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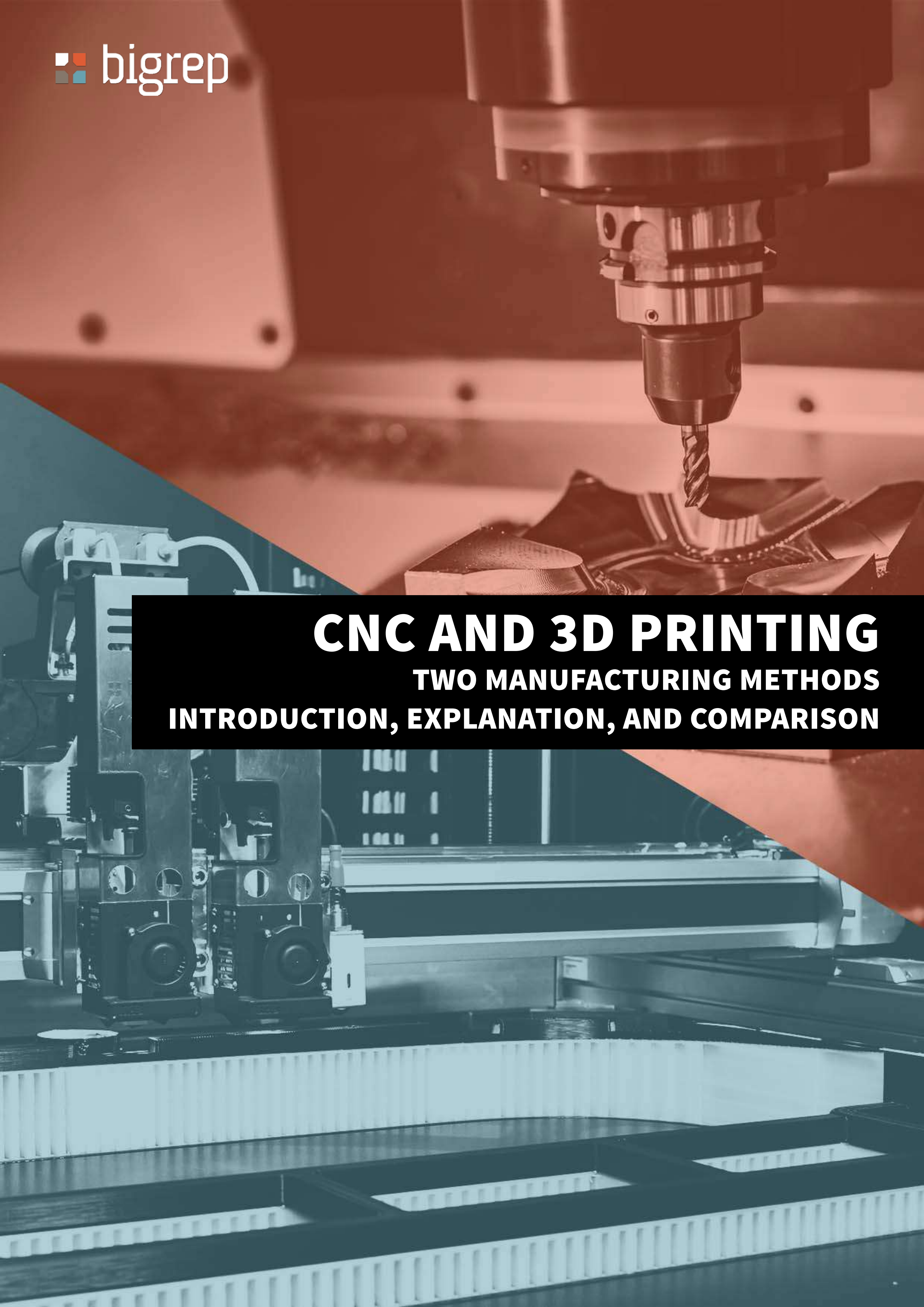


CNC AND 3D PRINTING

TWO MANUFACTURING METHODS
INTRODUCTION, EXPLANATION, AND COMPARISON

INTRODUCTION

For centuries, subtractive machining was the backbone of modern industrial manufacturing, eventually culminating in mills and lathes controlled by computers. Ever improving tools, materials, and control algorithms provided continuous market growth. By adopting new technologies like IoT (Internet of Things) and integrating and automating CNC (Computerized Numerical Control) machines, this manufacturing method is guaranteed to stay.

In the past 20 years, however, additive manufacturing, more commonly referred to as 3D printing, has become increasingly prominent in factories and production sites worldwide. Images of industrial parts, objets d'art, and even buildings, all 3D printed by various methods, can be found in news channels, magazines, and all over the internet. Additive Manufacturing (AM) offers enormous possibilities in terms of productivity and creativity and lets designers and engineers produce objects that were unthinkable a few years ago.

So many ask about the future importance of both manufacturing methods: if one or the other will be dominant in the next few years, will one replace the other, or if and how they can complement each other.

Two Manufacturing Methods: Introduction, Explenation, and Comparison.

