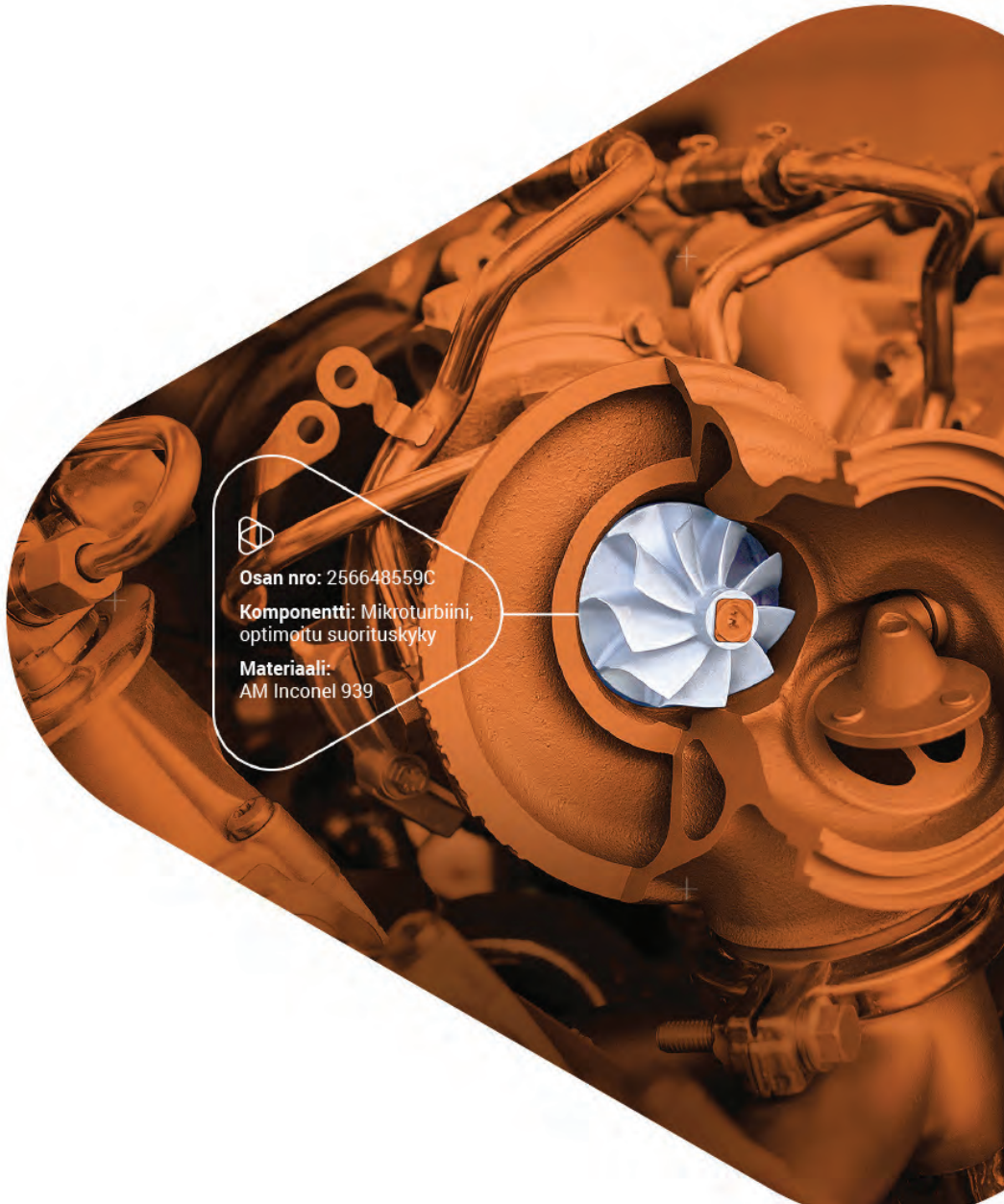
Well-chosen material multiplies the benefits of metal 3D printing

Delva

Content



Does the material play a role?

