

MICRO MIM

Revolutionizing Micro-Component Production in Medical Devices

As a medical engineer looking to design micro-sized parts, you face any number of unique challenges which include:

1. Material selection and their associated properties
2. The precision nature of the parts with related tolerances
3. Identifying the appropriate manufacturing method
4. Design complexity
5. Surface treatment and coating
6. Assembly and integration
7. Thermal and mechanical stress
8. Regulatory compliance
9. Quality control and inspection
10. Cost management



Addressing these challenges requires a multidisciplinary approach, combining expertise in materials science, mechanical engineering, precision manufacturing, and medical device regulations.

What is Micro Metal Injection Molding (Micro MIM)?



Micro Metal Injection Molding is an advanced manufacturing technique combining the benefits of plastic injection molding with the material properties of metals. This

process is particularly advantageous for producing small, complex, and high-precision metal components at scale. The technology involves mixing metal powders with a binder material to create a feedstock, which is then injected into molds to form intricate parts. The subsequent removal of the binder and sintering of the metal powder results in dense metal components with exceptional mechanical properties.

This process is revolutionizing the production of life science's smallest and most complex components, addressing the critical needs of today's medical device market. As medical technology evolves, the demand for highly precise, small-scale components is growing.

Current Challenges with Traditional Techniques

Micro MIM offers significant advantages over traditional machining and other manufacturing processes. It enables near-net-shape fabrication of complex geometries, reducing the need for finishing processes and minimizing material waste. This makes it particularly suitable for mass production of micro components where precision and cost-efficiency are paramount. In addition, traditional manufacturing techniques have other disadvantages, including:

- **Limited Limited Miniaturization:** Traditional machining struggles to create the ever-smaller, intricate metal components demanded by modern technology.
- **High Cost and Lead Times:** Machining complex parts is expensive, labor-intensive, and slow, hindering innovation and product development cycles.
- **Inconsistent Quality at Scale:** Producing large quantities of small parts with consistent dimensional tolerances is a major challenge for traditional methods.

Advanced Powder Products' advanced equipment and manufacturing techniques are able to meet the extremely high standards of precision and accuracy often in the micrometer range.

Comparative Benefits of Micro MIM

Micro MIM is an excellent choice for producing consistent, high-quality micro-sized components, especially important in fields like medical engineering where precision is paramount. Micro-MIM overcomes miniaturization limitations by being able to create highly intricate, near-micron-sized features in metal components. In addition, it is a highly repeatable process able to produce walls as thin as .002" with dimensional variability ranging from 0.2% to 0.5%.

To achieve high precision for specific dimensions,

Micro MIM is an excellent choice for producing consistent, high-quality micro-sized components, especially important in fields like medical engineering where precision is paramount.

It's crucial to work with experts to incorporate specific tooling and component design recommendations tailored for the MIM process. For example: embedding critical features into one piece of steel, avoiding the negative impacts of flash, gates, parting lines, and ejector pins.

Given your focus on ensuring quality and reliability in micro-sized parts for medical applications, understanding these nuances in Micro MIM can help in designing components that meet the stringent requirements of your field, much like crafting a well-balanced diet to meet specific health goals.

Micro MIM also offers a high degree of automation and repeatability, leading to significant cost savings for large volume production. It is particularly advantageous for mass production due to several key factors that contribute to its cost-effectiveness:

- Production of complex and highly detailed parts in a single step, eliminating the need for multiple machining or assembly operations. This capability reduces manufacturing time and costs.
- High precision and the ability to create intricate designs mean that parts often do not

require additional finishing processes, further saving labor and operational expenses.

- Processes are highly automated, reducing the need for manual labor and minimizing human error. Automation streamlines the production process, ensuring consistent quality and efficiency. Automated systems can handle complex geometries and intricate details with high precision, reducing the need for secondary operations and manual interventions.
- Exceptional repeatability, with dimensional variability ranging from 0.2% to 0.5% as mentioned above. This ensures that each part produced is nearly identical, meeting stringent quality standards. Consistent production quality reduces the rate of defective parts, minimizing waste and the costs associated with rework or scrap.
- By utilizing metal powders and binders, which are molded and then sintered to form the final part, this process allows for high material utilization, with minimal waste compared to traditional machining or casting processes. This efficient material use lowers the overall material costs, contributing to cost savings in large-scale production.

