without access obstruction [4]

In the case of riveting operations (Figure 7), the experiments showed that the average time used to pick up the tool, change the rivet, move the tool to the correct position, insert the rivet, and return the tool to the correct location reaches 7.3s. In cases where there is only obstruction of access, an additional 1s can be added to the total time, and this time is practically insignificant in the case of minimal clearances. In situations where, in addition to the obstruction of access, there are vision restrictions, the time increase starts to vary between 2 and 3s [5].

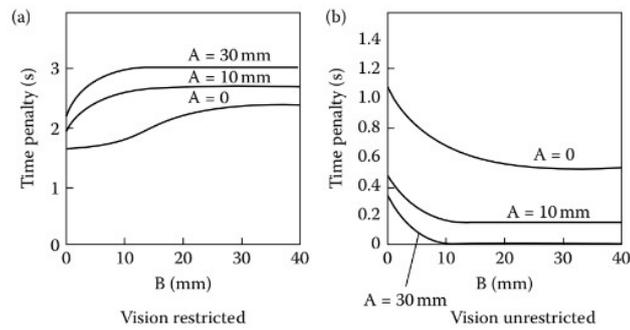


Figure 7. Comparison of riveting time with and without obstruction of vision [4].

4. USING DFA FOR POLYMER INJECTION MOLD ASSEMBLY DESIGN

Polymer Injection Molds have been developed for several decades and, for this reason, already possess a broad assortment of mature design rules. In this research, we investigate the possibility of further improving mold design by applying DFA techniques. Two cases are presented.

4.1 Case 1 – Adjustment or Pressure Plate

This Case was created with the help of the design team from Topline's tooling company and initially focused on DFA Principle 2 (minimizing the use of separate fastening elements). The team indicated the Adjustment Plate as one of the mold parts that could be redesigned to use fewer fastening elements. When designing injection molds, it is important to consider the pressure distribution over the mold parting surfaces. The adjustment or pressure plates permit optimal distribution of the mold pressure along parting surfaces and facilitate the mold adjustment stage. These parts can be designed with or without lubrication grooves.

Figure 8-a illustrates a typical design of adjustment plates. The original configuration uses two separate screws, which leads to operations such as drilling, tapping, and creating an undercut for the head are also performed. Figure 8-b shows the alternate design that replaces one of the bolts with a 45° surface to be attached to another similar surface machined into the mold. As it is a vertical restriction, the new geometry could also eliminate the need for the second bolt, replacing it with a pin. For such changes, despite adding two 45° milling operations in the manufacturing process, a total of four operations would be eliminated: 1 drilling, two undercuts for the bolt heads, two threading operations, and one assembly.

