Metal Injection Molding (MIM) Process and Production

MIM is the Offspring from a Marriage of Injection Molding with Powder Metallurgy

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Advantages of the MIM Process

- **Excellent shaping possibilities**: Very complex-shaped parts can be manufactured with or without very little secondary finishing. Undercuts in the parts, which are not possible with conventional sintering processes, can be realized with the MIM Process without problems.

- **Excellent surface quality**: The surface of MIM parts is far superior to that of precision cast parts. Thereby, finishing and polishing costs can be eliminated or substantially reduced.

- **Very good material properties**: The MIM process reaches densities of between 96% and 100% of the theoretical material density.

- **Low tolerance limits**: The MIM process allows an accuracy of better than +/- 0.3% of the required dimensions.

- **Material selection**: MIM parts usually do not have to be mechanically refinished. The harder it is for a material to be machined, the more advantageous the MIM process.

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The MIM Process

**Mixing**
At the mixing stage, both metal powder and the polymeric binder (thermoplastic types) are combined into a homogeneous mixture.

**Injection Molding**
Injection molding machines are used to inject the green part. The mould dimensions are calculated by applying a "shrinkage factor" which is around 15-20% for most material to the part drawing.

**Debinding**
Debinding is a process whereby the binder is removed from the molded part, leaving behind the metal 'skeleton' that retains the molded shape. This remaining element is known as the 'brown' part.

**Sintering**
Finally, the brown parts are sintered. The metal powder particles will be bonded together and consequently this step provides the strength in the finished product.
Batch Mixing

Sketches of two batch mixer geometries for combining binders with powders: double-planetary and Z-blade (sigma-blade) mixers.
Continuous Mixing

Figure 5.30. A continuous twin screw mixer relies on intermeshing screws that might be tapered to compress, shear, and extrude the feedstock. The powder and binder ingredients enter at the larger end and as they are conveyed and heated, the decreasing cross section causes compression and the turning screws generate shear.
Molding Machine in a MIM Shop
Molding Machine Schematic

A cross-sectional sketch of the operating region in an injection molding machine, showing the key components and feedstock heating and flow path.
Molding Steps

The sequence of steps in the molding cycle, showing the machine operation through one cycle.
Two Cavity Mold

A sketch of the flow path inside the tooling, showing how the feedstock flows from the nozzle through the sprue, runner, and gate for a two-cavity tool set.
Staging and Setters

The best part design incorporates a flat surface which may be used for placing on a flat ceramic. If this option is not available:

• Use Ceramic Shims
• Use Grooved Ceramics
• Use Special Contoured Ceramics
Example of Staging Parts
Primary Debinding

Primary Debinding depends on the Binder System:

• Polyacetal: Catalytic Debinding with Nitric Acid
• Water + Agar: Evaporation
• Water Soluble Polymers: Water
• Wax: Thermal or Solvent
Material after 1st Stage Debinding

A scanning electron micrograph of the binder located at the particle contacts after the first stage of debinding. This remaining binder holds the particles in position during handling prior to sintering (photograph courtesy of R. Kumar Enneti).
DSH Solvent Debind Unit
Secondary Debinding & Sintering

In older Processes Debinding (Secondary Binders) and Pre-sintering was done in one Furnace and Final Sintering in a Second one. Today, these Steps are done in One Furnace. Furnace types are:

• Continuous Furnaces: Pusher and Walking Beam

• Batch Furnaces: Graphite (limited material capabilities) or Refractory Metal
Typical Pusher

Model 368-72-3Z Automated

Figure: S. Bradbury, Powder Metallurgy Equipment Manual, Third Ed. MPIF, 1996.
Typical Walking Beam

Figure: S. Bradbury, Powder Metallurgy Equipment Manual, Third Ed. MPIF, 1996.
Typical Batch
Continuous Furnace Vs Batch

• Continuous furnaces need to run all the time; idling is expensive. Processing changes are difficult. Very high gas consumption. Requires large floor space.

• Batch furnaces are very flexible with materials and processes. Costs depend on usage. Higher power consumption but low gas consumption. Requires small floor space. Cost per part when compared to a continuous furnace of similar capacity is similar.
Furnace with Sintered Parts
Secondary Operations

- Coining: to align or straighten or meet certain dimensions
- Remove process blemishes, like gate marks
- Precision grinding to meet tolerances
- Secondary machining to add fine threads or precision holes
- Assemble or join pieces to form a single component
- Surface finishing, like polishing, burnishing, plating, black oxidizing etc.
- Heat treating to harden or carburize etc.