

MICROMOLDING

Micromolded Parts Need Micromold Machines

It is a fallacy that conventional injection molding machines can mold microparts. Medical device manufacturers should use micromolding machines.

**Scott Herbert
Rapidwerks Inc.**

Over the years, micromolding has become a hotbed for solutions to problems that have been plaguing medical device companies. As implants and other devices get smaller and smaller, they have tinier parts that need to be molded. However, some in industry have a faulty assumption that normal everyday injection molding machines can mold microparts. They may try, but there's a price to pay. You simply cannot apply the same principles of injection molding for regular-sized parts to injection molding for micro-sized parts. This article will explain why.

Different Principles

We often see people trying to use oversized machinery to injection mold microparts. Sometimes we are asked to take tools that were fabricated for larger machines and try to incorporate them into a micromolding system. There are many issues with doing that. The end result is unfortunate: a frustrated customer who is late on delivering product to market and has a variety of problems to figure out.

A 30-ton machine attempting to mold a part that is micro in size presents a plethora of issues. Yet some people apply the same principles of injection molding to micro-sized parts. They fail and often don't understand why. Typical symptoms are inconsistent part weights or short shots, yield issues, resonance problems, excessive material waste, and parting line flash. All are serious problems and can be solved by micromolding.

There are complexities with both conventional injection molding and micromolding. Much tooling and processing work goes into each system. However, there are misconceptions as to the complexity and detail that needs to be addressed when creating a tool that produces a part half the size of a human hair.

On the left are two photos comparing shot weight, sprue/runner weight, part weight, and cycle times. These photos clearly show differences based on the technology applied and truly will depict the savings in time and cost savings from not wasting material. The conventionally molded part took more than twice the shot weight and almost quadruple the sprue/runner weight than the micromolded part. Yet the micromolded part was produced at a rate almost three times faster.

Micromolding and small part molding are not the same thing. Here are the definitions that will be used for the purposes of this article.



These switch pins are an example of how micromolding saves time and materials. They have the same weight, 0.017 g. But the ones on the left, made by conventional molding, required a shot weight of 0.23 g, a sprue/runner weight of 0.165 g, and a cycle time of 6.3 sec. Whereas the ones on the right, made by micromolding, required a shot weight of 0.109 g, a sprue/runner weight of 0.044 g, and a cycle time of 2.7 sec.

- For micromolding, part weight is 0.001 g or smaller, and part size of 0.075 in. diameter or smaller. These parts require specialized machines for molding, specialized tooling, and custom part handling for part extraction and part packaging.
- A small part might have a part weight of 0.1 to 1.5 g or a diameter of 0.25 in. or larger. These are produced using a conventional molding machine and standard tooling practices with common-part ejection and handling.

Microtool Design

Designing a microtool can be broken into four different categories for discussion. They are: tool design and simulation, or “mold flow”; tool fabrication; tool assembly; and test shots.

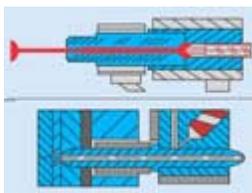
Once a tool is complete, simulation will help you understand material flow for your particular tool design and part. This may aid in such a way that you will identify problems before tool fabrication occurs. You might be able to identify potential voids, sink marks, too-small gate sizing, freezing off prematurely, or even incomplete filling of the cavity. Any of these issues will affect your part quality and dimensions. Some design software may provide condensed versions of this technology, but they are limited in options. They may not have enough options as far as rheology data for specific materials, gate size options, material types, location of gate, and cooling or heating of tool. A simulation system does have a full range of those options, and so it will certainly help you create a tool that is near-perfect before you even cut steel.

Fabricating your tool using conventional machining practices such as machining centers, mills, lathes, grinders, wire electrical-discharge machining (EDM), and sinker EDM technology is good, and in most applications, sufficient.

Some applications require an alternate process to be used, such as when the resolution of the EDM is not good enough to capture the fine detail of a cavity feature. In this case other options include laser, x-ray lithography, electroplating, silicon etching, and photolithography. All are acceptable means of creating fine detail for your cavity geometry.

Potential Problems

Typical problems of injection molding a micropart with an incorrect machine are material plasticizing (or plastification) and melt homogenization. This can be due to a number of issues. One may be that the part and runner are sized such that the screw of the molding machine might not have enough material to move (by screw rotation) before it has to switch over from injection to holding.



A micromolding system (bottom) has a smaller melt cushion, a lower resonance time, a shorter flow length, and much less runner loss than a conventional molding system (top).