CNC MACHINING

The basis for CNC machining is a commonly known subtractive manufacturing method, mainly milling and turning. By adding computerized control and automating the workflow using CAD/CAM software, these methods turned into CNC (Computerized Numerical Control) machining. Adopting new technologies like IoT (Internet of Things) and integrating and automating machines to a much larger extent guarantee that this manufacturing method will continue to play an important rule among all industries.

All CNC methods have a few things in common:

- A part is designed using CAD software.
- Tool paths are calculated by a CAM solution.
- A blank of the desired material is placed in the machine.
- The material which will not be part of the final object is turned into cuttings/dust.
- The tools must be able to reach the final boundary surfaces of the final object.

3D PRINTING

Additive manufacturing (AM) has only become a household name in the past 20 to 30 years. In AM – commonly known as 3D printing – parts are created by adding layer after layer of a base material until the final shape is established. The base material can be a liquid substance, like a resin, but it can also be a solid, like a powder or filament. All these processes have in common that the shape of the final object is independent of the shape of the base material. That means that small and big, cylindrical and cube-shaped, and all other objects are created from the same base material, and the final shape is determined by the manufacturing process alone.

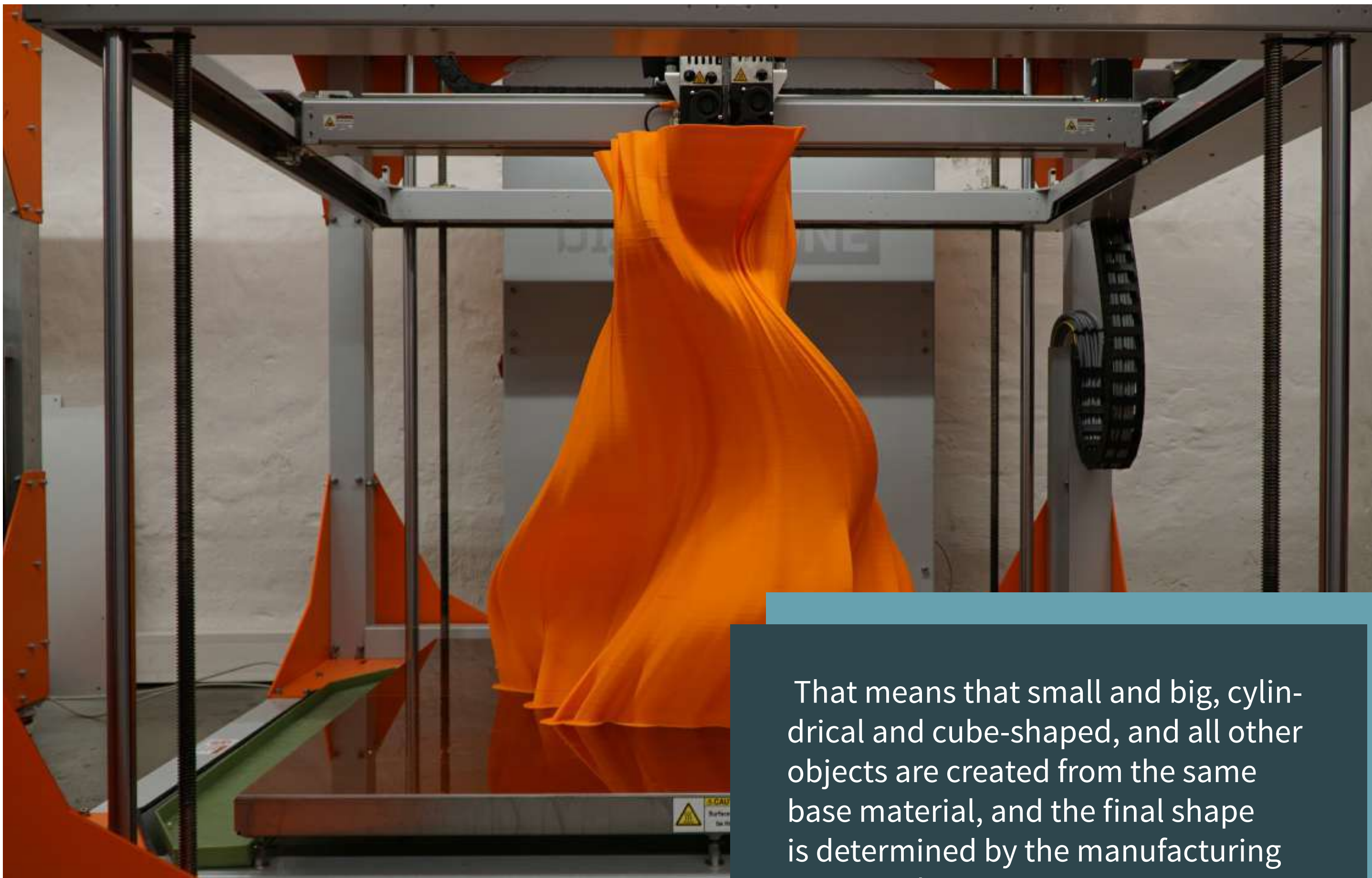
The workflow is quite simple:

1. An object is designed in CAD software so that a 3D model is obtained.

2. Another software (unless the CAD software has this functionality included) called a "Slicer" software slices this 3D model into individual layers. The height of these depends on parameters like desired print quality and speed, the machine setup, the print material, etc.

