



POSSIBILITIES AND LIMITATIONS OF METAL 3D PRINTING

A NEW TECHNOLOGY IN METAL
PART MANUFACTURING

Introduction to *Metal Additive Manufacturing*

Definition and Key Concepts

Additive Manufacturing (AM) is a production process that creates parts by successively adding layers of material based on a digital 3D model. This technology enables the fabrication of complex geometries that would be impossible—or prohibitively expensive—to achieve using traditional manufacturing methods such as machining or casting.

Technology Evolution in Recent Years

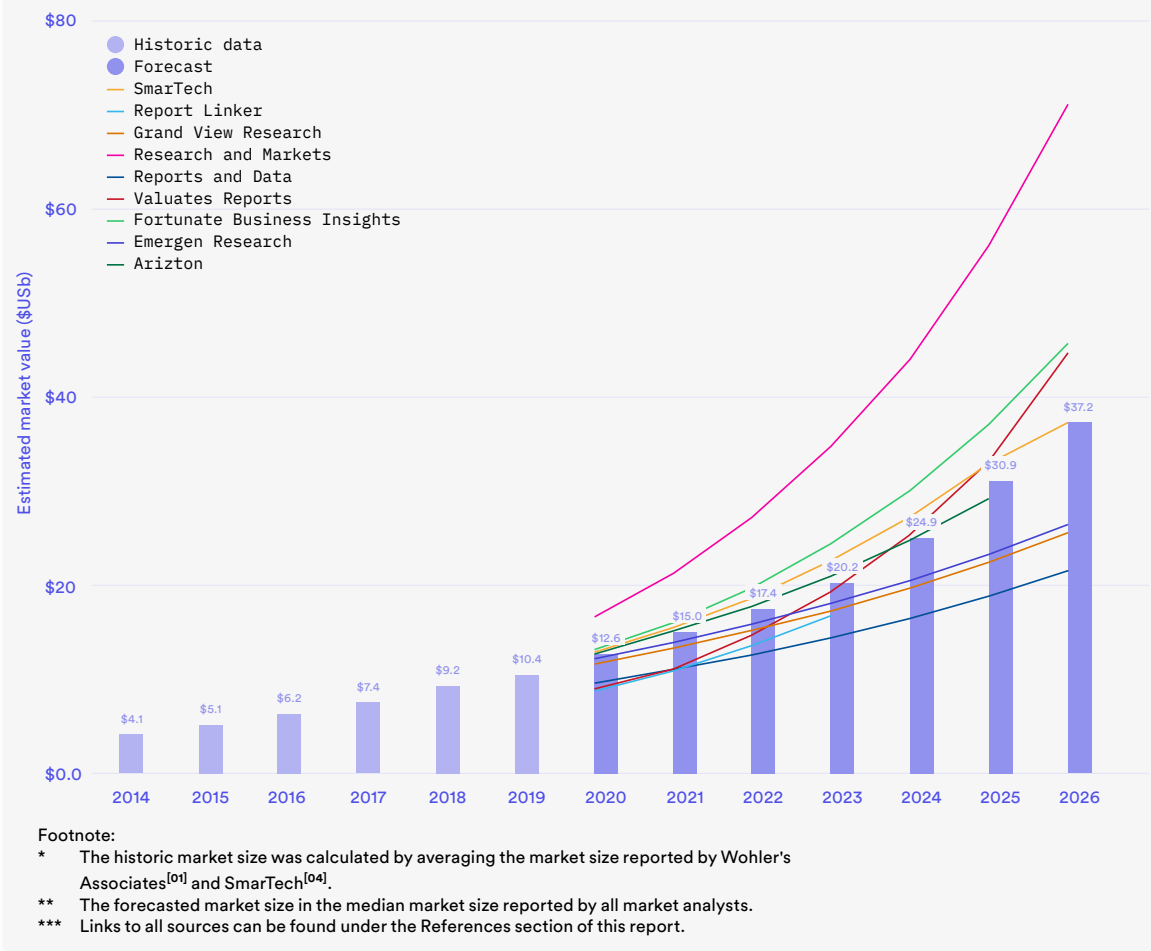
Over the past decade, Metal Additive Manufacturing has experienced remarkable growth. Initially used primarily for rapid prototyping, its application has expanded toward the direct production of functional parts. In 2019, the global 3D printing market was valued between \$9.9 and \$15 billion, with a compound annual growth rate of 24%. By 2024, the market value has reached \$20.24 billion. This growth has been driven by adoption in key sectors such as aerospace, automotive, and medical, as well as by the trend among major companies to integrate the technology as a standard manufacturing process.

