ECRIMESA
GROUP

METAL INJECTION MOLDING:

THE BEST GUIDE FOR THE DESIGN OF YOUR PARTS

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Metal injection molding manufacturing process

Rules and tips for the design of a part

METAL INJECTION MOLDING MANUFACTURING PROCESS

Metal injection molding (MIM) is one of several technologies used industrially for the production of metal parts.

In order to gain a deeper understanding of its importance, we consider it necessary to point out the different existing industrial processes for the manufacture of metal parts, and then delve into metal injection molding. There we will explain the technical details, which are the basis for selecting the most efficient technology when designing and manufacturing metal parts.

1. INDUSTRIAL PROCESSES FOR THE MANUFACTURING OF METAL PARTS

Today there is a wide range of possibilities for the production of parts made of steel and other materials at the industrial level. This range extends from machining to MIM (metal injection molding), including more classical techniques such as microfusion.

Broadly speaking, metal parts manufacturing technologies can be classified into the following technological areas:

PM (Powder Metallurgy)

It is the process of compacting fine powders of the chosen material to give the required geometry. This compaction is done through hydraulic or pneumatic presses.

This is followed by a sintering process in a muffle under controlled atmosphere to avoid oxidation. The main disadvantages of this technology are that its precision can be improved, since high densities are not achieved, and therefore the mechanical properties obtained are very limited.

Forming

Depending on the forming system and whether the process is hot or cold, there are different variants. The main ones are:

- **Forging**
  It consists of the deformation of red-hot metal through impact and pressure.

- **Stamping**
  In this case the deformation is done through pressure between 2 dies or molds.

- **Extrusion**
  It can be done hot or cold and consists of pushing the material through a die that has the desired shape.

Laminate

- In this case the objective is to reduce the thickness by using pairs of rollers.

Machining

It consists of the set of operations that, by cutting and chip removal, are used to obtain the dimensions and specifications of the parts, through different operations and abrasion and cutting tools.

In the case of obtaining a part with 100% machining, there is an obvious waste of material and tools, in addition to the time required. However, it is a complementary technology (and in many cases necessary) to obtain the required finishes of a part.

Foundry

It is a technology used since ancient times, which consists of melting the metal at high temperatures, pouring it into a mold and letting it cool.

The main variants of this process are:

- **Sand casting**
  As its name suggests, the casting is poured into a mold made of refractory sand. It is used in large pieces, since the mold is destroyed.

- **Investment casting or lost wax casting**
  It consists of the injection molding of the wax part. From this wax part, ceramic molds are created, where the chosen steel or other metal (for example, aluminum) will be cast. This is one of the main manufacturing processes in Ecrimesa Group.

  Die Casting
- Valid for low melting point metals such as aluminum, where aluminum, in its liquid state, is injected into a mold by applying a high clamping force to the 2 semi-molds. It is a process suitable for the production of large series.

Additive Manufacturing

It is the newest process of parts manufacturing, which continues with the advance of 3D printing technology so present nowadays.

At Ecrimesa Group we have implemented this technology both in the manufacture of prototypes prior to the manufacture of the mold, and to accelerate the MIM process through the study of prototypes of the final parts. Also, short series of parts with complex geometry are produced with Additive Manufacturing.

Metal Injection Moulding (MIM)

2. WHAT IS METAL INJECTION MOLDING?

MIM (Metal Injection Moulding) technology is a metal part manufacturing technology that **combines the versatility of injection molding with the sintering technique to produce high-density parts with very tight geometric tolerances.**

The **raw material** used is a mixture of metal powder and polymers, which is called **feedstock**. This material is introduced into a mold with the desired geometry by means of an injection machine similar to the one used in the plastic injection molding process.

This results in the so-called **green part**, which is subjected to a chemical-thermal process called **desbanderization**, the purpose of which is to extract the binder from the part, thus obtaining the brown part.

The part is then subjected to the **sintering** process, so that the particles are joined together to form a high-density metal part with narrow dimensional tolerances.

In a subsequent process, the polymer is removed to obtain the **steel part**.

2.1. When does it apply?

Generally speaking, any part that can be manufactured by plastic injection molding could be produced in steel by MIM, but there are some limitations or rules to keep in mind.

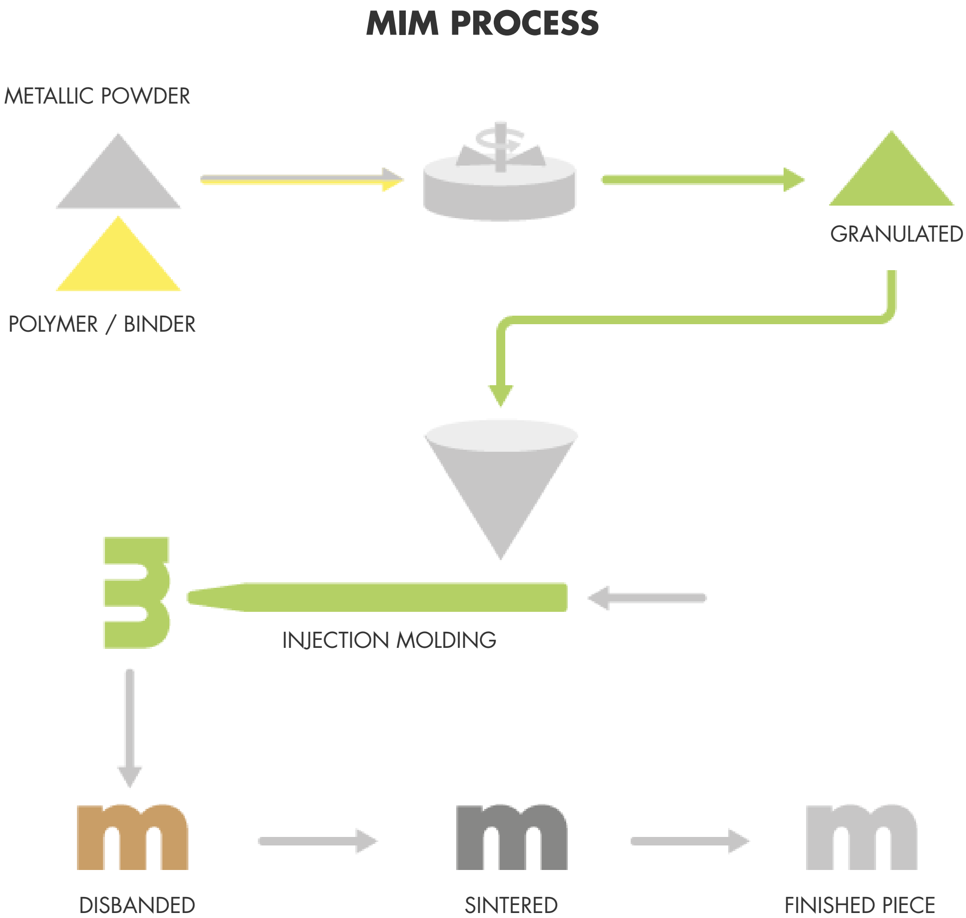
Although in Ecrimesa Group there are parts in production up to 350 gr ('record' in this technology, in force worldwide), MIM is a recommended process for parts under 100 gr and especially competitive below 40 gr. The weight reduction increases the precision of dimensional tolerances and reduces raw material consumption, which has a great influence on the total cost.

The maximum allowable radius is recommended for all edges, especially internal edges, as sharp edges can be sources of potential cracks.
Section changes should be gradual, facilitating material flow during injection and avoiding isolated masses.
A flat face will facilitate the palletizing of the part inside the MIM furnace. The more stable this support is, the smaller the deformations will be and the more precise the dimensional tolerances will be.

This so-called 'MIM process' is suitable for **manufacturing parts of complex geometry**, small to medium size in a **wide range of materials** (stainless steels, low alloy steels, soft magnetic, tool steel and ceramics).

