NetShape Technologies - MIM
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Frequently Asked Questions

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What is metal injection molding (MIM)?

MIM produces complex, high-volume, repeatable components out of high melting temperature alloys. The most common alloys done in MIM are ferrous.

All MIM processes have these four elements in common:

1. Mix a fine (<20 um) metal powder with a binder (usually polymer-based).
2. Mold the mixture using slightly modified plastic injection molding machines & molds.
3. Remove some or all of the binder from the molded component without disturbing its shape.
4. Sintering the component in a high temperature furnace, where it shrinks 15-20% & densifies to >95% of the alloy’s theoretical density.

What materials can be made through MIM?

Alloys with a higher melt temperature than copper are the most common materials done in MIM. Lower melting materials, like zinc & aluminum, are better suited for die casting. Alloys that form strong oxides (e.g. titanium) are difficult to process.

<table>
<thead>
<tr>
<th>Alloy Type</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-alloy steels</td>
<td>4650; 4140</td>
</tr>
<tr>
<td>Stainless steels</td>
<td>304L; 316L; 17-4 PH; 420; 440</td>
</tr>
<tr>
<td>Magnetic steels</td>
<td>50% Fe - 50% Co; Fe-3% Si</td>
</tr>
<tr>
<td>Controlled expansion alloys</td>
<td>Fe-Ni alloys like Invar</td>
</tr>
<tr>
<td>High density alloys</td>
<td>W-Ni-Fe; up to 18 g/cc</td>
</tr>
<tr>
<td>High Temperature Superalloys</td>
<td>Inconel 625, Hastalloy X</td>
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How does MIM compare to other processes?

Die Casting: MIM can handle higher-temperature alloys than die casting, since the MIM alloys are never melted - the polymer binder allows the powder to make the desired shape in a die at temperatures similar to plastic injection molding. This also results in very long tool life, with cavity lifetimes of over 250,000 shots without needing substantial rework.

Stamping/ Fine Blanking/ Screw Machining: By using tooling similar to plastic injection molding tooling, complex 3-dimensional geometries impossible to produce by stamping, fine blanking or screw machining are easily produced in MIM.

Powder Metal: Small powder sizes (typically < 25 um) can be used in MIM, smaller than the powder used in traditional powder metallurgy. The small size leads to a relatively high amount of free surface area, which during sintering allows MIM components to sinter to near full density. Also, the MIM molding process allows for more complex designs.

CNC/EDM: The use of multi-cavity tooling can provide high production rates (100,000’s per month) and lowers component costs in MIM that are difficult to match by CNC machining or EDM.

Investment Casting: MIM does better than investment casting in filling out thinner sections, surface finish, and providing accurate details. The smaller the piece is, the more competitive MIM will be vs. a casting.

Why are sintered densities higher in MIM than traditional powder metallurgy?

Traditional powder metallurgy (PM) processes use mechanical compaction of metal powder to create the component shape. To minimize frictional forces between the powder particles, relatively large (>150 um) powder is used. MIM, on the other hands, uses small (<20 um) powder because powder friction is greatly reduced when the powder is mixed with the binder. The large ratio of powder surface area/unit volume in MIM makes densification of the powder much easier.
What types of parts are suitable for MIM?

MIM’s core capability is making complex parts out of high-temperature alloys with good material properties, excellent repeatability, & reasonable cost. Here are the significant factors in deciding whether a component will benefit from MIM:

1. The material required has a relatively high melt temperature (>2000ºF), e.g. iron, nickel, cobalt, copper or tungsten-based alloys. If the properties of lower-melting alloys like zinc or aluminum are acceptable, then die casting is almost always a more economical approach.

2. The component design is too complex for processes like stamping, screw machining, fine blanking, cold heading or traditional powder metallurgy.

3. Component properties require performance (e.g. corrosion resistance, magnetic permeability, thermal expansion) similar to wrought alloys.

4. Thin sections & fine details are required which would be difficult to investment cast.

5. The geometry can be achieved using standard plastic injection molding tooling techniques, with secondary operations if necessary.

6. Good surface finish is required; MIM typically produces surface finishes better than 32 RMS.

7. Part cross-section thicknesses are < 8 mm & part weight is < 100 grams.
Can MIM tools be transferred?

Yes; a core capability of NetShape MIM is our in-house feedstock capability, which alloys materials to be custom mixed to match a tool’s shrink rate. In most cases this will allow tools to be transferred into NetShape MIM from another source. Contact NetShape MIM Engineering for details.

Can different materials be run with the same tool?

Yes; NetShape MIM’s ability to make feedstocks that match shrinkage rates allow a single tool to run multiple alloys.

Are multi-cavity tools used in MIM?

Yes; the majority of tools at NetShape MIM are at least two-cavity molds, which helps increase productivity rates & reduce part costs. Four & eight-cavity tools are common, with cavity counts as high as 32 for smaller parts possible.

What can be done to reduce tooling costs?

The complexity of the tooling & the number of cavities dictates the cost of the tool. Parts that use slides, threads, special ejection movements, etc. will increase the cost of the tool.

NetShape MIM uses standardized mold bases & hot runner systems wherever possible to reduce the cost of tooling to the customer. Additionally, if there is a group of parts that have similar features with minor part-to-part variations, then it may be possible to build a “family tool” with inserts that make different components from the same base cavity.

