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SECTOR SKILLS STRATEGY IN ADDITIVE MANUFACTURING

BASICS OF ADDITIVE MANUFACTURING

Project No. 601217-EPP-1-2018-1-BE-EPPKA2-SSA-B

INTRODUCTION

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- **Additive manufacturing**, also known as **3D printing**, rapid prototyping or free-form fabrication, is ‘the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies’ such as machining.

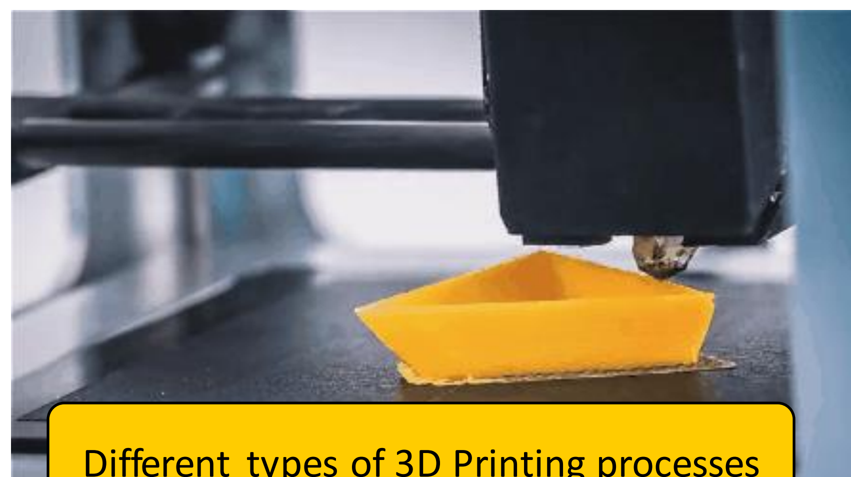
✓ **Design a 3D Model of an object with a software**

❖ Free software examples include TinkerCAD (*shown in this tutorial*), SketchUp

✓ **Convert the model into a format (called an STL file)** that the 3D printer understands

✓ **Print the object with a 3D printer**

❖ layer by layer, as shown below



Different types of 3D Printing processes

Applications

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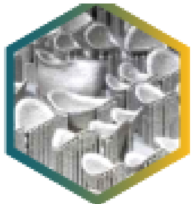
aerospace, energy, automotive, medical, tooling and consumer goods



DENTAL

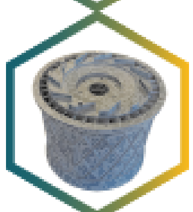
- Braces
- Bridges
- Prostheses
- Dental Aligners
- Crown
- Dentures

MEDICAL

- Implants
- Prosthetics
- Hearing Aids
- Surgical Models
- Bio - Tissue Implants
- Nanoscale Medicine

AEROSPACE

- Air Foils
- Guide Vanes
- Turbine Blades
- Fuel Nozzles & Systems
- Propellant Tanks for Satellites



AUTOMOTIVE

- Spares
- Embedded Sensors
- Functional Prototyping
- Engine Components
- Low Volume Interior Parts
- Design & Prototyping

CONSUMER GOODS

- Jewellery
- Antennas
- Musical Instruments
- Sports Equipment
- Customised Products
- Toys Characters, Figurines

SAM
SECTOR SKILLS STRATEGY IN ADDITIVE MANUFACTURING

THE BENEFITS OF AM TECHNOLOGY

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Design freedom

Ability to design parts with geometric features that cannot be made any other way.

Material freedom

Functionally graded materials can be specifically designed for improved material properties.

Mass customisation

As tooling is not required, parts can be manufactured in hours/days.

Reduced part count

Enables complex systems to be designed and manufactured as one part due to design freedom.

Waste reduction

Builds components layer by layer to near final geometry resulting in significant material savings.

Reduced Inventory

It allows a reduced inventory as more industrial technologies are able to produce and repair parts with lower production time.

