Co-funded by
the European Union

TE@CH

additive manufacturing academy
to boost trainers' competences in industry

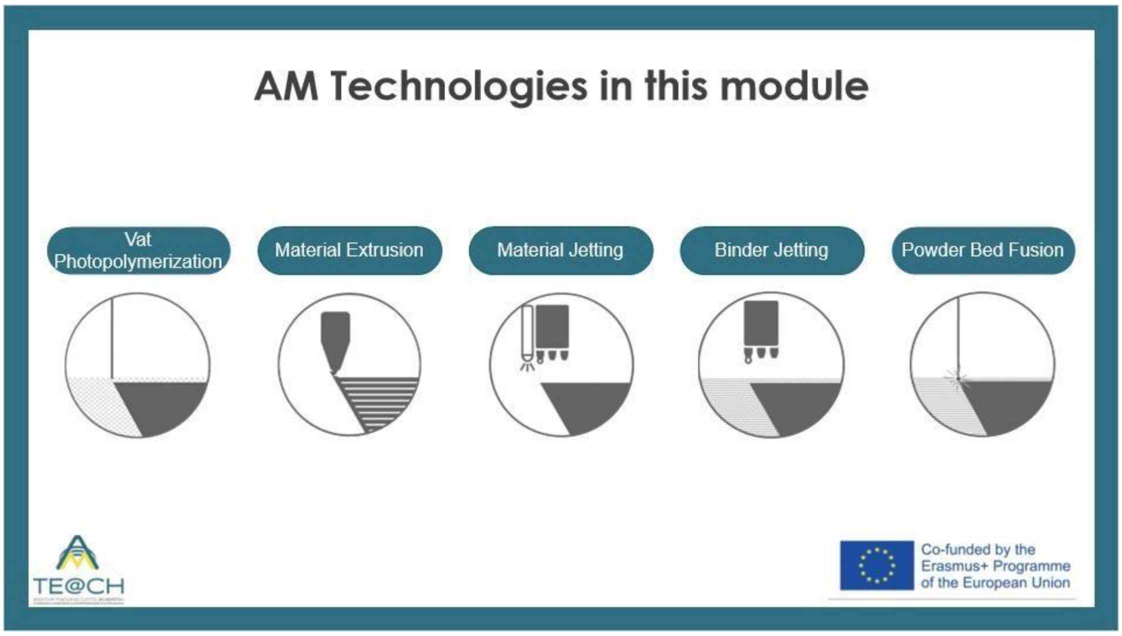
Summary

Polymer Additive Manufacturing Technologies

Project Number: 2021-1-IT01-KA220-VET-000033365

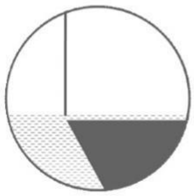
Co-funded by
the European Union

Course Content



This module describes the main additive manufacturing technologies used for polymer printing. It gives an overview of how they work, what their advantages and disadvantages are and finally a comparison between them and how to identify the best printing type for a specific use case.

VAT Polymerization



How does it work?

Quick: Liquid polymer is selectively cured by a light-activated polymerization in a vat.

The laser (in SLA) or projector (in DLP) cures the material where it is desired for the part or support structures. After that the build platform is lowered. These two steps are repeated until the part is completed. In the next stept the liquid is washed away and the supports are removed which leaves the completed part.

Direct Light Processing (DLP) vs Stereolithography (SLA)

DLP utilizes digital micromirror devices in order to control where the light is projected and to generate the light pattern which cures the complete layer at once. SLA on the other hand utilizes a moving UV laser that moves around to cure the material. DLP generally is faster than SLA.