Impact on the Manufacturing Industry

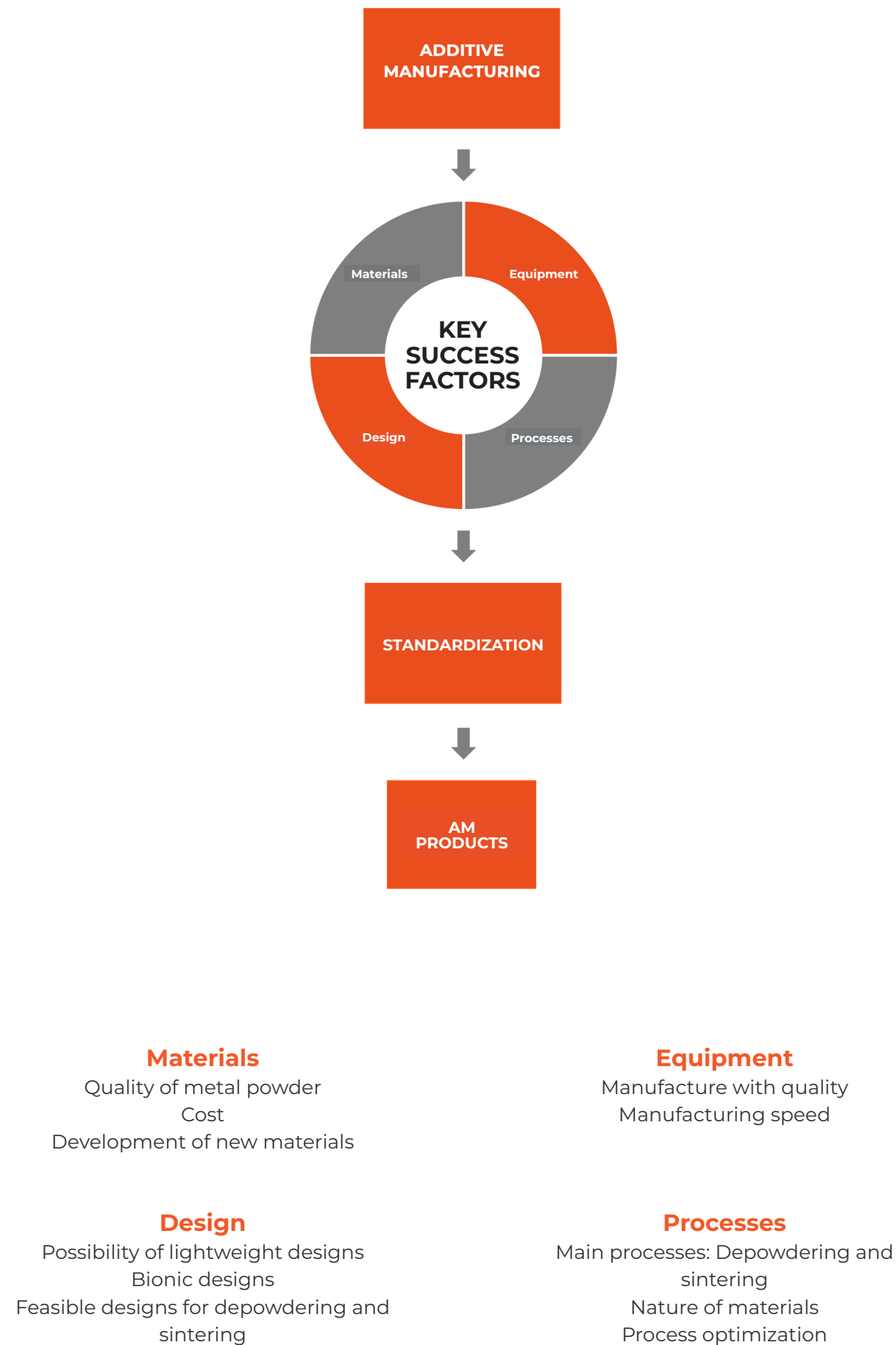
There is a growing trend among large companies to implement additive manufacturing as a standard production process. Specifically, metal additive manufacturing is transforming the manufacturing industry by reducing development times and production costs—particularly for short runs and prototypes. Additionally, the geometric flexibility it offers enables companies to innovate in design, delivering customized solutions for high-tech sectors.

Metal additive manufacturing is transforming the manufacturing industry by reducing development times and production costs.

Figure 2: 3D Printing market forecast



Growth and Future Outlook of Additive Manufacturing Technology
 Source: 3Dhubs



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Characteristics of Additive Manufacturing

Geometric flexibility and customization are two of the most notable features of metal additive manufacturing. This technology enables the production of parts with **complex and customized geometries** that would be difficult or impossible to achieve using traditional methods. The ability to manufacture tailor-made components is particularly valuable in sectors such as aerospace and medical, where unique, high-precision parts are required.

