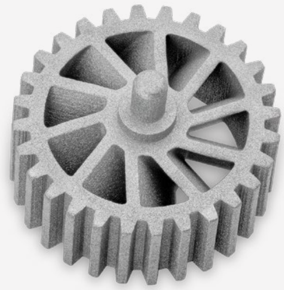


ADDITIVE MANUFACTURING OF SMALL AND MICRO METAL PARTS

Guide to choose a suitable AM technology for your application

WHITEPAPER

MetShape GmbH

www.metshape.com

info@metshape.com

Introduction

Additive Manufacturing (AM) which is also known as 3D printing has received increased attention over the last couple of years and has proven to be an innovative manufacturing technology that can be applied in multiple industrial sectors.

However, the term „Additive Manufacturing“ includes a large variety of technologies that offer different advantages and disadvantages. Moreover, according to the desired characteristics of the finished part, one technology can be more suitable for the manufacturing of the part than another.
This results in the challenge to select the adequate technology for a specific application.

With so many different and especially rather new technologies on the market it is challenging to possess the needed knowledge and experience in order to choose the adequate technology.

Therefore, the following guide is supporting readers to solve this challenge by giving them an overview about the different factors that should influence the decision when choosing an AM technology for a specific application. This Whitepaper exclusively focuses on AM technologies that are suitable for the manufacturing of small and micro metal parts.

Apart from the guide, this paper offers a short introduction in AM as it includes an overview of the benefits as well as a landscape of the different technologies. Moreover, a description of the difference between direct and indirect technologies is provided.

Benefits of Additive Manufacturing

The various advantages that additive manufacturing offers show the possibilities and opportunity it can bring to businesses.

As a result of the different advantages AM offers, the manufacturing technology is already applied in a wide range of applications and areas in which industrial production is applied.

LMM part of MetShape

Freedom of design

The freedom of design that is possible with AM contributes to the development of new innovations. The unique production process where a part is built up layer by layer offers high flexibility, especially regarding the shape of a finished part and reduces restrictions in design. For many geometrically complex designs and shapes, the only alternative to AM is the manufacturing by hand.

LMM part of MetShape

Time & cost saving

In AM there is no need for tools or fixtures for the manufacturing of the desired parts which eliminates unnecessary production steps and contributes to reduced production costs and less risk.
Especially for the production of prototypes, single parts and small series AM presents a cost- and time-efficient as well as flexible manufacturing technique.

LMM part of MetShape

Precision & complexity

With AM it is possible to manufacture highly precise parts with extraordinarily complex geometric structures that are frequently demanded by businesses. Here AM clearly outperforms traditional technologies as they are either not capable of producing a part with the mentioned characteristics or the manufacturing would involve an unjustifiable high effort.

