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# Micromolding: A Cost-Effective Alternative to Micromachining

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## abstract

Historically, machining has been the only feasible manufacturing alternative for manufacturers sourcing low-to-moderate quantities of microcomponents. Molders, because of the modest volumes or the complexity of the components, have often shunned these manufacturers. However, with advances in technology, micromolding can now offer a range of cost-effective alternatives for components that are miniature, complex and require high-precision tolerances. Machining places limitations on the material selection process where high-cost ceramics or engineered metallic materials are commonly used. As a result, sourcing low-to-moderate volume microcomponents has been a costly challenge for manufacturers. Advances in material science and plastic injection-mold equipment permit complex machined microcomponents to be injection molded in metal, plastic or plastic with metal or ceramic filler. There are a number of cost and design advantages that can be obtained by converting. Engineers looking to decrease the overall size of their product, incorporate complex features, reduce the number of components or reduce costs should consider converting from machining to micromolding.

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# Micromolding: A Cost-Effective Alternative to Micromachining

*Finding new cost reductions when you thought you had run out of ideas. Micromolded plastic has grown to be an accepted choice to replace miniature machined components.*

**John Whynott,** Mikrotech, Division of ASYST Technologies LLC

Historically, machining has been the only feasible manufacturing alternative for manufacturers sourcing low to moderate quantities of micro components. Molders because of the modest volumes or the complexity of the components have often shunned these manufacturers. However, with advances in technology, micromolding can now offer a range of cost-effective alternatives for components that are miniature, complex and require high precision tolerances.

Machining places limitations on the material selection process where high-cost ceramics or engineered metallic materials are commonly used. As a result, sourcing low to moderate volume micro components has been a costly challenge for manufacturers. Advances in material science and plastic injection mold equipment permit complex machined micro components to be injection molded in metal, plastic, or plastic with metal or ceramic filler. There are a number of cost and design advantages that can be obtained by converting. Engineers looking to decrease the overall size of their product, incorporate complex features, reduce the number of components, or reduce costs should consider converting from machining to micromolding.

There are three key factors to the success of any micromolding project: the mold tool, the molding equipment and the quality inspection equipment. These variables are critical for obtaining a micromolded component to specification, yet individuals sourcing micromolded components commonly overlook them.

Attempts to micromold components using conventional molding equipment often fail. It is important that a buyer obtains an adequate understanding of the mold tooling and the capabilities of the equipment being utilized so that they can make an informed decision as to whether or not the micromolder can provide a successful product. Choosing a company that specializes in micromolding offers the best chance to succeed.

## Advantages of Micromolding

There are a number of benefits that can be achieved by converting to micromolding. The one big reason companies convert is the cost savings they incur. That’s because the amount of time it takes to mold a component is a fraction of what it takes to machine a component. Another is particle contamination. Designers do not want to have the possibility of foreign matter being introduced into their fluid-carrying medical devices. Micromolding eliminates the potential failure mode of having particulates left after machining.

Micromolding also gives more freedom to designers to place intricate features in products thereby enhancing their ability to create more innovative products. As the trend for components becomes smaller it might become more difficult to machine complex geometries making micromolding the only option. Table 1 summarizes the benefits of molding vs. machining.

Table 1. Benefits of Molding vs. Machining

| Benefits |
|---|
| Provides lower cost solution |
| Incorporate complex geometries (e.g., radii) |
| Dimensionally stable production process |
| No particle contamination |
| Use alternate resins or fillers to improve mechanical and/or electrical properties |
| Better surface finish |

In addition, micromolding offers solutions to some common manufacturing issues.

1. Medical devices that require visibility under an x-ray are typically made from metal. The density of the material provides the contrast needed to accurately locate the position of the device inside the body during the procedure. Plastic resins filled with radiopaque compounds can be visible under x-ray imaging and can be used to replace metal components. Materials typically added to base resins to add radiopacity are barium, bismuth and tungsten.[1]
2. Medical devices that carry current (amperes) need to be isolated from the main body of the instrument. This additional component increases the diameter of the product. Moving to a molded plastic component can remove the need to add isolation to metal components thereby reducing the size of the device.
3. Plastic with metal or ceramic filler can be a suitable replacement for metal injection molding (MIM). It eliminates the need for secondary operations associated with metal injection molding (MIM).

