

How To Get the Most from Injection Mold Tooling

An Essential Guide for Decision Makers





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Executive Summary

Successful injection mold tooling is essential to meeting your project goals and executing your carefully considered strategies. This white paper outlines the key considerations that impact your bottom line, informing your decisions and improving your outcomes. By selecting the right supplier, managing total cost of ownership, and ensuring seamless integration between tooling and production, companies can achieve efficient, high-quality outcomes that support long-term success in manufacturing.



Introduction to Technical Considerations

For decision makers looking to get the most from their injection mold tooling, knowing what can heavily impact your final product is essential to a successful outcome. In this section is an overview of key technical factors including:

- Design and material selection
- Tool construction and components
- Tolerances and precision
- Cycle time and production efficiency

These technical factors play critical roles in determining both the functionality and manufacturing effectiveness of injection mold tooling and can be leveraged for achieving cost and efficiency goals.

The Impact of Design and Material Selection

The choices made during the design phase and the materials selected for your mold tool can significantly impact not only the overall cost but also the efficiency and longevity of the tooling. In fact, design considerations and materials selection influence final cost by up to \$100k USD, or more. Since design informs materials selection, let's begin there.

Design Considerations

The primary driver for determining a mold tool's design is the part being molded. The first and most important step is to verify that the part design is injection moldable.



While some part designs are injection moldable as delivered, others require modifications to ensure manufacturability without altering the part’s form, fit, or function. For example, parts with complex geometries, such as undercuts or internal threads, or more sophisticated mold designs, potentially require actions, lifters, or unscrewing cores to achieve the desired features. Those features may require specific materials or design choices to ensure a successful outcome, or value engineering of the product itself to enhance manufacturability.

Material Selection

Tool steel selection is guided by factors such as production volume, the resin used in the molding process, and specific tool features. Common materials include hardened steels like H-13 and S-7, known for their toughness and resistance to wear, and stainless steels like 420, which are preferred for applications where corrosion resistance is critical.



Managing Parting Lines and Weld Lines

Parting lines and weld lines are unavoidable aspects of injection molding. Parting lines occur where the two halves of the mold come together, while weld lines form where separate flows of molten plastic converge. Although these lines typically do not affect the part’s structural integrity, they can be visually apparent. Mold designers can employ various techniques to minimize their appearance, but complete elimination is impossible.



Utilizing Mold Flow Simulation

Mold flow simulation is an essential process providing insights into how the mold will fill and pack, making it an invaluable tool in the tooling design process. Simulation allows for making adjustments before the mold is fabricated, reducing the risk of costly revisions and ensuring

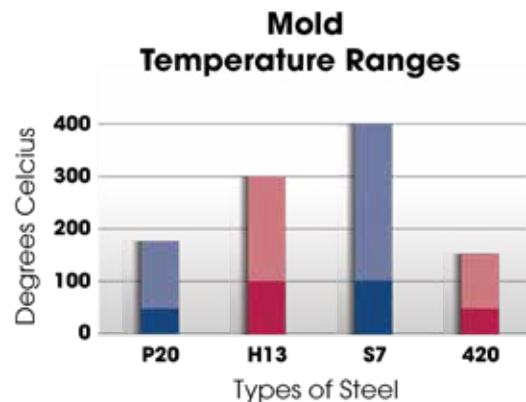
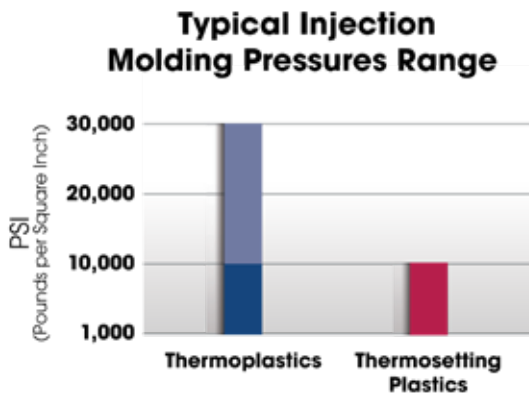
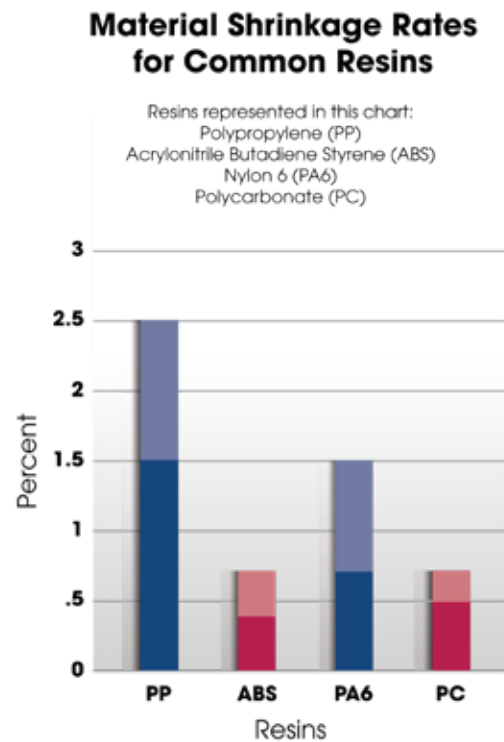
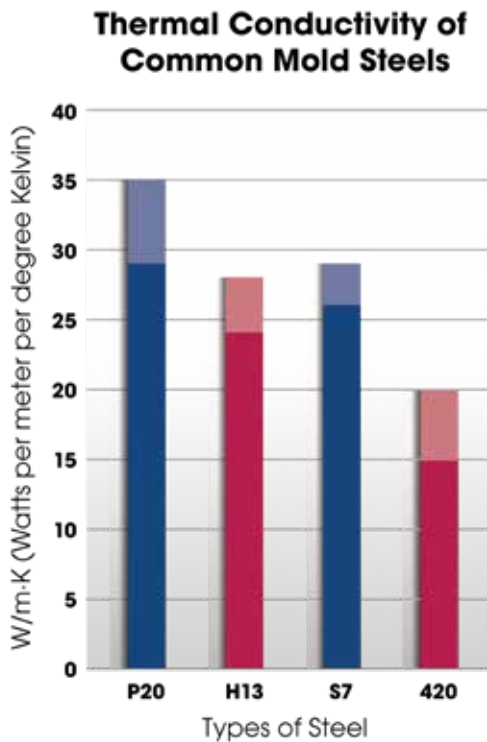