With metal 3D printing, commonly called metal additive manufacturing, we can solve, among others, functional, sourcing, and manufacturing challenges. At its best, metal additive manufacturing helps to create new solutions and new businesses. It has a proven record to improve competitiveness and gaining a real, sustainable competitive edge.

It is time to forget designing based on manufacturability and instead start with the targets set. We can build better functionality, energy, and material-saving designs by employing metal additive manufacturing. Metal prints are also lightweight and save space. On that basis, we can also design other components more lightweight and smaller and multiply the savings.

Metal additive manufacturing helps us to do things better.

Getting all the benefits out of metal 3D printing requires learning new thinking. Traditionally, we have subtracted material from the blank to reach the desired form; now, we add it. The less we subtract material, the less it costs us. In additive manufacturing, the formula is similar: the less we add material, the less it costs, which is the necessary basic comprehension.

We do not talk about additive manufacturing principles in this guidebook; for that, there are other guides. We think it is essential to view printing materials to maximise the benefits of metal 3D printing: to have insight and take advantage of some new means to develop better solutions. To help you with this is the target of this guidebook.
We start discussing material selection and introduce some advantages different metals can bring in additive manufacturing. Opening two customer cases supports the reflection. This section is followed by a description of printable materials and their features. In the end, we collect the materials into a table to inspire your organisation in your work.

Image: With metal 3D printing, we create better functionality and energy and material saving structures.

All this we have written from the perspective of Laser Powder Bed Fusion (L-PBF). L-PBF is the most mature metal additive manufacturing technology, and it produces components also for the most demanding applications in the industry. More about L-PBF in our guidebook, "Metal 3D printing is a mature production technology that boosts competitiveness."

Get to know the material offering and utilise the whole potential metal additive manufacturing offers. Whatever your needs, we at Delva are there to help.

Delva Oy

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Metal additive manufacturing is an enabler that material choice excellently supports

In mechanical engineering, we like to select materials that we know are economical and sufficient for their performance. It may feel laborious to change, but using the same materials leads to compromises, not bringing the best possible advantages. It is also worth noting that not all the earlier familiar materials are available for 3D printing. The reason is that printing them makes no sense. Getting to know new materials helps us to print results.

Metal printing paves the way for materials like Inconel into active use in industrial applications. Inconel is oxidation- and corrosion-resistant super nickel alloy, which works in extreme environments subjected to high mechanical loads. Different Inconel-alloys exist; good examples are Inconel 718 (IN718), Inconel 625 (IN625), and Inconel 939 (IN939), all of which have specific characteristics. Generally, Inconel retains strength in high-temperature applications, making it suitable for gas turbine blades, seals and combustors, heat exchangers, and many more, both on Earth and in Orbit.

Image: Metal printing helps us to utilise the excellent characteristics of Inconel in a new way. (Image: EOS GmbH).

The usage of Inconel has been limited, and stainless steel is used instead, even though Inconel´s performance is in many ways better than stainless steel's. Due to rapid work hardening, Inconel is challenging to machine with conventional methods. This limits the usage of this fine material and makes metal printing the game-changer. Adding material instead of removing it works well with both IN718 and IN939 and exceptionally well with IN718. Both materials are available from Delva.

Don't be afraid of overquality

Understandably, selecting a material one has no experience with feels challenging. Sometimes, the organisation raises resistance and doubt. With some materials, the fear of designing overquality causes reluctance. With overquality, we mean the situation where the component's performance exceeds the required level in one way or another. For example, thinking of titanium, the question of manufacturing something too well-performing – and too expensive – may raise. Overquality, however, may make sense because the printing costs of, for example, stainless steel, Titanium and Inconel are for equal parts quite the same. The printability of a material affects the machine time, and the needed machine time affects a printed piece's price the most. When we take advantage of materials performance and characterisation and optimise the design, it may be that the customarily as expensive categorised material turns out to be cheaper than, e.g., some bare structural steel. An optimisation is also the way to avoid overquality. Correspondingly, a 3D print made of traditionally used material may wrongly bolster the idea that additive manufacturing is generally costly. Often, a long printing time caused by a heavy structure increases the price to be unattractive.

With well-thought materials and designs, metal additive manufacturing brings cost savings and strengthens the industry's competitiveness.

