Injection Molding Program Planner

EMPIRE PRECISION
WHERE YOUR IDEAS TAKE SHAPE

Considerations for a Successful Program

Procurement has become more strategic and challenging, with a greater number of decision makers and active programs in place to reduce overall spending. How your company manages risk plays a key role in the success of your product.

When managing risk for an injection molding program, cost and quality are driven by three decisions:

1. Establishing the right specifications for development
2. Selecting the right supplier
3. Choosing the right path to production

Supplier selection, in particular, will greatly affect the success and value of your overall program. A supplier that acts as a strategic partner will be able to guide you in your development and production decisions. They will work to gain a clear understanding of your program requirements in order to provide the cost, quality, and delivery that will give you a competitive market advantage.

This whitepaper provides tips, considerations, and key factors in planning a high-volume injection molding program.

Size Comparisons

0.0035″ = Human hair

0.0010″ = Dust particle / plastic 'flash'

0.0005″ = Fingerprint depth

0.0002″ = Industrial smoke particle size / steel mold production

0.0001″ = Tobacco smoke

Developing Ideal Specifications

Small part tolerances can make a big difference to an injection molding program. Too tight, and you increase costs and rejection rates. Too loose, and you risk affecting assembly and performance. Understanding the variables will help you set suitable tolerances for your injection molded parts.

Sources of Variation

Tolerance is the minimum amount of variation allowed for the part. There are several sources of variation in an injection molded part.

1. **Material:** Plastic, like many materials, is larger when it is heated and injected into the mold; it shrinks as it cools. The material density may drop by as much as 25% in the molten processing state. The post-mold cooling may cause volumetric shrinkage of up to 3% or more. The shrink rate is unique to each material but is impacted by many factors, including additives such as fiber reinforcement or colorant. Each lot of plastic is slightly different, which can impact the material melt viscosity. The shrinkage behavior of plastic, specifically non-uniform shrink within a part, may also cause post-mold warp.
2. **Equipment:** Molding machines and auxiliary equipment all operate within a functional range. This will create noise in the process, impacting the material.
3. **Measurement:** Conditions of measurement may vary over time, temperature, and operators. Inconsistencies in the measurement process can produce slightly different measurements on the same test item.
4. **Mold:** The mold itself is dynamic and moving. The two halves may not align the same from run to run for a variety of reasons. As the mold runs, material will plate out on the tools, which changes the tool further. Molten plastic is injected into steel at pressures of 20 to 30,000 p.s.i. Opposing hydraulic tonnage is generated to hold the steel mold together at these forces. The molten hot plastic will "flash" (seep out between the steel plates) at about 0.001 inch. Steel molds are manufactured to tolerances of 0.0002 inch to eliminate flash.

Classification of Tolerance

Choosing the right level of tolerance depends on your intended application and several other parameters.

1. **Part design:** Dimensional considerations for molded part design (size and shape) relate to the flow of melt in a mold and take into account both performance and manufacturability.
2. **Mold design:** Factors such as the number of cavities, placement and size of cavities, runners, gates, cooling lines, side actions, and knockout pins are considered in mold design in order to maximize the performance of melt and cooling flow patterns and meet part performance requirements. Pre-engineering design helps to minimize wear and deformation of the mold (using the right steels), and proper layout of cooling lines helps to meet temperature-to-time cooling rates of plastics (particularly semi-crystalline types).
3. **Mold cycle:** The completed molding cycle is set up to repeatedly meet performance requirements at the lowest cost by interrelating material, machine, and mold controls.