optimal part quality. Tools like these are essential in predicting and mitigating potential issues such as shrinkage, warping, and weld line formation.

The Role of Material Properties

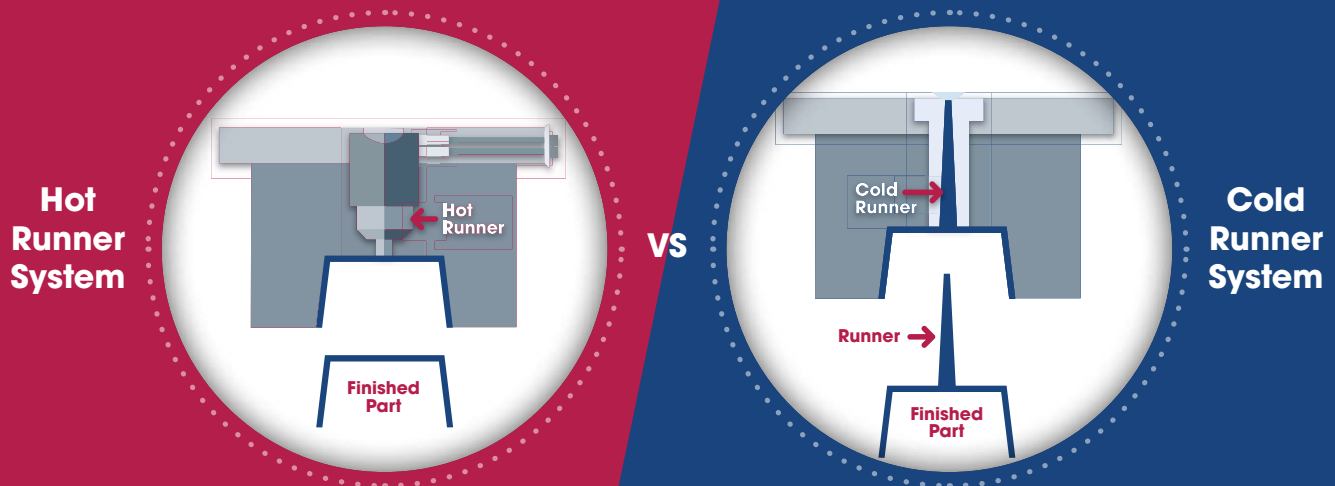
The properties of the materials used in both the mold tool and the resin greatly influence the molding process. For example, understanding the thermal conductivity and wear resistance of the selected steel is key to achieving the desired surface finish and tool longevity. Additionally, material shrinkage must be carefully accounted for during the design phase, with the mold cavity being slightly oversized to compensate for the expected shrinkage during cooling.





Tool Construction and Components

The construction of the mold tool and its components determine the efficiency, quality, and cost-effectiveness of the injection molding process. A firm grasp on these elements allows decision-makers to make informed choices that directly impact the overall production process.



Hot Runner vs. Cold Runner Systems

One of the primary considerations in tool construction is the choice between hot runner and cold runner systems, each of which comes with its own set of advantages and disadvantages.

- **Hot Runner Systems:** These systems are highly efficient, as they keep the plastic resin heated within the mold, eliminating waste and reducing cycle time. However, they come with a higher initial cost and require more complex maintenance due to the additional components involved.
- **Cold Runner Systems:** While cold runner systems are less expensive to implement, they generate more waste material, as the runners need to be trimmed from the finished part. Despite this, they are simpler to maintain and can be ideal for lower-volume production where material cost is not a primary concern.





Cooling Efficiency

Cooling is a critical aspect of tool design, as it directly affects cycle time and part quality. Best practices for optimizing cooling efficiency include the strategic placement of cooling channels within the mold and the use of advanced cooling methods. Proper cooling reduces warpage and shrinkage, leading to higher-quality parts and more efficient production cycles.