Materials

VAT PHOTOPOLIMERIZATION MATERIALS

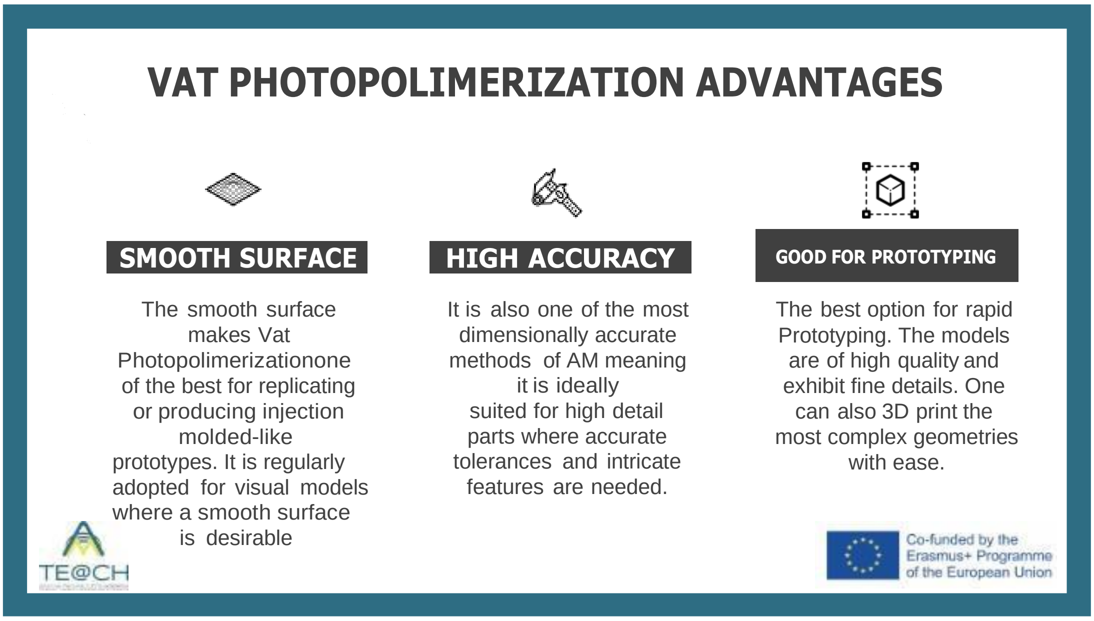
	Common brands	Characteristics
Standard	Formlabs Grey, VisiJet FTX Gray, Somos® Next	• Smooth surface finish • Brittle
Transparent	Formlabs Clear, WaterClear Ultra, Accura ClearVue	• Transparent
Castable	MoonRay Castable Resin, VisiJet FTX Cast, DWS DC100, Accura CastPro	• Castable with a low ash percentage after burnout
Tough/durable	Formlabs Tough Resin, Accura PEAK, Somo 9110, Accura Xtreme	• High stiffness • ABS-like or PP-like
High temperature	Somos ProtoTherm, Accura 48 HTR, Formlabs High Temp R esin	• Temperature resistance • Injection molding and thermoforming tooling
Dental	Detax Freeprint, VisiJet e -Stone, Formlabs Dental SG R esin	• Biocompatible • Abrasion resistant • High cost
Flexible	Carbon3D EPU 40, Formlabs Flexible Resin	• Rubber -like flexibility • Not suitable for ptint that require high accuracy

Co-funded by the Erasmus+ Programme of the European Union

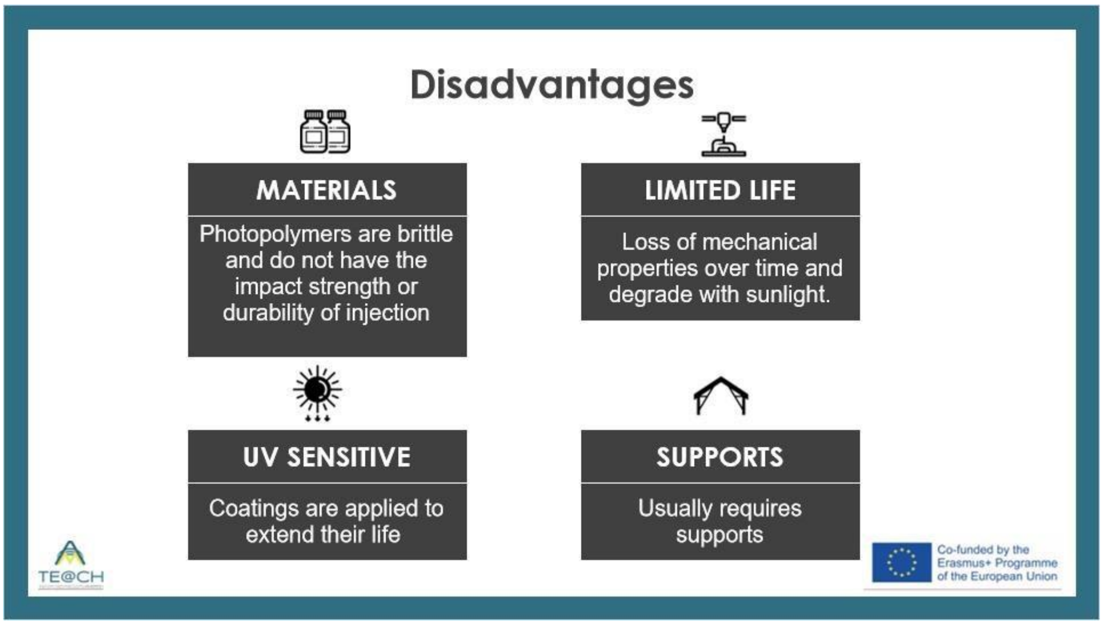
General Applications

Manufacturing, Health, Engineering & Product Design, Culture, Dental and Jewelry.

