Forming Technology

Metal Injection Molding

This process combines powder metallurgy with injection molding technology. It is suitable for the production of small parts in steel, stainless steel, magnetic alloys, bronze, nickel alloys and cobalt alloys.

Costs • High tooling costs • Moderate to low unit costs	**Typical Applications** • Aerospace • Automotive • Consumer electronics	**Suitability** • High volume production • Low to medium volume production for certain applications
Quality • Very high quality surface finish • High level of density	**Related Processes** • Die casting • Forging • Investment casting	**Speed** • Rapid cycle time similar to injection molding (30–60 seconds typically) • Debinding and sintering (2–3 days)

INTRODUCTION

Metal injection molding (MIM) is a powder process and a similar technique, known as powder injection molding (PIM), is used to shape ceramic materials and metal composites.

MIM combines the processing advantages of injection molding with the physical characteristics of metals. It is thereby possible to form complex shapes, with intricate surface details and precise dimensions. Parts are ductile, resilient and strong, and can be processed in the same way as other metal parts, including welding, machining, bending, polishing and electroplating.

This process is suitable for forming small components generally up to 100 g (3.53 oz). As with conventional injection molding (page 50), MIM is predominantly used for high volume production, although low to medium volumes can be viable where MIM offers technical, design or production advantages over other manufacturing processes.

TYPICAL APPLICATIONS

MIM is capable of producing a wide range of geometries and so is utilized in many industries. The accuracy and speed of the process make it ideal for manufacturing components for the aerospace, automotive and consumer electronics industries.

RELATED PROCESSES

Investment casting (page 130), die casting (page 124), forging (page 114) and CNC machining (page 182) can be used to produce similar geometries. In fact, investment casting and MIM are often interchangeable, depending on tolerances and intricacy of features. While die casting can produce similar features and tolerances to MIM, it can be used only for non-ferrous materials, not for steels and high melting point metals. Forging is generally chosen for larger components, typically those weighing more than 100 g (3.53 oz), in ferrous and non-ferrous metals, but forging cannot produce the intricate features and accuracy of MIM.

MIM reduces, or eliminates, the need for secondary operations such as machining. It is capable of producing parts with a complexity and intricacy that may not be feasible in any other processes. Secondary operations can also work out much more expensive for large volumes of production.

QUALITY

Like injection molding, the high pressures used in this process ensure good surface finish, fine reproduction of detail and, most importantly, excellent repeatability. However, MIM has the same potential defects, including sink marks, weld lines and flash. Unlike many plastics, metal parts can be ground and polished to improve surface finish.

Careful design will eliminate the need for secondary operations. This is especially important for flash at joint lines, which becomes a metal burr after sintering. This is normally readily removed after molding, but may be problematic in surface textures and threads. Incorporating flat areas in threads and locating the partition line in non-critical areas reduce such problems.

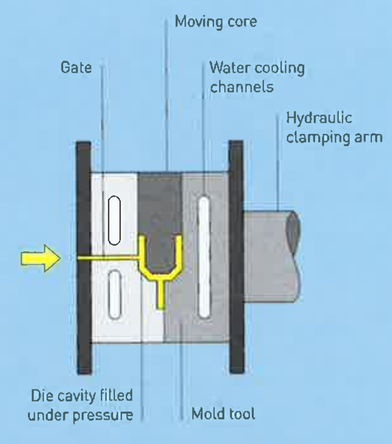
After sintering, MIM parts are almost 100% dense and have isotropic characteristics. In other words, there is very little porosity. This ensures the structural integrity and ductility of the metal part (see artwork, above, stage 2).