Drawing Code	Dimension (in)	Polyethylene, HD Commercial	Polyethylene, HD Fine	Polyethylene, LD Commercial	Polyethylene, LD Fine	Polypropylene Commercial	Polypropylene Fine	Polystyrene Commercial	Polystyrene Fine	Vinyl, Flexible Commercial	Vinyl, Flexible Fine	Vinyl, Flexible Commercial	Vinyl, Flexible Fine
A = Diameter*	To 1.000	0.008	0.006	0.007	0.004	0.007	0.004	0.004	0.0025	0.011	0.0070	0.008	0.0045
B = Depth** C = Height**	1,000 - 2,000	0.010	0.008	0.010	0.006	0.009	0.005	0.005	0.003	0.012	0.008	0.009	0.005
	2,000 - 3,000	0.013	0.011	0.012	0.008	0.011	0.007	0.007	0.004	0.014	0.009	0.010	0.006
	3,000 - 4,000	0.015	0.013	0.015	0.010	0.013	0.008	0.008	0.005	0.015	0.011	0.012	0.007
	4,000 - 5,000	0.018	0.016	0.017	0.011	0.015	0.009	0.010	0.006	0.017	0.012	0.013	0.008
	5,000 - 6,000	0.020	0.018	0.020	0.013	0.018	0.011	0.011	0.007	0.018	0.013	0.014	0.009
	6,000 - 12,000 for each additional inch	0.006	0.003	0.005	0.004	0.005	0.003	0.004	0.002	0.005	0.003	0.005	0.003
D = Bottom wall		0.006	0.004	0.005	0.004	0.006	0.003	0.0055	0.003	0.007	0.003	0.007	0.003
E = Side wall		0.006	0.004	0.005	0.004	0.006	0.003	0.007	0.0035	0.007	0.003	0.007	0.003
F = Hole diameter*	0.000 - 0.125	0.003	0.002	0.003	0.002	0.003	0.002	0.002	0.001	0.004	0.003	0.004	0.003
	0.125 - 0.250	0.005	0.003	0.004	0.003	0.004	0.003	0.002	0.001	0.005	0.004	0.004	0.003
	0.250 - 0.500	0.006	0.004	0.005	0.004	0.005	0.004	0.002	0.0015	0.006	0.005	0.005	0.004
	0.500 & over	0.008	0.005	0.006	0.005	0.008	0.006	0.0035	0.002	0.008	0.006	0.006	0.005
G = Hole depth	0.000 - 0.250	0.005	0.003	0.003	0.003	0.005	0.003	0.0035	0.002	0.004	0.003	0.004	0.003
	0.250 - 0.500	0.007	0.004	0.004	0.004	0.006	0.004	0.004	0.002	0.005	0.004	0.005	0.004
	0.500 - 1.000	0.009	0.006	0.008	0.005	0.009	0.006	0.005	0.003	0.006	0.005	0.006	0.005
Flatness	0.000 - 3.000	0.023	0.015	0.020	0.015	0.021	0.014	0.007	0.004	0.010	0.017	0.015	0.010
	3.000 - 6.000	0.037	0.022	0.030	0.020	0.035	0.021	0.013	0.005	0.020	0.015	0.020	0.015
Concentricity	TR	0.027	0.010	0.010	0.008	0.016	0.013	0.010	0.008	0.015	0.010	0.010	0.005

Source: designinfosystem.com

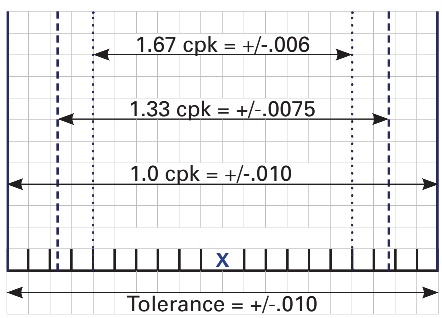
Plastic Molding Tolerances

Commercial
+/- 0.020 (0.508mm) or greater

Standard
+/- 0.005 (0.127mm)

Fine Tolerances
+/- 0.002 (0.051mm)

Process capability, Cpk, sets control limits within a tolerance range. Usually Cpk requirements will necessitate a capability study on those dimensions. There are added costs associated with studying process capability and repeatability. A 1.33 Cpk requirement, in effect, reduces the tolerance band to 75%. Likewise, requiring a 1.67 Cpk reduces the tolerance band to 60%. It is very important to verify your molder's ability to control their processes to attain your stated Cpk's. This will eliminate many issues as the product goes into production.



Gauge repeatability (Gauge R&R) determines how much of the tolerance is lost to measurement variation.

Another critical factor is geometric tolerancing and its application to the molding process. Geometric dimensioning and tolerancing allows for continuous quality assurance of a part, from design through entire production, as it exactly describes the function of a part or an assembly regarding dimensions, shape, and position. These are specifications for flatness, cylindricity, parallelism and others in respect to dependence of respective geometric datum structure.