Image: Metal additive manufacturing helps the industry benefit from new materials considerably.

The process of material selection in metal additive manufacturing

In metal additive manufacturing, the starting points are the functional targets and the purpose of design, not the manufactural restrictions. Material choice has a significant impact on the result. In the following, we represent the process of material selection.

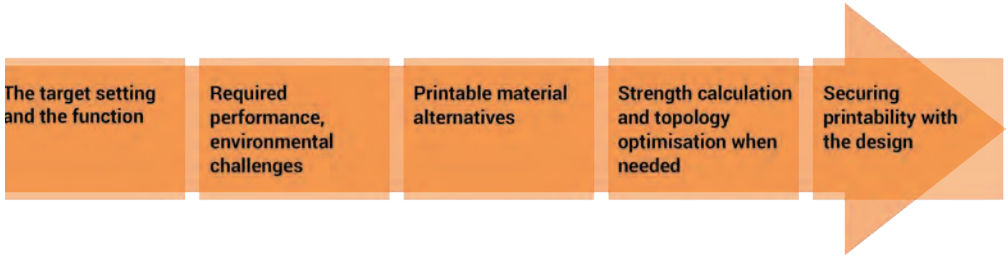

Image: Material selection process in metal additive manufacturing.

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The power of examples

More and more companies utilise metal 3D printing to improve their processes or further develop their products and services. In the best case, 3D printing is in use all over. Next, we demonstrate two industry examples..

Inconel improves the strength and wear resistance of components in the process industry

When improving industrial processes, we often start with an existing solution, which gives the frame – and often restricts the development. Nevertheless, it is worthwhile to develop; we can gain a lot also with existing processes. The renewed structures and used materials may significantly impact the outcome.

Our customer's component is a fine example of a case where metal 3D printing considerably simplified manufacturing of an earlier hard-to-produce structure. With metal 3D printing and the new design printing enabled, the manufacturing became more manageable, the quality problems of the regularly renewed component became less, and the performance, in this case, fluid flow, considerably improved. Improvements led to a better version of the component and the whole process. Like it many times is, by 3D printing, we could lower the weight of the part. Reducing manufacturing steps saved time and money. One of the success factors is the selected material, cost-effective IN718, which enabled the streamlined design and gave an excellent corrosion resistance and high strength in use. The surface hardness solved the earlier wearing problems.

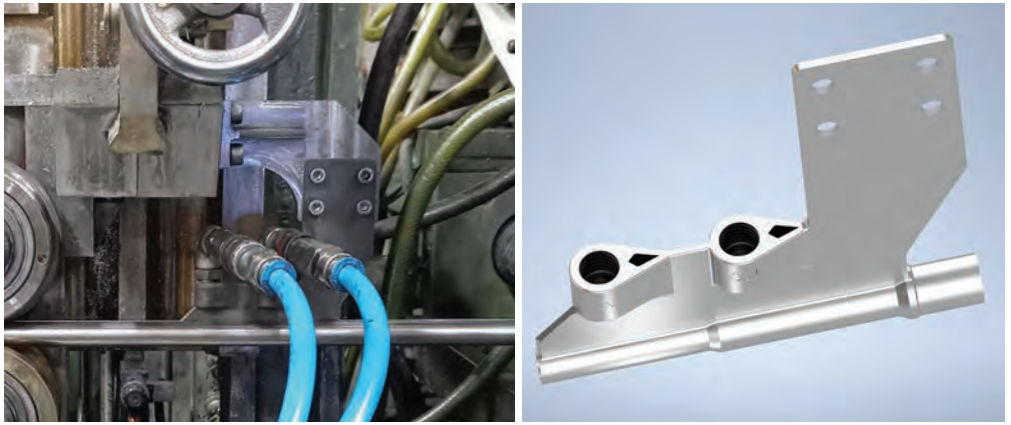

Image: Existing industrial processes can be developed with the help of metal 3D printing. With the material selection, we can grow the benefits.

New innovative solutions for snowmobile

Snowsus Oy is a company developing new, patented snowmobile suspension systems. It powerfully creates new solutions and has invented a more lightweight system for suspension. Delva is Snowsus's partner for metal 3D printing. Together the companies have refined weight and strength optimised, visually excellent component as a part of Snowsus's solution.

