Press review
Pollen AM

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"Several innovative start-ups and major equipment manufacturers such as Pollen AM, Desktop Metal, HP and even GE Additive, launched new 3D metal-free laser printing processes"

MIM applied to metal 3D printing in 10 questions

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Sprocket in 17-4 PH stainless steel printed on a PAM 3D printer in sintered state.

Since 2015, the metal additive manufacturing market has been a booming segment whose growth potential has aroused the interest of many players. While the sale of conventional laser fusion equipment stalled in 2018, the arrival of alternative technologies helped sustain this dynamic. Several innovative start-ups and major equipment manufacturers such as Pollen AM, Desktop Metal, HP and even GE Additive, have arrived with new 3D metal-laser printing processes. Inspired by MIM (Metal Injection Moulding), a technique derived from injection moulding well known in the industrial world, these 3D printers of a new kind "Mim-Like", facilitate financial access to this technology. To make you discover the other advantages and limits of this innovative approach by contributing to laser fusion techniques, Primante 3D interviewed Pollen AM, the French specialist in MIM-Like 3D printing by extrusion of granules.

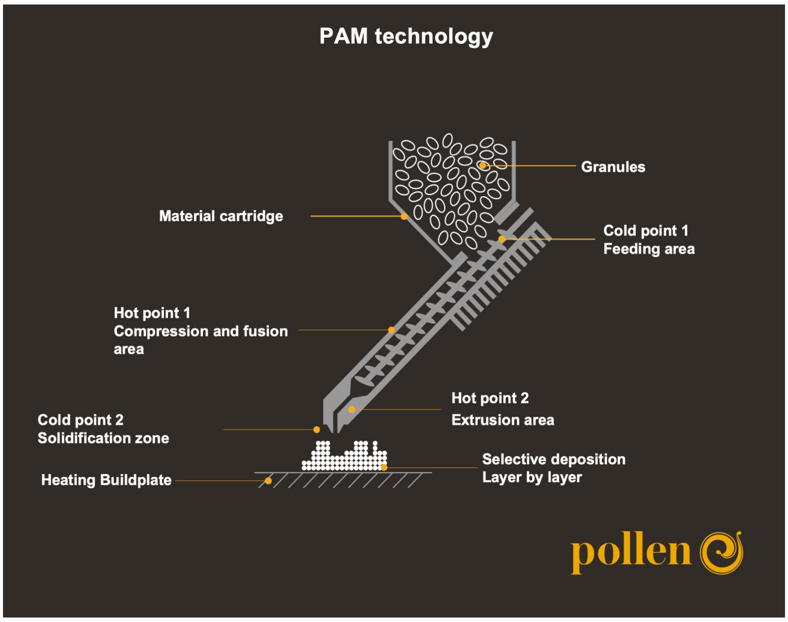
> ***"MIM is an ideal candidate for metal additive manufacturing and in particular compared to laser fusion processes on a powder bed"***

Didier Fonta Head of Operations at Pollen AM

Didier hello, for those of you who don't know you yet, could you introduce us Pollen AM?

Hello Alexandre, Pollen AM is a French manufacturer of industrial 3D printers. Created in September 2013, after 2 years of Research and Development, Pollen AM has developed a new FDM-type additive manufacturing technology, PAM technology (acronym for Pellet Additive Manufacturing) Truly open to industrial materials, PAM eliminates filaments, powders, liquid resins or any other format specific to additive manufacturing. Offering the advantage of using raw materials at the lowest cost on the market, PAM opens a virtually infinite library of compatible materials while benefiting from available material certificates (skin contact, food contact, smoke fire, etc.).

It is now possible to produce prototypes, jigs and fixtures, parts in small and medium series using the same material as in injection molding without investing in specific tools.

