MimEcri USA

METAL INJECTION MOLDING:

THE BEST GUIDE FOR THE DESIGN OF YOUR PARTS

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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)

The unique combination of injection molding and sintering technologies, allowing us to create high-density components with exceptionally tight geometric tolerances.

2. WHAT IS METAL INJECTION MOLDING?

MIM (Metal Injection Molding) technology is an advanced manufacturing process used to produce intricate metal parts with exceptional precision and dimensional accuracy. **It combines the flexibility of injection molding with the sintering technique, resulting in high-density components with tight geometric tolerances.**

The MIM process starts with the preparation of a feedstock, which consists of a fine mixture of metal powder and a thermoplastic binder. This feedstock is carefully formulated to achieve the desired material properties and flow characteristics. The feedstock is then heated and injected into a mold cavity using specialized equipment, similar to that used in plastic injection molding.

Once injected, the feedstock solidifies to form a "green part" with the desired shape. This green part contains both metal powder and a thermoplastic binder. To remove the binder and consolidate the metal particles, the green part undergoes a debinding process. This typically involves subjecting the part to a controlled thermal treatment, which volatilizes and removes the binder, leaving behind a porous structure known as a "brown part."

The brown part is then subjected to a high-temperature sintering process. During sintering, the brown part is heated in a controlled atmosphere to promote solid-state diffusion and particle bonding. This results in the formation of a fully dense metal part with excellent mechanical properties and dimensional accuracy.

After sintering, additional post-processing steps may be performed to achieve the desired surface finish and functional characteristics. These steps can include heat treatments, machining, surface coatings, and secondary operations as required by the specific application.

MIM technology offers manufacturers the ability to produce complex metal components with intricate geometries, fine details, and excellent material properties. It is widely used in industries such as automotive, aerospace, electronics, and medical, where small to medium-sized parts with high precision and performance are required. The MIM process provides a cost-effective solution for producing high-quality metal parts with reduced material waste and shorter lead times compared to traditional manufacturing methods.

3. WHEN DOES MIM APPLY?

The MIM (Metal Injection Molding) process is a highly versatile and precise manufacturing technique used to produce steel parts with complex geometries. It offers several advantages over traditional manufacturing methods, making it suitable for a wide range of applications.

MIM is particularly advantageous for parts weighing under 100 grams, with exceptional competitiveness for parts below 40 grams. The reduction in weight not only enhances dimensional precision but also reduces raw material consumption, leading to significant cost savings.

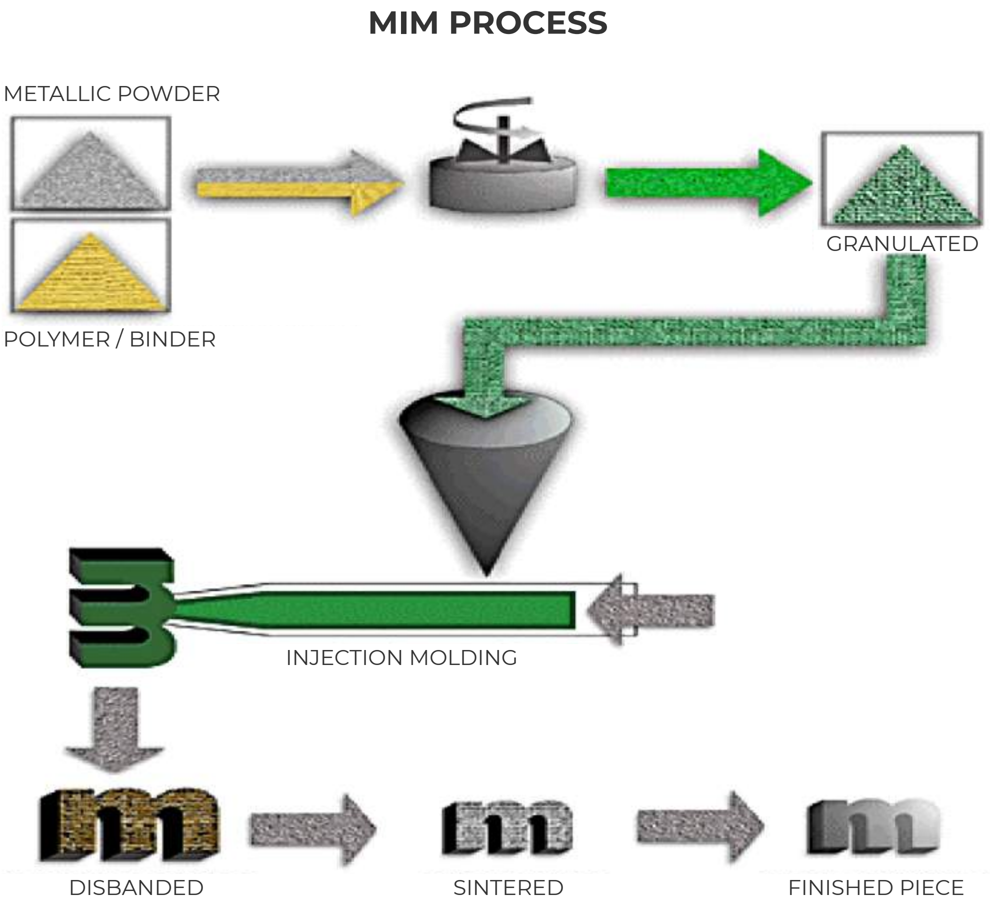
To ensure optimal part quality, it is crucial to consider certain design guidelines. Using maximum allowable radii, especially for internal edges, helps prevent potential cracks. Gradual section changes facilitate material flow during the injection process, minimizing the formation of isolated masses.