In the project's first phase, the prototype was additively manufactured of tool steel MS1. MS1 is an inexpensive printed material, enough for evaluating the functionality. In addition, MS1 is easy to join other structures by welding. The component can be further lightened in the next phase using different materials like titanium. Taking advantage of the high strength of titanium, the solution will be cost-efficient and reduce the mass of the whole suspension system further.

Generally, weight is a significant factor in mobile solutions, and metal printing is also an enabler here. We can assume that following electrification, the significance of the weight is becoming even more critical; batteries and other electrical components cause extra weight, which we must compensate for by lightening other parts. Here is also the central idea of the before described solution; the range of electric vehicles is related to their weight and charge capacity. Mass reduction of off-road vehicles makes very much sense and is meaningful also from the environmental perspective.

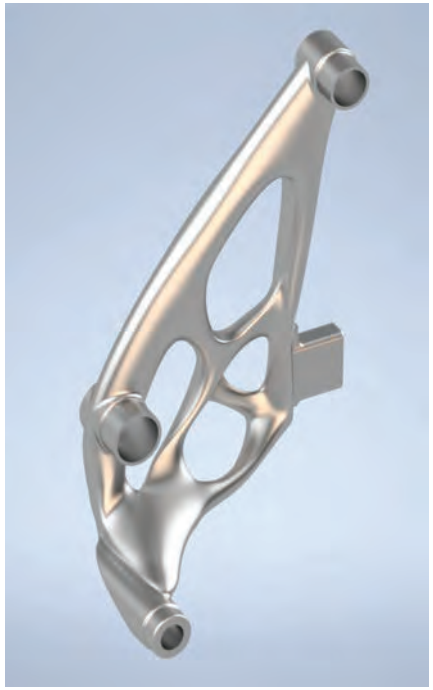

Image: Weight and strength optimised, a visually well-thought metal print is part of a suspension solution.

Image: Snowsus has innovated a lighter solution to a snowmobile suspension system using metal 3D printing.

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The need and the solution

Printed materials are available for most needs. We have gathered some environmental and performance factors typically affecting the material choices in the following.

A printed component manages corrosion

The corrosion resistance of printed components is at least the same level as conventionally manufactured parts. This is a sound basis for designing free-formed, 3D printed parts for highly corrosive environments.

- Different studies show that printed 316L has even better corrosion resistance than conventional material, thanks to different microstructures and low content of Cr-rich precipitates. Printing decreasing MnS inclusions improves pitting corrosion resistance, which makes a printed component, also in this perspective, better than conventionally produced.

- According to studies we have gone through, printed Ti64 is very similar to Ti64 produced conventionally.

Sources 1-4

Stainless steel is a common choice for many of us. Steel includes a minimum of 10,5% chrome, which creates a self-amending oxide layer on the product surface. Stainless steel is suitable for 3D printing. Depending on the surface quality requirements and the targeted dimensional accuracy, printing using slower or faster parameters is possible. The parameters directly connect to the printing speed and the price through it.

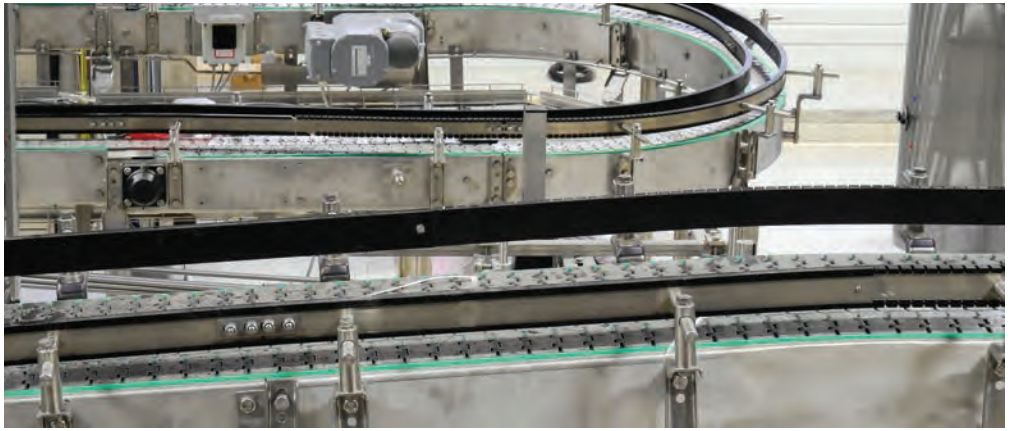


Image: Corrosion resistance is an essential feature for industrial components. Metal prints fulfil this requirement very well.