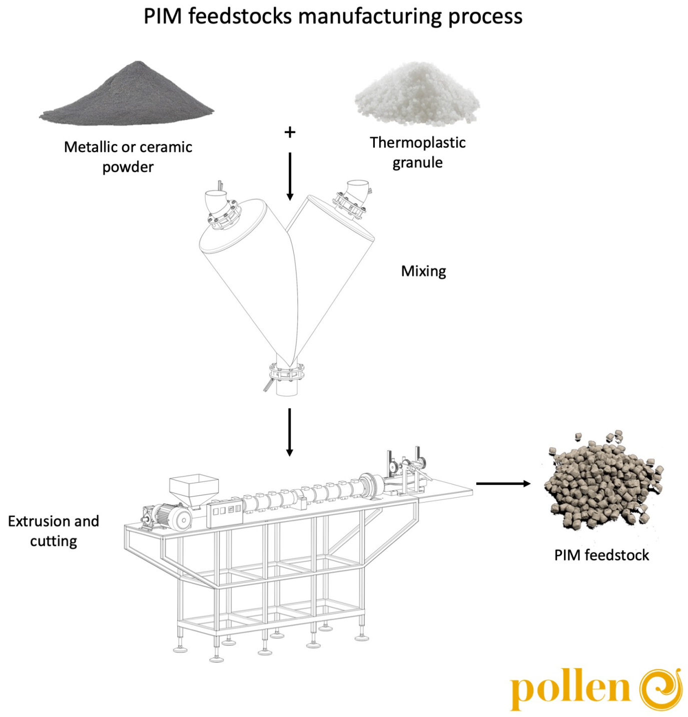


Presentation of the PAM technology developed by the company Pollen AM.

1. About two years ago, Pollen AM attacked the metal additive manufacturing market with the Pam Series M system, a metal 3D printer using your Pam technology and materials from metal injection molding (MIM) . What is the MIM process and how is it used in the conventional industry?

Compared to the forge or the foundry of metal parts, MIM (Metal injection moulding) is very recent, this technique belongs to the family of PIM's (Particle Injection Moulding).
Work was initiated in the United States in the 1920's on ceramic (CIM - Ceramic injection Moulding). The original idea was to plasticize powders, that is, to give them plastic properties by coating them with organic matter. This thermoplastic behavior "composite" is subsequently formed using a press and an injection mould to obtain a more or less complex part.
During the Second World War, work was extended on metallic powder, it was not until the 1970s that industrial applications of the MIM process surfaced.
Since then, the MIM market has grown enormously and covers a wide range of industrial applications, such as the automobile, watchmaking, defense, aerospace, medical (prostheses, implants, probes, etc.), connectors, etc. In short, we all cross paths in our daily lives and without being aware of the parts resulting from the MIM processes.

"To obtain a 100% metallic part it is necessary to post-treat the formed parts"



Presentation of the PIM feedstock manufacturing process.

2. MIM requires several post-processing steps to arrive at the final part. What are they ?

In fact, MIM is one of the techniques for manufacturing metallic parts called "indirect". That is to say, to obtain a 100% metallic part it is necessary to post-treat the formed parts.

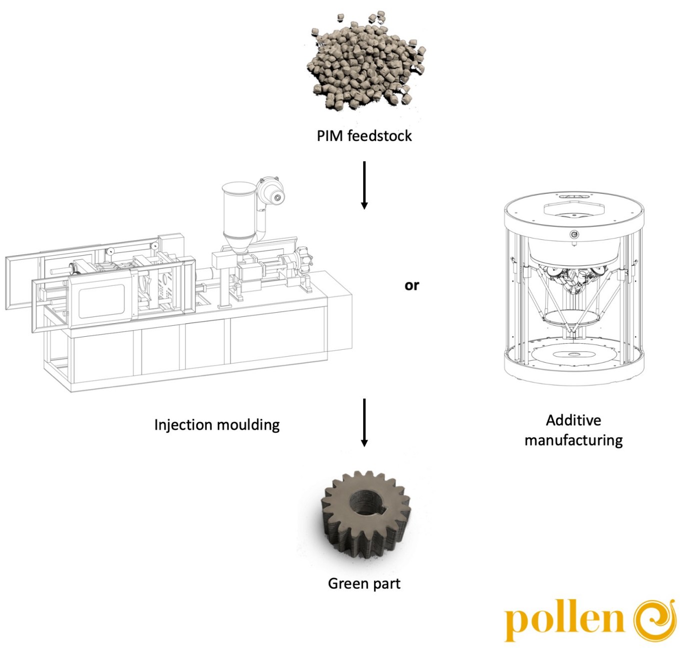
Overall, the MIM process is broken down into three main stages:

- Shaping: the first step in the manufacture of MIM parts is done either by a conventional process by injecting a feedstock into a mould under pressure using an injection press, or by using compatible metal additive manufacturing technologies with these materials.

The part thus produced is a preform, called "green part". The level of binder contained in the green parts varies according to its chemical nature and the powders used; the percentage of binder is generally between 35 and 50% by volume.