Some geometric tolerances such as profile of a surface can cause increased inspection time and add significant cost to the part.

Designing plastic parts is deceptively complicated. There are many factors to consider along with the obvious part function, performance, and cosmetic requirements. The checklist below outlines most of the important factors affecting performance and cost for any given application. While not all of these items will be applicable to every part you design, this list should give you a better understanding of your part and what it needs to do, which will help you make changes to optimize the part design.

Injection Molded Plastic Part Design Checklist:*

- [ ] **What is the function of the part?**
- [ ] **What is the expected lifetime of the part?**
- [ ] **What agency approvals are required?**
  For example: UL, FDA, USDA, NSF, USP, SAE, MIL-SPEC.
- [ ] **Will the part be implanted in humans?**
  If so, biocompatibility is your first concern.
- [ ] **What electrical characteristics are required and at what temperatures?**
  Some material properties of concern: Electrical Resistivity, Surface Resistance, Dielectric Constant, Dielectric Strength, Dissipation Factor, Arc Resistance, Comparative Tracking Index.
- [ ] **Will the part be used in an optical system?**
  Some material properties of concern: Refractive Index, Gloss, Haze, Transmission (in desired spectrum; i.e. IR, visible).
- [ ] **What temperature will the part see? And for how long?**
  Some material properties of concern: Coefficient of Linear Expansion, Specific Heat Capacity, Thermal Conductivity, Maximum Service Temperature, Deflection Temperatures, Vicat Softening Point, Glass Transition Temperature, Flammability, Glow Wire Test.
- [ ] **What chemicals will the part be exposed to?**
  Most material manufacturers test their materials with common chemicals. Contact individual suppliers for the results of their chemical compatibility testing.
- [ ] **Is moisture resistance necessary?**
  Some material properties of concern: Water Absorption, Water Absorption at Equilibrium, Water Absorption at Saturation, Maximum Moisture Content.
- [ ] **How will the part be assembled? Can parts be combined into one plastic part? Will one plastic part need to be divided into two or more parts?**
- [ ] **Is the assembly going to be permanent or one time only?**
- [ ] **Will adhesives be used?**
  Some resins require special adhesives.
- [ ] **Will fasteners be used? Will threads be molded in?**
- [ ] **Does the part have a snap fit?**
  Glass filled materials will require more force to close the snap fit, but will deflect less before breaking. Some material properties of concern: Flexural Modulus, Flexural Yield Strength.
- [ ] **Will the part be subjected to impact?**
  If so, add rounds to the corners to minimize stress concentration. Some material properties of concern: Izod Impact, Charpy Impact (Unnotched), Charpy Impact (Notched).

* In no particular order

Source: http://www.formlovesfunction.com/2010/02/injection-molded-plastic-part-design-checklist/

- [ ] **Is surface appearance important?**
If so, beware of weld lines, parting line, ejector location, wall thicknesses, surface texture, draft, and gate vestige.

- [ ] **What color is required for the part? Is a specific match required or will the part be color-coded?**
Some glass or mineral filled materials do not color as well as unfilled materials.

- [ ] **Will the part be painted?**
Some paints require a primer which may attack the molecular structure of the material. Other paints require a thermal cure, so you will need to verify that the material will withstand the oven cure temperature.

- [ ] **Is weathering or UV exposure a factor?**
Some material manufacturers test their materials for UV exposure. Contact individual suppliers for the results of their UV testing. If no testing has been done, plan on doing the UV testing yourself. UV exposure is often overlooked and be detrimental to the physical properties of the part.

- [ ] **What are the required tolerances? Can they be relaxed to make molding more economical?**

- [ ] **What is the expected weight of the part? Will it be too light (or too heavy)?**

- [ ] **Is wear resistance required?**
Some material properties of concern: Rockwell M Hardness, Rockwell R Hardness, Coefficient of Friction (Static), Coefficient of Friction (Dynamic). Surface Finish is also a factor, so adjust draft to allow for the desired finish within the tool, and plan for no ejection on wear surfaces.