Sometimes there is a point in reinventing the wheel: the features we can reach with Inconel are generally better than 316L. Inconel 718 has a yield strength of around 1200 MPa, Inconel 625 has 650 MPa, and 316L has only 500 MPa. The PRE-figure describing the corrosion resistance is for Inconel 625 52, Inconel 718 27 and 316L 26. The excellent corrosion resistance works for Nickel Alloys exceptionally well in low and high temperatures. The thermal conductivity of 316L is better than Inconel, and according to current understanding, it is also preferable in food industry applications.

Dense, denser, a 3D print – but only if you want it like that

The 3D printed component's density is with all combinations of EOS materials and related parameters shown to be excellent. The density of Inconel 718 is 99,97%, and titanium is on the same level. Stainless steel 316L has a density of 99,9-99,95% - near the earlier ones. In summary, we can say that the densities of 3D-printed parts are very near to the forged materials.

Metal printing allows us to create nondense structures too. Holes with a one-millimetre diameter or even 0,2-0,3 mm can be printed, depending on the material. This opens possibilities for new implementations.

Thermal and electrical conductivity

In many applications, good electrical or thermal conductivity is desired. These requirements are decisive in material choice. Aluminum has good conductivity and is widely in use in 3D printing. Copper, for example, is quite a newcomer as a 3D printing material choice, and it brings new possibilities to carry out different solutions.

Image: Printed copper has the same thermal and electrical conductivity level as the conventionally manufactured parts.

The rule of thumb is that 3D printed and heat-treated components have similar thermal and electrical conductivity to components manufactured with conventional methods. If you need support, please, contact our experts.

Joining and hybrid printing

Welding is a conventional and much-used joining method in machine building. Metal printing considerably reduces welding, as the components are manufactured in one piece. However, also the printed parts need to be joined with other structures. Welding of different material pairs has been studied to a certain extent and is studied constantly more. The general rule is that 3D printed parts are as weldable as other materials. The challenge might be that the materials we print are typically more challenging to weld, such as Inconel. These are weldable, too but require extreme expertise. If you do not have the necessary skills available, you can always contact Delva.

Image: Delva is an expert in hybrid printing.

There are a lot of structures where combining conventional manufacturing and metal 3D printing brings considerable cost advantage. In these cases, the machined component is fixed to the building plate, and the more demanding structure is printed on it, a structure with cooling channels as an example. It is not a simple matter as we need to consider several things. For example, the heat-carrying capacity of the machined part, suitability for joining, and adjustment of the printing are matters where we, as your partner, are ready to support you.

Materials and their characteristics

The descriptions of materials Delva is printing are available on Delva's website, https://delva.fi/en/3d-materials/.

In the following, we have picked up some central characteristics of each material. More details you can find on the websites.