It is an ideal technique for small parts of complex geometry that require high accuracy and surface quality.

2.2. Phases of the MIM process



Development of the MIM Process

The following are the different phases of the MIM process in detail:

PHASE 1

Mold manufacturing

The molds used in MIM are made of high-strength steel, more complex and more demanding than conventional plastic injection molds. The mold cavities with the shape of the part are manufactured with an enlargement factor, depending on the degree of shrinkage of the material to be injected. It is key to **apply the design rules** (downloadable on our website) of the technology to ensure a stable and defect-free injection.

The number of cavities in the mold depends on the geometry and dimensions of the part, ranging from a single cavity to more than 10. The most common are 2 or 4 cavities, and the cycle time ranges from 15 to 60 seconds.

PHASE 2

Feedstock

It consists of metal powder with a maximum particle size of 32 microns (at least 80% below 22 microns) mixed with binders or moldable binders, granulated and extruded to obtain pellets. The binder is a mixture of thermoplastics, waxes, polymers and other additives.

The **characterization and control of the feedstock** is key to adjust downstream process parameters (especially injection and sintering), in order to obtain the desired tolerances and repeatability.

PHASE 3

Injection

The feedstock is injected into a mold with the desired part shape. The main injection parameters are pressure, flow rate and temperatures (of the injection screw and mold). The injection parameters must be adapted to the part geometry. **Know-how as a manufacturer** is essential to obtain parts without internal defects. The part obtained is known as a **'green part'** and the first dimensional shrinkage with respect to the mold cavity (between 0.7% and 0.9% in carbon and low alloy steels, and 0.4% in austenitic stainless steels) occurs as soon as it comes out of the mold.

PHASE 4

Debanding

This is the process in which the binder or binder that has been used for injection is eliminated, and can be carried out by various methods: 100% thermal, water-based, solvent-based or by catalytic reaction.

At Ecrimesa Group we use **catalytic feedstock**, which has advantages over other methods, especially the process time, which is faster, and stability. The catalytic reaction takes place in a controlled atmosphere of N_2 and nitric acid at a temperature of 120ºC, in which the main component of the binder, POM, decomposes from a solid to a gas state, leaving the part with a high degree of porosity. The resulting part is called a **'brown part'**.

De-binderizing can be carried out in batch furnaces or in the first part of continuous furnaces. The advantage of performing it in continuous furnaces is that handling is avoided and the part advances directly to sintering. It must be taken into account that this is the point of the process where the piece is weaker, being susceptible to deformations or defects, so avoiding manipulation increases the reliability of the process. At Ecrimesa Group we have both equipments.

There is a small part of 'secondary' binders that still do not react at this stage and maintain the shape of the part. These secondary binders will be removed at the beginning of sintering.

PHASE 5

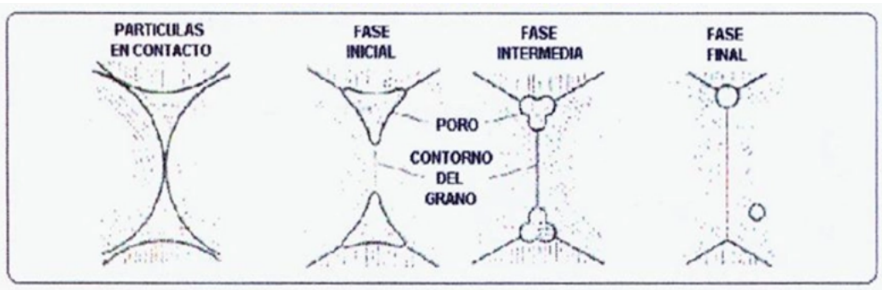
Sintering

This is the final process of interdiffusion bonding of the metal particles by the action of temperature and gases (depending on the alloy it will be H2 or N2), and in which the target density is reached (95-98% compared to 82% in traditional sintering). It can be carried out in batch furnaces (suitable for small batches or special materials) or in continuous furnaces (suitable for large production batches).

At Ecrimesa Group we have both equipments, with 3 continuous lines and 2 batch furnaces. The **positioning of the parts** during the debanding and sintering process can affect the dimensional results obtained, so the **definition and industrialization phase** is another key to obtain a robust and reliable process.

During sintering, the second and final shrinkage occurs with respect to the green part, obtaining the final dimensions desired by the customer.

In the case of carbon and low alloy steels, the shrinkage factor between the mold and the final part is 1.2165, and between the green part and the final part is 1.205. In the case of stainless steels, the shrinkage factor between the green part and the final part is 1.166, and between the green part and the final part is 1.160.



Sintering model

Sintering machinery

PHASE 6

Final-finishing operations

After the sintering process, the parts may require other types of operations and treatments to meet customer requirements. At Ecrimesa Group we have an advanced **heat treatment department** to be able to deliver completely finished parts. We also have **our own machining service** to be able to machine close tolerance dimensions, perform honing and final polishing operations for aesthetic or roughness requirements.

3. WHAT IS THE BEST TECHNOLOGY FOR MANUFACTURING METAL PARTS: MIM OR MICROFUSION?

Compared to microfusion, which represents one of the oldest metal molding processes in use, Metal Injection Moulding or MIM is a relatively new technology. MIM technology became known in the 1980s. However, even in the 1990s, many companies involved in the manufacture of metal parts were still using MIM. Especially in the 1980s, there were still doubts about the metallic integrity of parts made by MIM, which were mainly applied in the manufacture of plastics.

To this day, microfusion is considered as the main precision technology, and MIM as a complementary technology that is mainly used for the manufacture of small parts.

3.1. Similarities and differences between microfusion and MIM

Similarities::

Both technologies are applied to manufacture small-sized parts that stand out for a more complex structure or design, and therefore traditional industrial technologies such as forging cannot be used.

Differences:

One of the main differences between microfusion and MIM is the materials to which they can be applied. In general, the microfusion process allows for a wider variety of materials, as the MIM process can only be performed with alloys of a higher melting temperature. Materials such as aluminum, for example, do not work efficiently with MIM.

3.2. When to use each technology, Microfusion or MIM?

In addition to the materials to be processed, the decision between microfusion and MIM depends on other basic factors:

- The **size of the part**, the complexity of the structure and the tolerances it allows, as well as the number of parts to be produced. The ideal part for the MIM process has a length of less than 100 mm and is produced in batches of more than 5000 pieces. In general, we can say that most of the parts with a final weight of less than 50 grams (depending on the material) are produced with MIM, since this technology allows thinner structures and has a higher efficiency in the use of materials and energy.

  However, there are still designers who, even for smaller parts, rely more on microfusion, as it is still considered the most robust technology.

- Traditionally, regarding aspects such as the **weight of the parts**, at Ecrimesa Group 90 percent of the parts weighing more than 100 grams are manufactured with microfusion, since at that size the cost of the fine powder used in the MIM process is too high, as well as the energy required to produce them.

  However, due to the experience accumulated with MIM and the quality of the materials used, more and more references weighing more than 100 grams have been manufactured in recent years. The **supply** of tools required for MIM (e.g. injection molding machines) has also **improved**, allowing the technology to be applied in more cases. In any case, parts weighing up to 25 kg can be produced by microfusion, whereas with MIM, the maximum weight of the final part is 250 grams.

- There are **additional criteria**, such as d**evelopment time**, for deciding between microfusion and MIM. In general, it can be said that the **development and production process of new parts is shorter with MIM**, since there is no obligation to make several molds and prototypes before starting production, which may be necessary when working with microfusion.

  In addition, the final part design that starts the MIM process is closer to the final part, and machining processes are saved. Usually, parts manufactured with MIM have a very high surface and finish quality.