Lead time reduction

As tooling is not required for AM parts, each part can be tailored to its specific use or user.

Decreased cost

Can offer significant through-life benefits over traditional manufacturing processes for a wide range of products and production volumes.

THE LIMITS OF AM TECHNOLOGY

- **Part size:** For PBF, the part size is limited to powder bed size, such as 250 x 250 x 250mm. However, part sizes can be greater with DED (with laser or arc) processes. But, due to the low thickness of powder layers, it can be very slow and costly building tall or very large parts.
- **Part design:** In the case of PBF, removable support structures are needed when the overhang angle is below 45°.

- **Production series:** the AM processes are generally suitable for unitary or small series and is not relevant for mass production. Progress is made to increase productivity and the production of larger series. For small sized parts, series up to 25000 parts/year are already possible.
- **Material choice:** though many alloys are available, non weldable metals cannot be processed by additive manufacturing and difficult-to-weld alloys require specific approaches.
- **Part properties**: parts made by AM tend to show anisotropy in the Z axis (construction direction). Besides, though densities of 99.9% can be reached, there can be some residual internal porosities. Mechanical properties are usually superior to cast parts but in general inferior to wrought parts.

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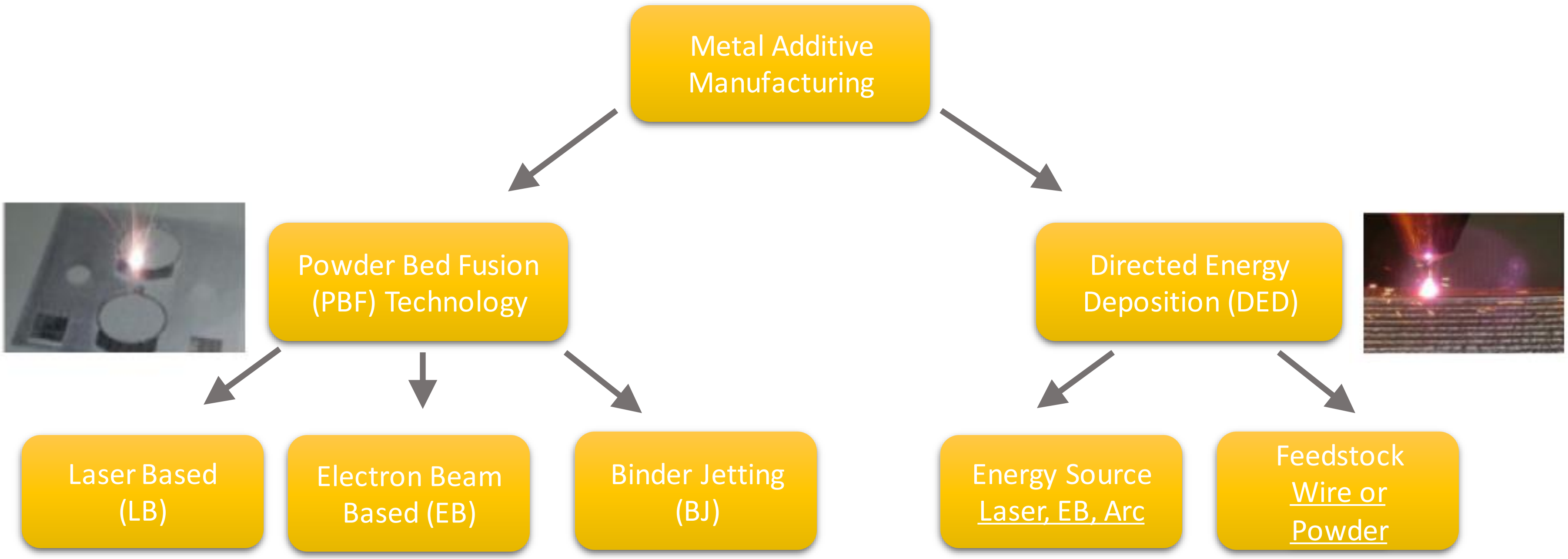
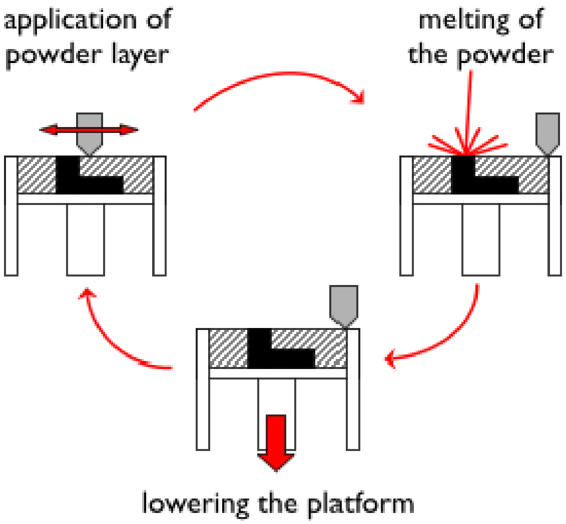
OVERVIEW OF METAL AM PROCESSES