In addition, incorporating a flat face in the part design facilitates palletizing within the MIM furnace, ensuring stable support and minimizing deformations. This, in turn, improves dimensional tolerances and overall part quality.

The MIM process is well-suited for manufacturing parts with complex geometries, ranging from small to medium size. It supports a wide range of materials, including stainless steels, low alloy steels, soft magnetic materials, tool steels, and ceramics.

By harnessing the capabilities of MIM technology, manufacturers can achieve exceptional precision, intricate details, and high surface quality in their steel parts. Whether for medical devices, automotive components, or various other industries, MIM offers a reliable and cost-effective solution for producing complex metal parts.

4. PHASES OF A MIM PROCESS



Development of the MIM Process

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

PHASE 1

Mold manufacturing

Mold manufacturing is a critical aspect of Metal Injection Molding (MIM) that requires high-strength steel molds, which are more complex and demanding compared to traditional plastic injection molds.

These molds are designed with cavities shaped according to the desired part, incorporating an enlargement factor to account for material shrinkage during injection. Adhering to the design rules, available for download on our website, is crucial to ensure a stable and defect-free injection process.

The number of cavities in the mold varies depending on the part's geometry and dimensions, ranging from a single cavity to more than 10. Typically, molds for MIM feature 2 or 4 cavities, and the cycle time for each injection can range from 15 to 60 seconds, depending on the specific requirements of the part.

PHASE 2

Feedstock

The feedstock used in Metal Injection Molding (MIM) comprises metal powder with a maximum particle size of 32 microns, with at least 80% of particles below 22 microns. This powder is mixed with binders or moldable binders, granulated, and extruded to form pellets. The binder itself is a combination of thermoplastics, waxes, polymers, and other additives.

Accurate characterization and control of the feedstock are crucial for adjusting downstream process parameters, particularly during injection and sintering stages. This meticulous control ensures the achievement of desired tolerances and repeatability in the final components.
By carefully managing the feedstock, we can optimize the production process and ensure consistent and high-quality results.

PHASE 3

Injection

The feedstock is precisely injected into a mold, taking on the shape of the desired part. Key parameters during injection include pressure, flow rate, and temperatures, both of the injection screw and the mold itself. These parameters are carefully adjusted to suit the specific geometry of the part. Our extensive manufacturing expertise is crucial in achieving defect-free parts with exceptional quality. The resulting component, referred to as a 'green part,' undergoes an initial dimensional shrinkage as it is ejected from the mold. This shrinkage typically ranges from 0.7% to 0.9% in carbon and low alloy steels, and 0.4% in austenitic stainless steels.

PHASE 4

Sintering

Sintering is the concluding process that involves interdiffusion bonding of metal particles through the application of temperature and gases (such as H_2 or N_2, depending on the alloy). This process allows the attainment of the target density, reaching 95-98% compared to the traditional sintering's 82%. Sintering can be performed in either batch furnaces, suitable for small batches or special materials, or continuous furnaces, ideal for large production batches.