> **"Remove approximately 98% of the organic binders contained in the green part"**

PIM feedstocks shaping process

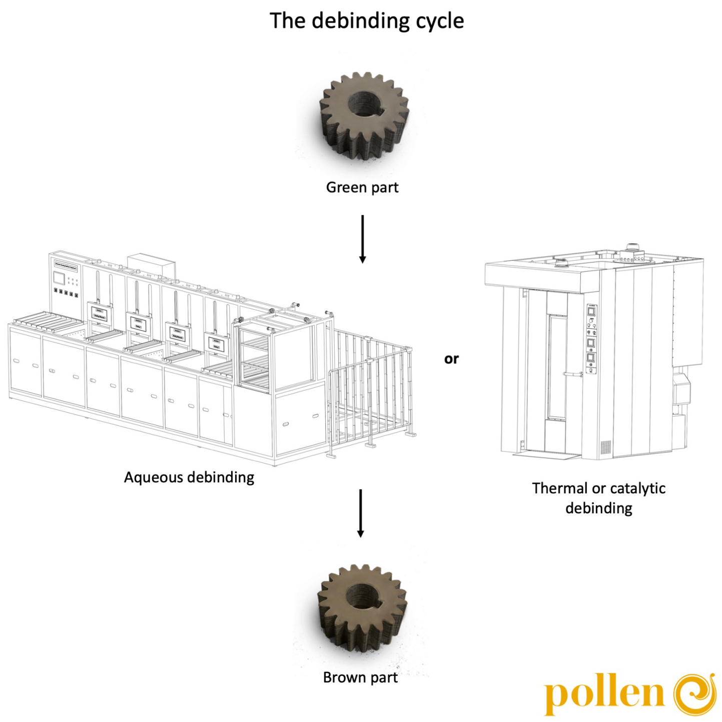


Presentation of the PIM feedstock shaping process.

- Debinding: this is a key operation of the PIM process, it makes it possible to prepare the parts for the sintering cycle and consists in removing approximately 98% of the organic binders contained in the “green part”. The residual binder is necessary for handling the debinded piece, called "brown part" and allows it to ensure good stability during the sintering process.

The quality of this operation is fundamental so as not to cause physical (cracking) or chemical (carburetion) degradation to the part. A very large part of the defects which appear after sintering is generated by unsuitable debinding.

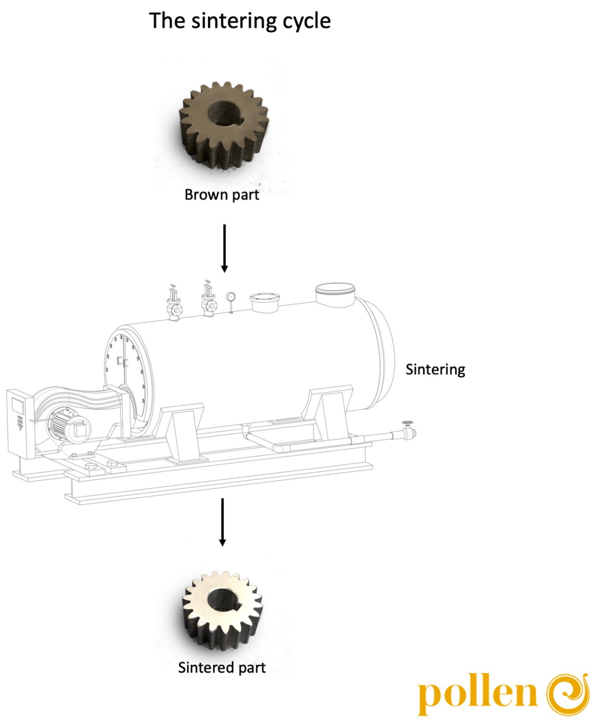
Depending on the chemical nature of the binder, debinding can be carried out catalytically, thermally or by solvent. At the end of the debinding cycle, the part has not undergone any dimensional change (shrinkage).