3. The sliced file is sent to the 3D printer.

4. The machine then builds up one layer after the other, moving up a layer whenever the previous one is completed.



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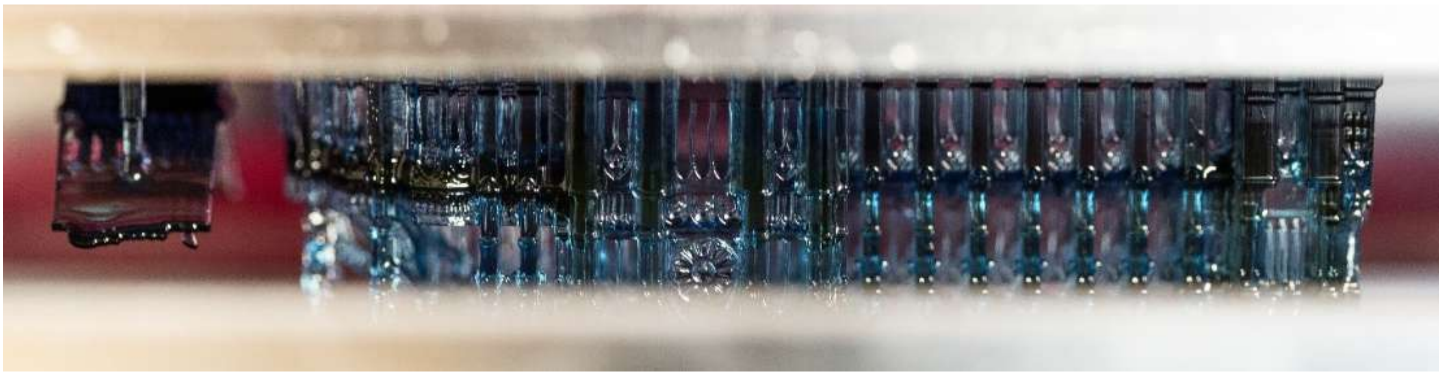
Fused Filament Fabrication

FFF is also known as FDM, under which name the process was patented in 1989. The basic principle is quite simple: A string of plastic filament is heated before being extruded through a nozzle. The nozzle is positioned directly above an often-heated surface, called the build plate. Then while extruding heated plastic through the nozzle, it is moved around so that the extruded material forms the first layer of the part. Then the nozzle and the build plate move one layer height further apart (either by moving the nozzle up or by moving the build plate down, depending on the 3D printer's mechanical design), and the next layer is formed. Among the AM manufacturing processes, FFF can produce the largest parts. Machines that can generate objects of up to one cubic meter - like BigRep large-format 3D printers - are commercially available.

Stereolithography

This process is also layer-based, as is FFF. But instead of filament, SLA 3D printers operate with photopolymers, a light-sensitive material that changes physical properties when exposed to light. Instead of an extrusion nozzle, SLA uses a laser to cure layers of a liquid resin into a physical piece through photopolymerization. As the focal point of the laser is extremely small, SLA can create objects with a high level of detail.



Selective Laser Sintering

A thin layer of metal or plastic powder is spread over a build plate. Then a laser is guided over the powder surface, melting the particles in selective areas and merging them into the first layer. After the first layer has been processed, the build plate moves down by one layer height, another layer of powder is spread over the first and the laser shapes the object's next layer. This process allows to create not only plastic, but also metal objects.

OTHER ADDITIVE MANUFACTURING METHODS

There are other 3D printing methods on the market, some of which could be seen as subcategories of the ones described above. As the AM technologies are still comparably new, inventions are still being made regularly that either improve the existing methods or come up with spectacular new ideas. Therefore, it is simply not possible to list all the current variations.

Binder Jetting

Similar to SLS in its fundamental principle, the base material for binder jetting is a powder. Rather than melting the powder, the particles are glued together by applying a binder fluid in the desired areas, using a print head quite like the ones used in inkjet printers. As no melting is required, the variety of usable material is more comprehensive, and dyed binder fluids can be used to create colorful prints.