At Ecrimesa Group, we possess both types of equipment, comprising three continuous lines and two batch furnaces. The positioning of the parts throughout the debinding and sintering process plays a crucial role in achieving the desired dimensional outcomes. Therefore, the meticulous definition and industrialization phase are paramount to establishing a robust and dependable process.

During the sintering phase, the second and final shrinkage occurs, resulting in the attainment of the customer's desired final dimensions. For carbon and low alloy steels, the shrinkage factor between the mold and the final part is 1.2165, while that between the green part and the final part is 1.205. As for stainless steels, the shrinkage factor between the green part and the final part is 1.166, with a corresponding factor of 1.160 between the mold and the final part.

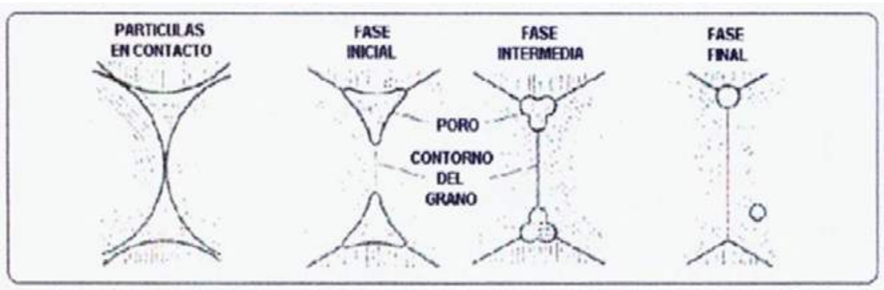
PHASE 5

Final-finishing operations

Following the completion of the sintering process, additional operations and treatments may be necessary to meet specific customer requirements. At Ecrimesa Group, we understand the importance of delivering fully finished parts, which is why we have an advanced heat treatment department. This allows us to provide comprehensive heat treatment services to optimize the hardness, strength, and other mechanical properties of the components.

In addition to heat treatment, we also offer our own in-house machining service. This enables us to achieve close tolerance dimensions and carry out precision machining operations to meet the exact specifications of our customers. Whether it's honing for precise surface finishes or final polishing for aesthetic or roughness requirements, our machining capabilities ensure that the parts are meticulously crafted to meet the highest standards of quality.

By offering comprehensive final-finishing operations, including heat treatment and machining services, we ensure that our customers receive fully finished parts that not only meet their technical requirements but also exhibit superior aesthetics and surface quality.



Sintering model

Sintering machinery

5. WHICH IS THE BEST TECHNOLOGY FOR MANUFACTURING METAL PARTS?

Investment Casting vs MIM

Compared to Investment Casting, 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.

In 1993, our parent company, Ecrimesa Group, was the first company worldwide to develop the process of fabrication in continuous furnace with catalytic debinding in collaboration with BASF and Cremer Termoprosessanlagen Gmbh.

Currently, it has expanded their capabilities with a total of 4 continuous lines for debinding and sintering and 2 vacuum batch lines with a production capacity of more than 250 tons of feedstock per year and 1.2 million pieces monthly.

Additive Manufacturing vs MIM

While some articles may show overlapping graphs comparing MIM technology and certain printing technologies like Binder Jetting, it is important to recognize that Additive Manufacturing (AM) and MIM are not competitive but rather complementary technologies. Here are some key differences between the two:

- **Manufacturing Speed:** AM allows for faster part development due to the elimination of mold manufacturing, while MIM excels in faster post-mold part production compared to printing technologies.
- **Porosity and Microstructure:** Printing technologies, particularly FDM, may result in larger porosity and printing defects, leading to lower metal part densities compared to MIM. The metal powder used in printing can also lead to incorrect microstructures, requiring additional heat treatments for improvement.
- **Portfolio of Materials:** MIM offers greater versatility in terms of available materials for manufacturing metal parts. While AM technologies continue to develop, their material portfolio is currently limited to stainless steels, some tool steel, and a few other materials.
- **Surface Finish:** AM techniques often exhibit increased roughness, necessitating secondary finishing operations to match the quality achieved in MIM. At Ecrimesa Group, we guarantee sintered roughness between 0.8 and 1.6 Ra.
- **Design:** AM technologies provide the opportunity to manufacture more complex parts, including hollow parts, bionic geometries, counter-flanges, and larger components.