Material	Tensile Stregth	Density	Commonly valued characteristics	Applications
Inconel 718	Even 1400 MPa (1170 MPa @ 680°C)	8,15 gr/cm3	Hardness 47 HRC Wear and corrosion resistance High expansion steel Kuumaluja Cost-efficient to print	Components for demanding environments in the process industry Instrumentation Energy industry Burners and gas turbine components High-temperature nozzles Heat exchangers, valves, pumps, etc.
Maraging Steel MS1	2000 MPa	8,05 gr/cm3	Hardness 54-57 HRC High strength Machinability Properties adjustable with different heat treatment	Injection moulds Tools and equipment Structural components requiring high strength Components that require durability
Maraging Steel 1.2709	2250 MPa	8,05 gr/cm3	Hardness 54-57 HRC High strength Machinability Easy to polish	Injection moulds and inserts Tools and equipment Structural components requiring high tolerance
Titanium Ti 64	1080 MPa	4,4 gr/cm3	Excellent strength-to-lightness ratio Excellent corrosion resistance Good printability	Robotic grippers Light machine parts Competitive sports (motorsports, boats, etc.) Aviation components
Stainless Steel 316L	600 MPa	7,97 gr/cm3	High ductility and toughness High strength High corrosion resistance	Food industry Chemical industry Heat exchangers Enclosures Consumer products
Aluminum AlSi10Mg	320 MPa	2,67 gr/cm3	Light material Good thermal and electrical conductivity Fast to print, so cost-effective High corrosion resistance	Heat exchangers Electrically conductive components Light yet strong structures Robotic tools, grippers Replacing casting Protos
Inconel 939	n.1500 Mpa (1400 MPa @ 600°C) (800 MPa @ 800°C)	8,15 gr/cm3	Excellent mechanical properties in high temperatures Excellent corrosion and oxidation resistance	Gas turbine components Burners Turbos Demanding components for the process industry Thermal protectors
Copper CuCP	n. 220 MPa	8,95 gr/cm3	Commercially pure copper (> 99.95% purity) Excellent electrical and heat conductivity	Electrical motors Inductors A variety of industrial applications require excellent conductivity properties

The material offering is developing

The offering of printable materials is developing. For example, we can mention new aluminum alloys, tool steels selection, Super duplex, magnetic materials, and case hardening steels.

It is also possible to apply new processes developed for existing materials, e.g. enabling printing with different layer thicknesses. Increasing the layer thickness speeds up the process and saves printing time, whereas decreasing it slows the speed down and helps to produce highly accurate characteristics. Printer manufacturers also supplying printing powders work hard to develop new, but so are many others. Metal printing is an attractive business opportunity.

A homogenous powder will not be enough while bringing new materials into use. To have success in printing, we need material and printer-specific parameters. Additionally, we need appropriate heat treatment. These factors need to work reliably and repeatably, and the development results must be tested and verified. A service provider needs to know the new material and its printing process inside out and have experience and a profound understanding of the details to be considered while printing.

Moreover, we must remember that a printing process needs much more powder than the actual printed parts; the powder is always spread out to the whole building plate, not only where the component is printed. Separate accessory equipment for each material requires investments. These are examples of why each new material needs volumes to be commercially reasonable.

Image: In the metal printing process, the amount of needed powder is many times bigger than the volume of the actual printed parts.

Shall I stick to familiar and safe or get to know something new?

The best way to utilise all the benefits metal printing offers is to carefully consider the performance and qualities required at the early beginning of the project. After these have been recognised, replacing a conventional material even with "overquality" can be considered to improve cost-effectiveness and to have a better overall solution. Printing cast iron makes no sense. In 3D printing, you can choose materials from a new perspective, as the price difference is no longer significant. Openness to options is important because a novel material can offer features that lead your solution to a new level.

The target and the purpose are decisive – also when selecting material.

Below are a few examples of alternatives for specific materials to get started.

Additive manufacturing enables you to choose also different materials than traditionally used:

Stainless Steel	▶	**Inconel**
Stainless Steel	▶	**Titanium**
Casted-iron	▶	**Aluminum**
Aluminum	▶	**Titanium**

