Design For Manufacturability For Micro Molded Devices
Conference on Micromanufacturing

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Abstract

Designing microscopic devices or microscopic features on miniature devices creates engineering challenges that result in lengthy product design cycles due to failures or restarts due to design flaws. Current standards of design criteria exist for larger, more conventional molding but developments in the area of micro molding has created a need to better understand the physical properties of micro injection molded parts that have been filled in .002"-.003" gates. This paper explores the solutions to design for manufacturability challenges for micro molded components.

Definitions

Webster's dictionary defines "micro" as:

- Very small; *especially***:** MICROSCOPIC
- Involving minute quantities or variations
- Extremely small in scale or scope or capability

Although there is no standard definition of micromolded components, most micro manufactured components have one or more of the following attributes:

- Fractions of a plastic pellet or weighing fractions of a gram
- Having wall thickness of less than .005"(0.127mm)
- Having tolerances of .0001" to .0002"(0.0025 to .0050mm)
- Having geometry seen only by use of a microscope

Introduction

Many new products exist today because of the introduction of micromolding just a decade old. At the beginning stages of micromolding, only two to three micromolding machines were available on the market that were considered small enough shot size machines. Today, there are over thirty entries of machines in the micromolding arena. The technology is ripe for creating new and innovative microscopic components but the technology is limited to a select few who had the foresight in an economic downturn to invest in the technology. For this reason, scarce knowledge is known and more importantly shared throughout the micromolding industry, creating a need for micro molding expertise and integrated, advanced solutions.

Creating and manufacturing successful solutions for the micromolding market is a subtle marriage between the making of extremely precise micro components and the packaging of micro assemblies. The industry demand for even smaller microscopic components and features leads component manufacturers to implement automated assembly and integrated solutions in order to maintain or improve the quality of their micro devices.

Faster times-to-market for new micro products are achieved by combining micro manufacturing experience and engineering input in the design and manufacturing of a custom-built integrated micro molding system. Cross-disciplinary teams of micro manufacturing and design engineers working together on a micromolding system provide expedited development cycle for new micro products.

Micro Molds

The economically viable and reliable production of micro-molds is critical to developing microscopic microscopic medical devices and components. Scaling of the process from the knowledge of the macro or conventional manufacturing world, however, creates new problems in the integrated process chain. Basic research of micro technology and the use of these technologies for creating micro molds is the enabling factor for making micromolded parts and features possible. Many technologies exist such as:

- Laser Machining
- Chemical Milling
- Electrochemical Machining
- EDM-WEDM
- Photochemical Milling
- Ultrasonic Machining
- Ion Machining
- CNC Machining

Although these technologies exist and are available, the challenge still exists to pull pieces of steel together that were made from different sources using different technologies to create a micro mold. Continuous research must be done in order to keep up-to-date with the latest micro machining methods that are useful, economical, and can be employed and utilized with for a particular micro mold project.

Practical Applications for Micro Molding

- Neurology coil insert molded assemblies
- Resorbable Polymer Implants
- Pharmaceutical Induced Polymers
- Pediatric catheter tips
- High speed reel to reel industrial assemblies
- Insulin delivery pump assemblies
- Disposable diagnostic devices
- Optical Lenses
- Silicone Implantables
- Micro Electronic Implantable Battery Cases

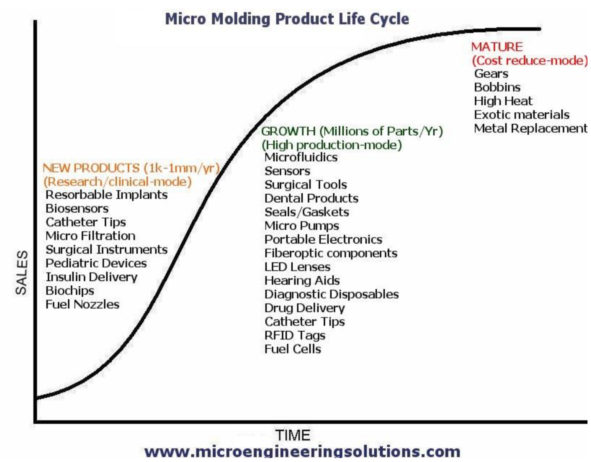

Table 1.1 Micro Molding Product Life Cycle

Worldwide Challenges in Micro Molding

Many challenges exist in micromolding and micromolding systems are a way to minimize these challenges and corresponding risk of failure to component manufacturers. These challenges include:

•**Modeling of Micro Components** – There remains a limited understanding of the fundamental physics at the micro scale, which are necessary to develop reliable models. Although there has been work performed in this area, much more research is required to perfect the modeling software, materials specifications, reliability models and simulation models for micro component manufacturing.