[1] Innovative Bulletin, Radiopaque Compounds (Winona, RTP Company, 2004).

4. Micromolding can be suitably vertically integrated into an entire manufacturing assembly process that may include stamping, insert molding, bonding or conventional molding.
5. Ceramic is traditionally very brittle. If a device is dropped it could break rendering the entire device unusable. Substituting ceramic for a plastic resin with ceramic filler can increase the toughness.

So what type of component makes a good fit for converting to micromolding? A component suitable for conversion has one or more of the following characteristics:

- Currently in production
- EAU between 5-250k
- Machined from metal, ceramic, glass or plastic
- Volume less than 1.0 $cm^3$
- Contains a high degree of complexity and/or high precision tolerances

Here is an example of a potential cost savings project we are currently working on. The project is for a medical device manufacturer and contains two components. It is currently in production. The EAU is 10k each. The customer noted the only problem they have with the current components is the cost. The customer is paying approximately $10.00 and $9.50. The equivalent cost for a micromolded component would be approximately $2.50 and $2.20 respectively. Table 2 below shows the potential savings for the project.

Table 2. Costs of Machining vs. Micromolding

| | **Pivot** | **Washer** |
|---|---|---|
| EAU | 10,000 | 10,000 |
| Machined cost | $10.00 | $9.00 |
| Micromolded cost | $2.50 | $2.20 |
| Annual savings per component | $75,000 | $68,000 |

If we switch to a molded PEEK substitute at approximately $2.50 & $2.20 per component would result in a savings of $143,000 per year! The annual savings would be enough to offset any costs associated with seeking regulatory approval again.

## Micromolding Materials

There are several injection molded grade resins on the market today that are suitable replacements for metal, ceramic, glass or plastic machined components. Products made from these resins are already used in the medical, defense and automotive markets. Table 3 lists some typical materials we found to be suitable replacements.  These replacements are by no means all the possible alternatives but are the ones we have worked with from one project or another.

Plastic resin manufactures will be challenged to make more products available for micromolding.  As parts become smaller there will be a greater emphasis placed on the consistency of plastic resins, not from lot-to-lot but from pellet-to-pellet.  More and more components require the volume of less than a plastic pellet.  Nanotechnology will play an important role filling this void.  Currently there are only a few types of micro-pellets and micro-pellet compounding equipment on the market.

Plastic resin manufacturers will also be challenged to reduce minimum order quantities.  Although the market for micromolded components is increasing, plastic resin manufacturers have actually been trending in the opposite direction and increasing minimum order quantities.  This places a burden on micromolders since most components require less than 50 lbs. of material per year.  There are a few large plastic resin manufacturers that allow customers to purchase sample bags approximately 10 lbs. or less.  Buyers should consider trying to use similar materials for all their components or use plastic resins micromolders are already using for other products in order to avoid having to purchase material quantities that will last for years.

Table 3.  Material Conversion Table

| Machined Material | Plastic Alternative |
|---|---|
| Ceramic | PSU, PPS, LCP, PEEK |
| Composites | LCP |
| Glass | LCP, PEEK, PC, PMP, PMMA |
| Plastic | PEEK, PPS |
| Metal | PA, PEI, LCP, PEEK, TPI, PPA, PAI |

## Mold Tooling and Equipment

Prior to evaluating tooling and equipment, the buyer must first determine if the micromolder is a strategic fit.  In other words does the micromolder have a business strategy that will suit your needs?  A micromolder with a business strategy and a manufacturing system in place specifically designed for low to moderate production volumes will be more attuned with the goals and objectives of your company.

### Mold Tooling

One factor buyers must consider is the mold tooling.  Mold design and manufacturing has been developed and used successfully for decades, however micromolding has made it far more complex.  At the micromolding level the importance of the tool increases exponentially due to tighter tolerances and smaller features.  This is the biggest roadblock converting from machining to micromolding. Machining requires little or no capital expense while micromolding tooling can cost from 5–30k depending on the complexity and cavtitation. Buyers must amortize the mold tool cost over the estimated annual usage (EAU) and the product life to justify converting. As EAU's get smaller (volumes between 5-10k) it becomes more difficult to justify converting. That's not to say that you can't convert at these volumes; it depends on the complexity of the part because as complexity increases so does the mold tool cost.