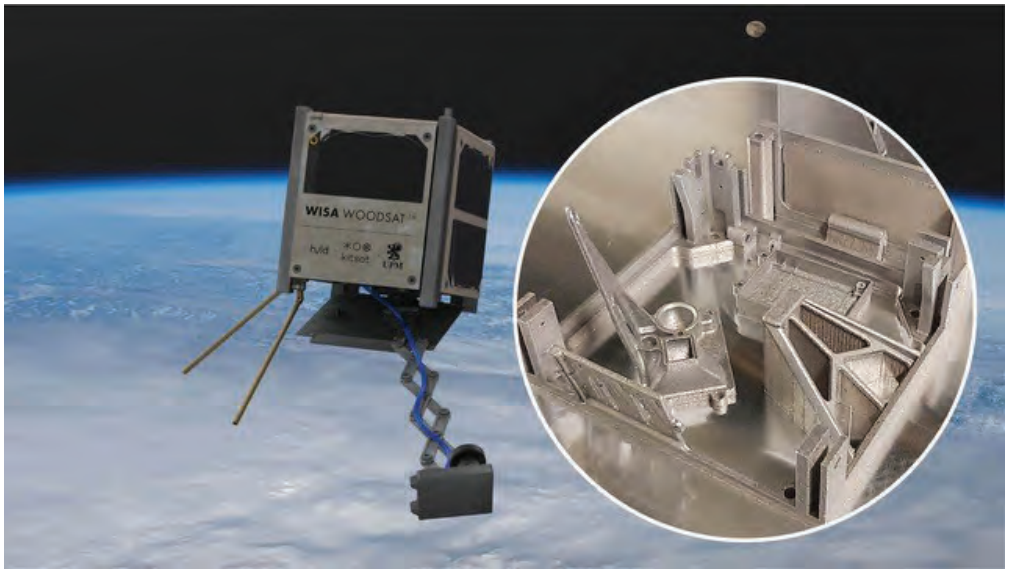


Image: The target and the purpose are decisive – also when selecting material. In the picture, there is the Wisa Woodsat with printed metal parts..

Conclusions

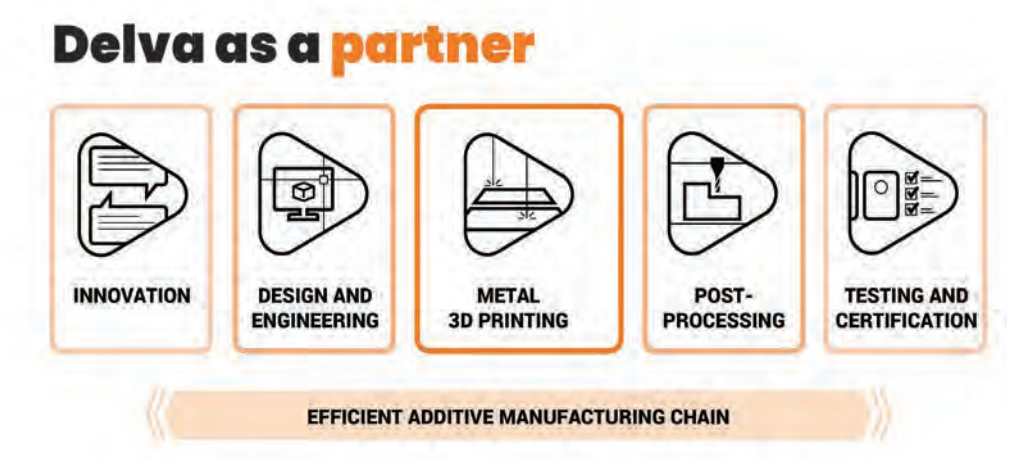
Delva's recommendations that will lead to a successful material selection are:

- Think out of the box; renew; think what is possible.
- Don't be afraid, do not assume certain materials to be expensive or hard to get. Remember that in metal printing, many things are differently.
- Listen to an expert, ask and challenge.
- Design something better – we all want to succeed; this is your chance!

May we help you with our metal 3D printing expertise – layer by layer

Delva is your experienced expert in industrial metal printing. As your partner, we offer co-development that goes deeper than the surface to find optimal solutions to our customers' individual needs.
We ensure quality results by combining the customer's knowledge of the requirements and possibilities of the components with our expertise in Metal AM. Delva offers you the whole additive manufacturing process as a service.

With our leading technical expertise, extensive metal 3D printing material portfolio, and insight into the possibilities, we have significantly maximised the benefits of industrial 3D printing for our customers. Delva supports companies from the very beginning to finished components.



Maybe you already have the first thought you would like to examine further, a more mature one, or a bold new idea of where you would like to apply metal 3D printing. Delva helps customers identify new applications for the technology and to increase their overall AM maturity.

Delva is your skilled partner in industrial metal 3D printing. We are tirelessly interested in the details and pave your way to stay ahead of the AM game.