In many cases where this occurs, the screw may move as little as 0.01 in., and then switch from injection over to holding. This is very typical when using a large tonnage machine to mold a micropart. When this occurs, the next few shots typically are good, but then the tool might flash, and the process starts all over. This is evidence of an inconsistent process due to using the incorrect machine for the application.

Most solve the problem by making the runner diameter large enough to allow the machine to control the dosing or shot size. This is one solution that does work. However, it is not ideal and it is extremely costly to the customer. Additionally, it does not solve the resonance problem that occurs due to excess material sitting idle in the screw. But it does allow

the machine to function and mold continuously.

The issue surrounding processing and resonance of material is nonexistent for a micromolder. They are well equipped to control small amounts of material while being very sensitive to shot size, runner size, and resonance time. This becomes more of an issue when utilizing engineering materials that cost hundreds of thousands of dollars per kg. Implantable, absorbable, or resorbable materials cannot withstand the exposure to heat, nor can the medical device manufacturer afford the material waste.

Additionally, it is difficult to properly control the correct amount of material to be injected into the cavity while holding extremely tight or close tolerances. The problems that result can include inconsistent or irreproducible shot sizes, material freezing due to extremely small mass, material degradation, melt homogenization, and static electricity issues.

Economic Justification

There are many reasons to move towards micromolding from standard injection molding, especially when considering large-volume runs where material costs and cycle times are extremely important. In many situations involving high-volume parts, the material savings alone justifies the new tool expenditures. In some cases, the cost savings in material usage justifies the cost of retooling even if you already have a tool created for a larger system.

Why? Raw material costs are half as much for micromolding as they are for standard injection molding. Standard machines have a significantly larger part-to-runner ratio than micromolding machines. That translates into increased cycle times, material usage, and costs to manufacture.

Conclusion

When considering a micropart to be molded, there is more to it than meets the eye. Using an oversized machine to mold a micropart can create process problems and part issues, including inconsistent shot size, degradation of material, and excessive flashing of the tool – which is ultimately a process that won't work.

Even without process and part problems, there is a cost associated with using the wrong machine. A significant difference in tooling, material usage, part handling, and cycle times all add costs to the part.

If you have a micro-sized part, don't assume that conventional injection molding is the best way to make it. For a better process at a better cost, micromolding may be the answer.

Scott Herbert is the president of Rapidwerks Inc. (Pleasanton, CA).

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STANDARD MOLDING VS. MICRO-MOLDING FOR MICROSIZED PARTS	
STANDARD MOLDING	MICROMOLDING
Slow process	High-speed, dynamic process
Large molds	Optimized mold technology
Large sprues	Small sprues
High energy consumption	Efficient energy consumption
Part free falling	Integrated part handling
Quality check afterwards	Automatic quality assurance
Oversized peripheral technology	Adjustable peripheral technology

MICROMOLDING

The Challenges of Micromolding

Donna Bibber
Technical Partner, microPEP

Micromolding is an unconventional method that can serve manufacturing initiatives in several ways. But it doesn't come without its challenges. These include:

- How to teach product designers about the new possibilities offered by micromolding.
- Determining limits on what is possible to mold. What are the limits on characteristics such as wall stock and gate sizes?
- How to ensure that mold flow is balanced during micromolding. What in terms of flow dynamics must be considered when the parts being molded are fractions of a pellet? This is particularly important when multiple cavities are involved.
- Figuring out the best way to perform mold flow analysis for micro-sized parts.
- Determining acceptable tolerances. Chances are, some tolerances acceptable in conventional molding won't be in micromolding.
- How to achieve accurate steel positioning to ultra-precise tolerances.
- How to determine the optimal way to handle micro-sized parts.

If you carefully consider materials properties and design an optimal process, you could benefit from implementing a micromolding strategy. This can be the case regardless of whether your product is new or mature.

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MICROMOLDING

Micromolding Techniques Grow with Demand

New micromolding materials and processes are emerging in response to demands from precision medical device manufacturers.

Beth W. Orenstein

Contrary to its name, micromolding has become very big in the manufacturing of medical devices over the last decade or so.

The push for smaller and smaller devices is driven by the enormous growth in the number of noninvasive procedures being performed in outpatient suites and operating rooms. That means there is more need for tools and implantable devices that can transverse orifices and tiny blood vessels.