- [ ] **Does the part need to be sterilized? With what methods (chemical, steam, radiation)?**
This requirement is similar to chemical compatibility. Some materials are tested and the results published by material manufacturers; others will need to be tested for your specific application.

- [ ] **What is the worst possible situation the part will be in?**
For example, will the part be outside for an extended period of time and intermittently put in water, or maybe see a constant high load while submerged in gasoline? Parts should be tested in the worst case environment.

- [ ] **Will the part be insert-molded or have a metal piece press-fit into the plastic part?**
There are tooling, process, and residual stress implications of insert-molded features and press-fits.

- [ ] **Is there a living hinge designed in the part?**
Be careful with living hinges designed for crystalline materials such as acetal.

- [ ] **What loading and resulting stress will the part see? And at what temperature and environment? Will the loading be continuous or intermittent?**
Some material properties of concern: Ultimate Tensile Strength, Tensile Yield Strength, Flexural Modulus, Flexural Yield, Elongation at Yield, Elongation at Break, Tensile Creep Modulus, Deflection Temperature.

- [ ] **What deflections are acceptable?**
Is the part moldable? Are there undercuts? Are there sections that are too thick or thin?

Supplier Selection Checklist

In a head-to-head comparison of injection molding suppliers, you can make an informed decision by asking the right questions. Does your program demand it? Does your supplier offer it? Consider:

Supplier 1	Empire	
		Design and Technical Support
☐	☑	**Engineering Support** – Computer aided design and production engineering, including DFMEA involvement and PFMEA creation and analysis.
☐	☑	**Design and Engineering Software** – Interprets STEP/DXF/Parasolid/IGES files.
☐	☑	**Rapid Prototyping** – SLA models, short-run tools of P-20 construction or aluminum. Bridge tools for initial small production quantities. Production Intent Prototype tooling.
☐	☑	**Process Prediction Tools** – Mold flow assessment, part shrinkage and warp analysis. Analytical software tools to detect problems early & improve quality.
☐	☑	**IP Protection** – Robust systems in place to protect your intellectual property.
		Tool Building and Support
☐	☑	**In-House Tool Building** – Progressive mold building techniques such as high-speed machining, lights-out manufacturing and unattended machining.
☐	☑	**Modern Equipment & Dedicated Machines** – Continual investment in equipment and automation, such as high-speed mill for hardened steel machining and EDM equipment for manufacturing quality tooling components.
☐	☑	**Strategic Tool Building Alliances** – Alliances with local, regional and international tooling suppliers.
☐	☑	**Tool Service Program** – Preventive maintenance, repair and service programs staffed by a dedicated mold maintenance group.
☐	☑	**Manufacturing Engineering Support** – Experts in processing and manufacturing are involved in tooling design, build and production implementation.
		Integrated Production Management
☐	☑	**Enterprise Resource Planning** – Fully integrated ERP system for production and resource management to ensure on-time delivery and accurate inventory management.
☐	☑	**Production Process Monitoring** – Specialized, real-time monitoring systems such as IQMS, RJG, or Empire's own PDW to ensure product quality.
☐	☑	**Controlled Environment** – Clean room molding and assembly environments, customized to specific project requirements. Class 1,000 to class 100,000.
☐	☑	**Modern Injection Molding Machines** – Hydraulic, advanced hydraulic and electric. Vertical and horizontal clamping. Process control and monitoring.
☐	☑	**Automation and Assembly** – Customer-specific automation for part and runner removal. Single-location quality control from injection molding to final assembly, eliminating variables and chance of defect.

Specialized Advanced Molding Processes

- ☐ ☑ **Scientific Molding** – Use of Scientific Molding principles to develop process for lot-to-lot consistency. Empire utilizes a proprietary software to determine rheology, gate solidification, pack and hold, cavity-to-cavity balance, thermal equilibrium.
- ☐ ☑ **MuCell® Micro Cellular Foam Technologies** – Offering unique performance and processing characteristics for thick wall, sink free parts as well as optimal flow for thin wall long length.
- ☐ ☑ **High Temperature** – Melt up to 800° F. Specialized engineered resins. Specialized annealing of parts.
- ☐ ☑ **Multi-Component** – Insert molding, over molding, including metal insert over molding and multi-material in-mold assembly applications.
- ☐ ☑ **Fine Tolerance** – Feature-rich components and complex plastic components.
- ☐ ☑ **Micro Molding** – Specialized tooling, metrology and molding equipment for the design and production of micro molded parts (less than a gram).