Advantages and Disadvantages



In general the surfaces of parts that were produced with VAT polymerization have comparatively smooth surfaces and the print overall is highly accurate, it also is highly suitable for prototyping thanks to its high printing speeds, ability to produce fine details and complex geometries.



On the disadvantage side, the materials are rather brittle and lack impact strength and durability of injection molded parts. The mechanical properties are lost over time and especially when exposed to UV light, e.g. by the sun, coatings can be applied to extend their lifetime. It also generally requires support structures for the optimal part quality.

Material Extrusion

How does it work?

Quick: Material is selectively dispensed through a nozzle or orifice.

Material extrusion prints using a string of solid thermoplastic material (filament), pushing it through a heated nozzle and melting it in the process. The printer deposits the material on a build platform in a predetermined path, where the filament cools and solidifies to form a solid part. After removing the support structures the part is finished. The most common material extrusion technology is Fused Filament Fabrication or FFF (more commonly referred to as Fused Deposition Modeling or FDM, a term trademarked by Stratasys).

Fused Filament Fabrication (FFF) vs Fused Deposition Modeling (FDM)

Both terms describe the same process, yet FDM is more widely used and trademarked by Stratasys.

Materials

TE@CH

MATERIAL EXTRUSION MATERIALS

	Common brands	Characteristics
ABS	eSun , Stratasys , Ultimaker	• Good mechanical properties • Good temperature resistance • Susceptible to warping
PLA	ColorFabb (PLA/PHA), Formfutura, Innofil, Polymaker, Ultimaker	• Most common 3D printing plastic • Easy to print with • Lower impact strength , elongation and temperatura resistance than ABS
Nylon (PA)	Stratasys, Taulman 3D, Ultimaker	• Suitable for end -use prints • Good flexibility • Excellent chemical resistance
PETG	ColorFabb (XT), eSun	• High impact & chemical resistance • Good termal properties • Susceptible to warping
TPU	Ninjaflex , Ultimaker TPU 95ª, Polymerker Polylex	• Flexible and rubber -like parts • Good elongation • Difficult to print accurately
PEI	Stratasys (ULTEM)	• Excellent strength to weight • Fire and chemical resistance • High cost

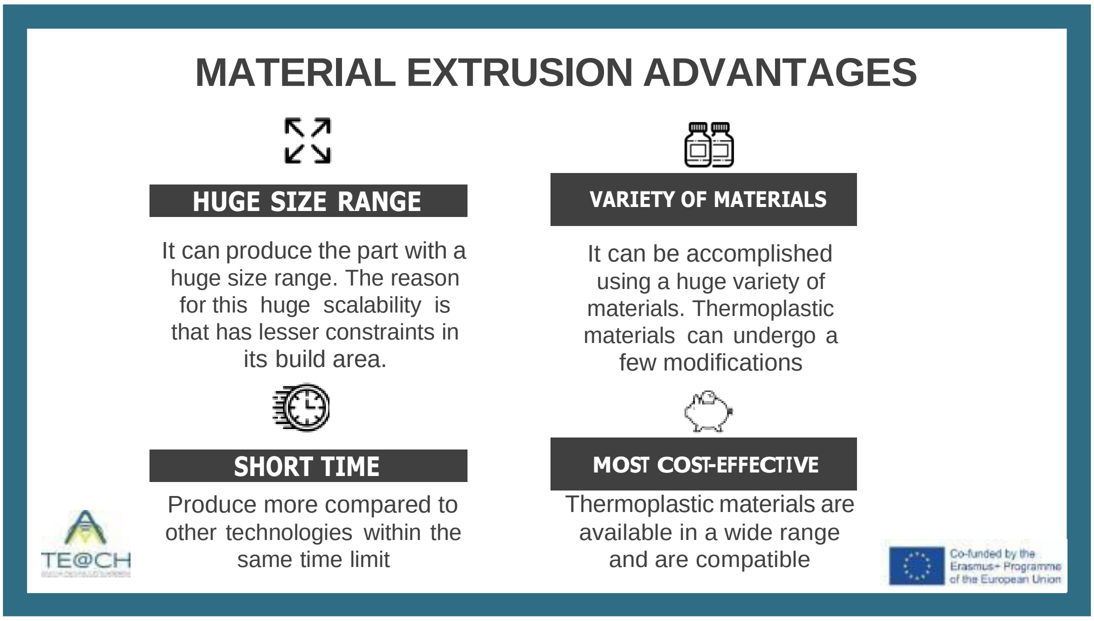
Co-funded by the Erasmus+ Programme of the European Union