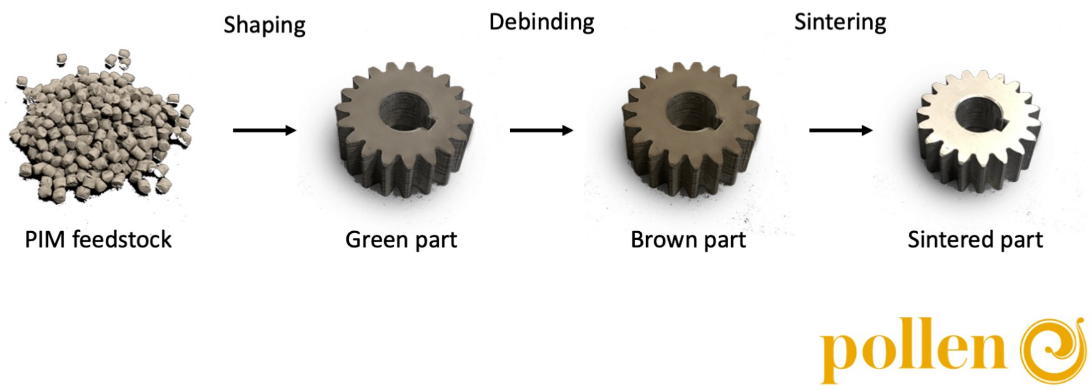
Presentation of the debinding cycle.

- Sintering: a pre-sintering cycle, also called 2nd debinding, is generally carried out before sintering. Its objective is to remove the residual organic binder retained at the end of the debinding cycle. This is followed by a heating cycle, called sintering, allowing the metal particles to be welded together, it is during this stage that the mechanical properties are given to the final part, called "sintered part". This operation takes place at a temperature close to the melting point of the treated metal, under a controlled atmosphere and sometimes under vacuum. The gaseous mixture composing the sintering atmosphere is specific for each metal to be sintered, it aims to reduce, among other things, the oxide present on the surface of the powders. The shrinkage accompanying the sintering is important, controlled and isotropic.

> **"A dimensional shrinkage occurs, it is due to the elimination of the porosity in the powder agglomerate"**



Presentation of the sintering cycle.



Presentation of the PIM part manufacturing process.

3. The debinding and sintering phase also involves certain precautions to be taken when designing the part. What are they ?

Indeed the debinding and sintering cycles are crucial stages requiring mastery and expertise. To obtain parts with the desired qualities, several design rules must be taken into account, including:

- Wall thickness: it is advisable to design parts with uniform wall thicknesses in order to avoid distortion and cracks. Sudden variations in these thicknesses can cause variations in shrinkage during sintering, making dimensional control difficult. The greater the wall thickness, the longer and more uncertain the debinding cycle.

- Support structure: it is preferable for PIM parts to design a flat surface on which they can be positioned for sintering and to avoid their collapse. Support structures can be created to minimize sagging of the parts during the sintering process is.

- Shrinkage: the "brown part" obtained after the debinding cycle has a porous structure, due to the elimination of the organic binder. During the sintering process, the powder particles are brought to a temperature close to their melting points allowing the powders to get closer to each other, thus reducing the quantity of pores present in the part.

Simultaneously, a dimensional shrinkage occurs, it is due to the elimination of the porosity in the powder agglomerate. This shrinkage is linear, that is to say identical in the three directions, its value is a function of the initial volume content of organic binder, it is between 12 and 20%. The shrinkage coefficient is a value communicated by the suppliers of PIM materials. It is to be anticipated during the part design phase by applying this multiplying coefficient to the preform.

4. How does MIM apply to metal 3D printing?

PAM offers the advantage of not disrupting the existing post-processing chain dedicated to "traditional" production of MIM parts. The post-processing equipment, the debinding and sintering cycles are therefore identical. In addition, using industrial materials, not requiring specific formats, or adjusting recipes (powder / organic binder ratio), the parts shrinkage are equivalent.

For the production of unit parts, in small and medium series, the Pam Series M printers replace the injection moulding machines by bringing more flexibility and freedom; thus limiting the costs of tooling (injection moulds).

Pam Series M 3D printer

5. What are the other metal 3D printing technologies available on the market today exploiting MIM?

In the additive manufacturing market, there are two main MIM-Like 3D printing technologies: FDM and Binder Jetting technologies. The main differences between these solutions will come from the format of the material, the chemical nature of the binder, the metal / binder ratio and the manufacturing process of the parts. All of these elements will impact, among other things, the behavior of the material during the shaping phase, the equipment and post-treatment cycles, the resistance of the parts to the "green part", shrinkage, and finally the final quality of the part in the sintered state.

In addition to the PAM process, there are FDM type 3D printers using MIM in the form of a filament or a rod. These materials differ from industrial MIM granules by their shape factors, by the nature and the ratio of the powder / binder mixture. In fact, to make them compatible with FDM printing processes, the amount of organic binder contained in the mixture is generally greater than the industrial MIM feedstock granules. This thus impacts the behavior of the part during the post-treatment phases, such as for example a higher shrinkage rate. In addition, the very nature of the organic binders used is very often different, preventing the integration of these printed parts into existing industrial flows. Indeed, they require dedicated debinding and sintering cycles.