Mold Cavitation: Single vs. Multi-Cavity Molds

How many cavities are in a mold tool is decided by production requirements. The optimal choice depends on the balance between production volume, cost, and the complexity of the parts being produced. Single-cavity molds are straightforward and less expensive but result in longer cycle times. Multi-cavity molds, on the other hand, increase production efficiency but require more complex tooling and higher upfront costs.

Venting and Ejection Systems

Venting and ejection systems are essential for the smooth operation of the molding process. Proper venting prevents defects from the formation of air pockets. Ejection systems, such as pins or lifters, ensure that parts are removed from the mold without damage. Optimizing these systems is crucial for maintaining part quality and minimizing cycle time.

Modular vs. Integrated Mold Bases

The choice between modular and integrated mold bases affects the flexibility and scalability of the tool design. Modular bases allow for easier adjustments and repairs, making them ideal for projects that may require frequent changes. Integrated bases, while more rigid, offer higher precision and are better suited for high-volume production where consistency is key.

Tolerances and Precision

Understanding tolerances and precision is necessary to ensure mold tools meet the exact specifications needed. These aspects impact functionality and overall cost-efficiency.

Critical Tolerances in Injection Molding

Achieving tight tolerances for parts that require high precision is essential. The challenge lies in maintaining these tolerances consistently across high production volumes. Proper tool design and regular maintenance ensure that the molds remain within specified tolerances over time.





Additionally, factors such as thermal expansion, material flow characteristics, and cooling rates must be carefully controlled to prevent variations that could impact the final product’s accuracy.

Ensuring Precision and Accuracy During Fabrication

Meticulous fabrication processes ensure mold tool precision. Tool and die makers play a critical role in this, using advanced techniques and technologies. Skilled journeypersons and machinists use Coordinate Measuring Machines (CMMs) and other high-precision measurement tools to verify that every mold component meets the required specifications.

Careful consideration of thermal expansion and contraction during the design process must account for material behavior under different temperatures, ensuring the final parts meet the desired tolerances.

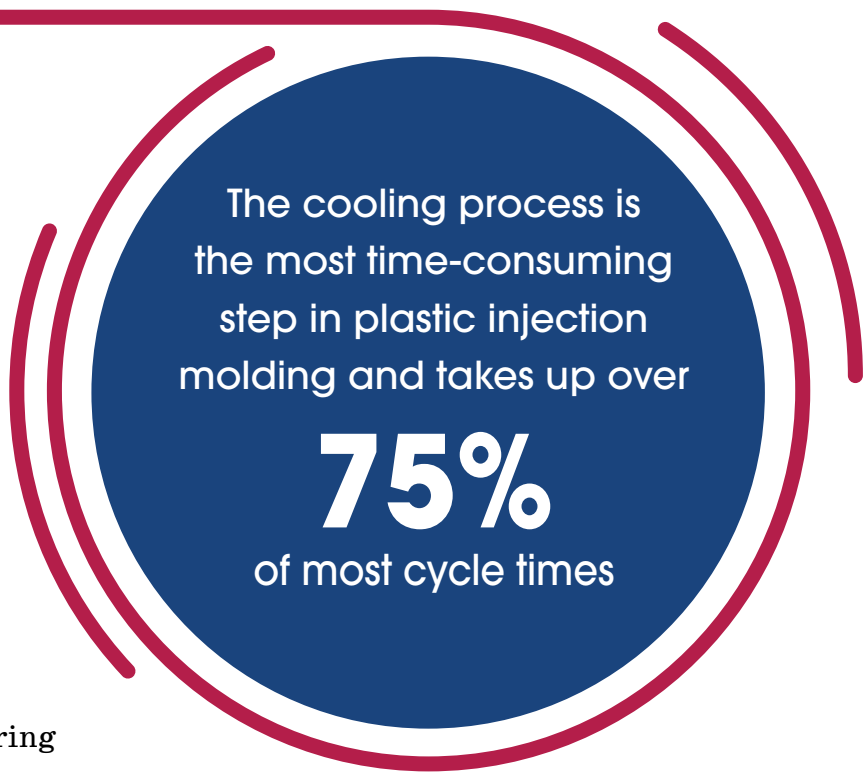
Cycle Time and Production Efficiency



Cycle time is a critical factor, directly impacting production efficiency and overall costs. Understanding and optimizing cycle time without compromising part quality is essential for a successful manufacturing process.

Impact of Mold Design on Cycle Time

The mold’s design has a profound effect on cycle time, with cooling making up most of the cycle duration. Optimizing cooling channels and ensuring efficient heat dissipation are key strategies to reduce cycle time while maintaining part quality. Properly designed venting also plays a role, as it prevents defects that could slow down the production process.