What is the expected tool life?

A cavity life of > 150,000 shots is typical. NetShape MIM will almost always take care of mold maintenance and replacement over the life of the program.
What secondary operations are possible?

MIM parts are typically processed to a high (>95%) density. At these densities the material’s response to secondary operations is similar to wrought product. Operations that are frequently performed include:

- Plating
- Drilling
- Tapping
- Grinding
- Coining
- Black Oxiding
- Heat Treating
- Machining

Since there may be slight differences from the wrought response, it is recommended that the operation in question be tested on sample material before full production is planned.

Designing for MIM – General Considerations

Material Properties

The strength & hardness for well-processed MIM materials will typically be approximately 90% of published values for the equivalent wrought counterparts. Impact & fatigue strengths may vary more due to the small amount of porosity in MIM materials.

Corrosion resistance for well-processed MIM materials is similar to comparable wrought alloys. The isotropic structures of MIM materials benefit corrosion resistance.

Magnetic response (permeability, maximum flux density, etc.) is comparable to wrought material.

Surface Finish

Typical MIM parts have a surface finish of 32-48 micro-inches. Surfaces requiring optimum finishes should be free of parting line & gates.
Tolerances

Typical linear dimensions can be held +/- 0.5% while meeting a 1.33 Cpk. As dimensions get smaller (< 0.100”) the tolerance % may need to increase due to tooling and gauging issues. Part geometry plays a large role in the tolerances that can be held:

- Gate locations, parting lines, flash & other tooling-related variations will increase dimension variability.
- Unsupported part features will tend to distort, especially during sintering. Furnace saggers or other support structures are often used to counteract these events.
- Multiple tight tolerances along different axes of the same part make centering part dimensions more difficult.
- Cylindrical features tend to become somewhat oval through the process.
- Secondary operations, like coining and machining, can be used to bring parts into tolerance but add to part cost.

Shrinkage

In MIM technology, the part is molded in a plastic injection molding-style tool with a mixture of powder and binder (polymer). A standard mixture will be roughly 60% powder, 40% binder by volume. In the first stages of the debinding & sintering process, the binder will be 100% eliminated, leaving a part that is 60% by volume powder, 40% empty space. In sintering, the 40% empty space will be reduced to 1-5% as the part sinters to 95-99% density. This results in the part shrinking, from mold to finished part, approximately 15-20%.

At NetShape MIM we make our own feedstocks, & by controlling our powder & binder material you can use the same tooling to make parts from a number of different alloys.

Maximum/Minimum Cross Sections

The NetShape MIM process can handle a cross-sectional thickness as large as 8 mm (0.320”) and as small as 0.25 mm (0.010”) over short distances. The preferred component is designed, as best possible, with a uniform wall thickness.
Tooling Tips

Use the advantages that plastic injection molding tooling provides. Here are some examples of attributes that may be costly with other metalworking methods.

Threads

Exterior threads can be often easily molded into a part. Providing a small flat along the threads helps molding quality.

Flats along the parting line minimize the effect of any tooling mismatch or flash.

Interior threads can be done with spin-out cores (most efficient in production but highest tooling cost), with a hand-loaded insert in the mold (less expensive tooling but more expensive in production) or as a secondary operation.
Surface Details

Many types of surface details like logos, letters, designs, knurls or serrations can often be directly molded into a part surface.

Either raised or recessed lettering, logos, etc. can be put into the part tooling.

Changeable Inserts

A part detail can be molded in with a tool insert, allowing functional characteristics like holes, flanges, threads, etc. to be changed to make different parts from the same cavities.

- Change inner diameter to a hex.
- Change circular holes to ovals.
Draft

Over short sections (< 5 mm) there is no draft necessary for pins or cores. For tool sections deeper than that a draft of 0.5 to 1.5 degree is preferable, depending on the part geometry.

Deeper tool details (>5 mm), like this internal diameter, will typically require 0.5° to 1.5° draft.

Over short distances (< 5 mm) draft in the tooling may not be required.
Sintering Supports

MIM parts will undergo shrinkage of 15-20% as they sinter to near full density during sintering. This results from the elimination (during sintering) of the empty space between the powder particles that was previously occupied by the binder. As the part is shrinking, unsupported areas may tend to sag or distort. Ceramic fixtures can be used to support the component through this process. Small design changes, like adding a flat surface for part stability in sintering, may also allow for better shape retention through the MIM process.

Removable supports can aid shape retention during sintering, and also assist material flow during molding.

“Lightweighting” Parts

Components designed for machining or other metalworking technologies often are bulkier than required by the application. A good way to make a MIM component more economical is to remove material that is not essential to performance. The freedom allowed by MIM tooling can often perform this task at no extra tooling cost.

In this case, “coring” the non-functional surfaces will reduce part weight by almost 50%.
Uniform Wall Thickness

A consistent wall thickness is helpful for molding and sintering MIM components. Modifying parts to help achieve this will often result in a lower-weight component.

Turning Assemblies into a Single Component

The design freedom of MIM can often turn subassemblies into single components, with resultant increases in reliability and economy. Using MIM as a straight component replacement option will often mean overlooking substantial cost-savings opportunities.