At Ecrimesa Group we have facilities for both microfusion and MIM, and we also have a design office where we can simulate manufacturing processes and offer technical advice on which technology to choose to manufacture a specific part. We also take advantage of the **synergies between both technologies**. The Ecrimesa Group was the first company in the world to develop the continuous furnace manufacturing process with catalytic debanding in collaboration with BASF and Cremer Thermoprozessanlagen GmbH.

Having internalized almost all machining processes, we can a**ccompany and support the customer in all manufacturing steps**, from the idea and design to the last steps of the final finishing, including the choice between the technologies that can be applied.

4. ADVANTAGES AND DISADVANTAGES OF MIM: COMPARISON WITH OTHER TECHNOLOGIES

MIM is essentially a manufacturing technology for precision steel parts, with complex three-dimensional shapes, fine details, good aesthetics, demanding mechanical requirements and high consumption.

It is colloquially known as **'the enemy of machining'**, because the tight geometric tolerances (±0.5%), low roughness (between Ra0.8 and Ra1.2) and high finishing quality (possibility of including threads, knurling, logos, etc. in the mold) greatly reduce the need for second operations to obtain a finished part ready for the corresponding assembly line.

When the **shape of the part** in question allows its manufacture by traditional powder metallurgy (pressing on a shaft + sintering), MIM may often appear uncompetitive. However, these types of parts are much more porous and fragile, so it is common for the application to force a switch to higher strength components such as MIM parts.

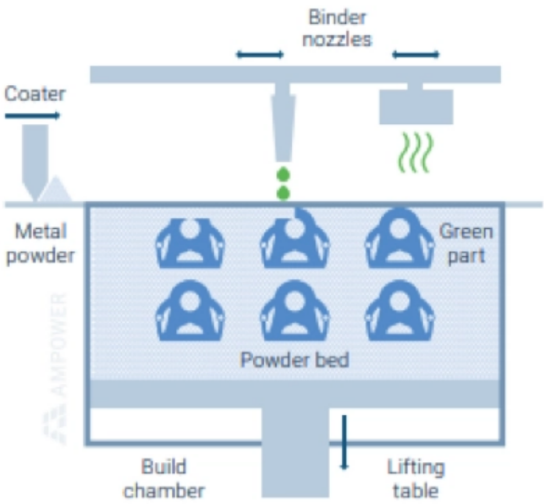
As an example, making a comparison between MIM and Microfusion, with respect to a potential part for an annual consumption of 45,000 parts/year, the cost study would be:

	MICROFUSION	MIMECRISA
PIEZA	1 €	0,94 €
MECANIZADO	0,54 €	NO
UTIL DE MECANIZADO	1.800 €	NO
MOLDE	6.500 €	16.000 €

However, in terms of **other technologies**, MIM can also be compared with **Binder Jetting and FDM**.

4.1. Binder Jetting

The manufacturing process of the Binder Jetting technology is based on the **deposition of a layer of metal powder on a printing platform and the agglomeration by deposition of polymeric material through a nozzle**. Subsequently, **polymer curing** processes are necessary in each printed layer and, once the printing is finished, the so-called **de-powdering process** to remove the remaining powder and obtain green parts. Finally, **debanding and sintering processes** are needed to obtain the metal parts. The debinding process in parts printed by Binder Jetting is less critical than usual, because the amount of binder deposited at the layer junction is minimal. This results in easy removal of the binder from the green part, but at the same time makes the printed green parts fragile and difficult to handle.

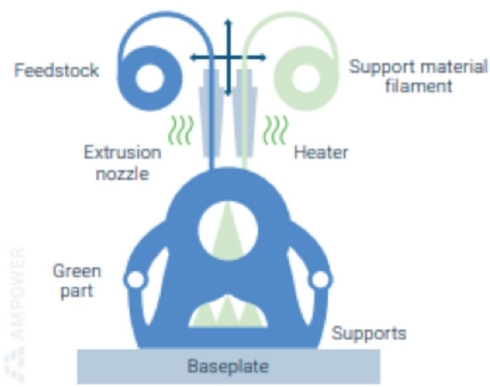


Binder Jetting printing scheme (source: AMPOWER)

4.2. FDM Printing

FDM (Fused Deposition Modeling) printing technology, also known as ME (Material Extrusion) or FFF (Fused Filament Fabrication), is the process by which **parts are manufactured layer by layer by depositing extruded material (metal powder + polymers) through a nozzle similar to those used in plastic filament printers.**

This technology can use filament, pellets or rods as raw material and, once the green part is printed, debanding and sintering processes are needed, as in MIM technology, to obtain the final metal part.



FDM printing scheme (source: AMPOWER)

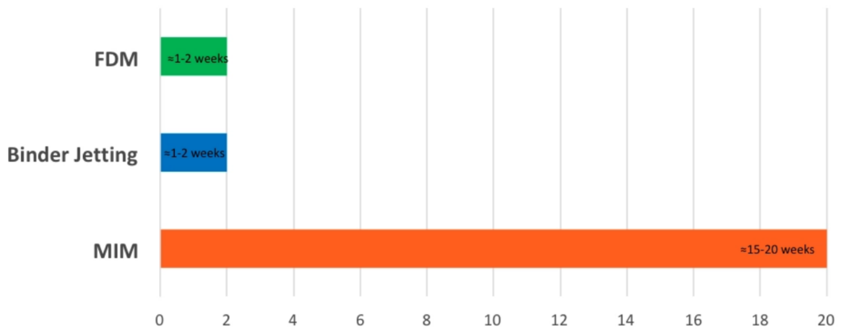
4.3. Characteristics compared between Binder Jetting, FDM and MIM

Although in many articles you can find comparative graphs of technologies where we see overlap between MIM technology and some printing technology, especially Binder Jetting, the reality is that today **Additive Manufacturing and MIM are not competitive technologies but complementary**.

Some fundamental differences between the two technologies are defined below:

Manufacturing speed

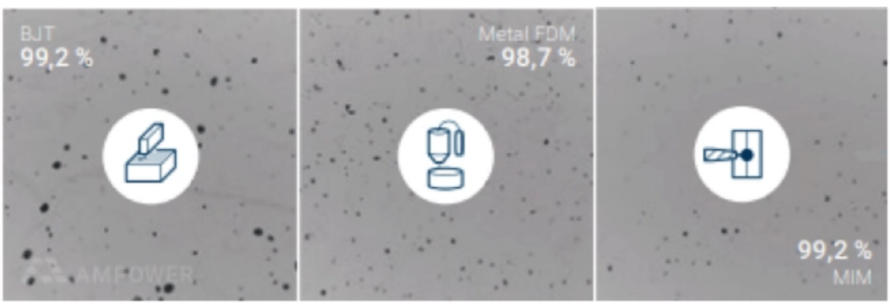
Although part developments are much faster in Additive Manufacturing compared to MIM, mainly due to mold manufacturing, post-mold part production becomes faster in MIM technology compared to printing technologies.



Manufacturing speed of FDM technologies VS Binder Jetting VS MIM

Porosity and microstructure

Large porosity associated with printing defects may appear, especially in parts manufactured by FDM. This can lead to lower metal part densities than those obtained by MIM. In addition, the nature of the metal powder used in manufacturing can generate incorrect microstructures that require subsequent heat treatments to improve it.