The buyer should make a thorough assessment of the risk and reward. If I spend $15,000 for a mold tool how much can I save during the life of the program? Can I save $50,000 per year? The buyer must not only look at one project but the savings he/she might incur if multiple conversions are available. If I spend $15,000 now will it allow me to potentially save $250,000 over five projects?

Buyers typically try to negotiate mold tooling costs. To reduce the cost the micromolder will try to eliminate features or functions from the mold tool. This could reduce the quality of the tool and could jeopardize the success of the project. The component might not be molded to specifications, causing lead-time delays. The buyer should allow the micromolder to build a mold tool they feel will be capable of micromolding a component to specification.

Shaving a few thousand dollars off the mold tool price could jeopardize the quality of the tool and the project. Unfortunately, we have learned this lesson the hard way. On a few occasions we have tried to accommodate the buyer by removing some functionality of the mold tool in an effort to reduce the mold tool cost. The net results were mold tools that did not work. We lost a potential customer and spent a large amount of time troubleshooting and re-working the mold tool. A successful micromold is one that is robustly designed and fabricated.

In the past, one of the drawbacks to converting to micromolding has been the lack of flexibility a mold tool has when design changes are required. New technology in laser welding has made it simple and economical to make mold tool modifications. Laser welding uses precise concentrated heat and doesn't alter the metal composition around the repair area.

**Mold Equipment**

Another important factor the buyer must consider is the type of injection molding equipment. A majority of micromolding utilizes conventional injection molding equipment. The major drawback to using conventional injection molding equipment is the residence time and control. The residence is the amount of time that the plastic material remains in the barrel prior to being injected into a finished product.[2] The smaller a component becomes the better the residence time and control needs to be. Melt cushion and the check ring valve dictate the residence control. Residence time is

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[2] Douglas M. Bryce. Plastic Injection Molding (Dearborn: SME, 1996), p. 236.

controlled by the screw/barrel or plunger system.  To alleviate these problems the molding equipment manufacturers typically downsize the conventional technology into a smaller frame.  This addresses some of the issues, but not all.

Conventional molding equipment contains a melt cushion.  The melt cushion (the area inside the nozzle of the molding machine) relative to the part weight plays a large role in shot-to-shot consistency due to compression of the material during injection.  The smaller the melt cushion, the better the shot-to-shot consistency.  Hydraulic and electric machines overshoot during the injection process and tend to cause material to flash; hydraulic being the worst.  Molding equipment that can give the injection system the ability to accelerate very quickly during injection and stop on a dime (or decelerate) and have little or no melt cushion would be optimum.

Conventional molding equipment also uses a check ring to seal off the screw during injection.  All check rings leak.  Variation from check valve wear over time is a common problem.  If the check ring is replaced, the new check ring may not be repeatable.  This may directly affect control on the melt cushion.  Equipment without a check ring would provide better control.  Shot size controlled using a servo-electric drive would be capable of producing a controlled shot volume consistency.

Lastly, conventional molding equipment has a high shot size relative to the barrel capacity.  If plastic resin is left in the screw for an extended period of time, it will affect the mechanical properties of the plastic resin.  The conventional machine screw, depending on the size, can carry several hundred shots of material in the injection barrel.  This is very important due to the fact that many conversions use high performance plastics in their applications.  These high performance plastic resins such as LCP, PEEK, and PEI have a high degree of thermal degradation.  One way molders try to alleviate this problem is to increase the number of cavities in the mold to increase the shot size.  This resolves the issue with the shot weight; however, it reduces the resolution of control.  Variability component-to-component becomes more apparent with a multi-cavity mold tool.

Equipment specifically designed for micromolding addresses these issues of melt cushion size, speed and pressure.  Europe and Japan have led the way developing injection molding equipment specifically designed for micromolding.  The technology is slowly migrating to North America.  The injection molding equipment has better residence time and control, utilizing a fully electric system and servo-electric drives capable of producing a controlled shot volume.