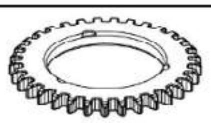
RULES AND TIPS FOR THE DESIGN OF A PART

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.

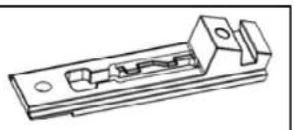
1. WHEN TO USE MIM?

Suitable materials

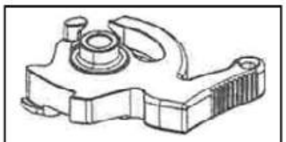
- **Stainless Steel:** Stainless steel alloys, such as 316L and 17-4 PH, are frequently utilized in MIM due to their excellent corrosion resistance, high strength, and durability.
- **Low Alloy Steels:** MIM is well-suited for producing components using low alloy steels, including materials like 4140, 4340, and 4605. These steels offer enhanced mechanical properties and are often chosen for their strength and wear resistance.
- **Tool Steels:** Tool steels like M2, H13, and A2 are commonly employed in MIM for manufacturing parts that require high hardness, toughness, and wear resistance. These materials are ideal for tooling applications and components subject to harsh operating conditions.
- **Soft Magnetic Alloys:** MIM is also suitable for producing soft magnetic alloys, such as magnetic stainless steels (e.g., 430F), that exhibit excellent magnetic properties and are widely used in industries like electronics and automotive.
- **Titanium Alloys:** MIM is increasingly being utilized for manufacturing titanium alloy components, such as Ti-6Al-4V, due to their excellent strength-to-weight ratio, corrosion resistance, and biocompatibility. These alloys find applications in aerospace, medical, and automotive industries.
- **Tungsten Alloys:** MIM is capable of producing high-density tungsten alloy components, such as tungsten heavy alloys (W-Ni-Fe), which are known for their exceptional density, strength, and radiation shielding properties.



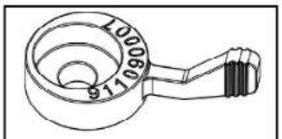
Material: FN08
Sector: Tools
Weight: 3,8 g



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

Size and Weight

Size plays a crucial role in MIM production, impacting both the weight of the parts and the sintering capacity. Our MIM process utilizes molybdenum trays with a size of 200*200, and maximizing the number of parts processed per box is essential for cost efficiency in continuous and batch furnace operations. Based on our historical data, the optimal size range for MIM parts falls between 0.5 grams and 40 grams. However, we have successfully manufactured parts exceeding 150 grams, which, thanks to their configuration and the resulting savings in machining, remain cost-effective compared to alternative technologies.

Equally important is the part's design, as it needs to be tailored to the technology's limitations and minimize the need for secondary operations such as machining, ultimately reducing costs. Design considerations include avoiding sharp edges and incorporating as many radii as possible to facilitate material injection, prevent segregation during the injection process, and minimize the occurrence of cracks after sintering.

Additionally, providing adequate space for injection points and ensuring homogeneous wall thickness is crucial for proper material flow during injection. It's important to note that injecting steel powder presents unique challenges due to its nature as a difficult material to inject. By carefully considering these design factors, we can optimize the MIM process and ensure the successful production of high-quality components.

2. HOW MUCH DOES IT COST TO MANUFACTURE A PART USING MIM?

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

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

1. MIM PART MATERIAL

The choice of material significantly impacts the cost of the parts due to two primary factors:

- **Material Cost**: Stainless steels (such as 316L and 17-4PH) are generally more expensive, approximately 30% higher in cost compared to carbon steels (such as 42CrMo4 and FN08). The price difference can be attributed to the fact that stainless steels are around 10-15 times more expensive than raw materials in the form of bars or ingots.
- **Sintering Process:** The sintering process for stainless steels requires a slower rate compared to carbon steels. Additionally, stainless steels are sintered in a hydrogen atmosphere, while carbon steels are typically sintered in a nitrogen atmosphere. Moreover, carbon steels have a higher sintering rate, approximately 30-40% faster than stainless steels.

These factors should be taken into consideration when evaluating the cost and sintering requirements for different materials in the manufacturing process.