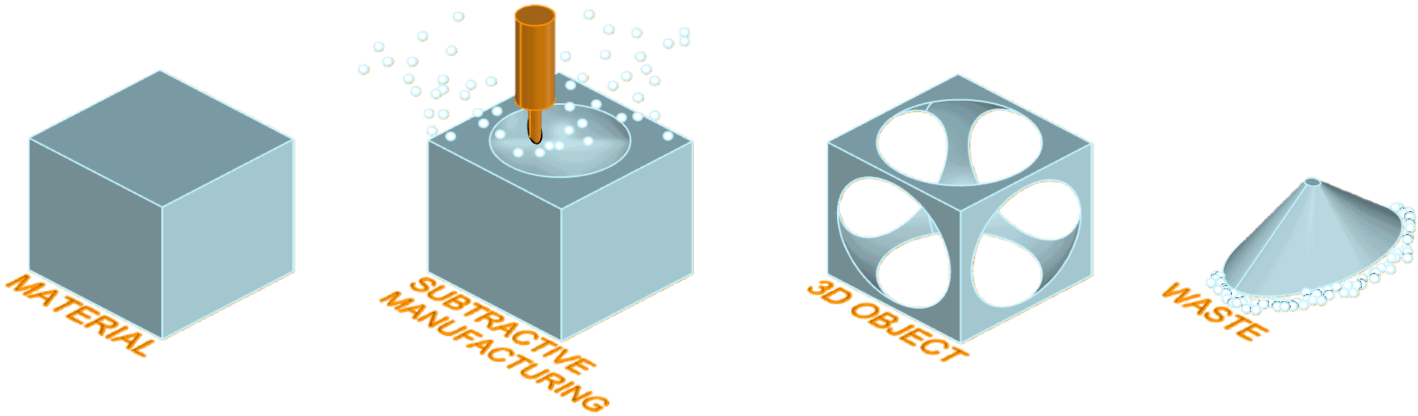
Wire Arc Additive Manufacturing (WAAM)

WAAM is similar to FFF, the difference being that an arc welder is used to form layer after layer of metal. Available material, which is supplied as a wire, ranges from various steel grades to titanium. Almost all parts produced by WAAM must be machined in post-processing to create clean and flat surfaces for the intended use.

Direct Energy Disposition (DED)

DED is one of the manufacturing methods currently being integrated into "common" machining processes. A metal powder is deposited onto a surface through a nozzle. Where it meets the surface, it is melted by a laser, and in this way, a part is formed. As the nozzle and the laser can be part of a large CNC mill, some manufacturers have already started to offer this as a part of the kit of tools available in their machines.

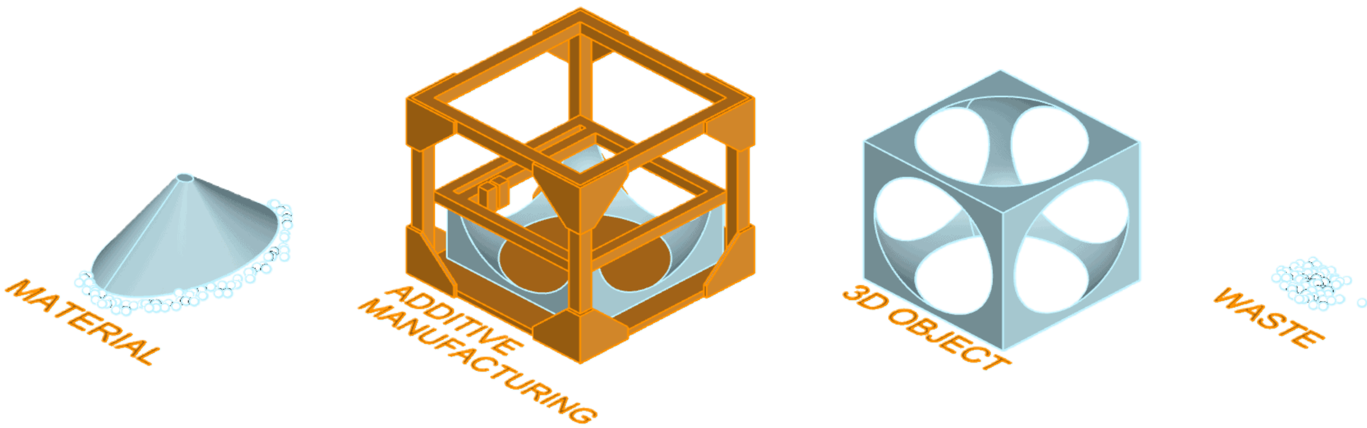
AM STRENGHTS AND WEAKNESSES



SUBTRACTIVE MANUFACTURING (CNC MACHINING)

Undoubtedly the most significant advantage of 3D printing is the total freedom to create and manufacture even the most complex objects. You can produce parts with hollow internal structures, reduce a part's weight by lowering the amount of material printed on the inside, and create organic forms that cannot be cast, milled, or manufactured in any other way. Most of the limitations posed by conventional manufacturing methods do not apply to additive manufacturing. This makes it the perfect tool for artists, industrial designers, engineers, and inventors. And as new AM technologies come into the market every year and more and more materials become available, this freedom is ever increasing.

Then there is the flexibility given by decoupling the size and shape of the final part from the material fed into the machine. No blanks are needed; a sufficient length of filament or amount of resin or powder is enough to enable the owner of a 3D printer to manufacture all the parts that come to mind. Therefore, stock-keeping is greatly simplified, reducing the time from idea to part.



