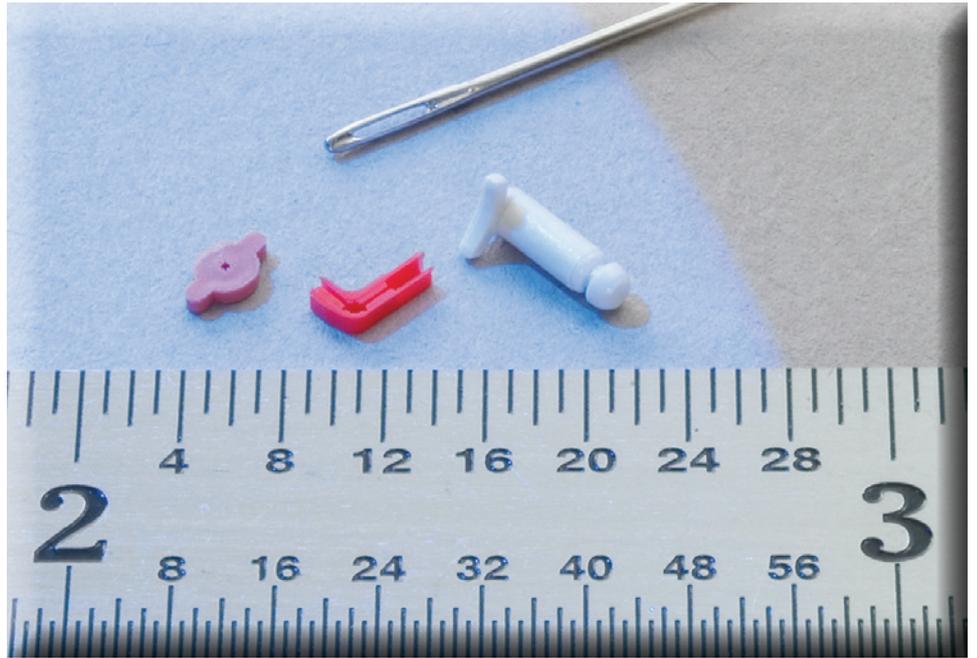


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This article looks at the technology of micro moulding from the perspective of a subcontract micro moulding specialist, Mikrotech. Mikrotech specialises in custom design micro moulded components and assemblies for the medical, electronic and automotive industries. It is an engineering and manufacturing service company that provides design assistance, prototyping, and automated short- and long-run production. What are the advantages of micro moulding, and what should you look for in a subcontract micro moulder? This article gives you the answers.

Historically, machining has been the only feasible manufacturing alternative for manufacturers sourcing low to moderate quantities of micro components. Moulders — because of the modest volumes or the complexity of the components — have often shunned these manufacturers. However, with advances in technology, micro moulding 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



Micro Moulding:

A Cost Effective Alternative to Micro Machining

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for manufacturers. Advances in material science and plastic injection mould equipment permit complex machined micro components to be injection moulded 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, to incorporate complex features, to reduce the number of components, or to reduce costs should consider micro moulding as an alternative to machining.

There are four key factors that contribute to the success of any micro moulding project: the mould tool design and

fabrication, the micro moulding equipment used, the quality inspection equipment used, and the business strategy. These variables are critical for obtaining a micro moulded component to specification, yet individuals sourcing micro moulded components commonly overlook one or more of them.

Attempts to micro mould components using conventional moulding equipment often fail. It is important that a buyer obtains an adequate understanding of the mould tooling and the capabilities of the equipment being utilised so that they can make an informed decision as to whether or not the micro moulder can provide a successful product.