Sintered part porosity according to manufacturing technology (source: AMPOWER)

Portfolio of materials

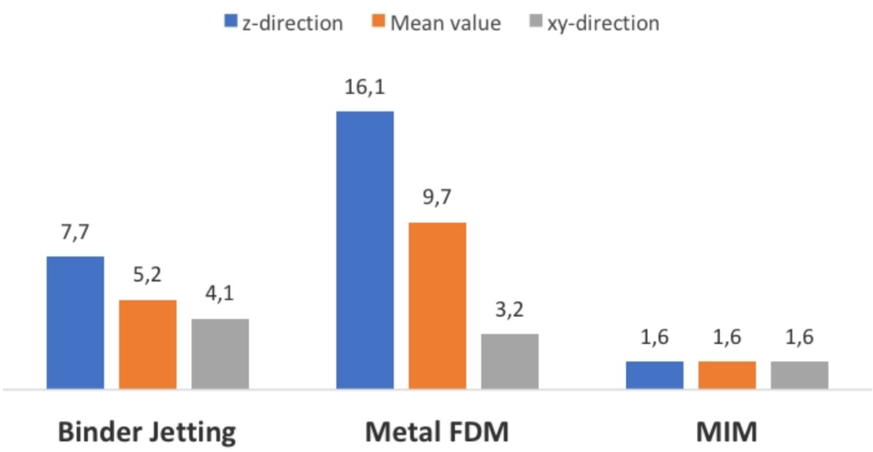
MIM technology is much more versatile in terms of the materials available for manufacturing metal parts. Keep in mind that Additive Manufacturing technologies are in the midst of development, and their material portfolio is likely to increase as the technology matures. As of today, the portfolio of materials available in printing technologies is limited to stainless steels, some tool steel and few other materials.

	MIM	Metal FDM	BJ
Stainless steel	●	●	●
Low alloy steel	●	○	○
Tool steel	●	○	○
Super alloy	●	○	○
Titanium	●	○	●
Copper/Bronce	●	●	●
Carbide	●	●	○

Comparison

Surface finish

Increased roughness in Additive Manufacturing techniques. Secondary finishing improvement operations are necessary to compete with MIM. At Ecrimesa Group we guarantee sintered roughness between 0.8 and 1.6 Ra.



Surface finish and roughness

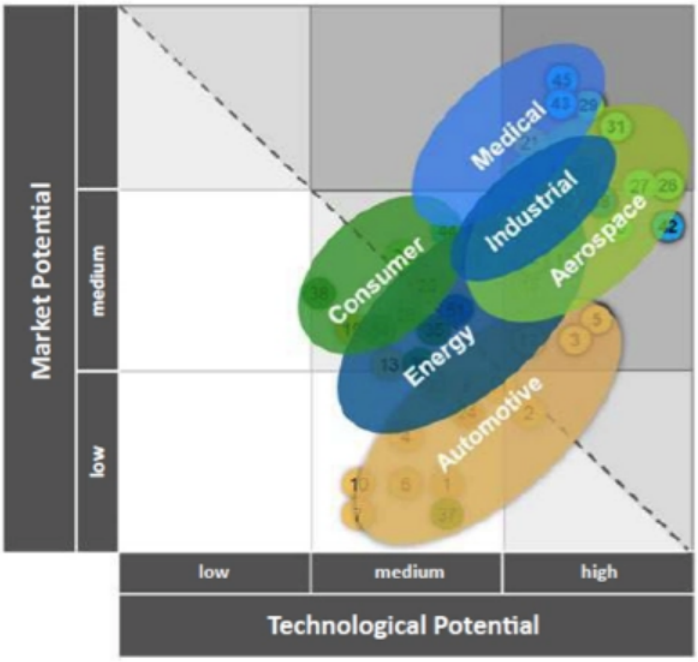
Design

Possibility of **manufacturing more complex parts** (hollow parts, bionic geometries, counter-flanges, etc.) and **larger parts** in Additive Manufacturing technologies.

Source: Metal AM Magazine

Market segments

Although Additive Manufacturing technology is constantly developing and there may be variations, it seems that **this manufacturing technology is positioning itself primarily in the medical, industrial and aeronautical sectors.**



Source: Metal AM Magazine

Mechanical properties

The results of a comparative study of mechanical properties (tensile test) of sintered 17-4PH specimens are shown. Tensile specimens are manufactured according to **ISO 2740** 'Sintered Metal Materials' (excluding hard metal) according to the different technologies and printers described in the following table:

Technology / Printer	Density (g/cc)	Hardness (HV10)	Ultimate tensile strength Rm (MPa)	Yield strength $Rp_{0,2}$ (MPa)	Elongation A (%)
MIM	7,63	296	951	839	5,1
FDM Conventional 3D printer	7,53	271	811	749	6,4
FDM Desktop Metal	7,57	274	852	806	3,2
Binder Jetting	7,57	260	870	777	6,7
ISO 22068 MIM-174PH Sinter	7,50	280	800	650	3

Comparative graph of mechanical properties

All the mechanical properties obtained are within the ISO 22068 'Sintered Metal Injection Moulded Materials Specifications' for sintered 17-4PH steel, with the MIM technology showing the best mechanical properties.

ONE-PIECE DESIGN RULES AND TIPS

It is important to pay a lot of attention to the manufacturing process of a part, depending on the material to be used. The metallic material par excellence with which we work in the group is steel. Below we will show important distinctions to be made in this process.

1. SUITABLE MATERIALS

The experience that Ecrimesa Group has acquired over the years in the manufacture of metal parts using MIM technology has been recognized at an institutional level. So much so that Ecrimesa Group has actively participated in the promotion and contribution of tests with different materials in the **ISO standard on MIM technology, ISO 22068 ‘Sintered Metal Injection Moulded materials - Specifications’.**

The following are the types of steels manufactured by Ecrimesa Group, the application for which they are intended and the main properties of each type:

1.1. Low alloy steels

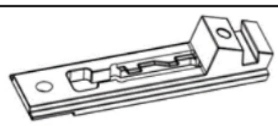
MATERIAL TYPE *Tipo de Material*	**TRADITIONAL MIM NAME** *Denominación clásica*	**STANDARD NAME** ISO 22068:2012	**STANDARD NAME** ASTM B 883-10 MPIF 35-2007	**CHEMICAL COMPOSITION** *Composición Química*						
				%C	**%NI**	**%Cr**	**%Mo**	**%Si**	**%Mn**	**OTHERS**
LOW ALLOY STEELS *Aceros baja aleación* **Iron-Nickel** *Hierro-Niquel*	FN08(00) FN08	MIM-Fe8Ni-210 MIM-Fe8NiC-300 MIM-Fe8NiC-500 MIM-Fe8NiC-700H MIM-Fe8NiC-1100H	MIM-2700	<0,1 0,4-0,8 0,45/0,65	6,5-8,5 6,5-8,5 better carbon control MIMECRISA process		<0,5 <0,5			<1,0 <1,0
	4605	MIM-4605-170 MIM-4605-1310H	MIM-4605 MIM-4605-HT	0,4-0,6	1,5-2,5		0,2-0,5	<1,0	<0,2	<1,0
LOW ALLOY STEELS *Aceros baja aleación* **Cr-Mo Alloys** *Aleaciones Cr-Mo*	MIM-42CrMo4	MIM-4140-400 MIM-4140-600H MIM-4140-1200H	MIM-4140	0,35-0,5 0,3-0,5		0,9-1,2 0,8-1,2	0,15-0,3 0,2-0,3	<0,4 < 0,6	<0,9 < 1,0	<1,0
	MIM-8740		8750	0,45-0,55	0,5-0,8	0,4-0,6	0,25-0,4	0,3-0,55	<0,1	
	MIM-4340	MIM-4340-500 MIM-4340-750H MIM-4340-1300H	4340	0,35-0,5	1,4-2	0,7-1,4	0,2-0,3	<0,4	<0,8	
	MIM-8620	21NiCrMo2	8620	0,18-0,23	0,4-0,7	0,4-0,6	0,15-0,25	<0,2	<0,2	