LMM part of MetShape

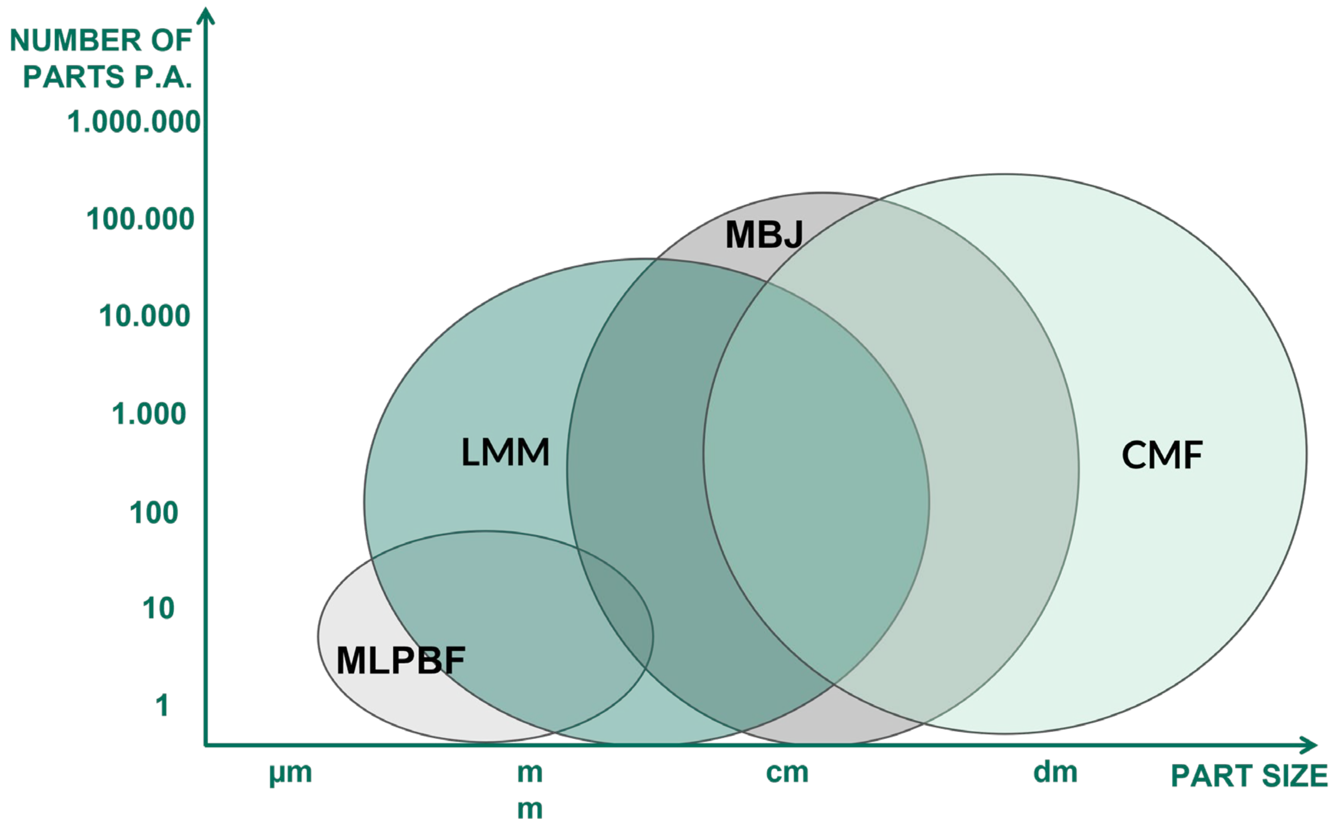
Individual & function optimised parts

AM enables the customization of parts. Especially, in sectors such as medical technology patient-specific parts are needed which would be complicated to produce with traditional manufacturing technologies. Functional requirements of the part can be fulfilled much easier than with traditional manufacturing. The possibility for funcitonal integration is another benefit that AM offers.

Overview of AM technologies

The graph displays an overview of the different AM technologies that are suitable to manufacutre small and micro metal parts. It also already demonstrates the challenge to choose the suitable technology for a specific application.

Of course there are much more AM technologies available on the market, however they are not covered in this whitepaper as it focuses on small and micro parts.



Direct & indirect technologies

Additive manufacturing technologies can be grouped into two categories, which are direct and indirect technologies.
Direct AM technologies are characterized by a one-step process where the part is directly produced during a welding process. Well-known examples of direct AM technologies are LPBF (Selective Laser Melting (SLM)) and Electron Beam Melting (EBM).
Indirect methods are characterized by a two-step process. In the first step, a green part is printed which subsequently is debinded and sintered.

Only in the last couple of years indirect methods reached increased attention. The reasons for this are the high productivity and the advantages that arise in the production of green parts, such as the fact that no support structures are required, which reduces or even eliminates cost-intensive post-processing.
Compared to direct, indirect methods are less explored yet. Especially, Metal FDM and binderjetting are well-known indirect AM technologies.

	Direct AM technologies	Indirect AM technologies
Process	One-step process: „direct“ manufacturing of part through a welding process	Two-step process: 1. manufacturing of green parts 2. debinding & sintering of green parts
Advantages	• comparatively short lead times • application on existing structures possible • high reproducibility • widely used and developed	• high output rate • quality control & Processing in green part condition possible • large variety of materials possible • component properties comparable with established MIM technology
Disadvantages	• high thermal stresses / distortion makes support structures necessary • high heat input • mostly sensitive processes • weld structure • comparatively rough surfaces • often edge porosity	• complex process chain • distortion due to sintering process • shrinkage tolerances • component densities <99.9
Examples	LPBF, M-LPBF, EBM	LMM, CMF, MBJ