2. SIZE AND CONFIGURATION OF THE MIM PART

The size of the parts is crucial as it impacts both the weight and the sintering capacity. MIM parts are processed in molybdenum trays measuring 200*200, and maximizing the number of parts per tray improves the cost efficiency of the continuous and batch furnace processes. Based on our historical data, the optimal size range for MIM parts is between 0.5 grams and 40 grams, although we have successfully produced parts weighing over 150 grams that offer cost advantages compared to other technologies due to their configuration and reduced machining requirements.

Equally important is the design of the part to accommodate the limitations of the technology and avoid secondary operations like machining, which helps reduce costs. It is crucial to avoid sharp edges and incorporate radii wherever possible to facilitate material injection, prevent segregation during injection, and minimize the occurrence of cracks after the sintering process. Ample space should be allocated for the injection point, and the walls should be homogenous to ensure proper material injection, considering that injecting steel powder presents inherent challenges.

Additionally, designing the part with suitable areas for settling during the debinding/sintering process significantly influences the cost. Flat support faces are preferred to avoid the need for special sintering supports, optimizing furnace load and cost efficiency. Lastly, for carbon or low alloy steel parts requiring heat treatments, careful consideration should be given to the placement of these treatments to prevent deformations or cracks that may result from the thermal processes.

ABOUT US

We are Mimecri USA, an American Company based in Thomasville Georgia. We are ready to serve American companies from various sectors: defense, health, automotive, aerospace, among others. The strategic location where we are situated, with fast communication routes, allows us to provide our customers with agile and efficient service.

Mimecri USA is part of Ecrimesa Group, a large european metal parts manufacturer group. The company has wide experience in the production of metal parts by investment casting and MIM technology, as well as machining and 3D printing / additive manufacturing.

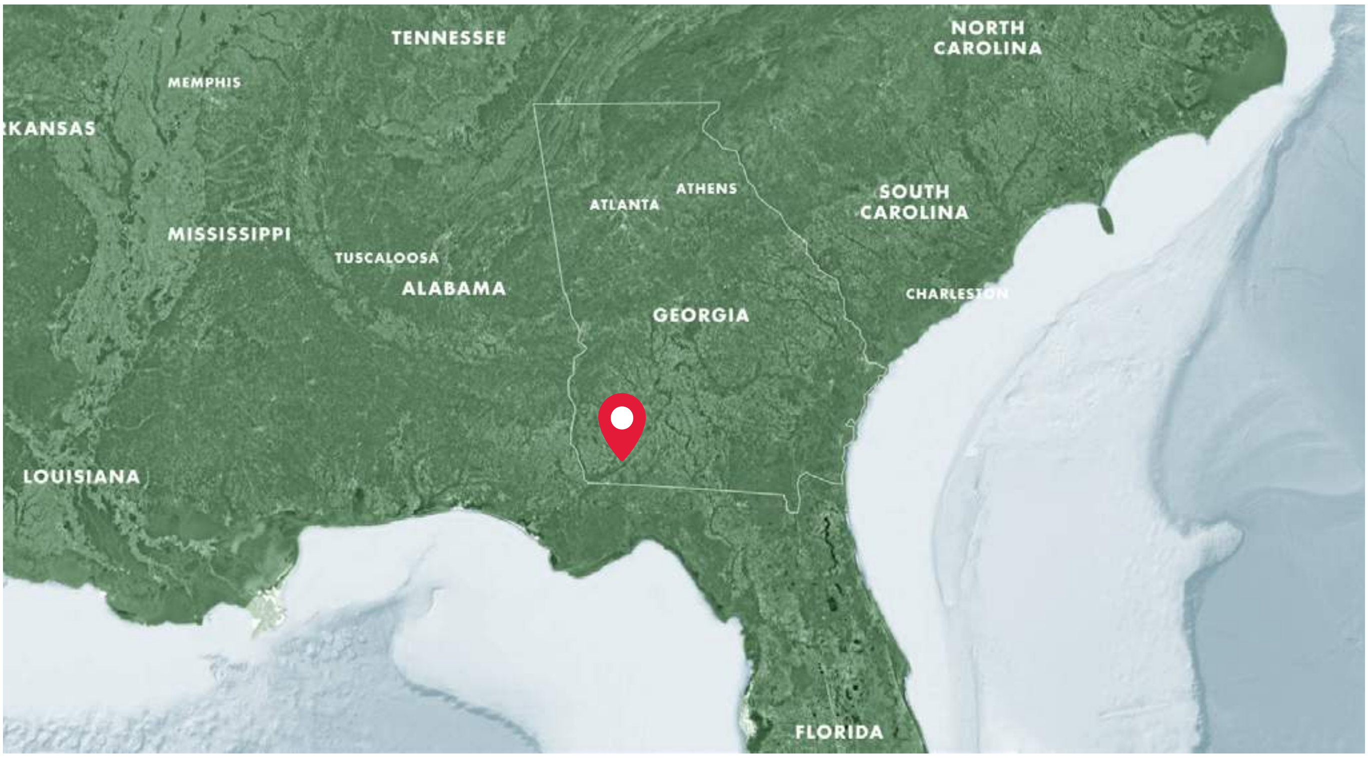
More than 50 years innovating in the production of metal parts, our parent company was the first firm worldwide to develop the process of producing in continuous furnace with catalytic debinding in collaboration with BASF and Cremer Termoprosessanlagen Gmbh.