Benefits

- PROVIDES LOWER COST SOLUTION
- COMPLEX GEOMETRIES (E.G., RADII) CAN BE INCORPORATED
- DIMENSIONALLY STABLE PRODUCTION PROCESS
- NO PARTICLE CONTAMINATION
- USE ALTERNATE RESINS OR FILLERS TO IMPROVE MECHANICAL AND/OR ELECTRICAL PROPERTIES
- BETTER SURFACE FINISH

Table 1. Benefits of Moulding vs. Machining

Advantages of Micro Moulding

There are a number of benefits that can be achieved by converting to micro moulding. The one big reason companies convert is the cost savings they incur. That's because the amount of time it takes to mould 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, for example. Micro moulding eliminates the potential failure mode of having particulates left after machining.

Micro moulding 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 smaller components becomes greater, it might become more difficult to machine complex geometries making micro moulding the only option. Table 1 summarises the benefits of moulding as against machining.

In addition, micro moulding offers solutions to some common

manufacturing issues, some specific to the medical device field, which has embraced micro moulding as a key enabling technology for micro manufacturing, and some relevant to all industry sectors. For example:

- 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.
- 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 moulded plastic component can remove the need to add isolation to metal components thereby reducing the size of the device.
- Plastic with metal or ceramic filler can be a suitable replacement for

“New technology in laser welding has made it simple and economical to make mould tool modifications.”

	Pivot	Washer
EAU	\$10,000	\$10,000
Machined cost	\$10.00	\$9.00
Micro moulded cost	\$2.50	\$2.20
Annual savings per component	\$75,000	\$68,000

Table 2. Costs of Machining vs. Micro Moulding

metal injection moulding (MIM). It eliminates the need for secondary operations associated with MIM.

• Micro moulding can be vertically integrated into an entire manufacturing assembly process that may include stamping, insert moulding, bonding or conventional moulding.

• Ceramic is traditionally very brittle. If a component is dropped it could break rendering the entire product 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 micro moulding? A component suitable for conversion usually has one or more of the following characteristics:

- It is machined from metal, ceramic, glass or plastic.
- It has a high degree of part and/or assembly complexity.
- It has high precision tolerances.
- A component volume of less than 1.0 cm³.

A Medical Device Example

Here is an example of a potential cost saving project. The project is for a medical device manufacturer and contains two components. It is currently in production. The Estimated Annual Usage (EAU) is \$10,000 (Euro 6760) each. The customer noted the only problem they have with the current components is the cost. The customer is paying approximately \$10.00 (Euro 6.75) and \$9.50 (Euro 6.4). The equivalent cost for a micro moulded component would be approximately \$2.50 (Euro 1.7) and \$2.20 (Euro 1.5) respectively. Table 2 shows the potential savings for the project.

If we switch to a moulded PEEK substitute at approximately \$2.50 (Euro 1.7) and \$2.20 (Euro 1.5) per component it would result in a saving of \$143,000 (Euro 96,650)

Machined Material	Plastic Alternative
<ul style="list-style-type: none"> • Ceramic • Composites • Glass • Plastic • Metal 	<ul style="list-style-type: none"> • PSU, PPS, LCP, PEEK • LCP • LCP, PEEK, PC, PMP, PMMA • PEEK, PPS • PA, PEI, LCP, PEEK, TPI, PPA, PAI

Table 3. Material Conversion Table.

per year! The annual savings would be enough to offset any costs associated with seeking regulatory approval again.

Micro Moulding Materials

There are several injection moulded 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, defence and automotive markets. Table 3 lists some typical materials that are suitable replacements. These replacements are by no means all the possible alternatives but are the ones Mikrotech has worked with from one project or another.

Plastic resin manufacturers will be challenged to make more products available for micro moulding. 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 micro moulded components is increasing, plastic resin manufacturers have actually been trending in the opposite direction and increasing minimum order quantities. This places a burden on micro moulders since

most components require less than 25 kg of material per year. There are a few large plastic resin manufacturers that allow customers to purchase sample bags approximately 4.5 kg or less. Buyers should consider trying to use similar materials for all their components or use plastic resins micro moulders they are already using for other products in order to avoid having to purchase material quantities that will last for years.