A distinction is also made between 3D printers of the Metal Binder Jetting (MBJ) type using “Free” powder. In this process, the parts are produced by selective deposit of binder on a bed of powder layer after layer. Since the binder is deposited in very small quantities, the debinding cycle is avoided. However, it turns out that parts produced by MBJ have a higher porosity rate than other technologies. Besides the fact that they offer faster production rates than FDM technologies; MBJ requires higher investments (machine costs, safety equipment, maintenance, consumable costs, etc.).

> ***"The handling and operability of FDM systems are very accessible"***

6. How is it advantageous to use MIM-Like 3D printing technologies rather than conventional powder bed laser fusion processes? Conversely, what are its limits and constraints?

MIM is an ideal candidate for metal additive manufacturing and in particular compared to laser fusion processes on a powder bed, which remain expensive and restrictive solutions (safety, ease of use, etc.).

Indeed, the handling and the operability of FDM systems are very accessible. The initial investments, maintenance and operating costs are relatively low compared to DMLS / SLM solutions. In addition, the powder being plasticized, it is not volatile. The powder therefore does not represent any health and safety risk unlike conventional solutions with laser fusion on a powder bed, where it is "free".

Compared to a DMLS / SLM solution, a Pam Series M machine, dedicated to MIM-Like applications, represents:
- an initial investment 5 to 10 times lower,
- the lowest consumable cost on the market, on average 10 times lower,
- no investment in specific equipment and infrastructure (clean room, safety suits, ventilation, etc.).

From an investment point of view, it is of course necessary to consider the installations already in place, indeed, the production of MIM parts requires post-processing equipment. For a company that already has this equipment, investing in a Pam Series M is particularly competitive. Conversely, investments in a debinding station and a sintering furnace can be expensive and require expertise to qualify them in relation to the applications and materials envisaged. Even if there are so-called "office" equipment, representing moderate investments; they remain limited and do not allow optimum processing of the materials.

In summary, debinding and sintering are a matter for experts. This is why Pollen AM and the company Alliance MIM (French leader in the production of MIM parts for over 25 years) offer a service solution for debinding and sintering of printed parts. It allows you to benefit from the expertise of Alliance MIM engineers and their installations.

Moreover, Alliance MIM having a large fleet of machines and having daily production rates, MIM-Like parts can be integrated into post-processing flows in a flexible, fast and competitive cost.

Also, the geometry of some parts requires the use of a support material to be printed. This support can be made with the same material, it will then be removed mechanically (by machining for example), or with a specific material, ideally not compatible with sintering. The latter must have a similar behavior to the structural material during debinding and sintering cycles (same organic binder for compatibility with the debinding cycle and a powder / binder ratio allowing a similar removal during the sintering phase).

Alliance MIM is the French leader in the production of MIM parts, its factory is located in Saint-Vit, in Bourgogne-Franche-Comté.

7. What do we know about the resistance level of a MIM-Like part, by adding to MIM parts and printed by laser sintering for example?

There is quite a bit of literature on this subject, especially since the performance of parts depends largely on machine settings and the nature of the raw material. However, it should be noted that the parts produced by these different processes respect the minimum normative values.

For example, ASTM International, through standard B883_19, framed the minimum mechanical properties of 316L Stainless Steel from the MIM process (Ultimate Strength: 450 MPa; Yield Strength: 140 MPa; Elongation at 25.4mm : 40%, etc.).
The technological choice is mainly made according to the needs and constraints of the project. The table below provides an overview of the advantages and disadvantages of the different technologies.

	DMLS/SLM	MBJ	MIM	MIM-Like – FDM	MIM-Like – Pam
Initial investments	€€€€	€€€	€€€	€€	€€
Material cost	€€€€	€€€€	€	€€€	€
Material diversity	++	++	+++	+	+++
Small series	+++	+++	-	+++	+++
Complex parts	+++	+++	++	+++	+++
Productivity	-	+	+++	-	-
Resolution	+	++	+++	+	+
Parts size	++	+	+	+	+
Multi-extrusion	N/A	N/A	N/A	+	+++

Comparative table of MIM and MIM-Like technologies.

MIM-Like from industrial granules is a versatile production tool offering a value for money comparable to conventional processes.