General Applications

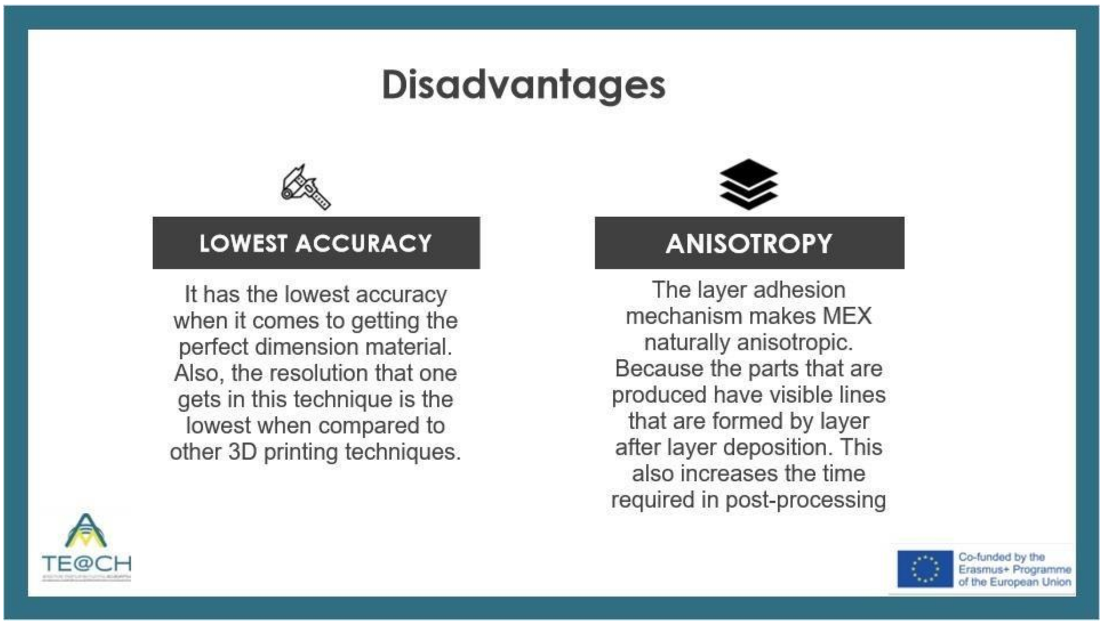
Manufacturing, Sports, Engineering & Product Design, Culture, Decoration and Toys.

TE@CH

Advantages and Disadvantages



In general material extrusion printed parts are less constraint to size and the variety of materials. Many thermoplastic materials are usable with small modifications. Additionally, the process itself is quite quick and among the most cost-effective as the materials themselves are widely available and in many case compatible with different systems.



Material extrusion is the least accurate process to print a part and the print resolution is also comparatively worse. Additionally, the process leads to a natural anisotropy, as lines are visible after the printing process. This also increases the required efforts in post-processing.

Material Jetting

How does it work?

Quick: Droplets of feedstock material are deposite and later cured.

Material Jetting works much like a standard inkjet printer however, instead of printing a single layer of ink, many layers are built upon one another to create a solid part. The print head jets hundreds of tiny droplets of photopolymer and then also cures (solidifies) them via a UV light. After a layer has been deposited and cured the build platform drops down one layer thickness and the process is repeated to build up a 3D part. After the part is finished, the gel-like support material is washed away and the part is finished.

Material Jetting (MJF) vs PolyJet

Both terms describe the same process, yet PolyJet is the trademarked process which license is currently owned by Stratasys.