LMM parts of MetShape

Challenge of choosing a suitable technology
for your appplication

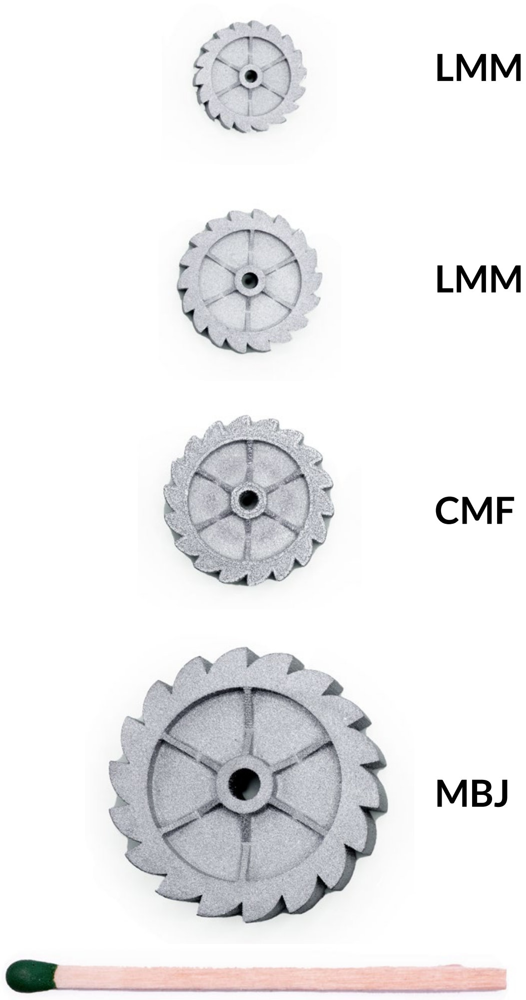
When deciding to apply additive manufacturing as a manufacturing process, the challenge appears to select a suitable technology for your application. However, as mentioned the term „additive manufacturing“ includes a wide range of technologies available on the market that differ in several aspects. For instance, not every technology is suitable for every application and requirements of the finished parts such as the roughness of the parts surface, precision, dimensional accuracy, and other characteristics of the desired part such as size or mechanical and material properties are decisive factors that need to be considered when choosing an AM technology.

Each technology offers different advantages as well as disadvantages and has its targeted applications. Therefore, it is crucial to choose the right manufacturing technology to match the application.

Guide to choose a suitable technology
for your application

This guide focuses on a comparison of four different AM technologies that are suitable for the manufacturing for small and micro metal parts which are Binder Jetting (BJ), Cold Metal Fusion (CMF), Lithography-based Metal Manufacturing (LMM) and Micro-Laser-Powder-Bed-Fusion (M-LPBF). As mentioned, there are many factors influencing the decision for the best AM solution for a specific application. The main factors discussed in this paper regarding the named technologies are surface quality, part size, precision & tolerances, lot sizes and costs.

LMM parts of MetShape



Parts of MetShape

Part size

The part size is a decisive attribute when deciding which AM technology should be chosen for the manufacturing of the desired application.

Moreover, in indirect AM technologies an important aspect to consider is the solidity of the green part that is manufactured during the process with a specific AM technology. This is also connected to the challenge to extract the green part out of the printer.

In general M-LPBF and LMM are the technologies which are best suited for small applications within 5mm in length, width and height. MLPBF can be efficiently used for parts up to 20mm in all dimensions and LMM is applicable for parts up to 35mm in each dimension. Metal Binder Jetting is best used for parts bigger than 5mm due to the lower surface quality and accuracy. For applications above 50mm CMF is a good alternative even tough the surface is significantly worse than with M-LPBF or LMM.

Surface quality

The surface quality of the part can be another crucial aspect when deciding which AM technology to apply. In some technologies support structures are required during the process which usually leads to surfaces with a higher roughness as the support structures need to be removed, which is often a manual process. Moreover, in sinter-based AM technologies the know-how regarding the sintering process can be decisive for a excellent surface quality. This also means that cost-intensive post-processing is needed. If the technology is sinter-based, the sintering know-how of the provider is another decisive variable that influences the quality of the surface.

For very smooth surfaces LMM is probably the best technology, because a surface roughness of 2 µm without post processing can be achieved. If a polishing procedure is used afterwards the surface can get even better than 1 µm. M-LPBF can achieve a surface roughness of 3 µm, but usually post processing is needed to remove all support structures. The surface quality of BJ applications is with about 5 µm also suitable for many parts. From the technologies described in this whitepaper CMF has the highest surface roughness with a value of 17 µm without post processing or polishing procedures.