Table of low alloy steels

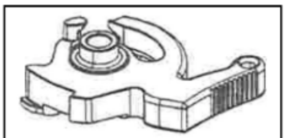
MATERIAL TYPE *Tipo de Material*	**TRADITIONAL MIM NAME** *Denominación clásica*	**STANDARD NAME** ISO 22068:2012	**STANDARD NAME** ASTM B 883-10 MPIF 35-2007	**CHEMICAL COMPOSITION** *Composición Química*						
				%C	**%NI**	**%Cr**	**%Mo**	**%Si**	**%Mn**	**OTHERS**
LOW ALLOY STEELS *Aceros baja aleación* **Iron-Nickel** *Hierro-Niquel*	FN08(00) FN08	MIM-Fe8Ni-210 MIM-Fe8NiC-300 MIM-Fe8NiC-500 MIM-Fe8NiC-700H MIM-Fe8NiC-1100H	MIM-2700	<0,1 0,4-0,8 0,45/0,65	6,5-8,5 6,5-8,5 better carbon control MIMECRISA process		<0,5 <0,5			<1,0 <1,0
	4605	MIM-4605-170 MIM-4605-1310H	MIM-4605 MIM-4605-HT	0,4-0,6	1,5-2,5		0,2-0,5	<1,0	<0,2	<1,0
LOW ALLOY STEELS *Aceros baja aleación* **Cr-Mo Alloys** *Aleaciones Cr-Mo*	MIM-42CrMo4	MIM-4140-400 MIM-4140-600H MIM-4140-1200H	MIM-4140	0,35-0,5 0,3-0,5		0,9-1,2 0,8-1,2	0,15-0,3 0,2-0,3	<0,4 < 0,6	<0,9 < 1,0	<1,0
	MIM-8740		8750	0,45-0,55	0,5-0,8	0,4-0,6	0,25-0,4	0,3-0,55	<0,1	
	MIM-4340	MIM-4340-500 MIM-4340-750H MIM-4340-1300H	4340	0,35-0,5	1,4-2	0,7-1,4	0,2-0,3	<0,4	<0,8	
	MIM-8620	21NiCrMo2	8620	0,18-0,23	0,4-0,7	0,4-0,6	0,15-0,25	<0,2	<0,2	

Mechanical properties of low alloy steels

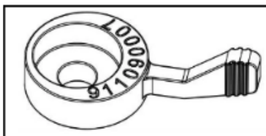
Material: FN08
Sector: Tools
Weight: 3,8 g



Material: 42CrMo4
Sector: Defense
Weight: 14,6 g



Material: 4605
Sector: Defense
Weight: 38,5 g



Material: 8620
Sector: Locksmith
Weight: 11,9 g

Application examples for low alloy steels

1.2. Tool steels

MATERIAL TYPE *Tipo de Material*	TRADITIONAL MIM NAME *Denominación clásica*	STANDARD NAME ISO 22068:2012	STANDARD NAME ASTM B 883-10 MPIF 35-2007	CHEMICAL COMPOSITION *Composición Química*						
				%C	%NI	%Cr	%Mo	%Si	%Mn	OTHERS
TOOL STEELS *Aceros herramienta*	MIM-100Cr6	MIM-52100	52100	0,85-1,05		1,35-1,65		<0,35	<0,45	
	MIM-M2	1. 3343	M2	0,78-1,05		3,75-4,5	4,5-5,5	0,2-0,45	0,15-0,4	%V 1,75-2,2 %W 5,5-6,75

Table of tool steels

MATERIAL TYPE *Tipo de Material*	TRADITIONAL MIM NAME *Denominación clásica*	STANDARD NAME ISO 22068:2012	STANDARD NAME ASTM B 883-10 MPIF 35-2007	MECHANICAL PROPERTIES (as sintered) *Propiedades mecánicas (Sinterizado)*				HEAT TREAT. *Trat. Térmico*	MECHANICAL PROPERTIES (Heat treated) *Prop. Mecánicas (+Tratamiento Térmico)*				DENSITY *densidad (g/cm3)*
				Rm (N/ mm2)	R0,2 (N/ mm2)	E %	HARDNESS HB		Rm (N/ mm2)	R0,2 (N/ mm2)	E %	HV10 (HRC)	
TOOL STEELS *Aceros herramienta*	MIM-100Cr6	MIM-52100	52100	>900	>500	>5	230-290 HV10	Harden				(60-62 HRC)	>7,50
	MIM-M2	1. 3343	M2	>1200	>800	>1	(>50 HRC)	Harden				(>65 HRC)	>7,95

Mechanical properties of tool steels

Material: M2
Sector: Industrial machine
Weight: 5,6 g

Material: M2
Sector: Industrial Machine
Weight: 17,8 g

Material: 100Cr6
Sector: Industrial machine
Weight: 15,6 g

Material: 100Cr6
Sector: Tools
Weight: 1,1 g

Application examples of tool steels

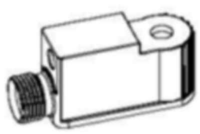
1.3. Soft Magnetic Steels

MATERIAL TYPE *Tipo de Material*	TRADITIONAL MIM NAME *Denominación clásica*	STANDARD NAME ISO 22068:2012	STANDARD NAME ASTM B 883-10 MPIF 35-2007	CHEMICAL COMPOSITION *Composición Química*						
				%C	%NI	%Cr	%Mo	%Si	%Mn	OTHERS
SOFT MAGNETIC	4605(00) FN50 FeSi3 430L	MIM-Fe2Ni-20 MIM-Fe50Ni-200 MIM-Fe3Si-55 MIM-430-10	MIM-2200 MIM-Fe50%Ni MIM-Fe-3%Si MIM-430L	<0,1 <0,05 <0,05 <0,05	1,5-2,5 49-51	16/18		<1 <1 2,5-3,5 <1	<1	

Table of soft magnetic steels available at Ecrimesa Group

MATERIAL TYPE *Tipo de Material*	TRADITIONAL MIM NAME *Denominación clásica*	STANDARD NAME ISO 22068:2012	STANDARD NAME ASTM B 883-10 MPIF 35-2007	MECHANICAL PROPERTIES (as sintered) *Propiedades mecánicas (Sinterizado)*				DENSITY *densidad (g/cm3)*	MAGNETIC PROPERTIES *Propiedades Magnéticas*	
				Rm (N/mm2)	R0,2 (N/mm2)	E %	HARDNESS HB		PERMEABILITY	IND.MAG. FIELD
SOFT MAGNETIC	4605(00) FN50 FeSi3 430L	MIM-Fe2Ni-20 MIM-Fe50Ni-200 MIM-Fe3Si-55 MIM-430-10	MIM-2200 MIM-Fe50%Ni MIM-Fe-3%Si MIM-430L	290 455 530 415	125 160 390 240	40 30 24 25	(45 HRB) (50 HRB) (80 HRB) (65 HRB)	>7,5 >7,7 >7,45 >7,50	>2000 u >20000 u >6000 u >1000 u	B25 >14 kG B25 >13 kG B25 >14 kG B25 >11 kG

Mechanical properties of soft magnetic steels



Material: 4605 (00)
Sector: Aeronautical
Weight: 67 g

Material: FN50
Sector: Locksmith
Weight: 3,4 g

Material: FESi3
Sector: Sensors
Weight: 3,4 g

Material: FESi3
Sector: Locksmith
Weight: 12 g

Application examples of soft magnetic steels

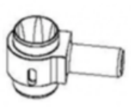
1.4. Stainless steels

MATERIAL TYPE *Tipo de Material*	**TRADITIONAL MIM NAME** *Denominación clásica*	**STANDARD NAME** ISO 22068:2012	**STANDARD NAME** ASTM B 883-10 MPIF 35-2007	**CHEMICAL COMPOSITION** *Composición Química*						
				%C	***%NI***	***%Cr***	***%Mo***	***%Si***	***%Mn***	***OTHERS***
STAINLESS STEELS *Aceros inoxidables* Ferritic	MIM-430L	MIM-430-210 1. 4016 / X6Cr17	MIM-430L	<0,08		16-18		<1	<1.5	
Martensitic	MIM-420	MIM-420-850H 1. 4028 / X30Cr14/	420	0,15-0,4 0,25-0,45		12-14		<1	<1	
Precipitation Hardening	17-4PH	MIM-17-4PH-650 MIM-17-4PH-700H MIM-17-4PH-1000H	MIM-17-4 PH	<0,07	3-5	15-17,5		<1	<1	%Cu 3,0/5,0 %Nb 0,15/0,45
Austenitic No Magnetic Fine Surface Simple geometry	316L 304	MIM-316L-140 MIM-304	MIM-316L	<0,03 <0,03	10-14 8-10,5	16-18,5 18-20	2-3	<1 <1	<2 <2	<1