Cost and Time Comparison with Traditional Methods

In terms of **cost and time**, metal additive manufacturing offers a significant advantage when dealing with small series or unique parts. Since it does not require molds, development and production times are considerably reduced, allowing for faster project launches. However, for mass production, technologies such as **MIM** (Metal Injection Molding) become more cost-effective once the mold investment is amortized, making them more suitable for large batches.

Challenges in Surface Finishing and Material Limitations

One of the main challenges in **metal additive manufacturing** is achieving **high-quality surface finishes**. Parts produced through this method often exhibit roughness due to the layer-by-layer deposition of material, requiring post-processing operations such as machining or polishing to meet required standards.

Moreover, although the range of materials available for additive manufacturing continues to grow, it is still more limited compared to other technologies like **MIM** (Metal Injection Molding).

However, recent advances in superalloy research are expanding the range of available **materials**, promising increased competitiveness of additive manufacturing against more traditional technologies.

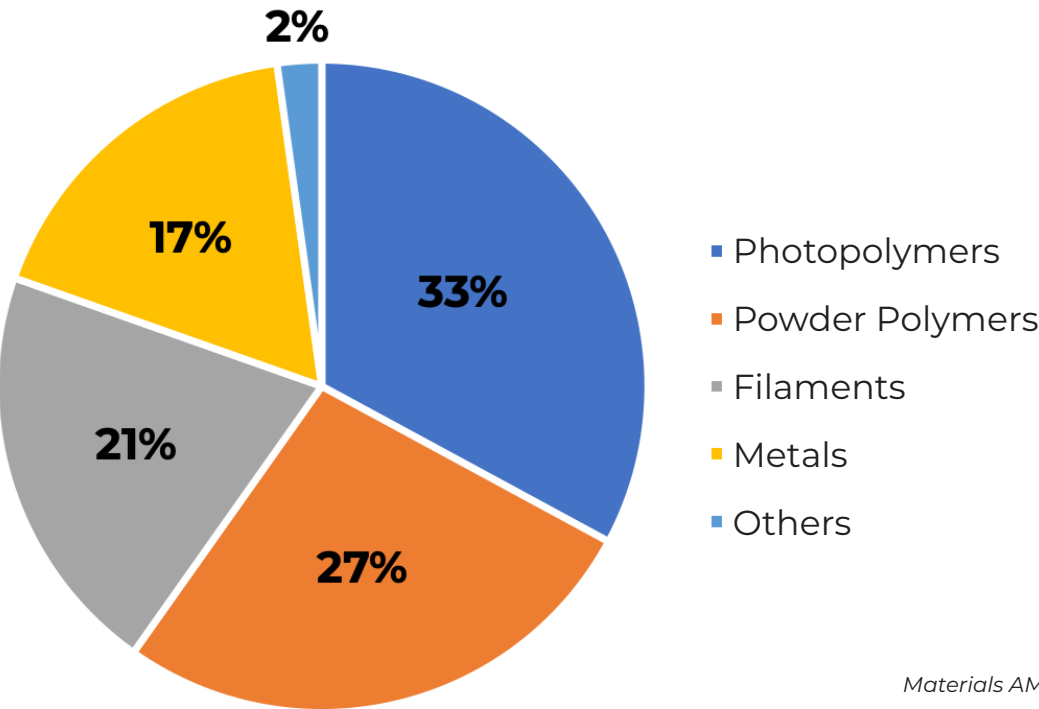
Metal Additive Manufacturing Technologies

Within **metal additive manufacturing**, several key technologies exist, such as **Fused Deposition Modeling (FDM)** and **Binder Jetting**. These technologies enable the production of parts with complex geometries and advanced mechanical properties, although each differs in terms of precision, strength, and surface finish quality.

Most Common and Emerging Metals in Metal Additive Manufacturing

In the field of metal additive manufacturing, the most commonly used materials to date are stainless steels and certain titanium alloys, although the portfolio of available metals continues to expand. Key materials include:

- Stainless steels:** Widely used for their corrosion resistance and good mechanical properties, with 316L stainless steel being one of the most common grades in industrial and medical applications.
- Titanium alloys:** Highly valued in sectors such as aerospace due to their strength-to-weight ratio, making them an ideal choice for high-performance components.
- Copper:** Although less commonly used, copper is beginning to gain ground due to its excellent thermal and electrical conductivity properties.



Materials AM. Source: Wholers Report 2019.



The evolution of materials in the field of metal additive manufacturing has been significant in recent years, enabling advancements that once seemed impossible. In the early stages, material options were primarily limited to stainless steels and titanium alloys. However, the industry has seen an increase in the availability of new materials such as copper and nickel alloys, thereby expanding the range of applications.