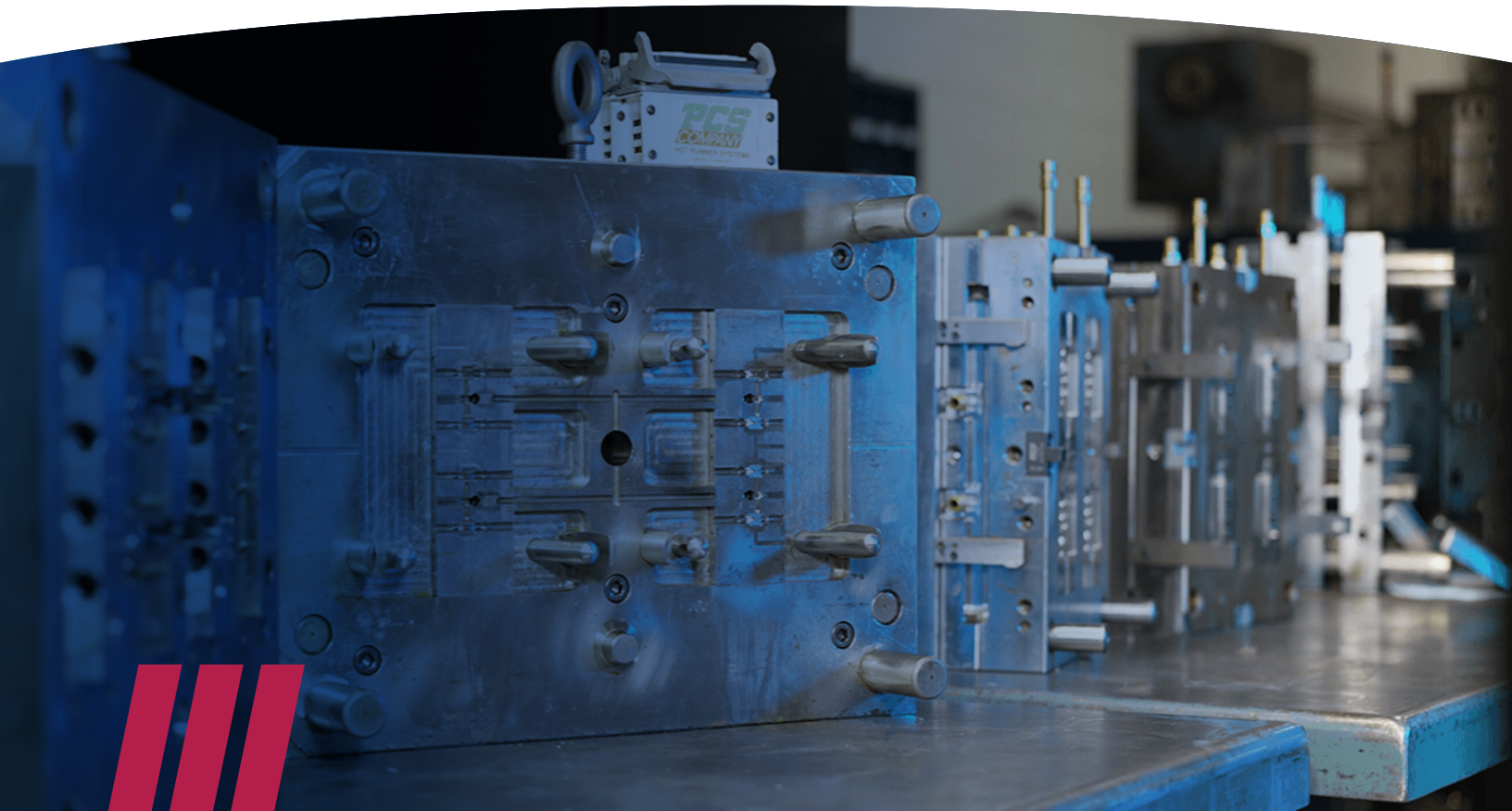
Strategies for Reducing Cycle Time

To reduce cycle time, engineers optimize cooling according to the specific part design. They maximize cooling efficiency through strategically placed cooling channels around critical components for each unique mold to meet the critical needs for cooling.

This tailored approach minimizes cycle time without compromising the integrity of the molded parts.

Advancements in Cooling Technologies

Crescent Industries stays at the forefront of cooling technology by designing molds that efficiently manage heat through traditional cooling channels. These methods are continually refined based on the unique requirements of each project, ensuring that cooling is optimized for both cycle time and part quality.



Introduction to Cost Considerations

The costs associated with injection molding vary significantly based on many factors, from initial tooling expenses to long-term operational efficiency. In this section, we will examine essential considerations that have a major impact on your budget and cost of ownership.

Essential Considerations

Several key factors influence the overall cost of injection molding, each playing a significant role in determining the total cost of ownership. The following considerations are crucial for making informed financial decisions:

- Initial Tooling Costs
- Maintenance and Longevity
- Production Volume and Cost-Efficiency
- Material Costs

These factors represent the bottom line of your project's success. Let's begin with a review of initial tooling costs and then move through these remaining factors to provide you with the considerations you need.

Initial Tooling Costs

The design choices you make, and the materials selected for the mold will have a substantial impact on these costs. Next, we will explore the cost impact of those decisions in detail.



Design and Material Selection



Molds with intricate designs or requiring high-quality materials, such as hardened steel or high-temperature alloys, will naturally be more expensive to produce.