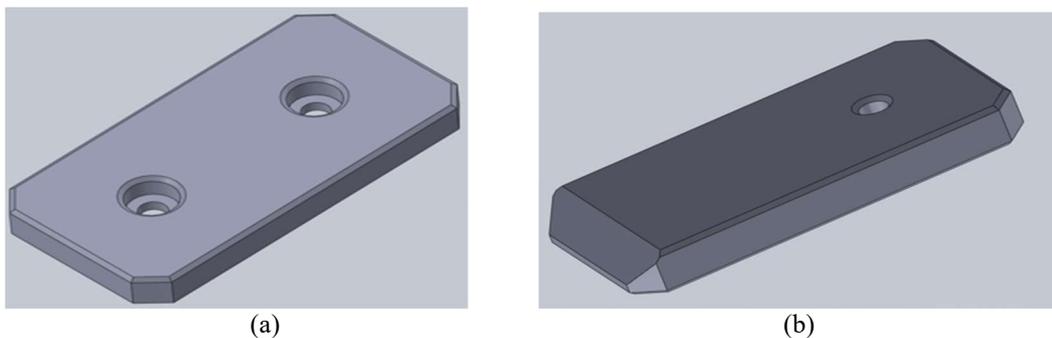


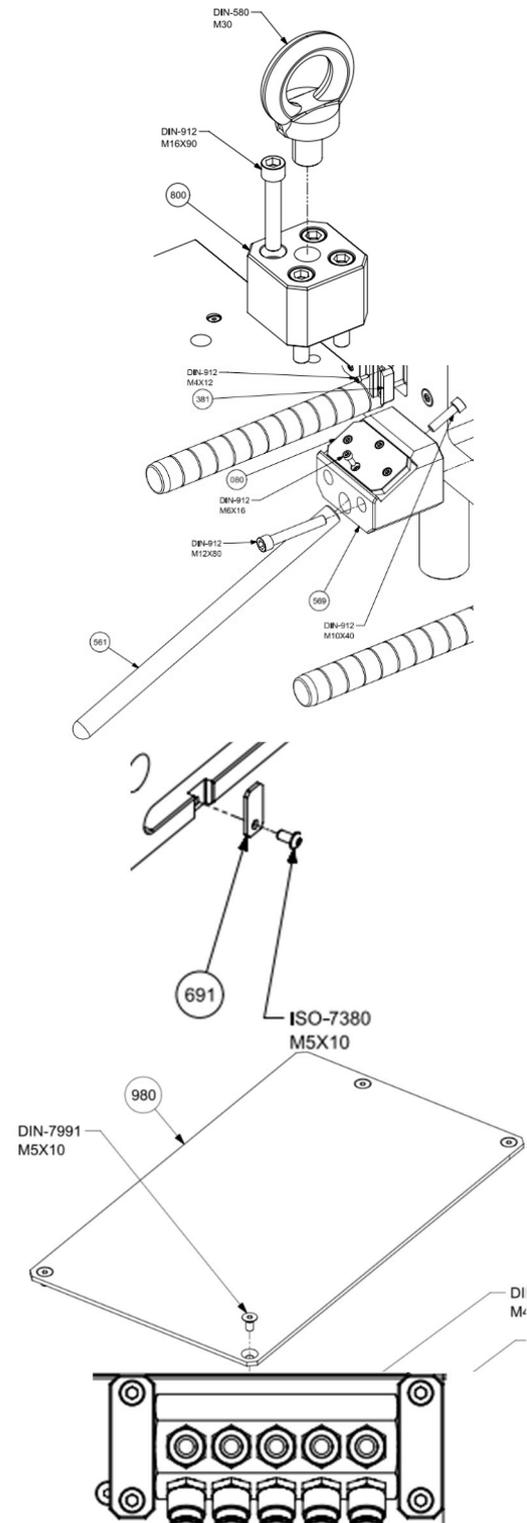
Figure 8. Adjustment Plate design (a) before and (b) after DFA analysis.

Therefore, with this new adjustment plate, it would be possible to reduce the number of fastening elements and, consequently, the time required to assemble the part. In addition to principle 2, the new design of the part also fits the other four DFA principles: the overall number of mold components is now reduced as a result of minimizing the number of fasteners; the mold has a more efficient assembly sequence, requiring only one fastener; considering adjustment plates with lubrication grooves, the design of the part to be even more asymmetrical, guaranteeing a unique assembly position.

4.2 Case 2 - Analysis of the injection mold design as a whole

The second case uses a complete drawing of a three-plate injection mold provided by the TopLine tooling company. The project was studied in a mold design class of the Postgraduate course in Engineering and Mechanical Sciences at the Federal University of Santa Catarina. Each DFA technique was evaluated individually, generating suggestions for improvement in the assembly of the studied mold. Table 1 presents some of the suggestions made.

Table 1. DFA suggestions for a polymer injection mold.

Rule#	Part(s)	Description
1. Minimizing the number of parts	 <p>The diagram shows an exploded view of a polymer injection mold assembly. Key components are labeled with standards and part numbers: <ul style="list-style-type: none"> DIN-580 M30: A circular ring component at the top. DIN-912 M16X90: A long vertical screw. 800: A small cylindrical part below the screw. DIN-912 M4X12: A short screw. 561: A long cylindrical component with a domed end. DIN-912 M6X16: A medium-length screw. DIN-912 M12X80: A long screw. 569: A small cylindrical part. DIN-912 M10X40: A medium-length screw. 691: A small rectangular component. ISO-7380 M5X10: A screw for a plate. 980: A square plate with four screw holes. DIN-7991 M5X10: A screw for the plate. DI M4: A small screw for the manifold. </p>	Parts 580 and 800: as there's no relative movement between the parts, it's possible to join them into one.
5. Use an efficient assembly sequence		Part 561: in this part, one side is domed and the other not. This way, it is possible to carry out machining where the drawer is fitted.
6. Avoid components with characteristics that complicate the assembly process		Part 691: By increasing the size of this part, manipulation would be easier and would need less assembly time.
7. Design components for a specific type of capture, manipulation, and insertion		Part 980 (extraction protection): one of the four screw holes is positioned in a different direction, which can lead to assembly errors. A design that allows assembly from either side is preferred.
12. Maximizing component accessibility		Manifold: Increasing the space between the parts would maximize the accessibility of the components, increasing the operator's efficiency.

5. CONCLUSION

Although polymer injection mold design has several decades of accumulated design knowledge, there is still room for application optimizations, including assembly. As the cases presented in this paper were able to highlight, there are opportunities for improvement based on practically all the DFA rules identified in the literature. One of the negative aspects identified in this project is the need for a greater project effort in terms of time dedicated to the project, which

could not be justified for a single mold design. However, a better correlation between design effort and production scale can be achieved by associating the effort to improve the assembly with the standardization of the mold, aiming to reuse its design in future projects.

Implementing Design for Assembly (DFA) yields numerous benefits in injection mold design, benefiting both toolmakers and consumers. These advantages include cost reduction in assembly and manufacturing, and shorter delivery times for the final product, thereby increasing product availability, among many other advantages. For these reasons, it is necessary for Design for Assembly to become an integral part of polymer injection mold design, as well as other engineering projects, not just as an innovative technique but as a natural step in the project conception. To make this a natural way of thinking for newly graduated engineers, it is beneficial to incorporate courses that cover Design for Assembly guidelines in engineering curricula so that students leave the university with a project-oriented mindset to achieve the best possible assembly design.

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