ADDITIVE MANUFACTURING (3D PRINTING)

Another huge benefit is the avoidance of waste. As only the material that constitutes the final part is needed in most cases, there is close to zero waste. This increases the processes' efficiency and dramatically reduces the need to handle any waste. And this, in turn, reduces costs.

One of the biggest challenges for AM methods is the achievable level of accuracy and precision. As the process is layer-based, these layers show and create a more or less rough surface. Also, parameters like nozzle size and printing speed influence the size of possible details, so specific smaller structures cannot be 3D printed. These effects can be reduced only to some degree by choosing the appropriate process – SLA will in most cases produce more delicate details and thinner lines than FDM, for example – or by choosing different machine settings.

Also, there is the issue of available materials. As each AM process is quite unique in its working principle, the primary material properties also have to fulfill specific requirements. For example, FDM requires a material that can first be turned into a filament and then melted. This rules out metals, even though some good progress has been made in attempting to overcome this obstacle. SLA only works with photopolymers, which in most cases do not possess the same mechanical strength as other plastic materials.

COMPARISON

From the descriptions above, 3D printing and CNC machining both have their advantages and disadvantages. However, it has to be said that no definitive answers are possible due to the complexity and diversity of both manufacturing methods. It might easily be that either way can produce a part. Or there might be a case where only one single and rare type of CNC machine can produce a part that would otherwise be 3D printed. So, before you choose either product, process or machine, look into all the details of your project, get recommendations and consulting, and then make the right choice based on all the information you have gathered.

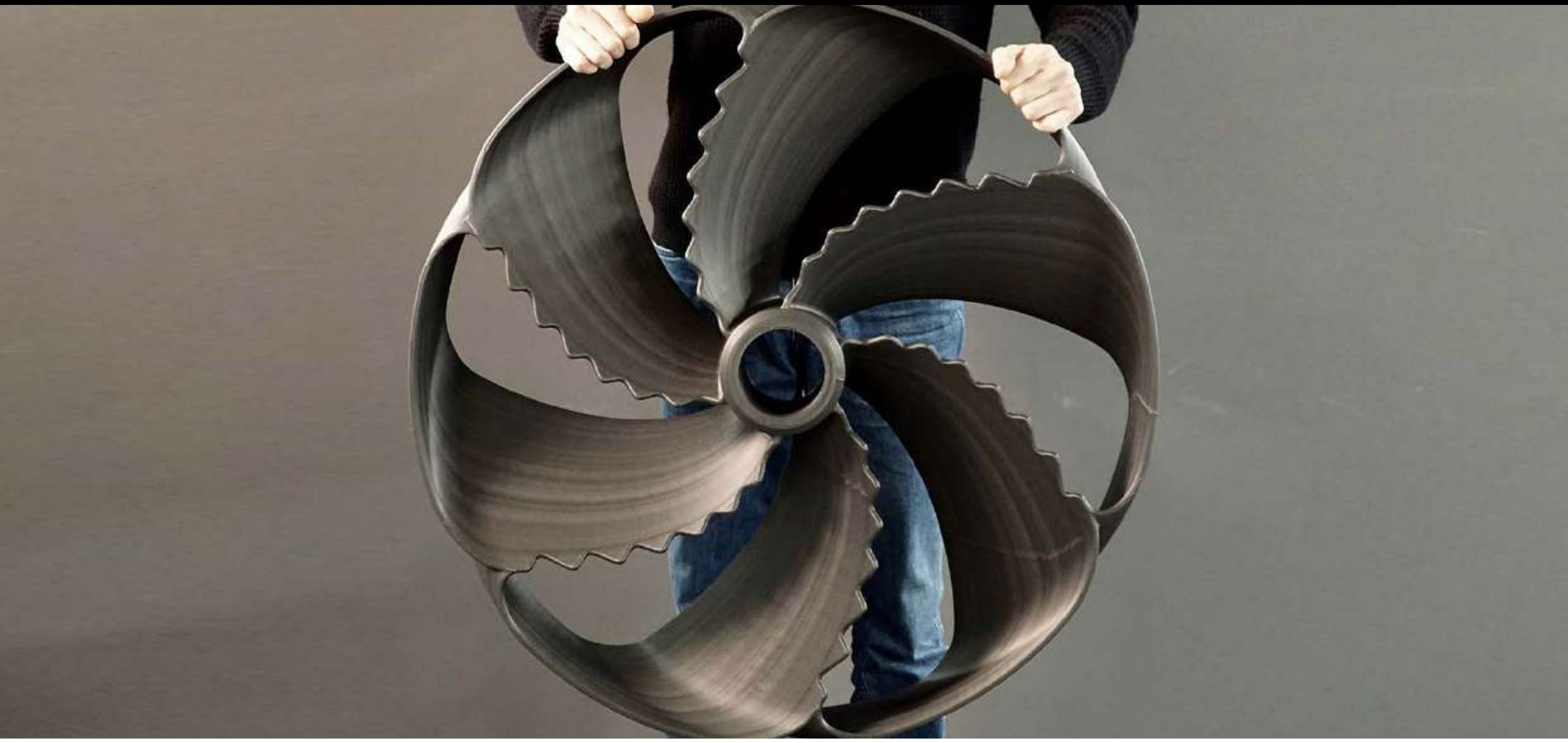
Before you choose either process look into all the details of your project, and then make the right choice based on all the information you have gath-ered.