Basic prototype molds can range from as little as \$5,000 to as much as \$20,000 USD, and more complex molds that require higher grade materials range as much as \$25,000 to \$100,000 or more.

Materials like P20 Steel sit on the lower end of the spectrum, and those like H13 would run from \$50,000 to \$100,000 depending on the mold they were used for.



High temperature alloys, like maraging steel or 420 Stainless steel, which are used for highly specialized applications that require extreme durability or temperature resistance often exceed \$100,000. However, their superior performance in demanding environments and in cases where precision is paramount more than justify that upfront investment by ensuring consistent production of the highest quality parts over a long period of time.

Impact on Cost and Other Considerations

Choosing the right design and materials not only controls initial costs but also ensures the efficiency and longevity of the mold. A well-designed mold made from durable materials minimizes the need for repairs, reduces downtime, and improves overall production efficiency, ultimately lowering the total cost of ownership (TCO), which we expand on next.

Maintenance and Longevity

Maintaining the longevity of injection mold tools is critical for ensuring consistent part quality and minimizing long-term costs. Proper maintenance practices extend the mold's life and reduce production downtime and expensive repairs.





Required Maintenance for Mold Longevity

Effective maintenance of mold tools involves regular inspections, cleaning, and preventative measures that maintain the mold's precision and accuracy. Thus, ensuring consistent part quality over time.

Key Maintenance Tasks Include:



Mold Cavity & Component Cleaning



Lubricating Moving Parts



Inspecting for Wear or Damage



Replacement of Worn Components

Predictive maintenance technologies, such as sensors within the injection molding machine, monitor process parameters to ensure that the mold is operating within optimal conditions, further extending its life.

Mold Lifespan Indicators

The lifespan of a mold tool can vary widely depending on factors, including:

- Materials Used
- Complexity of the Mold Tool
- Production Volume

Higher-quality materials and regular maintenance significantly prolong the life of the mold, reducing the need for early replacement and enhancing the tool's overall cost-effectiveness.



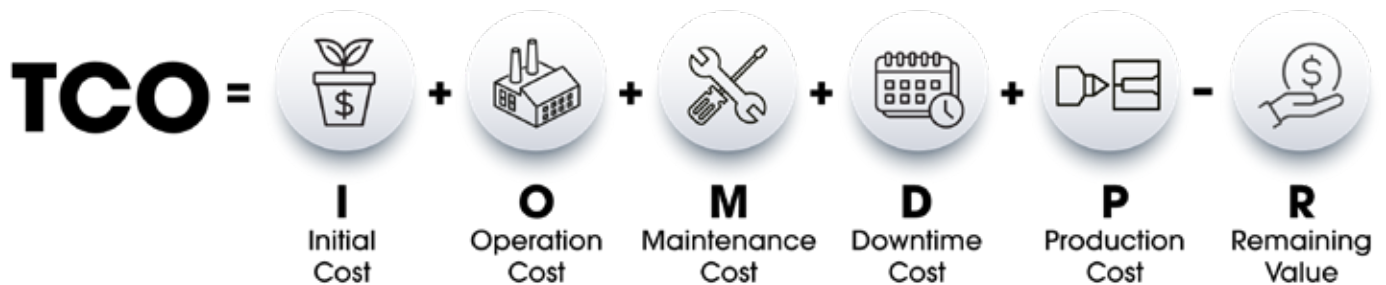


Total Cost of Ownership (TCO)

Calculating the total cost of ownership (TCO) for a mold tool involves considering the initial tooling costs, ongoing maintenance expenses, and the expected lifespan of the tool.

TCO can be broken down to a very simple formula, or a more complex one. Simply put, TCO is the initial cost (I), plus the cost of maintenance (M), minus the remaining value: $TCO = I + M - R$.