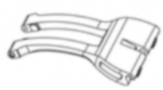
Classification and composition of stainless steels

MATERIAL TYPE *Tipo de Material*	**TRADITIONAL MIM NAME** *Denominación clásica*	**STANDARD NAME** ISO 22068:2012	**STANDARD NAME** ASTM B 883-10 MPIF 35-2007	**MECHANICAL PROPERTIES (as sintered)** *Propiedades mecánicas (Sinterizado)*				**HEAT TREAT.** *Trat. Térmico*	**MECHANICAL PROPERTIES (Heat treated)** *Prop. Mecánicas (+Tratamiento Térmico)*				**DENSITY** *densidad (g/cm3)*
				Rm (N/mm2)	***R0,2 (N/mm2)***	***E %***	***HARDNESS HB***		***Rm (N/mm2)***	***R0,2 (N/mm2)***	***E %***	***HV10 (HRC)***	
STAINLESS STEELS *Aceros inoxidables* Ferritic	MIM-430L	MIM-430-210 1. 4016 / X6Cr17	MIM-430L	>350	>210	>20	115 HV10						>7,5
Martensitic	MIM-420	MIM-420-850H 1. 4028 / X30Cr14/	420					Harden	>1000	>850	>2	50-55 HRC	>7,3
Precipitation Hardening	17-4PH	MIM-17-4PH-650 MIM-17-4PH-700H MIM-17-4PH-1000H	MIM-17-4 PH	>800 (>900)	>650 (>700)	>3	(30-35 HRC)	Sinter H1150 H900	>850 >1200	>700 >1000	>5 >2 (>4)	30-35 HRC 40-45 HRC	7,5 (>7,6)
Austenitic No Magnetic Fine Surface Simple geometry	316L 304	MIM-316L-140 MIM-304	MIM-316L	>450 (>500) >630	>140 (>180) >170	>40 (>50) >60	120 HV10 130 HV10						>7,70

Mechanical properties of stainless steels as a function of heat treatment

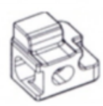


Material: 17-4PH
Sector: Automotive
Weight: 30,8 g

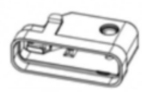


Material: 316L
Sector: Jewelry
Weight: 6,8 g

Material: 17-4PH
Sector: Medical
Weight: 13,3 g



Material: 420
Sector: Defense
Weight: 6,8 g



Material: 316L
Sector: Aeronautical
Weight: 4,2 g

Material: 17-4PH
Sektor: Locksmith
Weight: 48,3 g

Application examples of stainless steels

1.5. Other materials

MATERIAL TYPE *Tipo de Material*	TRADITIONAL MIM NAME *Denominación clásica*	STANDARD NAME ISO 22068:2012	STANDARD NAME ASTM B 883-10 MPIF 35-2007	CHEMICAL COMPOSITION *Composición Química*						
				%C	%NI	%Cr	%Mo	%Si	%Mn	OTHERS
HEAT RESISTANT *Refractario*	310N / 310NbC	1. 4841/ X15CrNiSi 25 21	310NbC	0,2/0,5	19/22	24/26		0,75/1,75	<1.5	%Nb 1,2/1,5 %N < 1
SUPERALLOYS *Ni base*	IN 713C	AMS 5391		0,08/020	base	12,0/14,0	3,8/5,2	<0,50	<0,25	%Fe<2,5 %Al 5,5/6,5 %Ti0,5/1,0 %Nb 1,8/2,9

Chemical composition table

MATERIAL TYPE *Tipo de Material*	TRADITIONAL MIM NAME *Denominación clásica*	STANDARD NAME ISO 22068:2012	STANDARD NAME ASTM B 883-10 MPIF 35-2007	MECHANICAL PROPERTIES (as sintered) *Propiedades mecánicas (Sinterizado)*				HEAT TREAT. *Trat. Térmico*	MECHANICAL PROPERTIES (Heat treated) *Prop. Mecánicas (+Tratamiento Térmico)*				DENSITY *densidad (g/cm3)*
				Rm (N/mm2)	R0,2 (N/mm2)	E %	HARDNESS HB		Rm (N/mm2)	R0,2 (N/mm2)	E %	HV10 (HRC)	
HEAT RESISTANT *Refractario*	310N / 310NbC	1. 4841/ X15CrNiSi 25 21	310NbC	>550 >750	>200 >400	>35 >10	>150 HV10 >230 HV10	Sinter Ar Sinter N2					>7,65 >7,7
SUPERALLOYS *Ni base*	IN 713C	AMS 5391					>300 HV10						>7,78

Table of mechanical properties and heat treatments

2. WHAT DOES THE OPTIMAL MIM PART LOOK LIKE?

The optimal MIM part could be defined with the following characteristics:

- Length less than 100 mm
- Ratio length/width must be less than 5
- Weight can vary between 0.5 and 50 grams
- Wall thicknesses between a range of 0.5 and 15 mm

Currently, **dimensional tolerances** are governed by an **ISO 2768 standard**, although for some dimensions Ecrimesa Group can offer a better range.

3. HOW MUCH DOES IT COST TO MANUFACTURE A PART WITH MIM?

The most important factors in setting a cost for a MIM part are:

3.1. First factor: MIM part material

The MIM process does not have such an important variety of materials as other metal forming technologies. In the case of Ecrimesa Group, these are **materials with commercial catalytic debanding.**

The list of materials we can offer are:

MATERIAL TYPE *Tipo de Material*	**TRADITIONAL MIM NAME** *Denominación clásica*	**STANDARD NAME** ISO 22068:2012	**STANDARD NAME** ASTM B 883-10 MPIF 35-2007	**CHEMICAL COMPOSITION** *Composición Química*							**MECHANICAL PROPERTIES (as sintered)** *Propiedades mecánicas (Sinterizado)*			
				%C	**%NI**	**%Cr**	**%Mo**	**%Si**	**%Mn**	**OTHERS**	**Rm (N/mm2)**	**R0,2 (N/mm2)**	**E %**	**HARDNESS HB**
LOW ALLOY STEELS *Aceros baja aleación* **Iron-Nickel** *Hierro-Niquel*	FN08(00) FN08	MIM-Fe8Ni-210 MIM-Fe8NiC-300 MIM-Fe8NiC-500 MIM-Fe8NiC-700H MIM-Fe8NiC-1100H	MIM-2700	<0,1 0,4-0,8 0,45/0,65	6,5-8,5 6,5-8,5 better carbon control MIMECRISA process		<0,5 <0,5			<1,0 <1,0	>380 >900	>210 >500	>20 >5	123 HV10 >280
	4605	MIM-4605-170 MIM-4605-1310H	MIM-4605 MIM-4605-HT	0,4-0,6	1,5-2,5		0,2-0,5	<1,0	<0,2	<1,0	>380	>170	>11	150 HV10
LOW ALLOY STEELS *Aceros baja aleación* **Cr-Mo Alloys** *Aleaciones Cr-Mo*	MIM-42CrMo4	MIM-4140-400 MIM-4140-600H MIM-4140-1200H	MIM-4140	0,35-0,5 0,3-0,5		0,9-1,2 0,8-1,2	0,15-0,3 0,2-0,3	<0,4 < 0,6	<0,9 < 1,0	<1,0	>700	>400	>3	210 HV10
	MIM-8740		8750	0,45-0,55	0,5-0,8	0,4-0,6	0,25-0,4	0,3-0,55	<0,1		>860	>530	>8	190-210 HV10
	MIM-4340	MIM-4340-500 MIM-4340-750H MIM-4340-1300H	4340	0,35-0,5	1,4-2	0,7-1,4	0,2-0,3	<0,4	<0,8		>700	>500	>7	200-250 HV10
	MIM-8620	21NiCrMo2	8620	0,18-0,23	0,4-0,7	0,4-0,6	0,15-0,25	<0,2	<0,2		>650	>400	>3	190-230 HV10
TOOL STEELS *Aceros herramienta*	MIM-100Cr6	MIM-52100	52100	0,85-1,05		1,35-1,65		<0,35	<0,45		>900	>500	>5	230-290 HV10
	MIM-M2	1. 3343	M2	0,78-1,05		3,75-4,5	4,5-5,5	0,2-0,45	0,15-0,4	%V 1,75-2,2 %W 5,5-6,75	>1200	>800	>1	(>50 HRC)
SOFT MAGNETIC	4605(00) FN50 FeSi3 430L	MIM-Fe2Ni-20 MIM-Fe50Ni-200 MIM-Fe3Si-55 MIM-430-10	MIM-2200 MIM-Fe50%Ni MIM-Fe-3%Si MIM-430L	<0,1 <0,05 <0,05 <0,05	1,5-2,5 49-51	16/18		<1 <1 2,5-3,5 <1	<1		290 455 530 415	125 160 390 240	40 30 24 25	(45 HRB) (50 HRB) (80 HRB) (65 HRB)
STAINLESS STEELS *Aceros inoxidables* Ferritic	MIM-430L	MIM-430-210 1. 4016 / X6Cr17	MIM-430L	<0,08		16-18		<1	<1.5		>350	>210	>20	115 HV10
Martensitic	MIM-420	MIM-420-850H 1. 4028 / X30Cr14/	420	0,15-0,4 0,25-0,45		12-14		<1	<1					
Precipitation Hardening	17-4PH	MIM-17-4PH-650 MIM-17-4PH-700H MIM-17-4PH-1000H	MIM-17-4 PH	<0,07	3-5	15-17,5		<1	<1	%Cu 3,0/5,0 %Nb 0,15/0,45	>800 (>900)	>650 (>700)	>3	(30-35 HRC)
Austenitic No Magnetic Fine Surface Simple geometry	316L 304	MIM-316L-140 MIM-304	MIM-316L	<0,03 <0,03	10-14 8-10,5	16-18,5 18-20	2-3	<1 <1	<2 <2	<1	>450 (>500) >630	>140 (>180) >170	>40 (>50) >60	120 HV10 130 HV10
HEAT RESISTANT *Refractario*	310N / 310NbC	1. 4841/ X15CrNiSi 25 21	310NbC	0,2/0,5	19/22	24/26		0,75/1,75	<1.5	%Nb 1,2/1,5 %N < 1	>550 >750	>200 >400	>35 >10	>150 HV10 >230 HV10
SUPERALLOYS *Ni base*	IN 713C	AMS 5391		0,08/020	base	12,0/14,0	3,8/5,2	<0,50	<0,25	%Fe<2,5 %Al 5,5/6,5 %Ti0,5/1,0 %Nb 1,8/2,9				>300 HV10

MATERIAL TYPE *Tipo de Material*	HEAT TREAT. *Trat. Térmico*	MECHANICAL PROPERTIES (Heat treated) *Prop. Mecánicas (+Tratamiento Térmico)*				DENSITY *densidad (g/cm3)*	MOLD FACTOR *Factor de molde*	MAGNETIC PROPERTIES *Propiedades Magnéticas*	
		Rm (N/mm2)	**R0,2 (N/mm2)**	**E %**	**HV10 (HRC)**			**PERMEABILITY**	**IND.MAG. FIELD**
LOW ALLOY STEELS *Aceros baja aleación* **Iron-Nickel** *Hierro-Niquel*	Case Harden Soft annealed Full annealed Full Harden Full Harden Full Harden	>380 Core >750 >550 (> 500) >800 (>1050) >1250 >1300	 >500 >300 >700 (>900) >1100 >1100	 >5 >6 (>15) >5 >3 >2	>600 Case <250 <180 (35 HRC) (40 HRC) (50 HRC) Max (50-55 HRC)	>7,55 (7,5)	1,216 1,216		
	Full harden	>1480	>1310	<1	48 HRC	>7,50	1,216		
LOW ALLOY STEELS *Aceros baja aleación* **Cr-Mo Alloys** *Aleaciones Cr-Mo*	Normalized Full Harden Full Harden Full Harden	>700 >750 >1300 >1380	>400 >600 >1200 > 1070	>3 (>6) >3 >2 >3	>210 (<180) (25 HRC) (50 HRC) (46 HRc)	>7,50	1,216		
	Normalized Full harden Full harden Full harden	>860 >1050 >1450 >1800	>530 >950 >1300 >1650	>8 >5 >3 >3	< 200 HV10 30HRC 40 HRC 45-50 HRC	> 7,50	1,216		
	Full Harden Full Harden	>900 >1600	>750 >1300	>3 >2	25 HRC 48 HRC	>7,50	1,216		
	Normalized Case harden	>650 >800 Core	>400	>3	190-230 HV10 >750 Case	>7,45	1,216		
TOOL STEELS *Aceros herramienta*	Harden				(60-62 HRC)	>7,50	1,216		
	Harden				(>65 HRC)	>7,95	1,167		
SOFT MAGNETIC						>7,5 >7,7 >7,45 >7,50	1,216 1,216 1,216 1,216	>2000 u >20000 u >6000 u >1000 u	B25 >14 kG B25 >13 kG B25 >14 kG B25 >11 kG
STAINLESS STEELS *Aceros inoxidables* Ferritic						>7,5	1,216		
Martensitic	Harden	>1000	>850	>2	50-55 HRC	>7,3	1,216		
Precipitation Hardening	Sinter H1150 H900	 >850 >1200	 >700 >1000	 >5 >2 (>4)	 30-35 HRC 40-45 HRC	7,5 (>7,6)	1,216 1,167		
Austenitic No Magnetic Fine Surface Simple geometry						>7,70	1,167		
HEAT RESISTANT *Refractario*	Sinter Ar Sinter N2					>7,65 >7,7	1,167 1,167		
SUPERALLOYS *Ni base*						>7,78	1,151		

BLUE: ISO 22068.

BLACK: Other Technologies Equivalent Standards.

RED: American Standards/*Datos en rojo corresponden con norma ASTM ó MPIF americana.*

GREEN: MIMECRISA own results not yet international standarized/ *Datos en verde corresponden con resultados garantizados por MIMECRISA aún no estandarizados oficialmente.*

Other materials as: Titanium, 1.4435, superalloys, etc.

WE ARE OPEN TO DEVELOP NEW MATERIALS ON DEMAND.

Review June 2021

Tables of material types

The **type of material** has an important influence on the cost of the parts for two main reasons:

- **Material price**
  More expensive in stainless steels (316L-174PH) than in carbon steels (42CrMo4-FN08), at around 30%. In relation to the price of the materials, they are 10-15 times more expensive than the material coming from bar or ingot to melt.

- **Sintering process**
  It must be at a slower rate for stainless steels, and in a hydrogen atmosphere as opposed to carbon steels, which are normally sintered in a nitrogen atmosphere and with a sintering rate 30-40 % higher.