> ***"The number of alloys available for MIM-Like 3D printing is closely linked to the technology used"***

8. In MIM what are the main advantages of printing with granules rather than with other technologies?

The number of alloys available for MIM-Like 3D printing is closely linked to the technology used and the openness of its materials. In fact, by choosing a so-called “closed” machine (where the consumable is developed and sold by the machine supplier), the user will be limited by the innovation potential and the ability to market new raw materials. In addition, the material cost will be much higher than its equivalent in granules, because the manufacture of specific formats (filaments, bars, etc.) requires additional manufacturing steps, formulation and composition adjustments.

Conversely, the use of a so-called “open” system on materials and compatible with industrial granules will allow the user to benefit from the entire MIM material catalog already available, at its lowest cost and not be dependent on a supplier, etc.

PAM technology, open to materials, is compatible with traditional feedstocks on the market.

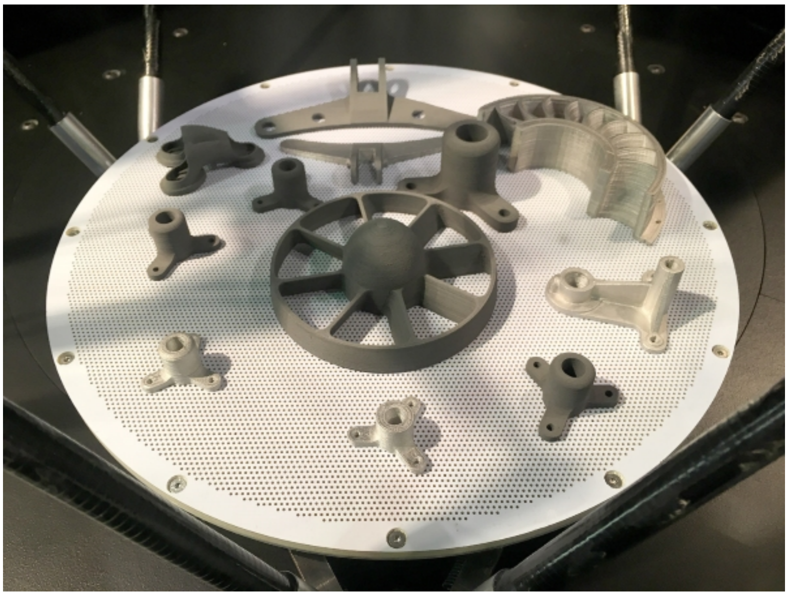
9. What can you tell us about the different materials available today for MIM metal 3D printing?

As PAM is open to materials, the consumable is widely available in its industrial format, that is to say at its fair price. It is this technological difference that gives access to the widest library of MIM materials on the market.
Note that almost all the alloys that can be atomized in powder form can be treated with MIM and therefore with PAM.

These alloys can be classified into four categories:
- Ferrous alloys: steels, stainless steels, tool steels, magnetic iron-nickel alloys and special ferrous alloys;
- Tungsten alloys: heavy alloys of tungsten and tungsten-copper;
- Hard materials: cemented carbides (tungsten carbide) and cermets (composite material composed of a ceramic reinforcement (Cer) and a metallic matrix (Met));
- Special materials including precious metals (silver, copper, gold, etc.), titanium alloys, aluminum, chromium-cobalt, nickel, nickel-based superalloys, molybdenum, and particulate composites.

In short, you will understand, MIM offers a very wide range of usable materials and they are compatible with PAM. For this, the user can adjust the machine parameters specific to the chosen MIM feedstock and make the production of reproducible parts.

> ***"The long-term objective is to produce small structural parts, connectors and finally forge-type blanks"***



Examples of printed MIM parts (317L stainless steel, 17-4PH stainless steel, Titanium).

10. Finally, what are the possible applications with 3D metal MIM printing and the sectors concerned?

Our collaboration with Alliance MIM started in 2018 with the integration of a Pam Series M into its design office. The Pam Series M allowed Alliance MIM to push the limits of conventional FDM additive manufacturing (limited to the printing of thermoplastics). Alliance MIM now uses PAM technology when thermoplastics reach their resistance limits. Currently, the main applications produced by Alliance MIM are dedicated to the production of positioning tools, grippers, and other production support elements. The long-term objective is to produce small structural parts, connectors and finally forge-type blanks which will tend towards the production of "net shape" parts which minimize material and eliminate machining operations.