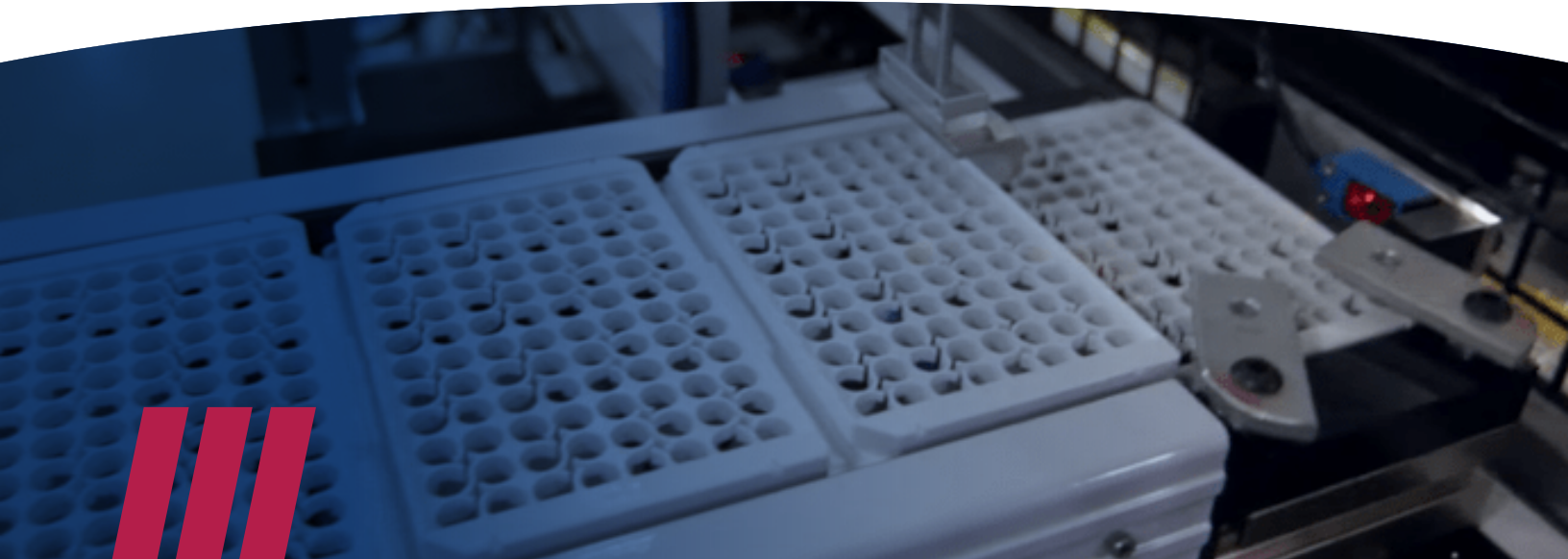
To further expand that formula and really break down TCO, you can add many other aspects, including Cost of Operation (O), Cost of Maintenance (M), Cost of Downtime (D), and Cost of Production (P).



A well-maintained mold tool significantly lowers the TCO by reducing the frequency of repairs and the need for early replacement, making regular maintenance a cost-effective strategy in the long run.

Production Volume and Cost Efficiency

Production volume is a key factor in determining the cost-efficiency of injection molding. Crucially, the relationship between production volume and cost maximizes profitability and ensures the economic viability of a project.





Impact of Production Volume on Cost-Efficiency

The cost-efficiency of injection molding improves as production volume increases. That is largely due to the amortization of the initial tooling costs over more parts. For high production volumes, a Class 101 tool, which is designed for extended use, may have a higher upfront cost but offers lower per-part pricing due to its durability and efficiency. As production volumes increase, the per-unit cost decreases, making high-volume production more cost-effective.

Understanding Mold Classification

Mold classification directly influences both the initial tooling costs and the long-term cost-efficiency of production. Molds are categorized into classes (e.g., Class 101, 102, 103) based on their expected lifespan and the materials used in their construction:

- **Class 101 Molds:** Designed for over 1 million cycles, these molds are built with high-quality materials, such as hardened steel, and feature advanced cooling and ejection systems. They are ideal for high-volume production, offering lower per-part costs despite higher upfront investment.
- **Class 102 Molds:** Suitable for up to 1 million cycles, these molds are slightly less durable but still offer significant cost-efficiency for mid to high-volume production. They are often used for parts made from abrasive materials or requiring tight tolerances.
- **Class 103 Molds:** Designed for up to 500,000 cycles, these molds are typically used for lower-volume production runs. They have lower hardness requirements and may lack some of the advanced features of higher-class molds, making them more affordable upfront but less durable over time.

Selecting the Right Press Size

The size of the injection molding press, measured in tonnage or clamping force, also impacts the production costs. Larger presses, which apply higher clamping pressure, are typically required for more complex or larger parts, influencing both the initial tooling costs and the ongoing production expenses.





Material Costs

Material choice is a critical factor that significantly affects the overall cost structure. Understanding the costs and trade-offs associated with different mold materials is essential for making informed decisions that balance performance and budgetary constraints.

Comparing Mold Material Costs and Trade-offs

The cost of mold materials varies based on their properties and intended applications. Common materials include P20, H13, S7, and 420 stainless steels. Each material offers a unique combination of hardness, thermal conductivity, and resistance to wear and corrosion:

- **P20 Steel:** A pre-hardened steel that is relatively cost-effective and commonly used for lower-volume production tools. It offers good machinability and moderate durability, making it a popular choice for many general-purpose molds.
- **H13 Steel:** Known for its toughness and resistance to thermal fatigue, H13 is a more expensive option but is ideal for high-volume production molds where durability is essential. It's also used in molds that require high thermal conductivity to manage heat more effectively.
- **S7 Steel:** S7 steel is highly resistant to impact and is often used in molds that require extra toughness, such as those used with abrasive materials. It is more costly than P20 but provides greater longevity and reliability under harsh conditions.
- **420 Stainless Steel:** This material is chosen for applications where corrosion resistance is critical, such as molds exposed to moisture or corrosive materials. While it offers excellent durability, the cost is higher due to its specialized properties.





Fluctuations in Raw Material Prices

The cost of mold tooling is influenced by fluctuations in raw material prices, particularly for the steel used in mold construction. While these fluctuations do occur, they typically don't have as immediate or dramatic an impact as changes in resin prices on part production costs.