Progressive Quality Systems

- ☐ ☑ **Comprehensive Quality Management System** – Fully integrated into the ERP software for record retention of quality and problem resolution.
- ☐ ☑ **Quality Certifications** – ISO-9001:2008 (Standard) and ISO 13485:2003 (Medical Device, 2010) Registration, with TS 16949:2003 (Automotive) Compliance.
- ☐ ☑ **Advanced Test Lab** – Fully programmable CMM and Vision measurement system, in-house fixture build capability, and Gauge R&R.
- ☐ ☑ **Six Sigma** – Certified Six Sigma Master Black Belt. Methodology driven throughout the company to strive for continuous improvement and zero variability.
- ☐ ☑ **DQ/IQ/OQ/PQ** – Validation of process to ensure components perform through all stages (Design, Installation, Operation and Performance).
- ☐ ☑ **Metrics Tracking** – Process Control, Design of Experiments, and Process Capability Studies for both Process Variables and Product Characteristics.
- ☐ ☑ **Process Monitoring** – Real-time monitoring of mold cavity pressure & temperature, material viscosity, fill pressures, water temperatures, cushion, etc.

Customer Service

- ☐ ☑ **24/7 Support** – Around-the-clock assistance from a dedicated staff.
- ☐ ☑ **Vendor-Managed Inventory** – Just-in-time and Kanban production planning capabilities.
- ☐ ☑ **After-Sales Support** – Continuous improvement (Kaizen), problem solving and root cause analysis to reduce cost and improve efficiency.

Tradeoffs to Consider

Fast turnaround

Low cost

Low-volume capable

High quality

Offered at Empire

Choosing a Prototype Path

If your program will ultimately be high volume (1M parts per year or more), your prototyping strategy is extremely important to ensuring a high-quality finished product. Empire can suggest a prototyping option that best suits your program and results in a seamless transition to full production.

The type of prototyping you choose will depend on:

- Type of part being made
- Required turnaround time
- Budget
- Materials used
- Anticipated level of design change post-prototype
- Your design team's experience with injection molded parts

Prototyping for Plastic Optical Components

Single Point Diamond Turning (SPDT)

Single Point Diamond Turning, or SPDT, can significantly reduce the cost of prototype optics. Plastic optical designs can be created without the added first step of building an expensive injection mold, saving time and development costs. Diamond turning is also well suited for the manufacture of precision plastic optics in limited quantities. SPDT small-volume runs help our customers meet early demands before moving into full-scale production.

Quick Facts: 2-4 week turnaround, cost varies

Prototyping for Opaque Plastic Parts

3D Printing

An adaptive process of prototyping is ideal for projects that require fast turnaround. 3D printing technology can produce precise models, prototypes, and patterns in record time. However, this technique also presents design limitations and fewer resin choices.

3D technology processes include: stereolithography (SLA), fused deposition modeling (FDM), selective laser sintering (SLS), PolyJet 3D printing using photopolymer, syringe extrusion

Quick Facts: 2-3 day turnaround, $500-1K

Take-apart Tooling

While take-apart tooling is useful for lower-volume programs or early-stage prototyping, it does not create parts in a continuous or consistent process, often making an additional form of prototyping necessary.

Quick Facts: 3-4 week turnaround, $2-5K

Rapid Aluminum Tooling

With rapid tooling, you own the tool. This method allows for easier design and mold changes, more resin choices, and higher-volume runs. Parts can also be grouped in a family tool for greater cost savings. An aluminum tool is considered a "production-intent prototype tool."

Quick Facts: 3-4 week turnaround, around $7-12K

Case Study

A U.S. handgun manufacturer designed a prototype from solid industrial metal. Now that they're ready for plastic, they can use take-apart tooling to minimize costs while working out final design details; they can then move to aluminum before their final production tooling.

Precision Machining

This subtractive method involves shaping stock materials using CNC mills and lathes.