Materials

MATERIAL JETTING MATERIALS

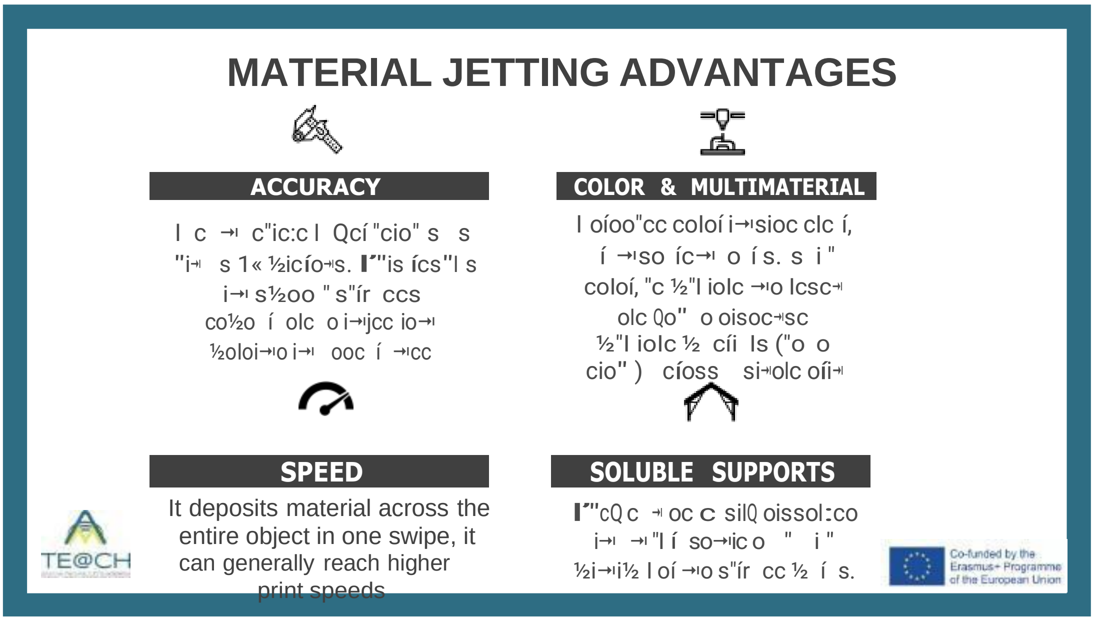
	Common brands	Characteristics
Standard	Vero, VeroBlue, Visijet M2, Visijet CR, full colorprints	• Rigid opaque plastic • Simulates injection molded parts • brittle
Flexible	Tango, Visijet M2-E	• Large range of flexibilities available • Customizable Shore hardness • Poor elongation and stretch compared to traditional materials
Polypropylene - like	Rigur, VisiJet M5 Black	• Simulates PP parts • Good flexural strength • Brittle
ABS-like	Digital ABS, VisiJet M3-X	• High temperaturaresistance • Used for low run injection molds • Brittle
Castable	Visijet M3 DentCast, Visijet M3 Proscast, InduraCast Wax	• No ash after burnout • Optimizedfor investment casting
High temperature	RGD525, VisiJet M3-X	• Excellent HDTproperties
Transparent	VeroClear, VisiJet M2, VisiJet CR	• Can be post processed to 100% clear

Co-funded by the Erasmus+ Programme of the European Union

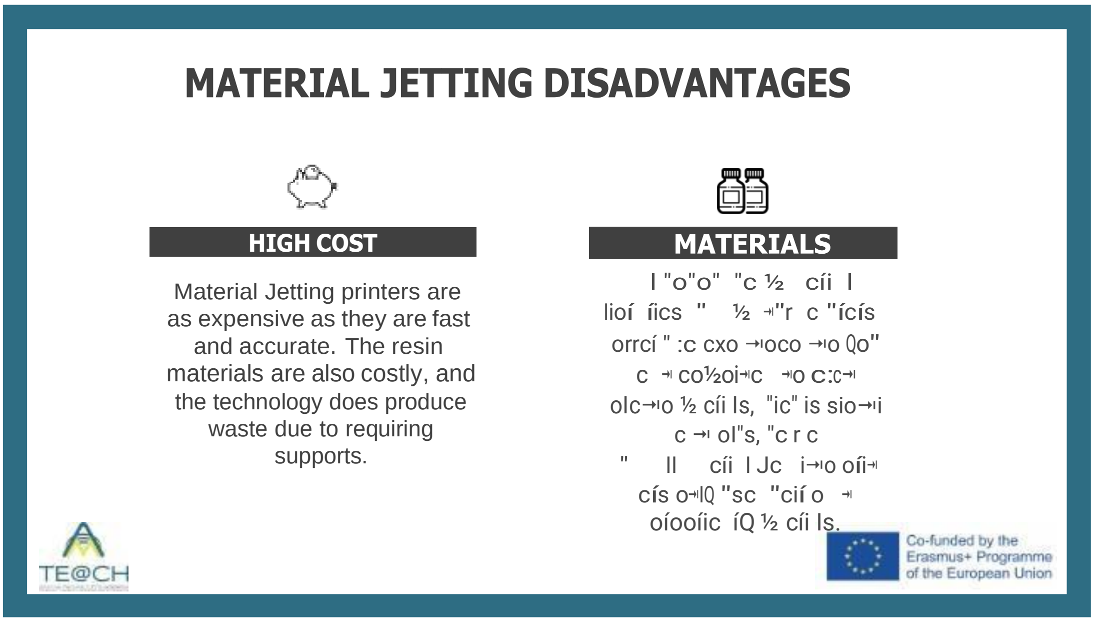
General Applications

Manufacturing, Fashion, Engineering & Product Design, Culture, Sports and Toys.

Advantages and Disadvantages

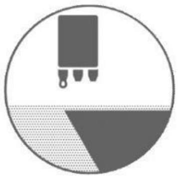


In general material jetting printed parts highly precise and have, compared to injection molded parts, smoother surfaces. Additionally, multiple materials can be printed across one single print and can thus produce transparent parts which have colors enclosed them. It also is comparatively quick and utilizes soluble supports which can be easily removed in a ultrasonic bath.



On the negative side are the high costs related to material jetting, as the printers themselves as well as the materials are costly. Additionally, the different systems only use their proprietary materials which limits the choice. But within their respective material catalogue, many materials can be blended which can be helpful in some applications.