However, sustained increases in steel prices can lead to higher tooling costs, which may need to be accounted for in long-term budget planning.

Specialty Materials and Their Cost Implications

For certain applications, especially those requiring high-temperature resistance or specific mechanical properties, specialty materials such as high-temperature alloys or maraging steels may be necessary. These materials are much more expensive than standard steels and are only used when necessary to achieve the desired quality and performance outcomes.

The decision to use such materials is made with careful consideration of the project's specific requirements and the cost implications for you.

For instance, in cases where a mold must withstand extreme temperatures or where precision is paramount, the use of high-temperature alloys can ensure the mold's performance and longevity, but this comes with increased upfront costs.

These trade-offs must be evaluated to ensure the best possible balance between cost and performance.



Introduction to Operational Considerations

In addition to cost and material considerations, operational factors play a large role in the successful execution of an injection molding project. We will discuss key operational concerns essential for ensuring projects are delivered on time and within budget, without compromising on quality.

Two primary factors need careful attention:

- **Lead Times:** The time it takes to design, manufacture, and deliver an injection mold tool can significantly impact project timelines and overall costs. Managing lead times effectively is crucial for maintaining production schedules.
- **Supplier Selection:** Choosing the right supplier ensures the project is executed smoothly. A reliable supplier with the right expertise and resources can help navigate potential challenges and ensure consistent quality throughout the production process.

These two essential factors are the bedrock of project success. First, we will take a deep dive into the factors that impact Lead Times, and then discuss Supplier Selection.

Lead Times

The duration required to complete an injection mold tool varies widely based on several factors, and understanding how to manage and refine these timelines is essential for keeping projects on track.



Typical Lead Times

The lead time for designing and manufacturing an injection mold tool depends on the project's complexity and the current workload of the toolmaker. There is no one-size-fits-all answer, as simpler molds with fewer components may have shorter lead times, while more complex tools with intricate features require more time and effort. Typically, lead times range from several weeks to a few months, depending on these variables.

Minimizing Lead Times Without Compromising Quality

One of the key strategies for minimizing lead times while maintaining quality is the use of advanced machining techniques, such as running machining operations "lights out." This approach allows machining processes to continue unattended during off-hours, enabling skilled operators to focus on other critical aspects of the tool build during regular working hours. This increases overall efficiency without compromising the precision and quality of the mold.

Critical Path Activities

For effective project management, your understanding of the critical path activities in the mold manufacturing timeline is pivotal. The stages of a new injection mold build typically include:

- **Kickoff:** Initial project launch where goals, timelines, and specifications are defined.
- **Design for Manufacturing (DFM) & Design:** This phase involves refining the mold design to ensure it meets all requirements and is optimized for manufacturing.
- **Mold Build:** The physical construction of the mold, which includes machining, assembly, and initial testing.
- **Sampling and Operational Qualification (OQ):** Initial testing of the mold to verify that it produces parts that meet the specified quality standards.
- **Production Qualification (PQ) Lot to Production:** Final validation and full-scale production readiness, ensuring the mold can consistently produce parts at the required volume and quality.

By effectively managing these critical path activities, lead times can be optimized, ensuring that the project stays on schedule and within budget.





Supplier Selection

Selecting the right supplier for mold tooling influences every aspect of your project, and predicts the overall success of your project. The choice of supplier affects the quality and reliability of the molds and has implications for lead times, cost, and long-term production efficiency.

Key Criteria for Selecting a Supplier

When selecting a supplier for mold tooling, consider the following key criteria:

- **Tooling Options and Experience:** Look for a supplier with a broad range of tooling options and extensive experience with varied materials like aluminum, steel, and composites.
- **Volume Capabilities:** Ensure the supplier can tailor the injection mold to your anticipated production volume, optimizing cost-effectiveness.
- **Quality and Turnaround Time:** A reliable supplier balances quality with reasonable timelines, ensuring high-quality tools without compromising delivery schedules.

Evaluating Supplier Capabilities and Reliability

To ensure a mold manufacturer meets your needs, evaluate their capabilities in terms of:

- **Total Cost of Ownership (TCO):** Consider the long-term costs of maintenance, potential downtime, and overall part quality.
- **Lifecycle Support:** Choose a supplier that offers support throughout the product lifecycle, from design to high-volume production.
- **Integrated Services:** Select a supplier that provides both tooling and injection molding services for seamless transitions and minimized risks.

For a more detailed evaluation process, including a comprehensive procurement checklist, visit our website at www.crescentind.com.





Key Performance Indicators (KPIs) for Supplier Assessment

Track specific KPIs to ensure consistent quality and reliability:

- On-Time Delivery Rate
- Quality Metrics
- Customer Satisfaction

Avoiding Hidden Costs

The saying, you get what you pay for, truly applies to mold tooling. Low upfront costs can lead to significant expenses down the road. When evaluating quotes, consider the long-term implications of the supplier's capabilities and how well they can support evolving production needs.



Case Study: Manufacturing Client Orthopedic Surgery Devices

Brief Overview

Our client was a manufacturer that makes medical devices for orthopedic surgeries. The devices are used to help repair tendons and ligaments.