Feel free to contact us to discuss further how metal 3D printing can support your organisation's competitiveness.

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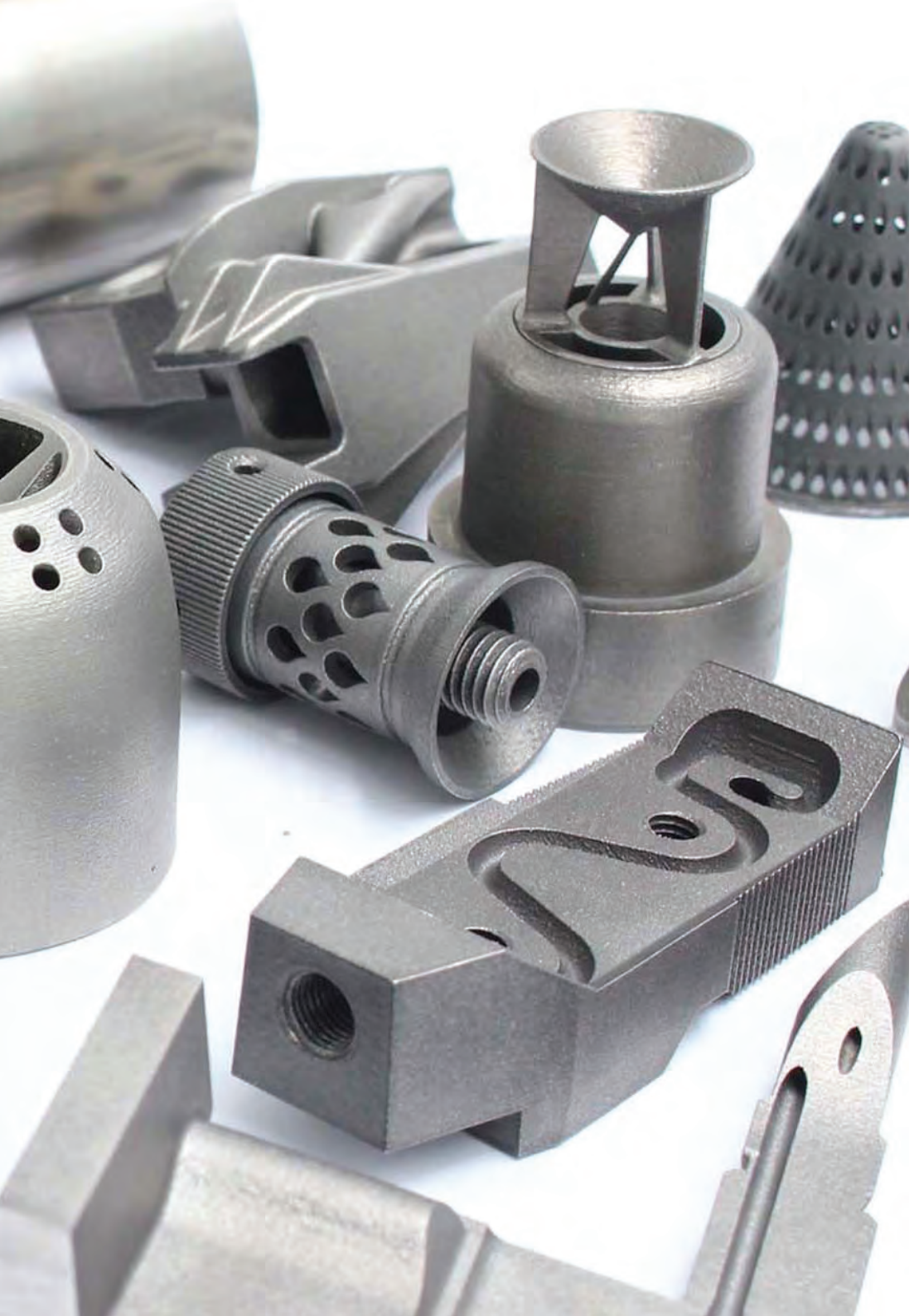
Metal 3D printing technology is developing and moving forward at a fast pace. Embrace this mature technology and improve the competitiveness of your company.



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