Binder Jetting



How does it work?

Quick: Droplets of liquid binder agent are deposited onto powdered material.

Binder Jetting moves a print head over the powder surface depositing binder droplets (typically 80 microns in diameter) that bind the powder particles together to produce each layer of the part. Once a layer has been printed, the powder bed is lowered and a new layer of powder is spread over the recently printed layer. This process is repeated until a solid part is generated.

The part is then left in the powder to cure and gain strength. After this the part is removed from the powder bed and the unbound powder is removed via compressed air.

Other materials

The Binder Jetting process can also be used to print parts in sand, such as sandstone or gypsum, but also metal.

Materials

BINDER JETTING MATERIALS

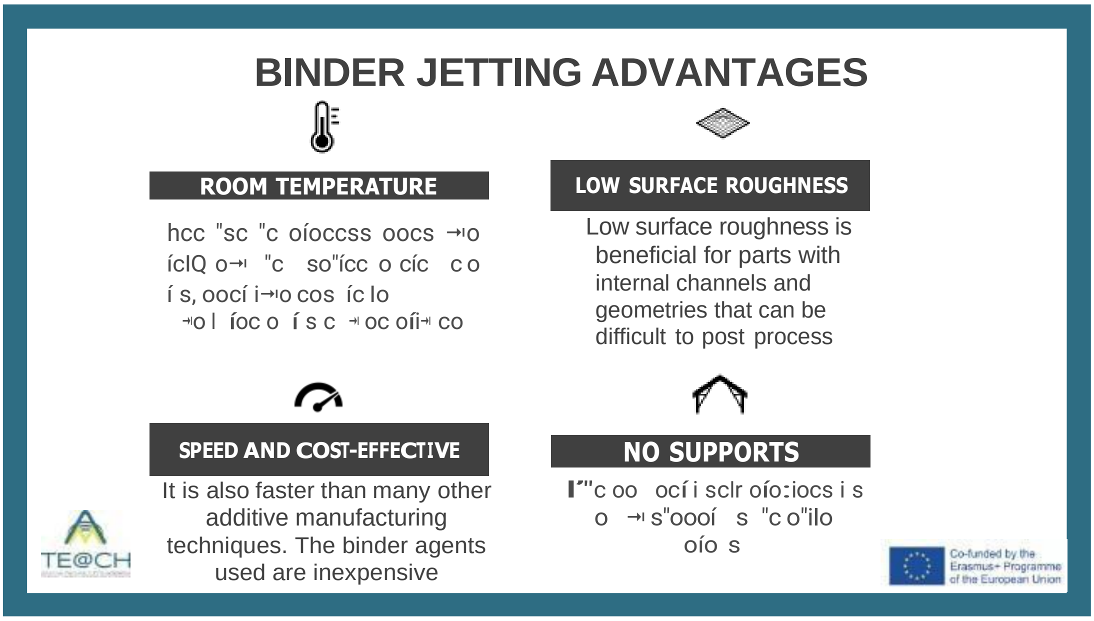
	Common brands	Characteristics
Sandstone	VisiJet PXL, Z Corp, Voxeljet	• Very low elongation at break • High stiffness • Full color presentation models
Stainless Steel-bronze matrix (infiltrated)	ExOne 420, ExOnce 316	• Excellent mechanical properties • Able to be machined
Stainless Steel (sintered)	ExOne 316L, ExOnce 17-4	• Corrosion resistance • Excellent mechanical properties
Inconel alloy (sintered)	ExOne IN Alloy 625	• Good temperatura resistance • Excellent mechanical properties • High chemical resistance
Tungsten carbide (sintered)	ExOne	• Very high hardness • Used for the production of cutting tools
Silica sand	ExOne , Voxeljet	• Excellent for sand casting applications