Four Key Factors for Successful Subcontract Micro Moulding

Business Strategy. Prior to evaluating the mould tool design and fabrication, micro moulding equipment, and quality inspection equipment, the buyer must first determine if the micro moulder is a strategic fit. In other words, does the micro moulder have a business strategy that will suit your needs? A micro moulder with a business strategy and a manufacturing system in place specifically designed to match your needs will be more attuned with the goals and objectives of your company. For example, a full service contract manufacturer manufacturing commodity components and devices may not be a good fit if you are looking to source a proprietary custom-designed medical device with annual requirements of 50,000 components per year. This factor can be determined during discussions with management, quality audits, and facility tours.

Mould Tool Design and Fabrication. One factor buyers must consider is the mould tooling.

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Mould design and manufacturing has been developed and used successfully for decades. Micro moulding, however, has made it far more complex. At the micro moulding level the importance of the tool increases exponentially due to tighter tolerances and smaller features. This is the biggest roadblock when converting from machining to micro moulding. Machining requires little or no capital expense while micro moulding tooling can cost from \$5,000 – \$30,000 (Euro 3380 – Euro 20,280) depending on the complexity and cavitation. Buyers must amortise the mould tool cost over the 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 mould tool cost.

The buyer should make a thorough assessment of the risk and reward. If you spend \$15,000 (Euro 10,150) for a mould tool, how much can you save during the life of the programme? Can you save \$50,000 (Euros 33,800) per year? The buyer must not only look at one project but the savings they might incur if multiple conversions are available. If you spend \$15,000 (Euro 10,140) now will it allow you to potentially save \$250,000 (Euro 170,000) over five projects?

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

Shaving a few thousand dollars off

the mould tool price could jeopardise the quality of the tool and the project. Unfortunately, Mikrotech has learned this lesson the hard way. On a few occasions the company has tried to accommodate the buyer by removing some functionality of the mould tool in an effort to reduce the mould tool cost. The net results were mould tools that did not work. Mikrotech lost a potential customer and spent a large amount of time troubleshooting and re-working the mould tool. A successful micro mould is one that is robustly designed and fabricated.

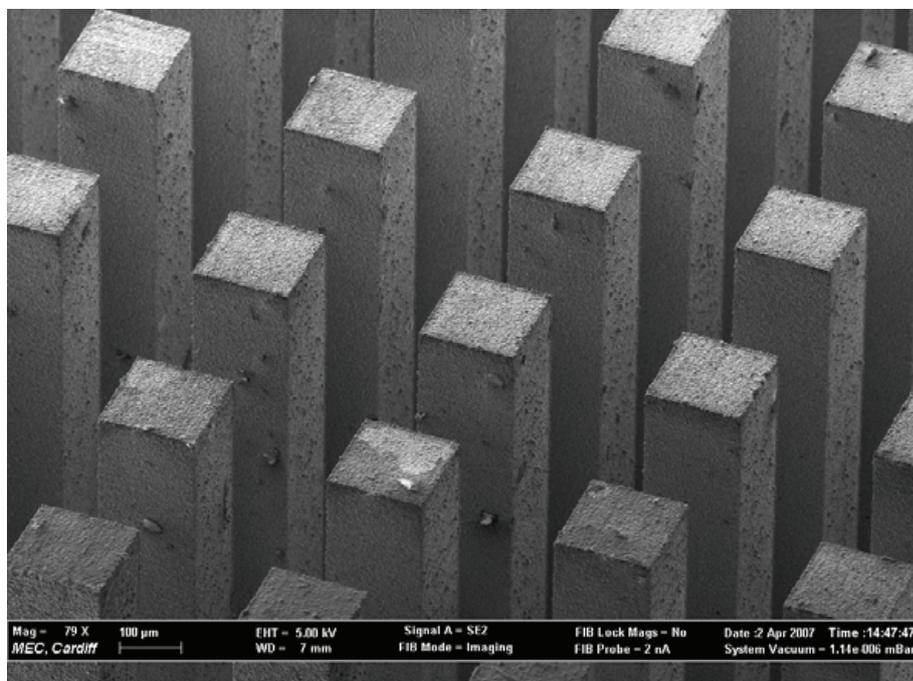
In the past, one of the drawbacks of converting to micro moulding has been the lack of flexibility a mould tool has when design changes are required. New technology in laser welding has made it simple and economical to make mould tool modifications. Laser welding uses precise concentrated heat and doesn't alter the metal composition around the repair area. If you deem that tool modifications may be necessary it is important to perform a design review of tool steel options prior to mould tool fabrication. Each tool steel reacts differently to laser welding.