DESIGN OPPORTUNITIES

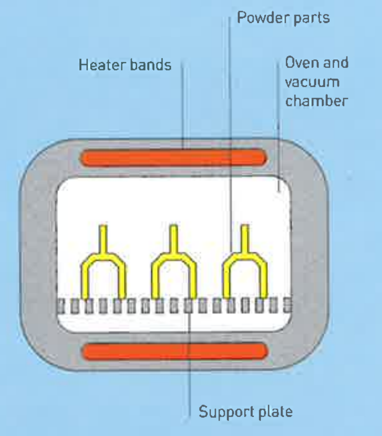
Design opportunities and consideration for MIM are more closely related to injection molding than to conventional metalwork. For example, MIM can reduce the number of components and subsequent secondary operations of conventional metalworking because it can produce complex and intricate geometries in a single operation. Tools can have moving cores and unscrewing threads for example, making the inclusion of internal threads, undercuts and blind holes possible.

Complex tooling, because it comprises moving parts, may increase tool costs significantly, but if it eliminates secondary operations on the MIM parts the extra costs can be offset, particularly where large volumes are required.

Metal Injection Molding Process



Stage 1: Injection molding



Stage 2: Heating and sintering

TECHNICAL DESCRIPTION

Fine metal powder, typically no larger than 25 microns (0.00098 in.) in diameter, is compounded with a thermoplastic and wax binder. The spherical metal particles make up roughly 80% of the mixture. The manufacturers themselves often make up this feedstock and so the exact ingredients are likely to be a well-guarded secret.

For MIM, the injection molding machines are modified slightly in order to accommodate the plasticized powder composite material.

In stage 1, the injection cycle is much the same as for other injection molding processes, although the molded parts are roughly 20% larger in every dimension prior to heating and sintering. This is to allow for the shrinkage, which will take place as the binder is removed.

In stage 2, the 'green' parts are heated in a special debind oven, to vaporize and remove the thermoplastic and wax binder. The molded parts are now in pure metal, with all binder material removed.

The final stage is to sinter the parts in a vacuum furnace. This typically starts with a nitrogen/hydrogen mixture, (depending on material type) changing to a vacuum as the sintering temperature increases. The 'green' part will shrink roughly 15–20% during sintering, to accommodate the loss of material during debinding. The resulting metal part has very little porosity.

Certain parts, especially those with overhanging features, are supported in specially designed ceramic support plates so that they do not sag at high temperature. Parts with flat bases usually do not require additional support.

Left
These bent samples demonstrate the structural integrity and ductility of MIM material.