The Challenge

The project required the creation of multiple molds to be used to mass produce the 13 components making up one surgical orthopedic device. Each component of the device required intricately woven design demanding the highest level of precision and quality of the tooling to allow the parts to fit seamlessly together.

The Solution

The project began with a mold simulation to proactively uncover any potential issues and address them from the start to reduce time and costs. Our team used a unique, robust process leveraging scientific data to determine barrel temps, pressure, cooling time, and other key factors prior to moving to production. We then created molds for 13 different parts needed to complete the design of the orthopedic device by using five different injection mold tools. Production was then run in Crescent's certified ISO 7 cleanroom facility.

The Outcome

Upfront engineering and design for manufacturability saves time and money by finalizing the finalizing the design of the tool before it is fabricated. This ensures every aspect of the project is delivered satisfactorily and ready to move into production.



Detailed Process

As our partner, you receive a custom, proactive approach to your project, leveraging scientific data and testing to ensure a smooth, cost-effective manufacturing process.

The step-by-step process Crescent undertook to ensure our orthopedic surgery device manufacturing client highlights what all clients can expect when working with our manufacturing and engineering teams.

- **Design project proposal stage:** Includes a full disclosure of the mold design and function using experience, judgment, and artistic skill for conceptualization
- **Conceptualization of the Design:** Action features, Runner & gates & venting, Determine mold steels, Type of mold, Ejection system
- **Projections:** Anticipated part volume needed will determine the cavities, and mold steels, and these then determine the injection mold costs
- **Mold fill simulation:** Helps to uncover and address any issues upfront before going to production, such as the potential for parts to stick, as uncovered in this project
- **Approval and fabrication:** Crescent’s PMO team uses collaborative planning tool software to communicate mold building internally
- **Performance evaluation:** Robust process (unique to Crescent) using scientific data to ensure the injection mold produces quality parts reliably and repeatably

5X8 Master Unit Die
Type Unit Mold



1+1 family for
the slide parts

Class 103, 1 Cav
Dedicated Mold



For a needle
block component

3 1/2" x 5" Master Unit
Die Type Unit Mold



1+1+1 family tool for the lock
button top, bottom, and cap

Parts can run together in
equal quantities



And in the same Lustran
resin and the same color





- **Prep for trial:** Gather prints of the parts, material data sheets, and mold simulation to get baselines for barrel temperatures, water temperatures, pressure, and time
- **Key information determined:** the cooling time, hold time, and clamp tonnage is determined prior to moving forward
- **Documentation:** part size, appearance, and mold function are documented and debugged to hit quality specifications of the parts
- **Approval:** Form 1061, FAIR, and quality documentation of part measurements and sample shots are sent to the customer for approval
- **Production:** Once all steps were complete and the customer fully approved, the mold was launched to full production

Benefits

When you partner with us, you experience the Crescent difference and realize the following benefits.

- **Certified mold-makers:** All mold designers were, at one time, mold makers with hands on experience
- **Proactive approach:** Save time and keep costs low by perfecting the product design prior to moving to production
- **Avoid trial and error:** Uncover potential issues and eliminate the high cost of trial and error
- **Engineered for complexity:** Able to design products with multiple components to ensure the exact fit and smooth design





Takeaways

Below, we have created a short collection of key takeaways for decision makers, representing the critical aspects covered in this guide per section.

Key Takeaway 1: Technical Considerations

Successful injection molding begins with understanding the technical aspects, including design, material selection, and tool construction. These factors determine the quality and efficiency of the production process, making them essential for achieving consistent, high-quality results.

Key Takeaway 2: Cost Considerations

When planning for injection molding, it's vital to consider both initial tooling costs and long-term expenses. A thorough evaluation of factors like maintenance, production volume, and material costs will help in managing the total cost of ownership (TCO) effectively, ensuring cost-efficiency throughout the product lifecycle.

Key Takeaway 3: Operational Considerations

Operational factors such as lead times and supplier selection significantly impact project timelines and success. Choosing a supplier that offers integrated services, including both tooling and injection molding, can streamline processes, reduce risks, and ensure timely delivery.

Key Takeaway 4: Supplier Selection

Selecting the right supplier is critical. Evaluate potential partners based on their experience, capabilities, and the ability to support your project from concept to production. A reliable supplier should offer comprehensive services, including design for manufacturing (DFM), in-house mold fabrication, and lifecycle support.

Key Takeaway 5: Long Term Risk Management

Forming a long-term partnership with your supplier is essential for managing risks and ensuring consistent quality. A strong partnership is built on trust, clear communication, and the supplier's ability to adapt to your evolving needs, ultimately contributing to the long-term success of your projects.





Crescent Industries: Your Preferred Partner for Injection Molding

Crescent Industries is a USA-based, employee-owned plastic injection molding company offering single-source solutions for all your manufacturing needs. Our injection molding experience spans many industries, including medical, pharmaceutical, dental, defense, and industrial markets.

To learn more about how we can help you get the most out of your next injection mold tooling project, reach out to Crescent Industries today.

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