Materials

The choice of materials that can be CNC machined is practically unlimited. There is the proper subtractive method to shape almost all materials currently used in modern-day business, industry, or arts. AM is at a disadvantage here because each of the respective methods is based on a specific working mechanism. This limits the variety of materials, whereas CNC machining only requires the right tools and machines. There are a few materials, however, where AM has an advantage. For example, it is easy to 3D print flexible materials like TPU and other elastomers, while those cannot be adequately machined and usually are cast. Biocompatible materials and parts in medical applications could sometimes be machined conventionally but often require specific properties that can only be produced by 3D printing.

Freedom of design

This point clearly goes to additive manufacturing. Even though subtractive manufacturing has come a long way since its early days, many shapes cannot be milled, turned, made by EDM, or even cast. Internal hollow sections, integral objects that are produced in one piece instead of several parts that must be glued or otherwise fixed together, and last but not least: complicated, intricate structures that are the result of a Generative Design process. All of these can typically only be produced by additive manufacturing.



Cost

The subject of costs is a more complicated matter than those above. ROI calculations are complex when two utterly different manufacturing methods are compared, as many factors come into play here. But, for example, the hourly rates for operating a large-scale FDM printer are lower than those of a similarly sized CNC machine. AM also has the edge over CNC machining in terms of miscellaneous costs. Material storage and handling, purchasing processes, and waste material treatment are much more expensive if you need specific blanks, 80% of which are then turned into chips. So, in case a modern CNC mill is used to produce parts that could also be made on the 3D printer, the costs will be lower for the printer.

Flexibility in development and production

There is a reason why additive manufacturing was initially more commonly known as Rapid Prototyping. The possibility to produce parts quickly, on-site, and without a lot of technical knowledge gives engineers and designers in all industries the chance to hold objects in their hands with minimal delay. This accelerates development cycles and increases the number of iteration steps that fit into a given time. Internal and external project stakeholders have a chance to evaluate a product early in the development stage, allowing quick and qualified feedback.

AM can also play a significant role in production. Tools, jigs, and fixtures can be made on short notice. End-use parts and other objects no longer block storage space. They don’t even have to be produced in one single manufacturing space or central factory. All it takes is the file and a 3D printer on-site, for parts to be made to order.

HOW CAN CNC MACHINING AND 3D PRINTING COMPLEMENT EACH OTHER?

The previous paragraphs have shown that Additive Manufacturing has its benefits, but that there are also situations where conventional manufacturing methods are superior to 3D printing. So it is natural to ask where both methods can be used in combination, be it on the same shopfloor or even for the same product, to bring the best of both worlds together.

Shift workload

Probably the first solution that comes to mind is to shift workload from CNC machines to 3D printers where CNC machining is not strictly required. Aluminum parts can often be made from plastic, or plastic parts of a rather complicated shape very often can be produced on a 3D printer more easily and often cheaper than by CNC machining.

An example for such an application can be seen below. A car manufacturer required a handheld device that would be customized for each type of car built.

Previously, this part was made from aluminum on the customers own CNC machines. However, due to the part's dimensions (130 cm x 14 cm x 22 cm) in-house machining capacities were limited. As shown below, not only were the manufacturing time and costs for the 3D printed part were significantly lower than with both other options. An additional benefit, especially important when a tool is concerned that is handled manually: the part made from HIGH TEMP-CF, one of our fiber filled filaments, weighs only half that of the aluminum counterpart.

HOW CAN CNC MACHINING AND 3D PRINTING COMPLEMENT EACH OTHER?