CMF

LMM

parts of MetShape

M-LPBF

M-LPBF part of 3D MicroPrint

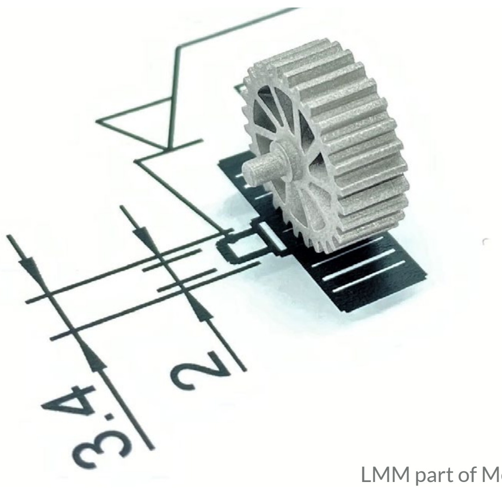
Costs

To generate a cost comparison between the evaluated technologies the part shown below was selected, which is printable with all four technologies. The prices were calculated for a series of 10 prototypes and the sizes of the part is 14 mm in diameter and a hight of 3 mm. The costs for 10 parts with M-LPBF are 3.800 euros, so 380 euros per part. With LMM its about 48 euros per part and with BJ 38 euros. The least costs arise with the CMF technology with only 10 euros per part.

Tolerances

Achievable tolerances and the precision of a technology are very important for functional applications, which have to work in combination with other parts. Therefore it is necessary to know which technology can reach the needed tolerances. Like the surface quality also the tolerances highly depend on support structures which some technologies need.

The best accuracy of micro applications can be achieved with M-LPBF, where in best cases tolerances within ±0.005 mm (ISO 2768-1 f) can be guaranteed. With LMM tolerances up to ± 0.05 mm (ISO 2768-1 f) are achievable whereas BJ and CMF claim tolerances between ± 0.1 mm (ISO 2768-1 m).



LMM part of MetShape

Parts of MetShape

Lot size

Also the lot size is a relevant factor for the decision of a suitable technology. Some processes have a very high productivity where others require manual post processing which will decrease the productivity.

In general M-LPBF and BJ are technologies best used for prototypes or small series. Especially BJ is not that reproducable in terms of consistent results due to complex process parameters. LMM is a technology which can be used for small series or even lot sizes up to 100.000 parts, if the application is quite small. This is due to the fact, that the building chamber is quite limited and the smaller the part the more parts can be printed in a short period of time. The best solution for mass production is CMF due to a high productivity and reproducability of the technology.

MetShape

Summary

Each technology has its own advantages and disadvantages. The suitable technology for your individual application depends on several factors. You need to consider which factor is crucial for your application. Do you need a tolerance of +/- 0.05 mm or is it more important to save costs. In the table below the facts and classifications of the technology specific factors are shown to help you find the best solution for your application.

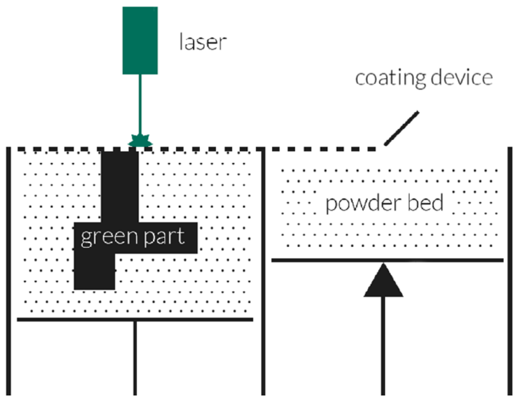
We believe there is a technology for every kind of need. Indentify your most important factors and you'll find the technology you can start your AM experience with, accelerate your development and improve your products. If you need some further assist for choosing a technology do not hesitate to contact MetShape. All contact information can be found on the last page of this paper.

FACTOR		M-LPBF	LMM	MBJ	CMF
Part size	1 - 5 mm	++	++	+	-
	5 - 50 mm	+	+	++	+
	> 50 mm	-	-	++	++
Surface	[Ra in µm]	3	3	5	17
Tolerances	[in mm]	± 0.005	± 0.05	± 0.1	± 0.1
Support structures		yes	no	no	no
Lot size	1 - 99	++	++	++	-
	100 - 999	+	++	+	++
	1.000 - 9.999	-	+	-	++
	≥ 10.000	-	+	-	++
Costs	[in €/pc]	380	48	38	10

Glossary: description of technologies

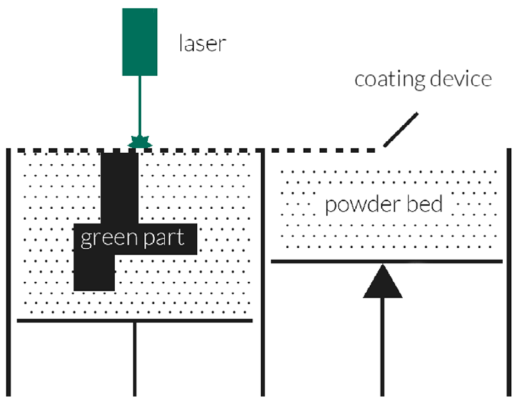
Micro-Laser-Powder-Bed-Fusion (M-LPBF)