Co-funded by the Erasmus+ Programme of the European Union

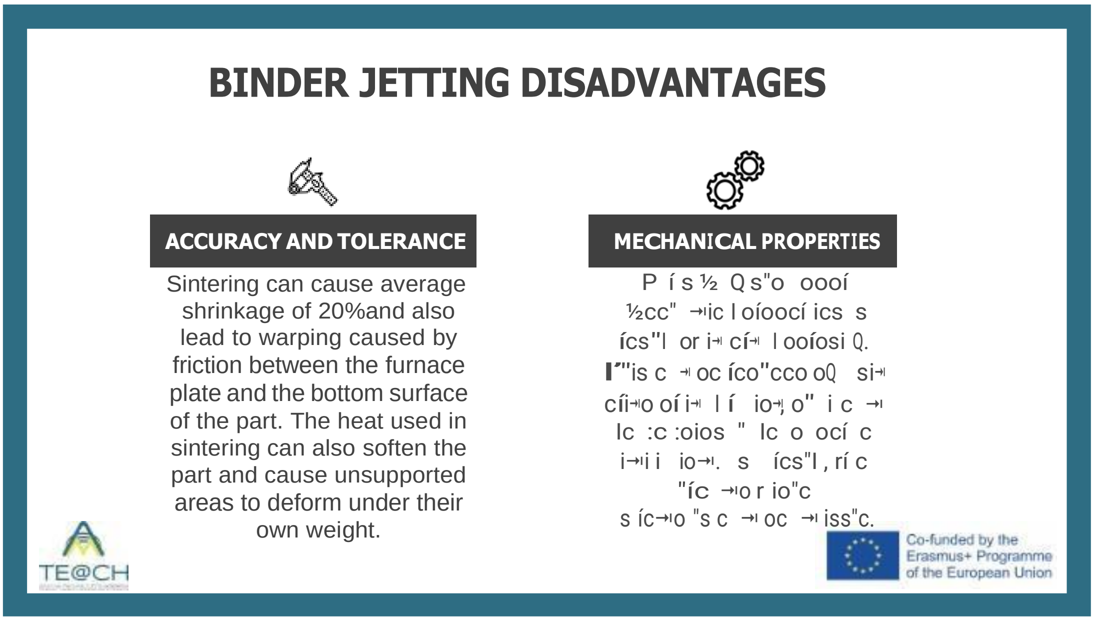
General Applications

Architecture, Food, Engineering & Product Design, Jewelry, Decoration and Entertainment.

Advantages and Disadvantages

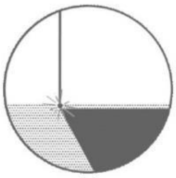


The Binder Jetting process itself is highly cost effective as it is quick, there is no additional heat necessary, the binder agents are inexpensive and also large parts can be printed. Additionally, the low surface roughness allows for easy production of parts with internal channels or complex geometries for which post-processing could pose difficulties. Finally, thanks to the powder used there are generally no supports needed during the print process.



Against Binder Jetting stands that the sintering of the part causes a shrinkage and can lead to warping. The part can also be generally deformed if the sections are not supported enough by the geometry. Additionally, the general mechanical properties are considered poor as the internal porosity is rather high. This can be tried to be counteracted by infiltration or sintering, but these processes can lead to other issues such as the mentioned shrinkage, and potential voids which can lead to cracks.

Powder Bed Fusion



How does it work?

Quick: Thermal energy selectively fuses region of a powder bed.

The most used process, called Selective Laser Sintering (SLS), begins with a bin of the polymer powder being heated to a temperature just below the melting point of the polymer. A recoating blade deposits a very thin layer of the powdered material (typically 0.1 mm) onto a build platform. A CO_2 laser beam then starts to scan the surface. The laser selectively sinters the powder and solidifies a cross-section of the part. When the entire cross section is scanned, the building platform moves down one layer thickness in height. The recoating blade deposits a new layer of powder on top of the recently scanned layer and the laser starts to sinter the successive cross section of the part onto the previously solidified cross-sections. This process is repeated until all parts are fully manufactured. When finished, the loose powder is removed and the part is finished.

SLS vs Multijet

While SLS uses a laser to melt the powder, Multijet utilises a fusing and a detailing agent in order to selectively melt the powder, and constantly moving lamps to apply heat onto the material. This is the main difference, otherwise the processes are similar as both are powder based.

Materials

POWDER BED FUSION MATERIALS (SLS)

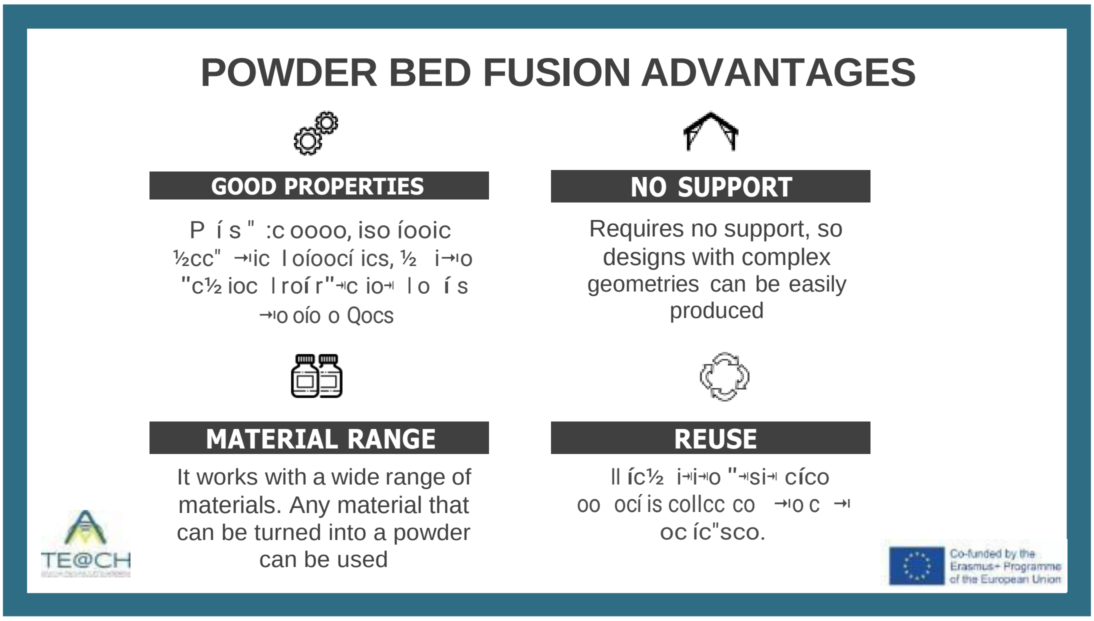
	Common brands	Characteristics
Nylon 12	EOS Balance 2200, 3D Systems DuraForm PA	• Cost effective • Good mechanical properties • Matte, rough surface
Alumide	EOS Alumide	• Metallic appearance • Temperature resistance
PA-GF (glass filled)	3D Systems DuraForm ProX GF, EOS PA 3200 GF	• High stiffness • Good strength -weights ratio • Wear resistance