Left
This range of parts has been produced by the MIM process.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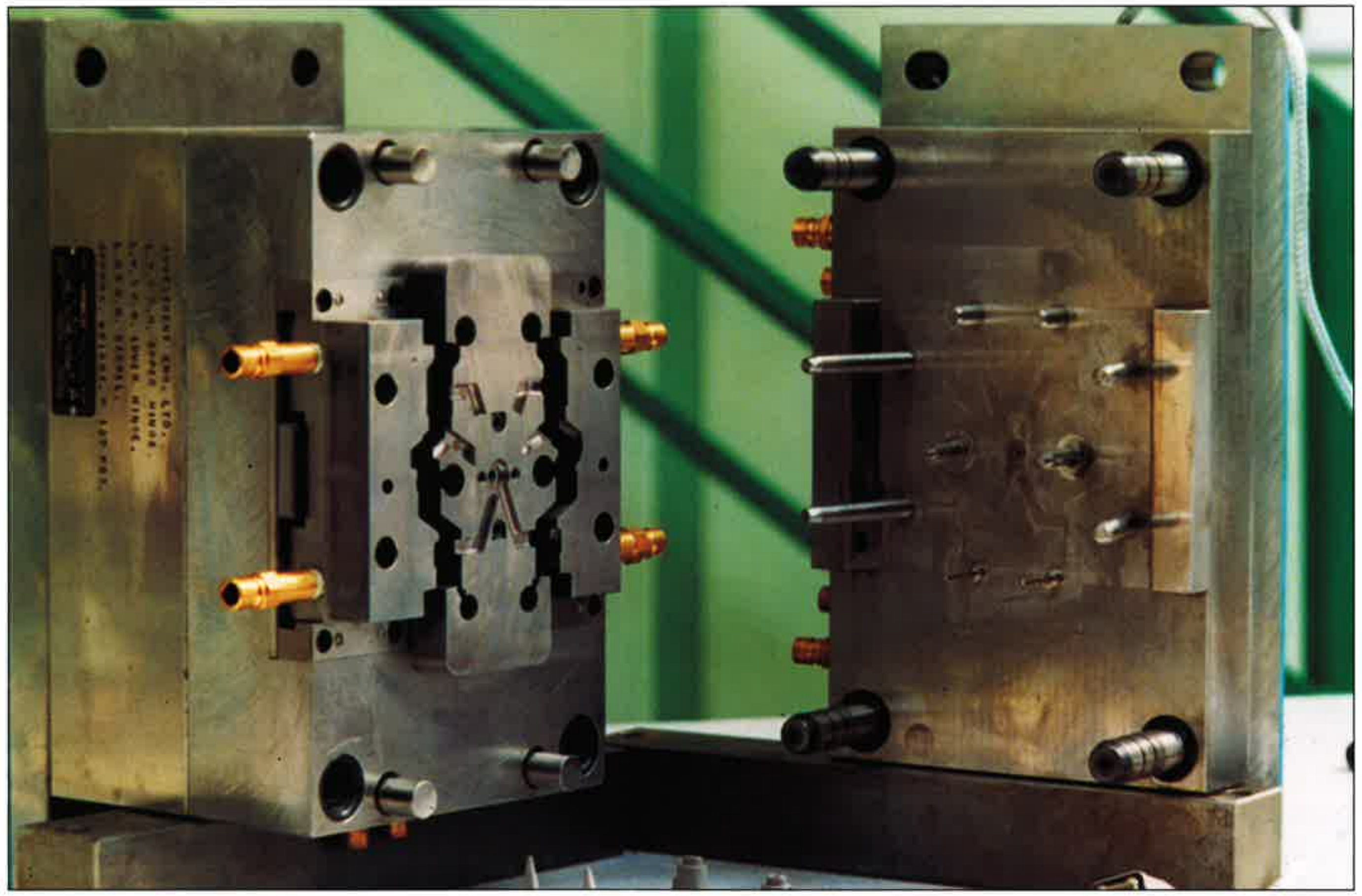
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Without any additional costs textures and other surface details can be incorporated into the molding process, eliminating these as finishing operations.

Holes and recesses can be molded into the metal part and it is feasible to produce these with a depth to diameter ratio of up to 10 to 1.

DESIGN CONSIDERATIONS

Like conventional injection molding, when designing for MIM it is essential to involve the manufacturer in the development process to ensure that the part is designed to optimize the full advantage of the MIM process.

A significant consideration and limitation on the process is the size of part. The general size range is from 0.1 g to 100 g (0.0035–3.53 oz), or up to 150 mm (5.91 in.) in length. Such size restrictions relate to the sintering operation, which removes the plastic matrix and causes the part to shrink considerably. Large parts and thick wall sections are more likely to distort during the heating and sintering process.

Wall thickness is generally between 1 mm and 5 mm (0.04–0.2 in.). It is possible to produce wall thicknesses of 0.3 mm to 10 mm (0.012–0.4 in.), but such extreme measurements may cause problems. Like injection molding, the wall thickness should remain constant.

To maintain a uniform wall thickness and keep material consumption to a minimum, it is necessary to core out bulk parts with recesses, blind holes and even through holes.

Internal corners are a source of stress concentration and so should have a minimum radius of 0.4 mm (0.016 in.). Outside corners can be sharp or curved, depending on the requirements of the design. Draft angles are not normally required, except for long draw faces, which makes the designer's job easier.

Case Study

Metal injection molding a cog from a window lock mechanism

The compounded metal powder and thermoplastic and wax binder are formed into pellets for injection molding (**image 1**). The metal powder is very fine and the particles spherical to give a final dense sintered structure.