Today, research into improving metal powders and developing new alloys is booming. Material innovations are enabling the production of parts with exceptional mechanical properties, enhancing strength and optimizing internal structures. These improvements are critical in sectors such as aerospace and medical, where reliability and performance under extreme conditions are essential.

Looking ahead, the portfolio of available materials is expected to continue expanding, with the goal of more directly competing with traditional manufacturing methods. In addition to enhancing mechanical properties, these new alloys allow for shorter production times and cost reductions—factors that are especially important in sectors where precision and durability are key, such as aerospace and healthcare.

Market Sectors and Applications of Metal Additive Manufacturing

The demand for parts produced through metal additive manufacturing technologies comes primarily from sectors such as automotive, aerospace, industrial machinery, electronics, and healthcare. These industries value additive manufacturing for its ability to create complex and customized geometries with advanced mechanical properties. Over 70% of current demand originates from these markets, reflecting the central role of the technology in their development.

The additive manufacturing market is in constant growth, and the technology is expected to continue expanding into new sectors such as defense and robotics.

In addition, the ability to produce customized parts in small series has led to the increasing use of additive manufacturing for both prototyping and the final production of functional components. The evolution of materials and advancements in the automation of the additive manufacturing process will further drive its adoption in emerging sectors.

Binder Jetting, Fused Deposition Modeling (FDM), and Comparison with Other Technologies

Overview and Properties

Binder Jetting is a metal additive manufacturing technology that involves the deposition of layers of metal powder onto a build platform, followed by the application of a polymeric binder. The process is repeated layer by layer, with each layer requiring curing before the next is deposited. Once printing is complete, excess powder is removed through a process known as depowdering, and the green part undergoes a debinding and sintering cycle to form the final metallic component. Although this method uses a minimal amount of binder—making the debinding process more efficient—the green parts produced are typically fragile and difficult to handle.

On the other hand, **Fused Deposition Modeling (FDM)**—also known as material extrusion or *fused filament fabrication (FFF)*—builds parts by extruding material, typically a mixture of metal powder and polymer, layer by layer through a nozzle. Similar to Binder Jetting, the resulting green part undergoes debinding and sintering processes to become a fully metallic component. This technology is more adaptable in terms of materials, as it can use filament, pellets, or rods depending on the machine configuration.

Although it is efficient for prototyping, FDM typically produces parts with higher porosity and rougher surfaces, requiring additional finishing steps to match the quality of parts produced by MIM.

Comparative Analysis: Binder Jetting, FDM, and MIM

- **Production Speed:** Metal additive manufacturing technologies such as Binder Jetting and FDM enable rapid prototyping by eliminating the need for mold fabrication. However, once the mold is produced, MIM offers significantly faster production times for large volumes, as it can mold many parts in a single injection cycle.
- **Surface Finish and Post-Processing:** MIM outperforms both Binder Jetting and FDM in terms of surface finish quality. While metal additive manufacturing technologies often require secondary processes such as polishing to improve surface texture, MIM delivers smoother results directly from the mold, with roughness values ranging between Ra 0.8 and 1.6. Binder Jetting, in particular, tends to produce rougher surfaces that demand more extensive finishing processes.
- **Porosity and Microstructure:** MIM offers better control over the porosity and microstructure of the final part, resulting in higher mechanical strength and density. In contrast, Binder Jetting and FDM can introduce large pores during the printing process, leading to lower part densities. These technologies often require additional heat treatments to enhance the mechanical properties of the component.
- **Material Portfolio:** MIM has a more versatile material portfolio, offering a wide range of metals such as stainless steels, soft magnetic alloys, and tool steels. Although metal additive manufacturing technologies are expanding their range of available materials, they are still largely limited to a few metals, such as stainless steels and certain tool steel alloys.

Specific Analysis: Metal Additive Manufacturing vs. MIM

Comparison of Part and Process Properties with MIM

Both Metal **Additive Manufacturing** and Metal Injection Molding (MIM) offer unique advantages and challenges. While MIM delivers parts with outstanding mechanical properties and exceptional surface finishes, additive manufacturing provides greater design flexibility and enables the production of more complex geometries.

In terms of mechanical properties, MIM still outperforms additive manufacturing in density and part strength—particularly with materials such as 17-4PH stainless steel, where MIM parts exhibit higher density and superior mechanical performance compared to those produced through additive techniques like Binder Jetting or FDM.

Comparison of Results Between Metal Additive Manufacturing and MIM

MIM remains the most suitable technology for producing small to moderately complex parts in large volumes, offering a superior cost-efficiency ratio for this type of product. However, additive manufacturing excels in the creation of prototypes and short production runs, especially for geometries that would be impossible or too expensive to manufacture using MIM.