**Quality**

The last factor to consider, and one that is also often overlooked, is the quality inspection equipment.  Buyers must verify whether or not the suppliers have the capability to measure micromolded components.  We have had customers tell us that they tried micromolding with another supplier who was unable to measure the parts.  The buyers ended up inspecting the components themselves.  Coordinate measures machines (CMM) have difficulty measuring small complex geometries.  For first-piece inspection, optical measurement inspection systems are suitable (0-200X) and can handle a majority of the workload. For visual inspection a microscope (0-50X) is needed. For in-process inspection, it is advantageous for the micromolder to have a camera inspection system incorporated in the injection molding equipment. In combination with a robot, the equipment provides continuous 100% visual inspection. This ensures the molded component has been inspected and separated correctly from rejects. Otherwise an operator would have to perform a manual in-process inspection. Using a plug gage to inspect a hole on a large component would not be difficult. However, performing in-process inspection on micromolded part that has a .003" diameter hole might not be as simple.

## Conclusion

Micromolding can be an excellent lower cost alternative to machining. Every micromolder is different; therefore the buyer must find a supplier who matches their business strategy. The buyer must also be comfortable with the capabilities of the micromolder and must be prepared to ask the right questions to determine whether or not the company will have capability to mold their component(s) or assembly. Table 4 provides a list of questions and guidelines for a prospective buyer looking to source micromolded components.

Utilizing plastic injection molding equipment specifically designed to fabricate micromolded components and assemblies will provide the best chance to create successful innovative products. Trying to micromold with the wrong mold tooling and equipment can result in missing key project milestones, late delivery to market, and a loss in capital investment. Many new customers come to us because the current supplier is unable to provide a component to specification. The first micromolder was likely using an inadequate mold tool design, the wrong type of micromolding equipment and/or could not inspect the component. This remains one of the biggest roadblocks to converting. If the buyer's first experience with a micromolding project is a failure, it becomes difficult to get them to try again. Once the customer does find the right micromolder, they might not want to make a change as they will have to make another capital investment.

Table 4. Questions for Prospective Suppliers

| Questions | Guidelines (What to look for) |
|---|---|
| Business Strategy | |
| What type of business structure does the micromolder have? | Manufacturing processes geared toward low to moderate volume. |
| | |
| Mold Tooling | |
| What types of materials are used to fabricate prototype tooling? Production tooling? | Use high quality tool steel that is dimensionally stable. |
| | |
| Mold Equipment | |
| What is the size of the melt cushion relative to the part weight?<br>What type of equipment are they proposing to use? Is it Hydraulic or Electric?<br>How are you going to ensure shot to shot consistency and compensate for this tendency? | Look for little to no melt cushion to reduce or eliminate the possibility of compressing the material.<br>Use molding equipment that can accelerate quickly and stop on a dime and eliminate overshooting<br>Use mold equipment with a positive displacement system. Will provide better accuracy shot-to-shot. |
| | |
| Is the supplier using a screw/barrel system or a plunger system?<br>How long will the residence time be?<br>What is the shot size relative to the barrel capacity? | Deplete screw/barrel after 3 to 4 shots<br>Use equipment with a 14mm diameter screw or equivalent |
| | |
| What is the repeatability of the leaking check valve? Will you see potential variation from check valve wear? | Use a electric molding machine with servo-driven drives<br>Use molding equipment that does not use a check valve. Check valves are prone to wear. |
| | |
| Quality | |
| Do you have adequate inspection equipment to measure micromolded components? First piece inspection? Production? | Audit or request first piece inspection reports for micromolding |
| Does the molding equipment have a vision system? | Camera system mounted on the machine can provide a close-loop automated molding system |

The other roadblock is fear of the unknown. It is not uncommon for buyers to believe that it (micromolding) can't be done. Since this technology is in its infancy buyers have little or no experience in micromolding and cannot determine if a supplier can provide a component to specifications. Nearly every micromolding project is a test to show buyers that it can be done. We are challenged to convince buyers that this is an opportunity that can provide benefits. Micromolders must be prepared to answer the above questions in order to instill confidence in the buyer about your abilities. Providing data and samples to demonstrate how accurate the parts are from shot-to-shot and cavity-to-cavity can also be helpful.

There is always an element of risk with any new micromolding project and not all projects will be successful. However, the previous Pivot and Washer example shows that the cost savings can be substantial. Micromolding becomes a calculated risk and that risk must be weighed vs. the reward that can obtained. Consider the benefits your company can achieve by converting your machined components to micromolding. Choosing a company that has the right equipment and tooling experience can improve the chances of success markedly.

## Bibliography

Bryce, Douglass M. Plastic Injection Molding. Dearborn: SME, 1996.

Innovative Bulletin, Radiopaque Compounds. Winona: RTP Company, 2004.