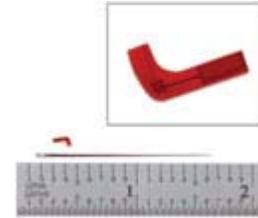
"They're doing a lot of minimally invasive procedures, such as single port surgery and NOTES—natural orifice transluminal endoscopic surgery—where the surgeon enters the body through a natural orifice such as the mouth, navel, or urethra to avoid having to make incisions," says Jim Jock, marketing coordinator of Micro Medical Technologies (Somerset, NJ). As a result, the endoscopes, catheters, needles, and other instruments the surgeons use for the procedures have to be that much smaller and more flexible, he says.



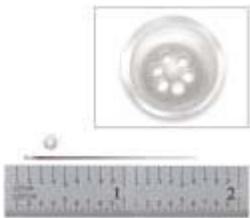
Micro-Mold brand thermoplastic parts from Accumold are used in a variety of medical and microelectronic applications. (ALL PHOTOS COURTESY OF DONATELLE.)

One challenge however, is that micromolding can change the properties of a polymer as it is being squeezed into such a small area. The material has to be forgiving, and the manufacturing process must be designed so that there is little, if any, waste from the process, she says.

Bibber notes that resorbable materials are not that new. Although they've been available for at least 10 years, she says, the early ones were like mud, "and you just weren't able to create thin-walled parts." However, newer materials that are coming onto the market are much easier to work with. As a result, the number of applications is growing, and micromolders are having to step up to meet the demand for sensors, catheter tips, tubes, and implants that their designers want downsized considerably.



A sensor housing implantable made from polyoxymethylene for hearing aids. Part volume is 3.7 mm³, and shot volume is 159 mm³.

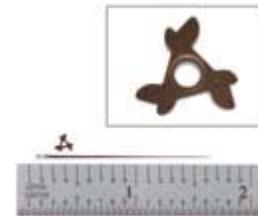


A micro filter made from polyoxymethylene for hearing aids. Part volume is 3.9 mm³, and shot volume is 288 mm³.

Johnson says that while he has certainly seen a lot more interest in bioresorbable materials lately, some issues remain. One is that they can start to dissolve, depending on the temperature. As a result, he says, manufacturers have to be more innovative than ever when it comes to designing the parts in which they are used.

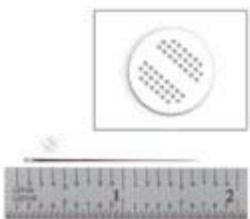
A Slow Conversion

John Whynott, technical product manager for Mikrotech, a division of Asyst Technologies LLC, (Kenosha, WI), expects the demand for micromolded devices from resorbable polymers to continue to increase. However, he says it will be a slow conversion. The medical field has been using metals, including stainless steel, for its devices for the last century, and as a profession, it is rather conservative. Even though "there may be better, newer, cheaper technology out there," it will take a while to catch on, Whynott says. "Buyers have no experience with it and to them, it's a huge element of risk going forward."



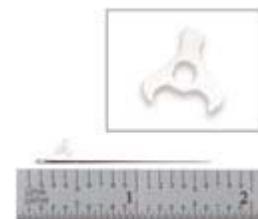
A catch wheel made from polyamide and glass for micro switch applications. Part volume is 5.3 mm³, and shot volume is 112 mm³.

However, he says, that lack of confidence in the newer materials and micromachining methods is going to slowly erode as they continue to prove themselves.



An 80-µm micro filter made from polyoxymethylene for applications in medical and acoustics. Part volume is 0.63 mm³ and shot volume is 112 mm³.

Johnson also expects that the demand for micromolding with bioresorbable polymers will increase as the technology improves and the price comes down. "We've been asked about it many, many times recently," he says. "But often the customer goes down another route, because it is cost prohibitive. Eventually the price will come down or processes will be developed that help reduce the cost, and the interest will be there and companies will go with it."



A locking lever made from polyoxymethylene.

Johnson says a lot is being investigated that holds much promise. For example, he says, one biomaterials solutions firm, Invibio (West Conshohocken, PA), recently announced that it embarked on a major project with Smith & Nephew plc (London), a global orthopedics maker. “[The goal is] to develop advanced structural bioresorbable materials with the performance specifications needed for more rigid, load bearing applications typically not attainable by today’s resorbable biomaterial technologies,” says Johnson.

polyoxymethylene for micromechanical and microswitch applications. Part volume is 0.70 mm³, and shot volume is 93 mm³.

New Techniques in Micromolding

Another trend in micromolding is the development of new techniques to provide tighter tolerances and better quality control and surface finishes.

Tolerance is a big issue nowadays. It’s not just about how small the part can be made, Bibber says.

Regardless of size, micromolded parts must have tight tolerances, ranging from ± 0.001 to ± 0.0001 in. and down. That presents designers and engineers with multiple challenges, says Mike Wilkinson, principal tooling engineer for GW Plastics (Bethel, VT).