Thus, while MIM is more competitive for large series due to its fast production once tooling is in place, additive manufacturing enables shorter development times for complex parts.

Benefits of Integrating Both Technologies into the Production Process

Rather than being competing technologies, **Metal Additive Manufacturing** and MIM complement each other effectively. Additive manufacturing can serve as a key tool in the early stages of product development, enabling rapid prototyping and design iterations before transitioning to mass production through MIM.

Additionally, Metal Additive Manufacturing can help optimize the sintering process and part positioning, thereby accelerating MIM production and reducing both development time and overall costs.

Comparison of Cost, Time, and Part Properties

In terms of cost, **Metal Additive Manufacturing** tends to be more expensive than **MIM** for large production runs due to the high cost of equipment and materials, as well as the need for secondary operations on many parts to improve surface finish. However, for short runs and parts with highly complex geometries, the elimination of mold fabrication makes additive manufacturing more competitive.

Additionally, additive manufacturing allows for a significant reduction in development time, which can be crucial for products that require rapid design iterations.

Metal Additive Manufacturing vs. MIM: Competition or Complement?

Far from being direct competitors, these technologies are positioned as complementary within the manufacturing value chain. The ability to create impossible geometries with **Metal Additive Manufacturing**, combined with the mass production efficiency of **MIM**, provides companies with the flexibility to choose the most suitable technology for each stage of the production cycle—maximizing both quality and cost-efficiency.

Innovations and the Future of Metal Additive Manufacturing in Relation to MIM

The future of **Metal Additive Manufacturing** points toward greater integration with **MIM** and other industrial processes. As new materials are developed and 3D printing technologies are optimized, additive manufacturing will become viable for a broader range of industrial applications, reducing the barriers between both technologies and opening up new production opportunities.

Use in Key Sectors: Automotive, Aerospace, Medical, and Consumer

Metal Additive Manufacturing has found key applications in industrial sectors such as automotive, aerospace, medical, and consumer goods. In each of these sectors, the ability to produce parts with complex, customized geometries and high-quality mechanical properties has transformed the way critical components are developed.

In the **automotive sector**, additive manufacturing is primarily used for the production of lightweight, optimized parts that enhance vehicle energy efficiency. These components also enable function integration and the reduction of complex assemblies. At Ecrimesa Group, innovative solutions have been developed for this sector, enabling the creation of customized parts and short production runs at competitive prices, allowing for rapid adaptation to evolving needs.

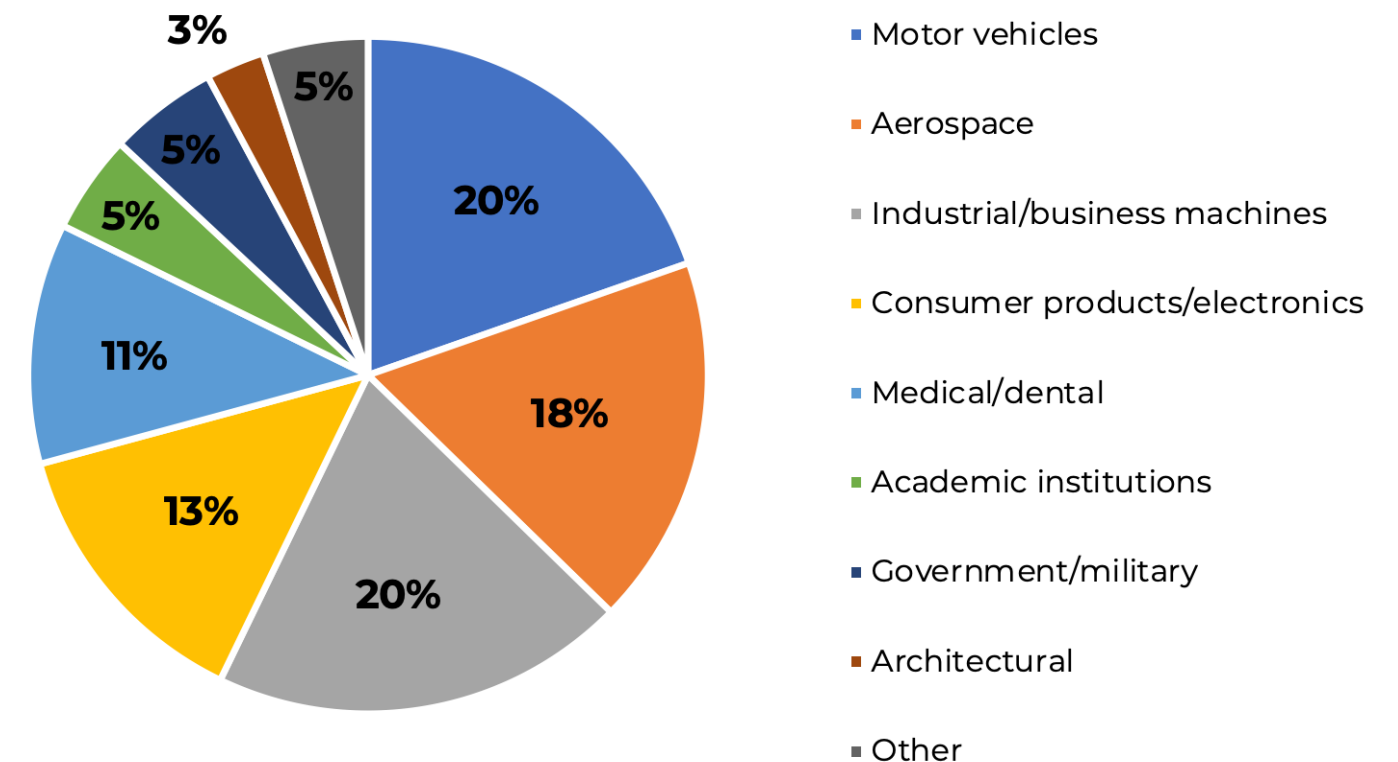
In the **aerospace** market, the precision and strength of parts produced through additive technologies enable the development of components that meet the stringent requirements of the industry. The manufactured products are resistant to extreme temperature and pressure conditions and comply with strict international quality standards. Ecrimesa Group holds certifications such as EN9100 for the production of components intended for the aerospace industry.

