TECH FRONTIERS

Powder injection moulding for flexibility of design

The powder injection moulding process in the manufacture of complex and precision components, besides offering flexibility of design, is cost-effective, ensuring less wastage

CSIR-CMERI

Global PIM market

Powder injection moulding (PIM) is one of the near net manufacturing technologies for the manufacturing of complex, precise components from either metal or ceramic powder. The method combines the design flexibility of the plastic injection moulding process and material selection choices from powder metallurgy to combine into a single process.

Net shape manufacturing

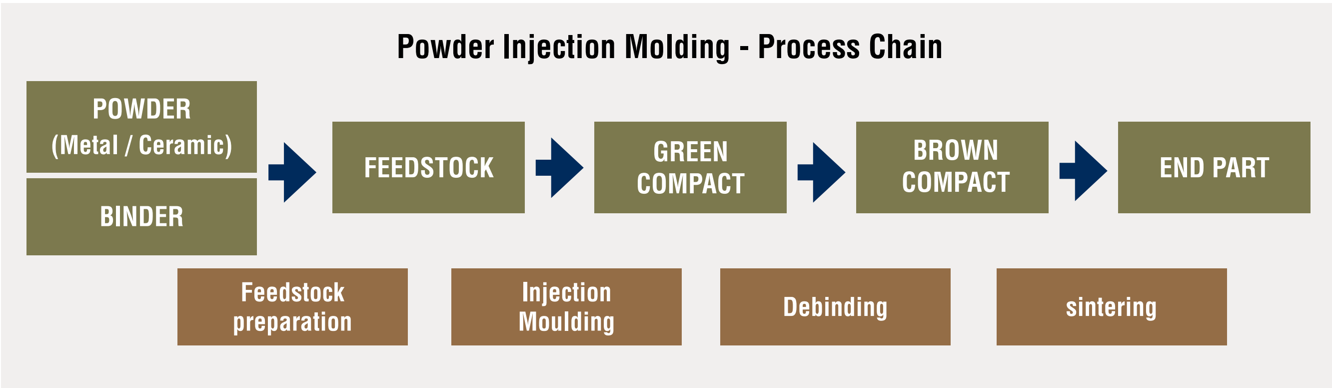
The name implies that the technology produces components that are closer to the finished size and shape with minimal final processing or machining and further reducing energy consumption in secondary processes, ensuring less material wastage, and usage of cooling fluids.

Process overview

The PIM process basically involves the following steps from the stage of Feedstock Preparation, Injection Moulding,

Debinding, and Sintering.

Feedstock preparation involves homogenous pelletized mixture of metal or ceramic powder and a binder. This mixture is fed into the moulding machine, and the oversized moulded part produced is referred to as 'green part.' This part is allowed to shrink during sintering after the removal of binder, which is time-consuming, involving thermal, solvents and catalytic methods.



POWDER MATERIALS AND CHARACTERISTICS

Stainless steels, nickel alloys, low-alloy steels, cobalt alloys, and binary alloys have been used extensively in powder metal injection.

The ideal characteristics of these materials would be to hold spherical morphology for excellent flow, low oxygen levels with high packing density allowing faster sintering process, and sufficient inter-particle friction to avoid distortion after binder removal process, free of internal voids.

Powder metals are available in wide range of particle size distributions with an ideal characteristic of 4-8 microns as mean particle size, tap density >50 percent rth and contacted angle of repose >55. A few typical examples are listed in **Table1**.