Plastic micromolded and small parts made by Micro Medical Technologies used for RealHand High-Dexterity Surgical Instruments. The RealHand won a Medical Design Excellence Award in 2008.

Product and mold designs for microparts have been going through a learning curve over the last several years, Wilkinson says. “Mold manufacturing techniques have evolved. Specialized CNC [computer numerical control] machines, modified electrical discharge machining, and silicon water technology are now being used to produce precise cavity geometry for very small parts,” he says.

Specialized micromolding machines also have improved significantly over the last several years, according to Wilkinson. Today, some of the specialized micromolding machines offer integrated part removal, packaging, and vision inspection.

Johnson says that Accumold, too, “is continually being asked to push the envelope with what you can do with plastic, and we’re answering the demand from a tolerance and part-size standpoint.”

Bibber says one of the many challenges of micromolding is that with small parts, “what you have in steel is what you have in plastic.” Typically, a macromolded part will shrink away from the cavity and onto the core, making the transfer from the cavity side to the ejector side of the mold easier. However, because smaller parts have less shrinkage, the transfer forces are not as great, which means the release from the cavity side can be affected significantly by the surface finish. With conventionally sized parts, the machine cavity finish can be stoned and polished, but for a part with features as small as 0.005 in., it would be impossible to improve the finish by hand.

Like most micromolders, Bibber says, microPEP is developing ways to improve the surface finishes of micromolded parts. It has become an art form just to get the micro parts off the gates cleanly, and when parts go into the human body, they can’t have any jagged edges.

Vadlamudi says micromolders of medical devices are studying and adapting techniques used by watchmakers so that they don’t have to reinvent the wheel.

One technique to finish micromolded parts that has been on the rise is stereolithography.

Bibber says it also is becoming more common for micromolders to remove the miniscule parts from the gates with ultrasonic energy.

Developments with hot runner and cold runner systems also have helped to improve the precision of micromolded parts and the speed at which they can be manufactured.

D-M-E Co. (Madison Heights, MI) has adapted its hot runner system to work specifically for small parts, says Trevor Pruden, a mechanical engineer at the company. "We focus on going smaller and smaller with our channels and making our nozzles more precise," he says.

Validating the micropart is yet another challenge, Bibber says. Using certain vision systems and microscopes that magnify to 600X aids in measuring surfaces and tolerances, but this is an area where companies are always looking for better ways, she says.

Due to the high cost of some materials, companies get upset when they are throwing out more material than they are molding, says Whynott. Thus, the trend in the field has been to utilize processes that are precise and that waste little of the material as it is pushed into the cavities, he says.

As the parts get smaller and smaller, many manufacturers agree that the techniques used to build molds and to develop the molding process has to be changed.

Vadlamudi points out that the analytical technology aids such as pressure sensors and temperature sensors used to understand the process behavior must be redesigned to suit microsized parts. One promising technology uses ultrasonic waves to characterize the micromolding process, he says. "Atomic force microscopy and nanoindentation are the other techniques that are being developed to derive relationships between the process variables and product characteristics," he adds.

Turnaround Time Improving

Yet another trend in micromolding is the increased speed at which the parts can be turned around.

"As manufacturers get more experience with these kinds of tolerances, it's getting much easier for them to turn around projects," Vadlamudi says. "It used to take a lot of time to make a micromolded part. Not anymore."

Bigger parts afforded manufacturers more freedom, because if a part changed by 0.001 in., it didn't matter to the finished product, but that isn't the case with a microsized part. "Being off that much on a dust-speck-sized part and you could lose a quarter of the part," Vadlamudi says.

Pruden says that thanks to its hot runner and other technologies, the turnaround time for equipment needed in micromolding is now four to six weeks. That's down from the eight to ten



A variety of micromolded and small plastic components made at the Largo, FL facility of Micro Star Innovations, a sister company of Micro Medical Technologies.

weeks it would take when the process wasn't as computerized, and the micromolded part geometries had to be input into the equipment by hand.

How Small Can It Go?

Micromolders see the demand for microsized medical device parts only continuing to grow. The question then becomes how small parts can go and what's the limit.

Many micromolders don't see an end to the downsizing of parts. "With the development of new technologies, new materials and new processes, there is no telling what tomorrow will bring in the world of micromolding," Wilkinson says.

He and his colleagues agree—the trend in the world of micromolding is going to keep the sentiment that "if it can be conceived, it likely can be achieved," says Wilkinson.

Beth W. Orenstein is a freelance writer based in Northampton, PA.

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