The **medical sector** has found in additive manufacturing an essential tool for the development of prosthetics, implants, and other medical devices. The ability to customize each part to the specific needs of the patient, combined with the capability to produce complex geometries, has enabled greater precision and improved fit in medical treatments.

Finally, **consumer sectors** are experiencing growth in the application of additive manufacturing technologies, particularly in the production of customized products such as eyewear, jewelry, and other high-end items. This technology enables the creation of unique, highly personalized pieces, expanding design possibilities and allowing for mass production through short-run manufacturing.

Expansion into New Markets

In addition to these key sectors, additive manufacturing is entering emerging markets such as robotics, drones, and the energy industry. In these areas, the advantages of additive manufacturing—such as the ability to develop lightweight and durable parts—are highly valued for improving operational efficiency and product customization. Ecrimesa Group's ability to adapt to these new markets is a crucial element of its growth strategy.



Market Demand by Sector
Source: Wohlers Associates, Inc.

Prototypes and Pilot Parts: How We Accelerate the Design Process

At Ecrimesa Group, prototype manufacturing is a crucial stage to ensure the quality and feasibility of parts before moving to mass production. Thanks to **Metal Additive Manufacturing** technology, we accelerate design processes, optimizing both time and cost, which allows us to offer rapid solutions to our clients.

3D printers such as the **Studio System from Desktop Metal and Raise3D** enable us to produce prototypes with mechanical and dimensional properties very close to those achieved through traditional processes like MIM. With this technology, we not only reduce prototype lead times, but also conduct detailed design studies, sintering optimization, and part positioning—minimizing potential defects or deformations during production.

Equipment and Technology: Desktop Metal and Raise3D Printers

Our choice of equipment is based on extensive benchmarking to evaluate the best solutions available on the market. The Desktop **Metal Studio System** and **Raise3D** printers stand out for their ability to produce high-precision prototypes, minimizing errors and reducing the number of manual steps in the manufacturing process.

These printers not only enable the production of evaluation prototypes but are also useful for small-batch manufacturing of complex parts—where investing in molds would be prohibitively expensive.

Case Studies in the Industrialization of Parts Using Metal Additive Manufacturing Technology at Ecrimesa Group

One of the most representative examples of how we use **Metal Additive Manufacturing** to accelerate industrialization is the production of green support prototypes, which made it possible to prevent deformations during the sintering process. This technology has also been crucial for conducting feasibility studies prior to mold fabrication, allowing us to provide our clients with a complete and efficient solution from the early stages of the project through to final production.



Industry 4.0: The Evolution Toward Mass Production with Metal Additive Manufacturing

The incorporation of **Industry 4.0** into manufacturing systems has opened new opportunities for the growth and development of **Metal Additive Manufacturing (AM)**. This approach—combining automation, data, and connectivity—is enabling AM technology to evolve toward mass production, integrating into more complex and advanced production chains.

Development of New Materials and Expansion of Applications

One of the key factors in the evolution of **additive manufacturing** is the continuous development of new materials. Currently, **stainless steels and titanium** alloys dominate the market; however, research into superalloys and advanced materials such as copper and nickel is rapidly advancing. These new materials are expanding **AM** applications in sectors such as automotive, heavy industry, and others, where demands for strength and durability are critical.