The M-LPBF Technology is part of the direct additive manufacturing technologies. In comparison to LPBF even finer powders (1-5 µm) and even smaller layer thicknesses can be processed.
During the process, the fine-grained powder material that is melted by laser radiation. Then the melted powder solidifies and forms a solid material layer. A three-dimensional component is created by a corresponding number of connected layers as a new layer of powder is applied and processed repeatedly until a finished part is created.



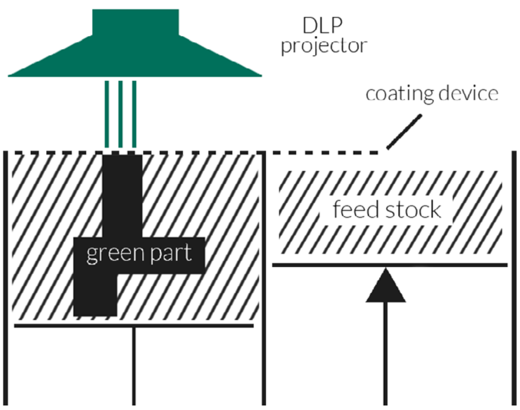
Cold Metal Fusion (CMF)

Cold Metal Fusion is also an indirect AM technology. Similar to the LMM technology a feedstock is created consisting of metal powder and binder. This feedstock is then melted during the 3D printing process to get a green part. The feedstock system can be processed on selective laser sintering (SLS) 3D printing system. During this process the green part is created layer by layer as the feedstock is melted. As a second step the green part is then debinded and later sintered to get a finished part.



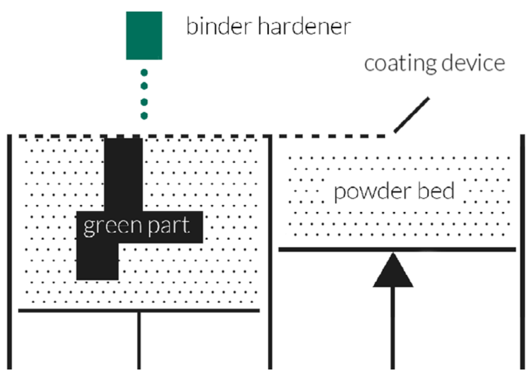
Lithography-based Metal Manufacturing (LMM)

The LMM technology is an indirect AM technology which is characterized by a two-step process. The starting material is a combination of metal powder and photosensitive polymer binder. This so-called feedstock is applied to a building platform and selectively crosslinked from above by means of mask exposure of UV light. Layer by layer, a green part is created. This green part is then debinded and sintered.



Metal Binder Jetting (MBJ)

MBJ is an indirect AM technology that includes two process steps to create a metal part. In the first step a green part is printed by applying loose particles of metal powder to the platform of an ink jet printer. Those particles are then connected layer by layer using a binder which is applied by the printer. After the application of the binder the platform of the printer is lowered, and e.g. a counter-rotating roller or a blade applies a new layer of powder on top of the previous layer. This "new" layer is then connected to the previous layer through the binder. The part is then tempered and as a second production step the resulting fragile green part is sintered at high temperatures creating a solid finished metal part.



LMM parts of MetShape

About MetShape

MetShape GmbH is a production service provider specializing in sinter-based additive manufacturing of small and micro metal parts. The company was spun off from Pforzheim University in April 2019 and has been developing very dynamically ever since.

The idea to found the technology start-up arose during a research project on the recycling of rare-earth magnets, in the context of which the Lithography-based Metal Manufacturing (LMM) technology was developed. This technology makes it possible to print high-precision metal components with exceptionally good surfaces.

Meanwhile MetShape has developed a unique process know-how and focused especially on the sintering process and consequently also offers services alongside the part production with the LMM technology.

With its unique sintering know-how, MetShape offers high-quality, finished components that can be used for series applications, compared to other 3D printing service providers that specialize in prototypes and single-part production. In addition, MetShape offers its customers who use other sinter-based additive manufacturing technologies to sinter their parts at a high quality.

MetShape GmbH
Tiefenbronner Straße 59
75175 Pforzheim
Germany

info@metshape.com

+49 (0) 7231 3744 180

www.metshape.com