Table1: Some typical examples of powder metals

Powder	Size	Apparent density	Tap density	Repose angle
	µm	g/cm3	g/cm3	deg
Al2O3	0.5	1.1	1.3	42
Fe	4.0	2.4	3.8	61
316L	11.0	3.9	4.9	40
Ti-6Al-4V	32.0	2.1	2.8	44
W	2.9	3.6	6.0	55
WC-15Co	1.3	2.0	3.1	60

Binder material

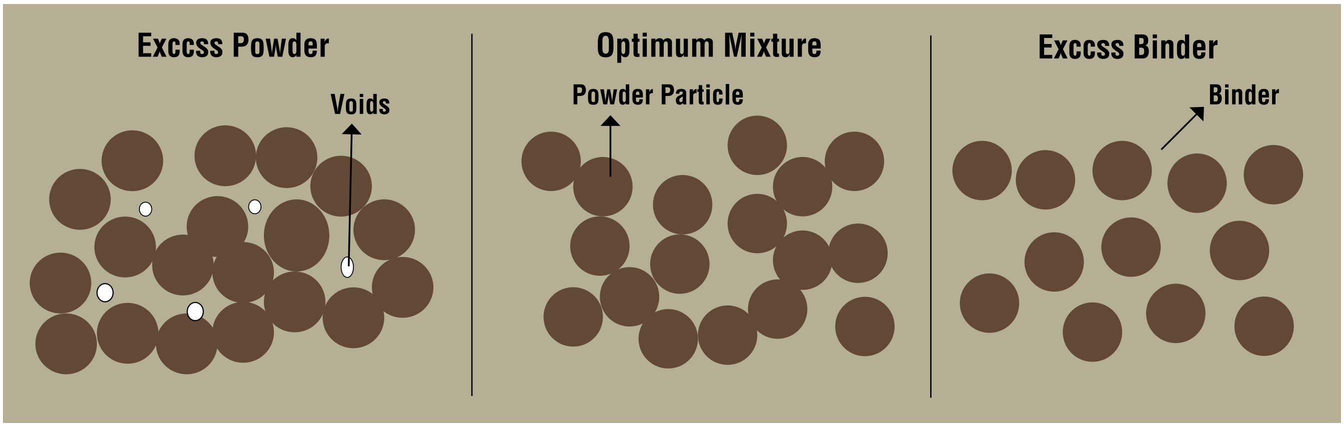
Another important aspect is binder selection. The most common binders are thermoplastics such as wax or polyethylene. They usually consist of two or three components.

An example would be binder which consists of 65 percent paraffin wax, 30 percent polypropylene, and 5 percent stearic; binder content is usually near 40 vol. percent of the mixture.

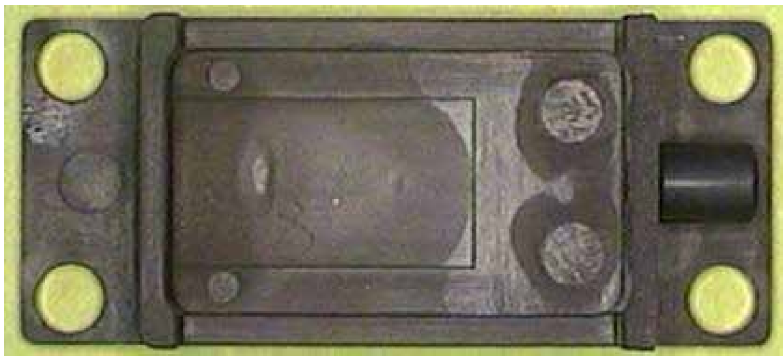
Injection moulding

The technology is similar to plastic processing; the binder added in the feedstock is melted in the processing unit through heating elements before being injected to the mould. The hardened green part

Feedstock preparation



Before sintering



After sintering

is ejected or removed manually or by robotic arms in an automated system for next process.

Debinding

The polymer binding agent added is removed from the green compact by catalytic processes, dissolving or thermal decomposition. This enables the binder to be separated; the moulded part becomes brown compact. In this condition the parts are porous, fragile and unstable.

Solvent debinding uses a solvent to remove the soluble ingredients of the binder.

Whereas in ***Thermal debinding***, the parts are exposed to temperatures where the polymer binding is evaporated and extracted out of furnace through a medium.

In ***Catalytic decomposition***, gaseous nitric acid or oxalic acid is widely used de-binding method.