La **optimización topológica** y la posibilidad de crear geometrías complejas han hecho que la fabricación aditiva sea especialmente atractiva para aplicaciones personalizadas en el sector **médico** y **aeroespacial**, donde el peso y la personalización juegan un rol fundamental. A medida que se desarrollen más materiales, la AM podrá competir directamente con tecnologías tradicionales en un mayor número de sectores.

Technological and Economic Challenges to Overcome in the Coming Years

Despite recent advancements, the widespread adoption of Metal Additive Manufacturing faces several technological and economic challenges. The main obstacles include:

- **Production speed:** While additive manufacturing is ideal for short runs and prototypes, it remains less competitive than traditional methods for mass production. The challenge lies in increasing printing speed without compromising quality, which would significantly reduce the cost per part.
- **Equipment costs:** The high cost of metal 3D printers and materials limits large-scale adoption, especially in price-sensitive sectors such as automotive. Reducing operational and equipment costs will be key for AM to gain broader traction in high-volume industries.
- **Part quality and surface finish:** There is still a need to improve the surface quality of printed parts and reduce the reliance on secondary processes such as polishing and machining in order to make production more efficient.

Innovations and the Future of Additive Manufacturing

The future of metal additive manufacturing is expected to be full of innovations and improvements that could further revolutionize the industry. Some of the key areas where advancements are anticipated include:

1. **Improved printing speed:** Optimizing printing systems to make them faster and more efficient will help reduce the per-part production cost. This improvement is crucial for AM to become a competitive technology compared to traditional large-scale manufacturing methods.
2. **Development of new materials:** In addition to stainless steels and titanium alloys, the emergence of **new metal alloys** is expected to expand the material portfolio. This will enable AM to compete more effectively in sectors such as automotive and heavy industry, where its current presence is more limited.
3. **Automation and robotics:** The use of robotics and automation in AM processes will help optimize operations and reduce production times, aligning with **Industry 4.0** principles. The integration of these technologies will be key to making mass production viable.

Standardization in Additive Manufacturing

One of the most important factors for the widespread adoption of additive manufacturing in regulated industries such as aerospace and healthcare is the **standardization of processes**. For AM to become firmly established, it is crucial to develop **international standards** that unify procedures, ensure quality, and guarantee the safety of the parts.

Significant progress has already been made in this area, with the development of standards by organizations such as **ISO** and **ASTM**, which address key aspects such as **metal powder quality**, **machine operator qualification**, and requirements for **manufactured parts**. However, there is still a long way to go before these standards are adopted globally and greater confidence in the technology is achieved.

International Standards and Quality Regulations (ISO/ASTM)

Metal additive manufacturing, like other industrial technologies, must comply with **international regulations** that ensure the quality, safety, and reliability of the parts produced. In critical sectors such as **aerospace, medical, and defense**—where quality standards are extremely high—compliance with these regulations is essential for the adoption and expansion of the technology.

International Regulations and Standards (ISO/ASTM)

Two of the main organizations responsible for developing and maintaining standards in additive manufacturing are ISO (International Organization for Standardization) and **ASTM** (American Society for Testing and Materials). Both have developed a set of specific standards for metal additive manufacturing, covering aspects such as **material quality, manufacturing processes, and testing of finished parts**. Some of the most relevant standards include:

- **ISO/ASTM 52900:2015** – General principles and terminology for additive manufacturing.
- **ISO/ASTM 52901:2017** – General requirements for purchasing parts produced using additive manufacturing.
- **ISO/ASTM 52910:2018** – Guidelines for design for additive manufacturing, with a focus on process feasibility.
- **ISO/ASTM DIS 52907** – Technical specifications for metal powders used in additive manufacturing.
- **ISO/ASTM 52941** – Performance and reliability of laser-based powder bed fusion systems used in aerospace applications.

These standards are fundamental to ensuring that additive manufacturing processes and products meet the highest levels of quality and safety, thereby facilitating their adoption in regulated industries.

Impact on the Aerospace, Medical, and Other Regulated Industries

The **aerospace industry** is one of the primary users of metal additive manufacturing due to the technology's ability to produce lightweight and highly durable components. However, because of the strict safety and quality requirements demanded by this sector, **certification of both processes** and materials is essential. Standards such as **EN9100** (which Ecrimesa Group complies with) ensure that parts manufactured through AM are not only efficient, but also meet or exceed the rigorous testing standards for strength, tolerance, and reliability required in this field.

In the **medical industry**, customization is key, and additive manufacturing has proven to be a revolutionary technology for creating **personalized prosthetics, implants, and surgical devices**. Standards such as **ISO 13485**, which applies to medical devices, are essential to ensure that parts meet the necessary safety and quality requirements in medical environments.