•**Environment** – As one single degree of temperature change can affect precision when machining at the submicron level, many micromolders and micro machining experts enclose the entire machine and/or inspection area in order to create a controlled working environment.

•**Metrology/Inspection Techniques** – Inspection techniques in measuring very small micromolded parts requires customized vises, tweezers, and fixturing. Inspecting steel measurements usually provides a flat, robust surface that can be measured with non-contact means or in some cases contact measurement. These same surfaces that make the molded components can be used to "certify" the dimensions much closer in repeatability and reproducibility than attempting the same corresponding measurement in the micromolded components. It's not uncommon for the first article inspection to consume as much time if not more time than the entire micro moldmaking and micromolding project combined. Gage R&R from client to vendor requires duplicate fixturing and exact methods of inspection technique to repeat the results to near micron tolerances. Only a select few sources of inspection equipment exist that are capable of measuring to sub-micron tolerances and extremely clean and hepa-filtered, air controlled rooms are necessary to the environment needed for repeatable measurements. It's also common in macro components and specifically with medical devices to insist on 1.33 Cpk or better with respect to performance to drawing dimensions or tolerance. 1.33 Cpk on .0001" tolerances requires a mathematical impossibility in some cases when the gage R&R and operator R&R are taken into account. Component manufacturers and micromolders require similar inspection machines with identical fixtures to validate tolerances in micro components.

•**Properly sized machines** – It's very common to see micromolded components that have sprue and runner systems amount to 75% or more of the total shot. For many molders trying to enter this market, micromolding parts in larger machines is commonly attempted. Molding parts in this manner is not recommended on machines larger than 0.5 ounce because it is hard to control such small shot sizes. Also, long residence times and material degradation would occur with oversize screw and barrel combinations. Tabletop machines are not considered good candidates for micromolding, as they are not usually designed for high-volume production and process control capability.

•**Standardization –** In the macro world or conventional molding arena, much research and development was done to provide tensile testing, Izod impact bars, and spiral flow molds-all great tools of prediction and theory on mold flow and physical properties of macro components. These standards are not applicable to micromolding because an extra element of shear and extreme injection pressures and velocities are inflicted in micromolding that change the viscosity of the material and all of the “rules” of general purpose molding and the predictability values that we once knew in theory and practice. Also, the polymer “skin” properties of many materials dominate since there is virtually no wall thickness to these parts. Companies are working with ASTM and NIST to investigate some alternatives to these challenges that will provide tools of prediction, verification, and validation for micro components.

•Part Handling/Static – Part handling can be challenging given the sizes of micromolded components. Many micromolders use edge-gated runners to carry their parts from one location to another and many are used as part of the automation process. If parts cannot be edge-gated, customized end of arm tooling, vacuum systems, reel-to-reel take-up equipment and blister packs are utilized accordingly.

Static electricity is a micromolders nightmare. Parts as small as dust can easily be lost if proper grounding of part collection systems, robotics, packaging, and inspection systems are not performed. Static guns, wands, air curtains, and grounding mats are commonplace in micromolding facilities.

Micro Material Process Matrix

Process	Metal Injection Molding (MIM)	Centrifugal Investment Casting (CIC)	Machining	Micro Molding	Ceramic Molding	Liquid Silicone Molding
Complexity	HIGH	MEDIUM	HIGH	MEDIUM	HIGH	MEDIUM
Density	95-100%	95-99%	100%	95-100%	95-100%	95-100%
Material Possibilities	MANY	FEW	MANY	MANY	FEW	MANY
Production Volumes	MED TO HIGH	LOW TO MED	LOW	LOW TO HIGH	LOW TO MED	LOW TO HIGH
Size Range	0.003g to 250 g	1.0g +	1.0g +	.0001g to 250 g	.0001g to 250 g	.01g to 250g
Strength	95 to 100%	98%	100%	95 to 100%	95 to 100%	95 to 100%
Surface Finish	0.4 to 0.8um	3um	0.4 to 2um	0.4 to 0.8um	0.4 to 0.8um	0.4 to 2um
Wall Thickness	10 to 0.1mm	5mm	2mm	.04 to 1.0 mm	10 to 0.1mm	.04 to 1.0 mm

Table 1.2 Micro Manufacturing Processing Matrix

Conclusion

Medical Device, Electronics, and Biopharmaceutical manufactures need new products that create tinier, less invasive, fluid-induced, and/or space saving micro devices. These products require integrated, micro and automated solutions to ensure their success out of the gate. The tiniest parts in an assembly are the ones most likely to be a challenge and are also usually the enabling component of the entire devices form, fit, and function. Many new advances in micro technology have been developed worldwide for the creation of microscopic features and components. More advances of micro molding technology will push the envelope of tiny components and features enabling even smaller micro devices of the future.

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