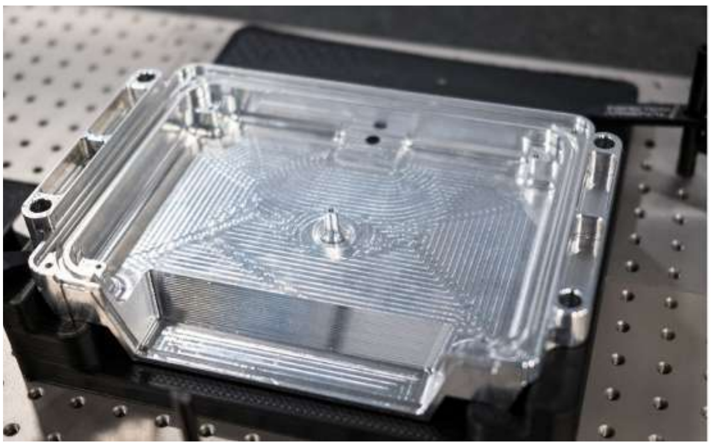
Provide customized tooling

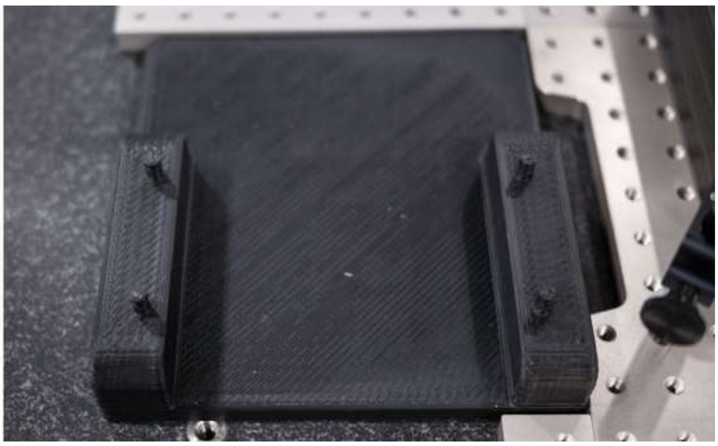
Many automated processes, CNC among them, required tooling that assists in handling, holding, and organizing manufacturing tools as well as blanks and parts. As the parts change that are made, so does the tooling. Here 3D printing, with its short lead times and simple workflow can be of great use.

To increase productivity in their in-house production, Nikola Motors makes jigs and fixtures on their 3D printer. Here, a positioning tool for an aluminum part that was urgently required could be produced on short notice. From the moment the need for such a part arose to the final part it took less than one day! That speed of manufacturing was made possible only by using additive manufacturing methods. And it not only gives designers the freedom to think in new, creative ways and speeds up manufacturing processes, companies also gain more flexibility in using their CNC machines.
Quality checks in production often require taking large numbers of measurements in a short time. To facilitate this, and to reduce the risk of errors, Walter Automobiltechnik GmbH created and printed a handheld jig. The jig keeps the sensors in the right place, indicating at first sight if structures of a car frame have been machined at the right place and in the right size. Being able to create this part in one piece ensures that the relative positions of the measuring points stay within the required tolerances.

It is also possible to 3D print soft jaws that secure metal parts in place while they are being machined. A good example of this can be seen below, where several metal parts that are about to be CNC machined are held in a fixture that can be clamped in a vice. The fixture can easily be adapted to hold objects of varying shapes and is strong enough to hold five parts during the milling process. CNC machining new soft jaws out of aluminum every time a part changes would lead to huge costs and a delay in the manufacturing workflow.

LEAD TIME AND COST COMPARISON FOR A CMM JIG AT NIKOLA CORP.





HOW CAN CNC MACHINING AND 3D PRINTING COMPLEMENT EACH OTHER?

Integrate 3D printed and CNC machined parts

Oftentimes CNC machines are used to reproduce parts that are similar to previously made ones, differing only in small details. However, if these parts exceed a certain size, machining the whole part again because of minor changes in shape becomes increasingly uneconomical.

Metso Outotec, a supplier of equipment for mining and metals refining, found a perfect solution for this problem. A large body of a wooden pattern for sandcasting is produced on a CNC mill. Then 3D printed components are added, enabling Metso Outotec to use the same wooden pattern to cast different versions of the part. Their large-scale 3D printer allowed for the large components to be printed in one piece, matching the large CNC machined parts. Also, while Metso Outotec wanted to integrate 3D printing into their production process, they could not afford to spend too much time on it. The simple workflow made the introduction quick and easy. Patricia Moraes, Global Engineering at METSO OUTOTEC: "The ramp-up was very short. After only three months we have achieved a machine efficiency of 80%."