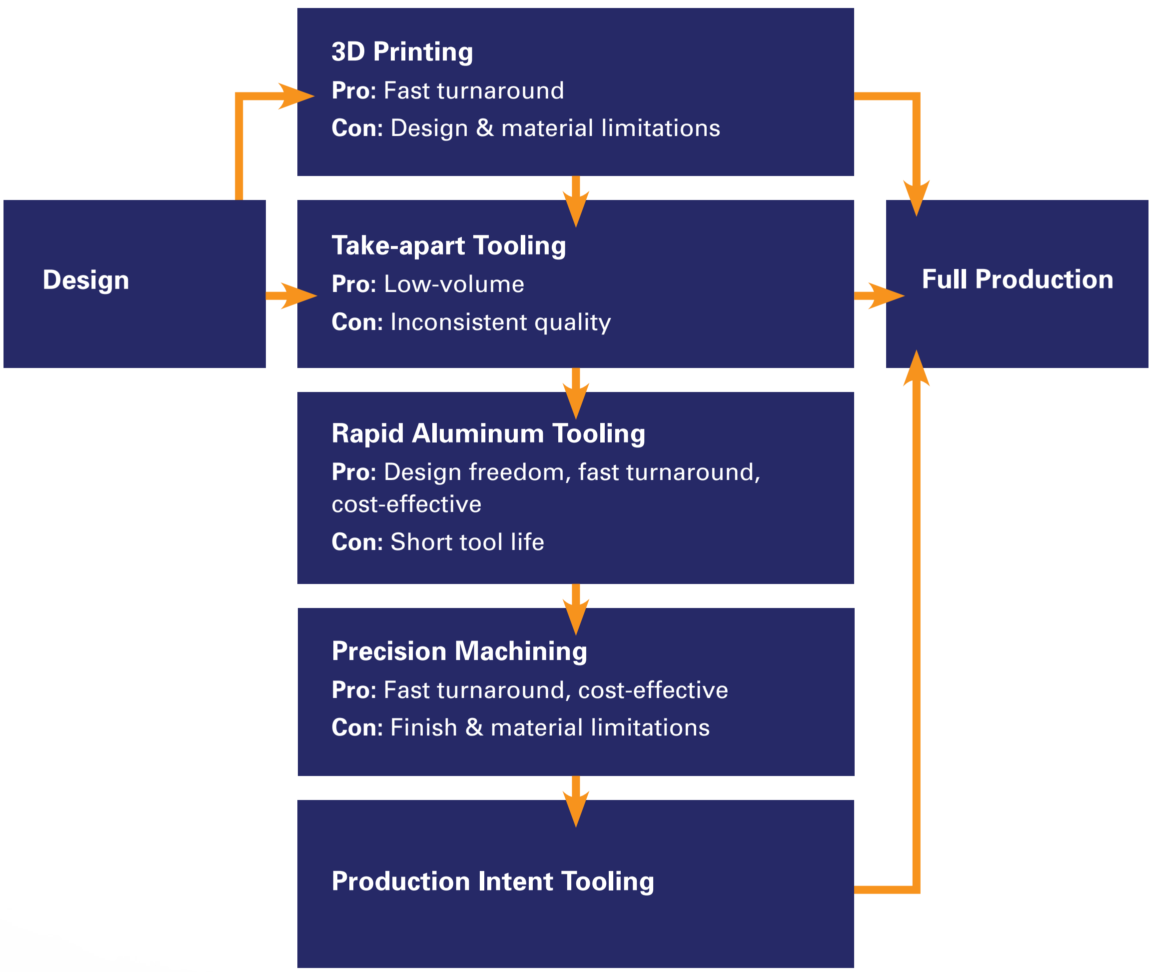
Quick Facts: 2-4 week turnaround, cost varies

Production Intent Tooling

Once the final design is established, high volume injection molded programs will require production intent prototype tooling. This type of tooling involves the same gating, ejection, and cooling procedures as will be applied in full production. Production-intent prototypes, unlike take-apart tooling, are created using rigorous Scientific Molding processes.

Not One-Size-Fits-All

Each part and program has to be individually evaluated to determine the best-fit prototype process. Every method has strengths and weaknesses that make it suitable or unsuitable in different situations. New technology is continually broadening the boundaries of what is possible and creating new methods to effectively bring programs to production.



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