Sintering

Sintering is a thermal diffusion process where the surface area of the powder compacts is transformed into solid material of high density.

The brown compact is subject to heat treatment, to firmly bond the particles; it is sintered to high temperatures in a furnace under controlled temperature and time environment and just below melting point. This process compresses parts homogeneously and attains it material properties, surface qualities and minimal part tolerances.

Both debinding and sintering can be done in a continuous process or discontinuous manner depending on the volume of production. High volume of large parts are processed continuously and small volumes and small parts are processed separately.

Dimensional changes, microscopic level – Sintering process

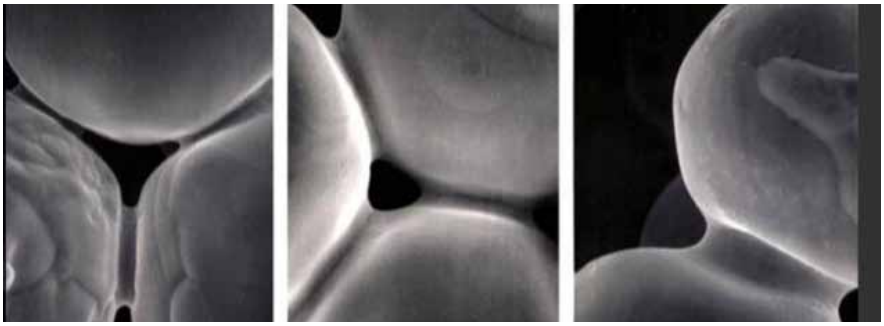


Table2: Component feature tolerances achievable		
Features	**Minimum**	**Typical**
Angle	±0.5˚	±2˚
Fractional Density	±0.2%	±1%
Relative Dimension	±0.1%	±0.3%
Absolute Dimension	±0.04mm	±0.1mm
Hole Diameter	±0.04%	±0.1%
Surface Roughness	1μm	5μm
Weight	±0.1%	±0.4%

Benefits of the technology

Powder injection moulding offers manufacturers and product designers flexibility to choose among the select variety of materials which provides excellent material properties to the product, good surface finish of finished components with high precision and an attractive option for economic mass production of complex shapes. Accordingly designers and manufactures could choose this technology for the right application intended for the end product being developed.

Powder injection moulding has found vast applications in sectors of biomedical devices like dental implants, surgical tools, mobile phone cases and accessories, and industrial power tools and industrial valves, where high performance materials such as stainless steel, tungsten, titanium, ceramics, carbides play a vital role with high strength, high stiffness, higher operating temperatures, excellent electrical, magnetic, thermal properties, and produced with surface finish achievable at Ra nearly 0.3 microns. They also have multiple features adding to complexity in part design which would have been a complex production task with general production practices when compared to such near net manufacturing process. Typical components produced are from 280g down to 0.03g.

Standards at glance

ISO 22068:2012 - Sintered-metal injection-moulded materials – Specifications

ISO 2740:2009 - Sintered metal materials, excluding hard metals – Tensile test pieces

- the die cavity dimensions used for making tensile test pieces by pressing and sintering, and by metal injection moulding (MIM) and sintering;

- the dimensions of tensile test pieces machined from sintered and powder forged materials.

ASTM B883 - 19 – Standard specification for metal injection moulded (MIM) materials

WORK DONE/IN-PROGRESS AT CSIR-CMERI

Copper nozzles developed for Bargachia cluster

Injection moulded green nozzles, materials savings: >50 percent

Sintered nozzles, wt: 9.5 g

Density: 8.01g/cc

Atmosphere: Argon

316 L MIM product

The MIM process technology has been transferred to ANTICO-Mumbai

Nickel wick for LHP of ISRO

Porosity level: 55 vol percent

Avg. pore diameter: 2.6µm

Permeability: 1.94 × 10-12 m2

Thermal conductivity: 9.37 W/mK

Maximum variation of roundness: 5 percent