Micro Moulding Equipment. Another important factor the buyer must consider is the type of injection moulding equipment. A majority of micro moulding utilises conventional injection moulding equipment. The major drawback to using conventional injection moulding 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. 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 controlled by the screw/barrel or plunger system. To alleviate these problems the moulding equipment manufacturers typically downsize the conventional technology into a smaller frame. This addresses some of the issues, but not all.

Conventional moulding equipment contains a melt cushion. The melt cushion (the area inside the nozzle of the moulding 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. Moulding 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 the best.

Conventional moulding 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 consistently.



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Lastly, conventional moulding 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 moulders try to alleviate this problem is to increase the number of cavities in the mould 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 mould tool.

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

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Quality Inspection Equipment.

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 micro moulded components. Mikrotech has had customers who state that they tried micro moulding with another supplier that was unable to measure the parts. The buyers ended up inspecting the components themselves. Coordinate measuring machines (CMMs) 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 micro moulder to have a camera inspection system incorporated in the injection moulding equipment. In combination with a robot, the equipment provides continuous 100% visual inspection. This ensures the moulded component has been inspected and separated correctly from rejects. Otherwise an operator would have to perform a manual in-process inspection. Using a plug gauge to inspect a hole on a large component would not be difficult. However, performing in-process inspection on a micro moulded part that has a 0.01 mm diameter hole might not be as simple.

Conclusion

Micro moulding can be an excellent lower cost alternative to machining. Every micro moulder is different; therefore buyers must find a supplier that matches their business strategy. Buyers must also be comfortable with the capabilities of the micro moulder and must be prepared to ask the right questions to determine whether or not the company will have the capability to mould their component(s) or assembly.

Utilising plastic injection moulding equipment specifically designed to fabricate micro moulded components and assemblies will provide the best chance of creating successful, innovative products. Trying to micro mould with the wrong mould tooling and equipment can result in missing key project milestones, late delivery to market, and a loss of capital investment. If the buyer's first experience with a micro moulding project is a failure, it becomes difficult to get them to try again.

Another roadblock is fear of the unknown. It is not uncommon for buyers to believe that micro moulding can't be done. Since this technology is in its infancy buyers have little or no experience in micro moulding and cannot determine if a supplier can provide a component to specifications. Nearly every micro moulding project is a test to show buyers that it can be done.

There is always an element of risk with any new micro moulding project and not all projects will be successful. However, the previous "Pivot and Washer" example shows that the cost savings can be substantial. Micro moulding becomes a calculated risk and that risk must be weighed against the reward that can be obtained. Consider the benefits a company can achieve by converting its machined components to micro moulding. Choosing a company that has the right mould tool fabrication equipment and experience, micro moulding equipment, quality inspection equipment and similar business strategy can improve the chances of success markedly.

John Whyntott is Technical Product Manager of Mikrotech a division of ASYST Technologies LLC. He was appointed to his current role in January 2004. Previously, he served as Engineering Manager and Project Engineer. John has six years experience in micro moulding and a combined twenty years experience in engineering and management. He earned a bachelor's degree in mechanical engineering technology from the University of Wisconsin-Parkside and a master's degree in engineering management from the Milwaukee School of Engineering.