Co-funded by the Erasmus+ Programme of the European Union

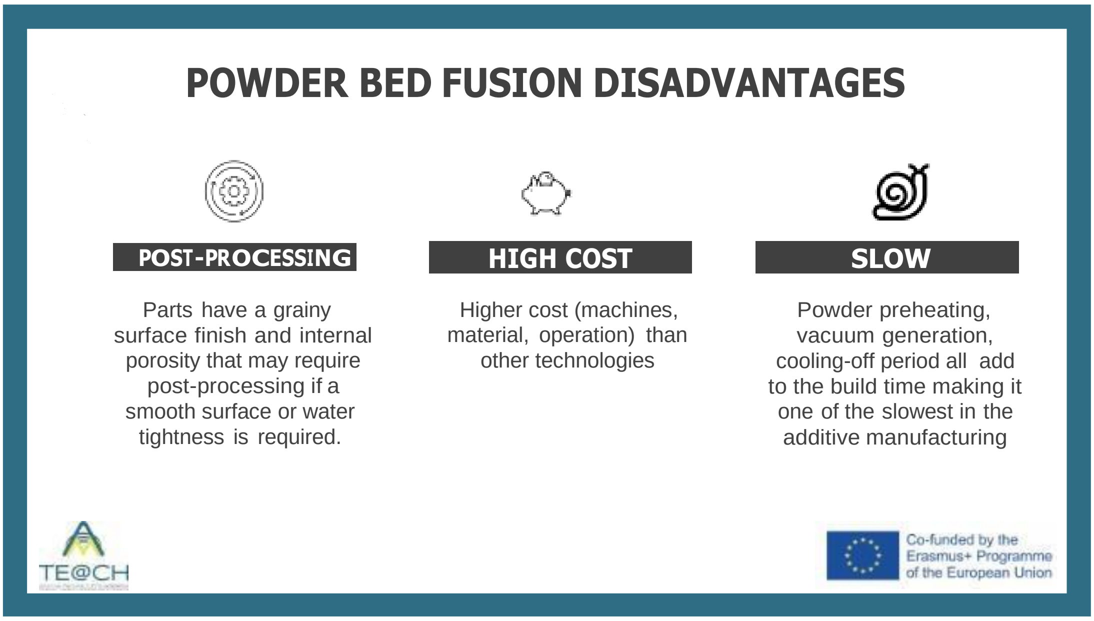
General Applications

Manufacturing, Health, Engineering & Product Design, Fashion, Food and Entertainment.

Advantages and Disadvantages



Powder Bed Fusion results in parts with good mechanical properties which makes it ideal for functional parts. Additionally, there are no supports required and complex geometries can also be easily produced. The range of usable materials is very large, as any material can be turned into a powder and thus be used in Powder Bed Fusion. Finally, unsintered powder can be collected and reused.



The process itself leaves a grainy surface finish and internal porosity that post-processing might be required to achieve water tightness or smooth surfaces. Also the process is comparatively expensive, based on machine, material and operating costs, and it is rather slow. The material needs to be preheated, a vacuum created, and also cooling-off periods are needed for the machine. This results in the slowest production speed of all polymer printing processes.

For further information and contact details, have a look here:

http://additive-minds-academy.com

https://store.eos.info/

Headquarters

EOS GmbH – Electro Optical Systems

Robert-Stirling-Ring 1

D-82152 Krailling / Munich

Germany

Phone: +49 (0)89 / 893 36-0

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.