3.2. Second factor: size and configuration of the MIM part

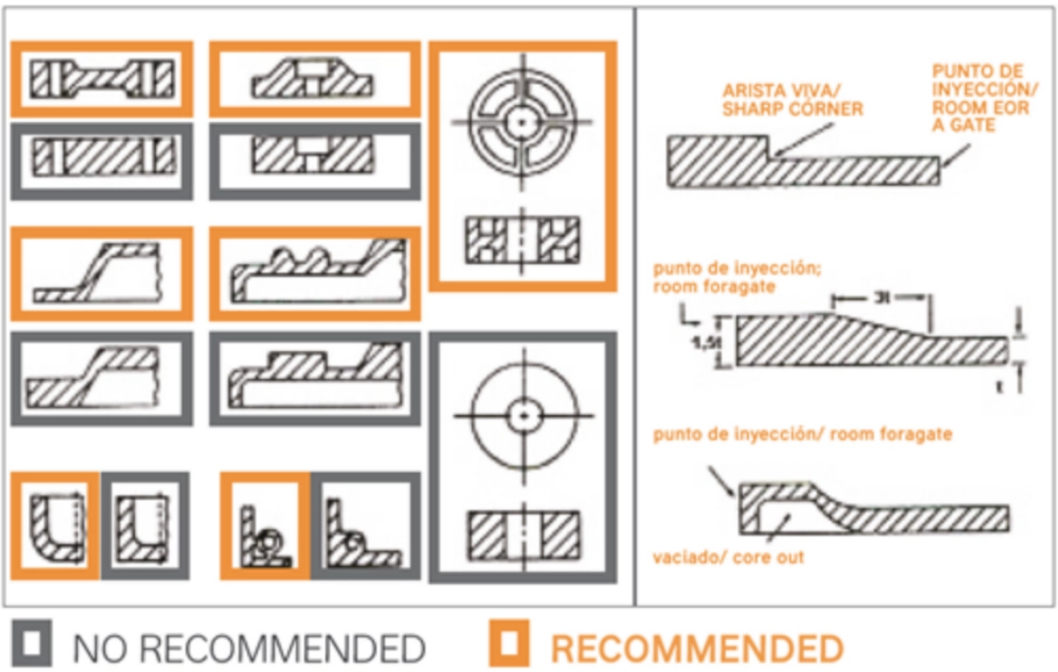
The size is important, since it influences the weight mentioned above, as well as the sintering capacity, since the parts are processed in molybdenum trays of size **200*200**. The greater the number of parts that can be processed per box, the better the cost of this process, both in continuous furnace and in batch furnace.

According to our historical data, the **optimum sizes** of MIM parts are **between 0.5 grms and 40 grms**, although we have parts above 150 grms which, due to their configuration and the machining savings obtained, are profitable compared to other technologies.

On the other hand, and no less important, is the design of the part, in order to adapt it to the limitations of the technology, to avoid secondary operations such as machining and reduce the costs of the same.

It is very important that the parts are not designed with sharp edges, and that they have as many radii as possible to facilitate the injection of the material, avoid segregation during injection and the appearance of cracks after the sintering process.

They must also have s**pace for the placement of the injection point and homogeneous walls** for a correct injection of the material (since it must be taken into account that steel powder will be injected with the difficulty that this entails since it is not an easy material to inject).

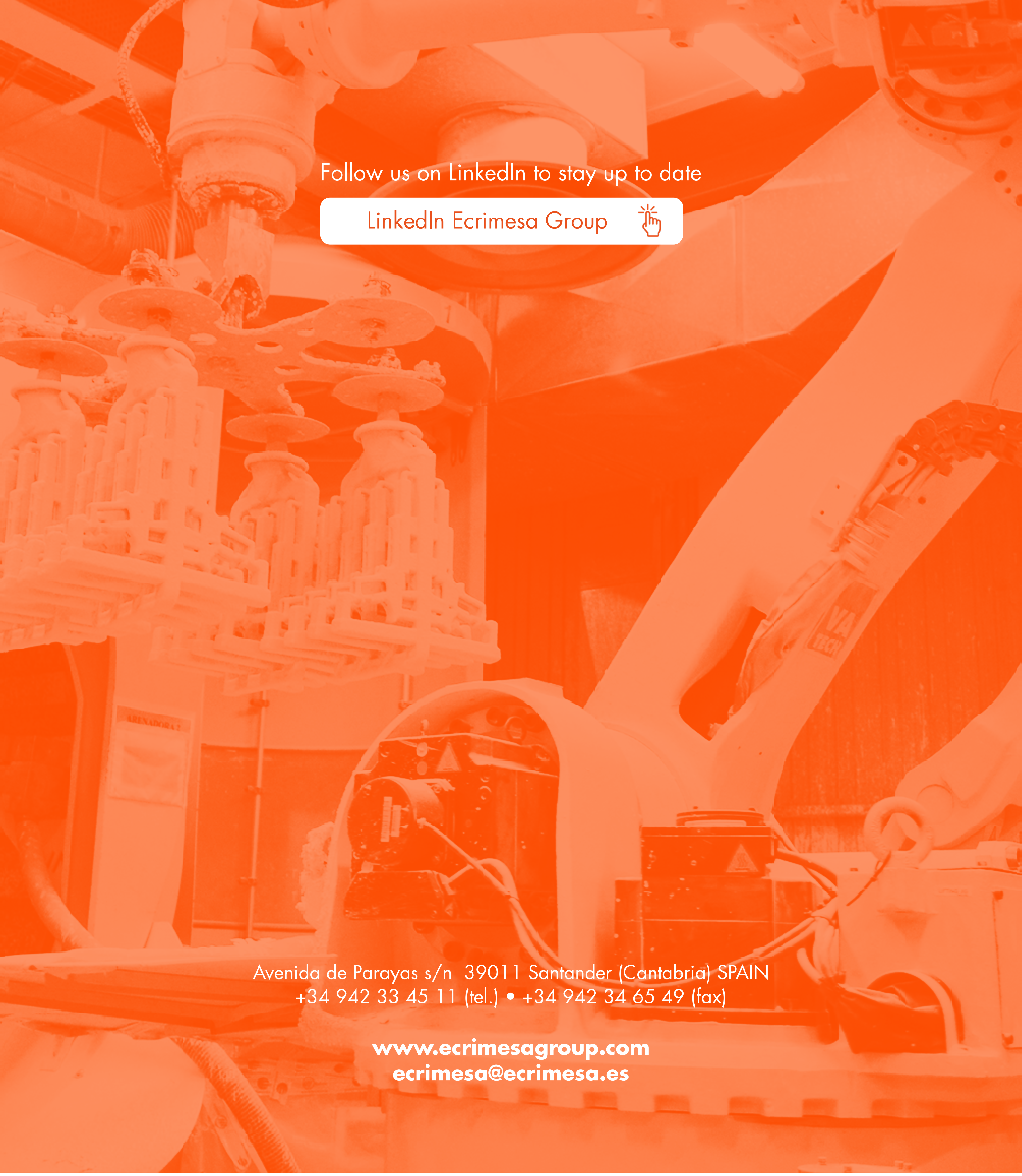


Comparison of injection methods

Designing the part with adequate areas for the part settling during the debanding/sintering process also has a very important influence on the cost, since in case of not having flat support faces, it forces to use special sintering supports, reducing the load in the furnaces and therefore not maximizing the cost advantage.

Finally, in carbon or low alloy steel parts that require heat treatments, it is of special importance to establish adequate placements for the performance of these heat treatments, in order to avoid deformations during them or cracks generated by the heat treatment on the part.

At Ecrimesa Group, having its own facilities for heat treatments, we adapt them to the requirements of the parts in order to maximize the cost and quality of the part.



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Avenida de Parayas s/n 39011 Santander (Cantabria) SPAIN
+34 942 33 45 11 (tel.) • +34 942 34 65 49 (fax)

www.ecrimesagroup.com
ecrimesa@ecrimesa.es

ECRIMESA GROUP | Ecrimesa | MimEcrisa | Mecansa | MimEcri USA