METSO BIGREP PRO OPERATING HOURS FROM DAY 1

CNC-machine 3D printed parts

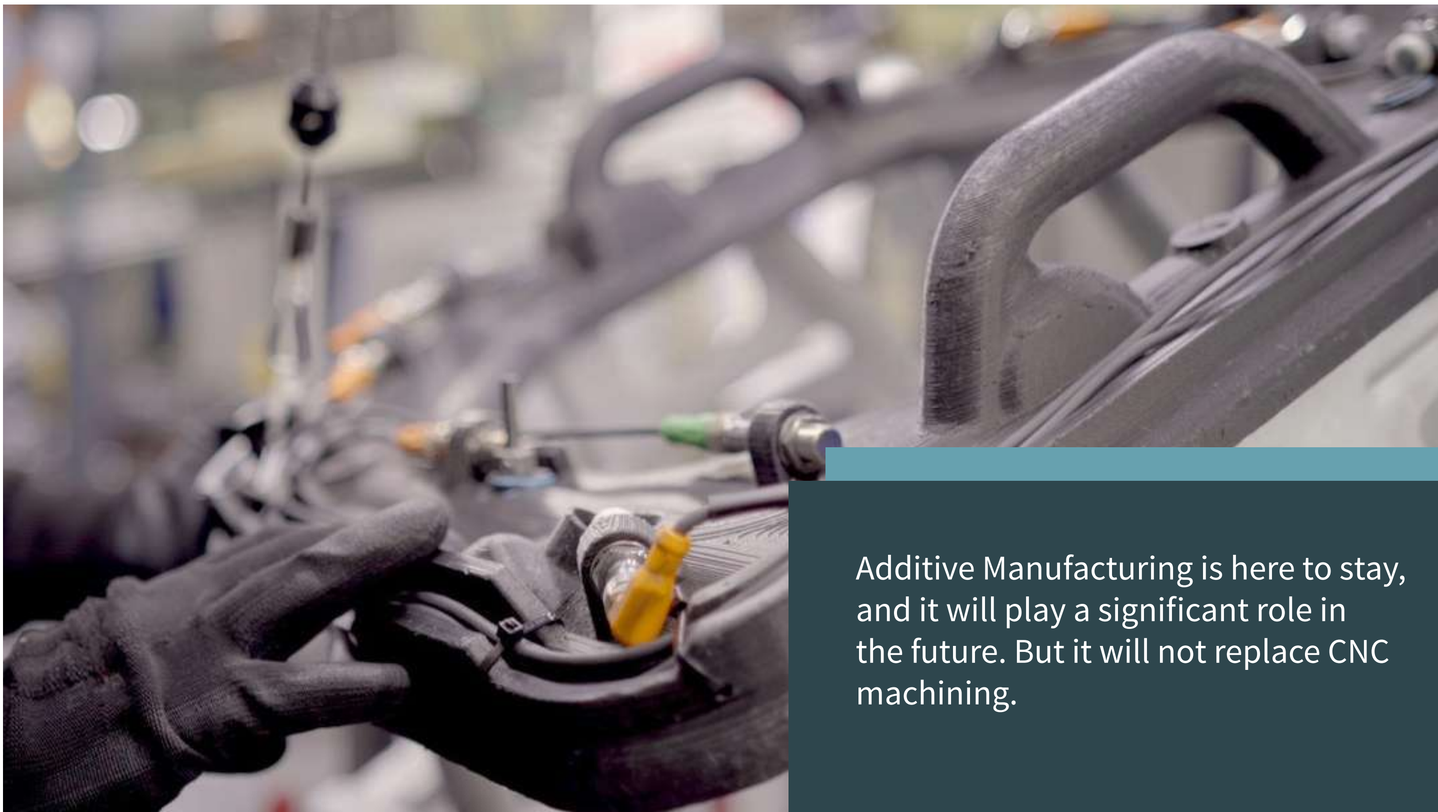
Sometimes it is not possible to 3D print structures in the required accuracy. In other applications, the workflow requires adding holes, recesses, and other features at a later stage of the production process. In this case, it is of course possible to machine the 3D printed parts on a CNC or any other machine like a lathe, a mill, and others. If it is planned to do this, one only must make sure that there is enough material to be removed in the relevant places. The part can then be machined in the same way as it is normally done with cast or forged blanks.

CONCLUSION

When 3D printing was still in its infancy, subtractive machining had already brought forth some impressive technologies. Only with the developments in Additive Manufacturing made in the past few decades processes like FDM, SLA, and SLS have become serious contenders. Only during the last ten years shop owners, production managers, and design engineers have started to look to 3D printing regularly as the solution for problems they sometimes didn’t even know they had. But even so, CNC machining is still widely spread and the most popular and well-known manufacturing method in most industries. With factors like costs, ease of use, design freedom, and the uncertainty of maybe leaving a trusted manufacturing method behind for something completely new, the decision between CNC and 3D printing will, in most cases, require some solid research and calculation.

Additive Manufacturing is here to stay, and it will play a significant role in the future. But, it will not replace CNC machining. The market for both manufacturing methods is projected to constantly grow over the following years. That means that both processes can, should, and will complement each other. 3D printing helps companies to produce faster, more flexible, and with a degree of freedom never seen before. CNC mills, lathes, and other machines will continue to deliver accurate parts that cannot be 3D printed. Additive manufacturing can free CNC machines from tasks for which they were never designed or are too expensive.

If you are interested in learning more about large-format 3D printing, or if you want to know how additive manufacturing can support you and your business, do not hesitate to ask! Our expert team will happily answer all your questions. If you already have a part in mind to 3D print, feel free to send us your 3D file! We will analyze it and give you a detailed print report that contains all the information you need to calculate the additional value that 3D printing can bring to your company.



Additive Manufacturing is here to stay, and it will play a significant role in the future. But it will not replace CNC machining.

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A global leader in large-format FFF 3D printing, BigRep strives to transform its user's productivity and creativity with easy-to-use additive manufacturing solutions. With an aim to help companies accelerate innovation and rethink manufacturing, BigRep's German-engineered 3D printers enable engineers, designers and manufacturers from start-ups to fortune 100 companies to go from prototyping to production faster, getting their products to market first. Through collaborations with strategic partners – including BASF, Bosch Rexroth, Etihad Airways, and Deutsche Bahn – BigRep continues to develop complete additive manufacturing solutions comprising of industrial 3D printers, software, and advanced materials.

Founded in 2014, BigRep is headquartered in Berlin with offices and technical centers in Boston and Singapore.

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