Other regulated sectors, such as **defense and the automotive industry**, are also gradually adopting AM technology. Regulations in these fields focus primarily on ensuring the strength and durability of parts under extreme conditions, as well as on weight reduction without compromising safety.

How Ecrimesa Group Meets the Market's Most Demanding Standards

Ecrimesa Group has positioned itself as a leader in the adoption of international standards across all its manufacturing processes. The company holds a series of certifications that ensure its products comply with the most stringent regulations in highly regulated sectors:

- **EN9100:** Certification that ensures quality in the manufacturing of components for the aerospace sector, guaranteeing compliance with the strict international requirements of this industry.
- **IATF 16949:** This international certification ensures quality in the production of parts for the automotive industry, confirming that Ecrimesa Group meets global standards for safety, quality, and efficiency.
- **ISO 14001:** Focused on environmental management, this standard certifies that Ecrimesa Group's manufacturing processes are not only efficient but also minimize environmental impact.
- **CQI-9:** Specification for the control of heat treatment processes, essential in the manufacturing of metal components with optimal mechanical properties.

These certifications, combined with a rigorous quality control system and compliance with ISO/ASTM standards, ensure that **Ecrimesa Group** remains a reliable supplier for highly regulated sectors. In addition, the company is committed to continuous improvement and innovation, allowing it to stay at the forefront of **Industry 4.0** and advancements in **Metal Additive Manufacturing**.

Integration of AI in Additive Manufacturing Technology

The integration of **Artificial Intelligence** into **Metal Additive Manufacturing** technology is revolutionizing the design, optimization, and production of metal parts.

The main applications of **AI** in **AM** technology are:

1. **Generative design optimization**
Creation of complex geometries optimized for weight, strength, and performance through the use of algorithms, while simultaneously reducing material waste and improving part efficiency.
2. **Quality monitoring and control**
Detection of defects during the printing process using sensors, with automatic parameter adjustments to minimize rejection rates and improve repeatability.
3. **Simulation and prediction of material behavior**
AI models can predict deformations, residual stresses, and microstructures in metal parts, allowing for adjustments before printing and during post-processing to prevent errors and enhance mechanical properties.
4. **Workflow automation**
AI supports the management of print planning, selection of materials according to required properties, and optimization of part placement on the build plate—enhancing productivity and reducing processing costs.
5. **Improved energy efficiency and sustainability**
AI can also optimize energy and material usage, reducing environmental impact.

In short, the combination of **AI and additive manufacturing** is enabling greater customization, shorter production times, and lower costs in the sectors where the technology is most established—such as aerospace, automotive, and medical. As AI continues to advance, additive manufacturing is becoming more autonomous, precise, and accessible for large-scale industrial applications.



Conclusions: Metal Additive Manufacturing at Ecrimesa Group

The evolution of **Metal Additive Manufacturing** has transformed the way companies approach the design and production of complex metal parts. Throughout this guide, we have explored how technologies such as **Binder Jetting and Fused Deposition Modeling (FDM)** offer new opportunities for manufacturing components with geometries that would be impossible to achieve using traditional methods. While these technologies present certain challenges, they are proving to be valuable tools across a wide range of sectors, including **aerospace, automotive, and medical**.

Ecrimesa Group, with its solid experience of over 60 years in metal part manufacturing, has successfully integrated additive manufacturing as an essential part of its technological strategy. It has combined its know-how in **MIM (Metal Injection Molding)** with the flexibility and speed offered by **Metal Additive Manufacturing (AM)**.

Ecrimesa Group's ability to integrate additive manufacturing into its production process has brought a range of advantages:

- **Reduced development times:** Acceleration of the design and prototyping process, offering clients the ability to iterate quickly before moving to mass production via MIM.
- **Customization and flexibility:** Capability to produce customized parts with complex geometries that would be impossible to manufacture using traditional technologies
- **Complementarity with MIM:** Rather than viewing additive manufacturing as a competitor to MIM, Ecrimesa Group has adopted a complementary approach. Additive Manufacturing enables the creation of prototypes and short series, while MIM remains the ideal option for mass production of parts with demanding mechanical properties.

Looking Ahead: Innovation and Growth

The future of **Metal Additive Manufacturing** at **Ecrimesa Group** is defined by innovation and continuous improvement. The company has made significant investments in enhancing its processes, including the acquisition of advanced equipment such as the **Desktop Metal Studio System and Raise3D printers**, which enable not only the production of prototypes but also short series of highly precise parts.

In addition, **Ecrimesa Group** continues to expand its material portfolio, which will allow it to increase its presence in new markets and offer more comprehensive solutions to its clients. This approach, along with its commitment to **sustainability** and compliance with **international standards**, positions the company as a benchmark in the **manufacturing of advanced metal components**.





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