The injection molding equipment is similar to that used for plastic injection (**image 2**). The mixed materials are not as fluid as thermoplastics. The tooling is generally machined from tool steel and can have moving cores, inserts and complex ejector systems for intricate shapes (**image 3**). On release from the injection molding equipment, the parts are a dull greyish colour – which is referred to as 'green' state – and they are surprisingly heavy, due to their high level of metal content. They are replaced onto support trays, which are stacked up in the debind oven (**images 4** and **5**). This stage is often manually operated, but is suitable for automation if the volumes justify it.

The binder is completely removed in the debind oven, then high temperature sintering causes the metal particles to fuse together. The finished parts have a bright lustre (**image 6**). They are solid metal, with very little porosity. MIM parts have good mechanical properties and are stronger and less brittle than conventionally sintered components.


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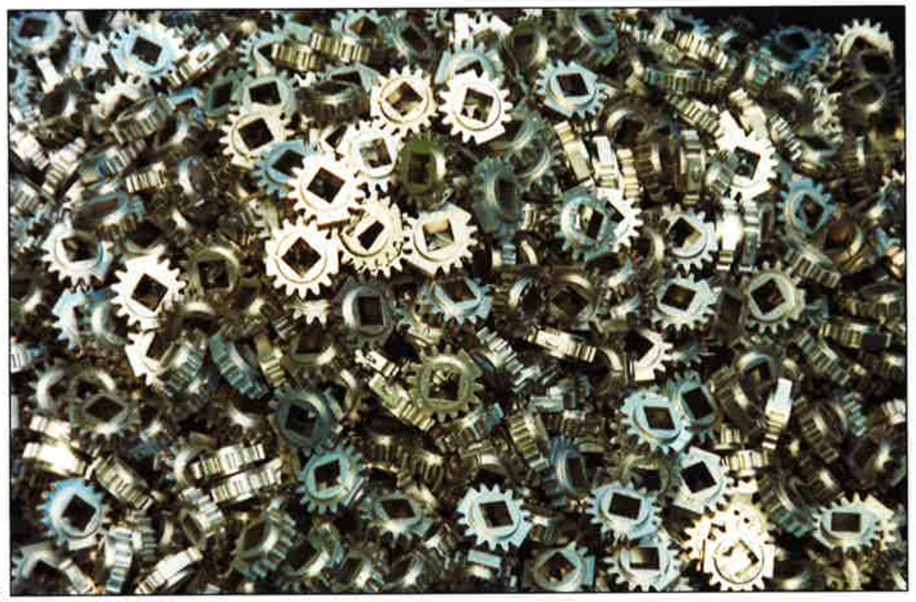
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COMPATIBLE MATERIALS

The most common metallic materials for MIM are ferrous metals including low alloy steels, tool steels, stainless steels, magnetic alloys and bronze. Aluminium and zinc are not suitable, and parts in these materials can usually be made as die castings.

COSTS

Tooling costs are similar to plastic injection mold tools. The MIM materials are typically high cost, due to the level of processing and pretreatment necessary to make them suitable for the injection molding operation.

Injection cycle time is rapid: like plastic injection, the part is molded in 30–60 seconds. Unlike injection molding, the parts need to have the binder removed and then be sintered, which is usually done over a further 2–3 days, as the debinding time is 15–20 hours, plus several hours for sintering. Labour costs are low for injection molding because it is often fully automated. However, MIM requires sintering, which does increase manual operations and so costs.

ENVIRONMENTAL IMPACTS

Scrap material in the injection molding cycle, including feeders, can be directly recycled. Once the material has been sintered it cannot be recycled so easily, but rejects are rare at that stage as parts are accurate and repeatable.

The plastic binder is vaporized during the debinding operation and collected in waste traps, without any environmental problem.

Featured Manufacturer

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