And then there is scaling. Initial setup costs for Micro MIM, including mold creation, process development, and qualification, are spread out over large production volumes. As the volume of parts produced increases, the cost per part decreases significantly. Large-scale production benefits from reduced per-unit costs, making it highly cost-effective for producing thousands or millions of micro-sized parts.

Also, molds used are typically made from durable

materials that can withstand the high pressures and temperatures of the injection molding process. These molds have a long service life, providing excellent return on investment. The longevity of the tooling reduces the frequency of replacements and associated downtime, enhancing overall production efficiency.

By leveraging all these advantages, Micro MIM enables manufacturers to produce high-quality, precise micro-sized parts at a fraction of the cost of traditional manufacturing methods.

What about Traditional Metal Injection Molding (MIM)?

In considering traditional Metal Injection Molding components weighing less than 100g and fitting in the palm of your hand are ideal candidates for MIM technology, with a typical mean size of 15g. MIM is best for smaller parts, offers thinner wall thicknesses, excellent surface finish, and is suited for high-volume production.

Citing the “Handbook of Metal Injection Molding” Second Edition (Edited by Donald F. Heaney and Woodhead Publications, 2019, page 25) the following are some general design considerations for traditional MIM:

- Avoid components over 12.5mm (0.5 in.) thick. This is a function of MIM technology and alloy, for example 4140 and alloys that use carbonyl powder can have thicker wall sections than those that use gas-atomized powders that have larger particles. Also, modifications to binder systems can be made to allow thicker sections to debind.
- Avoid components over 100g in mass; however, 300g is possible for some technologies.
- Avoid long pieces without a draft (2 degrees)

to allow ejection.

- Avoid holes smaller than 0.1mm (0.0039 in.) in diameter.
- Avoid walls thinner than 0.1mm (0.0039 in.), although 0.030mm walls are possible in some cases.
- Maintain uniform wall thickness; thin, slender sections attached to thick sections should be avoided to enhance flow during molding, to avoid sinks and voids, and to limit distortion during sintering.
- Core out thick areas to avoid sinks, warpage, and debinding defects.
- Avoid sharp corners. The desired radius is >0.05mm (0.002 in.).

Micro MIM challenges and shatters even the limitations of conventional Metal Injection Molding (MIM). While MIM excels at small parts (15-20 grams), Micro-MIM takes precision to a whole new level. It's specifically designed to manufacture intricate metal components.

It provides the ability for substantially reduced mass since parts can weigh less than 1 gram, which is ideal for miniaturized devices. It allows for the creation of microscopic features with critical dimensions as small as 100 microns, enabling highly complex geometries.

Micro MIM not only challenges traditional manufacturing methods, but also traditional MIM manufacturing.

Typical Attributes Produced by the Micro MIM Process

ATTRIBUTE	MICRO MIM	TYPICAL MIM
Component Mass (g)	0.020 - 1.00	10 - 100
Dimension (in)	2.0 (0.08 in.)	1 - 6
Wall Thickness (in)	.002 - .25	.25 - .50
Tolerance (%)	+/- 0.2%	+/- 0.5%
Density	97 - 99%	97 - 99%
Production Quantity	5,000 - 1,000,000+	5,000 - 1,000,000+

**Features this small may cause distortion*

Material Selection is a Critical Aspect of Micro MIM for Medical Devices

The material you select must be biocompatible, meaning it won't cause adverse reactions within the body. Common biocompatible materials for Micro MIM medical devices include:

- **Stainless steels** which offer good corrosion resistance, strength, and are well-established for medical use (e.g., 316L stainless steel).
- **Titanium alloys** provide excellent biocompatibility, strength, and low weight, making them ideal for implants (e.g., Ti-6Al-4V).
- **Cobalt-chrome alloys** offer high strength, wear resistance, and biocompatibility (e.g., F75, MP35N).

Finally, the material needs to comply with relevant medical device regulations, such as those set by the FDA.

Application-specific needs: Factors like strength, weight, corrosion resistance, and radiolucency (X-ray visibility) may influence material selection depending on the specific medical device application.