The facilities of Ecrimesa Group in Europe feature state-of-the-art machinery and highly skilled personnel to undertake projects in steel and aluminum part fabrication through investment casting, MIM, machining, and additive manufacturing.

At our Technical Office, we provide comprehensive consulting services to customize the original design according to the most suitable technology, ensuring a strong foundation for production right from the beginning.

With our robust infrastructure, we possess a wide range of capabilities to support our manufacturing processes. In addition to our technical office, we have a fully equipped mold workshop, a state-of-the-art metallurgical laboratory, and a specialized metrology department in order to assure the quality of the final parts. Furthermore, we boast a cutting-edge heat treatment plant and a highly efficient machining plant.

These facilities enable us to offer end-to-end solutions, from design and prototyping to manufacturing and quality control. Our integrated setup ensures seamless coordination and efficient execution of projects, allowing us to deliver exceptional results to our customers.



INDUSTRIES

Wide experience with the development of projects for various industries.

Defense

We bring extensive experience to the table when it comes to developing metal parts for the defense sector, catering to companies and governments across Europe, the United States, South America, and Asia. We have a proven track record of successfully delivering projects for small firearms, including pistols, rifles, and shotguns, as well as military vehicles.

To ensure our commitment to quality and industry standards, Ecrimesa Group holds the EN9100:2018 certification for both MIM (Metal Injection Molding) and investment casting processes. This certification attests to our compliance with stringent requirements in the defense and aviation sectors.

Aeronautical

With our extensive experience, certifications, and rigorous quality control measures, we are fully equipped to meet the demanding requirements of the aerospace sector. We are committed to providing exceptional services and delivering high-quality solutions that meet and exceed the expectations of aerospace companies.

To ensure the integrity of our products, our headquaters team includes certified technicians who specialize in conducting non-destructive testing (NDT) controls. These controls encompass various techniques, such as radioscopy, magnetic particle inspections, and liquid penetrant investigations. We also adhere to the EN9100:2018 standard, ensuring the highest level of quality throughout our operations.

Health

We specialize in producing high-complexity components for the healthcare industry, serving sectors such as hospital equipment, medical instruments, and orthotic parts.

With a diverse range of technologies, we have the versatility to select the most suitable approach for each project. Leveraging over 50 years of experience in aluminum component production, we are the ideal partner for healthcare companies seeking reliable and innovative solutions.

Automotive

We meticulously oversee the production process, ensuring precision and adherence to industry standards. Our skilled technicians and engineers are dedicated to achieving the highest level of quality in every automotive part we manufacture. Additionally, we offer comprehensive surface treatments to enhance the durability, corrosion resistance, and aesthetics of the components.

Our dedicated team conducts thorough inspections and tests at various stages of production, ensuring that the parts meet the strictest specifications. We are committed to delivering exceptional results, meeting the demanding requirements of the automotive industry and providing our customers with reliable and high-quality components.

REQUEST A QUOTE FOR THE PRODUCTION OF YOUR MIM PART!

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Discover Ecrimesa Group's history and capabilities. Visit our website now!

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