Metal materials currently applied for Micro MIM, typical powder sizes

MATERIAL	MEAN PARTICLE SIZE, d_{50} (μm)	TYPICAL ASPECT RATIO (AR)	MIN. LATERAL DIMENSIONS (μm)
Stainless Steel 316L (1.4404)	1.5 - 5 (up to 12) ^a	1 - 5 (up to 10)	50 (down to 5 ^b)
Stainless Steel 17-4PH (1.4542)	3 - 5 (up to 12) ^a	1 - 5 (up to 10)	50 (down to 20)
Carbonyl Iron Nickel-iron Alloy (NiFe)	1.5 - 5 ^a	Up to 15	Down to 10
Titanium Alloys	>20		< 60
Copper	0.5 - 2		Down to 10
Copper-diamond Tungsten-copper Alloy (WCu)	1.5 - 3	Up to 100	250
Tungsten Alloys	0.5 - 6	6	< 30
Hard Metal (WC-xCo)	0.5 - 4	Up to 10	50 (down to 20)

^a Finer fractions tested on laboratory level.

^b AR < 1.

Designing for the Micro MIM Process

In order to provide the benefits over other processes, all the key aspects of the process need to be modified and adjusted to a micro component. You must have:

- The Appropriate Particle Size:** Ensuring the particle size is sufficiently small allows for precise and uniform material flow during molding, which is crucial for achieving detailed and accurate micro-sized parts.
- The Appropriate Feedstock:** Using a tailored feedstock blend of metal powders and binders ensures optimal mold filling, uniform shrinkage, and high-quality final components in the Micro MIM process.
- The Appropriate Tooling at a Much Smaller Scale:** Specialized tooling designed for micro-scale production provides the necessary precision and detail to mold intricate geometries accurately.
- The Appropriate Molding Equipment:** Advanced micro molding equipment can handle the high precision and control required to produce consistent and high-quality micro-sized parts.
- The Appropriate Sintering:** Precision sintering processes are essential to achieve the desired material properties and dimensions, minimizing distortions and defects in the final micro components.

- **The Appropriate Work Handling Flow:**

Efficient work handling systems ensure the delicate micro parts are carefully managed throughout the production process, maintaining their integrity and quality from molding to final assembly.

Micro MIM empowers life science OEMs to push the boundaries of medical device design. Advanced engineering is made possible through the superior quality and feature definition of the parts and unlock the potential for groundbreaking medical technologies. It ensures your medical devices will perform consistently and flawlessly, every time.

APP's advanced equipment and manufacturing techniques are able to meet all these extremely high standards of precision and accuracy.



Today's Micro MIM medical applications include:

- Robotic surgical micro components
- Implantables
- Catheter components and sacrificial cores for stent production
- Staples and stapling anvils
- Laparoscopic and suturing jaws
- Minimally invasive biopsy cutters and graspers
- Dental surgery
- Drug delivery systems

Wrapping It All Up!

As the landscape of minimally invasive surgery evolves, the demand for increasingly smaller and more precise components will drive innovation and present new challenges for design and production teams. By integrating Micro Metal Injection Molding capabilities into your portfolio, you position your teams at the forefront of this technological revolution. This is not just a method of manufacturing; it is a catalyst for innovation, driving your business towards faster production, enhanced flexibility, and lower costs.

Micro MIM offers unprecedented design freedom, enabling the creation of intricate and high-quality micro-components with remarkable consistency. This repeatable nature ensures a rapid production ramp-up, allowing you to meet critical deadlines for new product launches without compromising on quality. Unlike traditional machining, where variations can occur with each part, it delivers reliable and precise results every time. This consistency simplifies the assembly process, reducing the need for extensive part sorting or adjustments, and streamlining your manufacturing workflow.

Furthermore, Micro MIM significantly lowers production costs, enhancing your profitability. The technology's efficiency translates to reduced set-up costs, lower cost per part, and minimized scrap rates. These cost-saving benefits, combined with the ability to produce large batches of micro-components, make this process a superior choice for manufacturing. By minimizing wasted materials and ensuring high-quality output, this process maximizes your return on investment, making it a strategic asset for any forward-thinking business.

In conclusion, Micro MIM is a game-changing technology that offers unparalleled precision, efficiency, and cost savings for manufacturing small, complex metal components. Its potential to revolutionize various industries is immense, fueled by ongoing research and development efforts. Embrace the power of Micro MIM to achieve new heights in performance and profitability and secure your place at the cutting edge of innovation.

Schedule your Micro-Component Consultation Today!

Get a part review, advice on the best materials to use, design recommendations and a cost-savings estimate.

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