Mapping of main metal powder additive manufacturing technologies

POWDER BED FUSION SYSTEMS

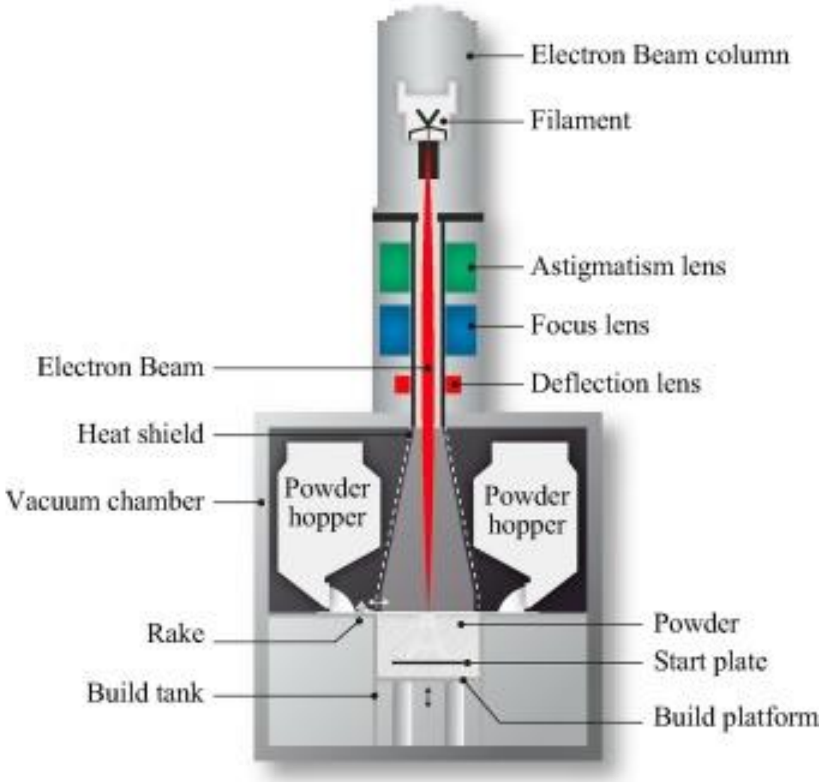
- In powder bed fusion systems (Laser Beam or Electron Beam), a powder layer is first applied on a building platform.
- Then a laser or electron beam selectively melts the upper layer of powder. It is an "Additive manufacturing process in which thermal energy selectively fuses regions of a powder bed", according to ISO/ASTM 52900-18.
- After melting, the platform is lowered and the cycle is repeated until the part is fully built, embedded in the powder bed.



The powder bed manufacturing cycle (Courtesy of Fraunhofer)

ELECTRON BEAM MELTING (EBM)

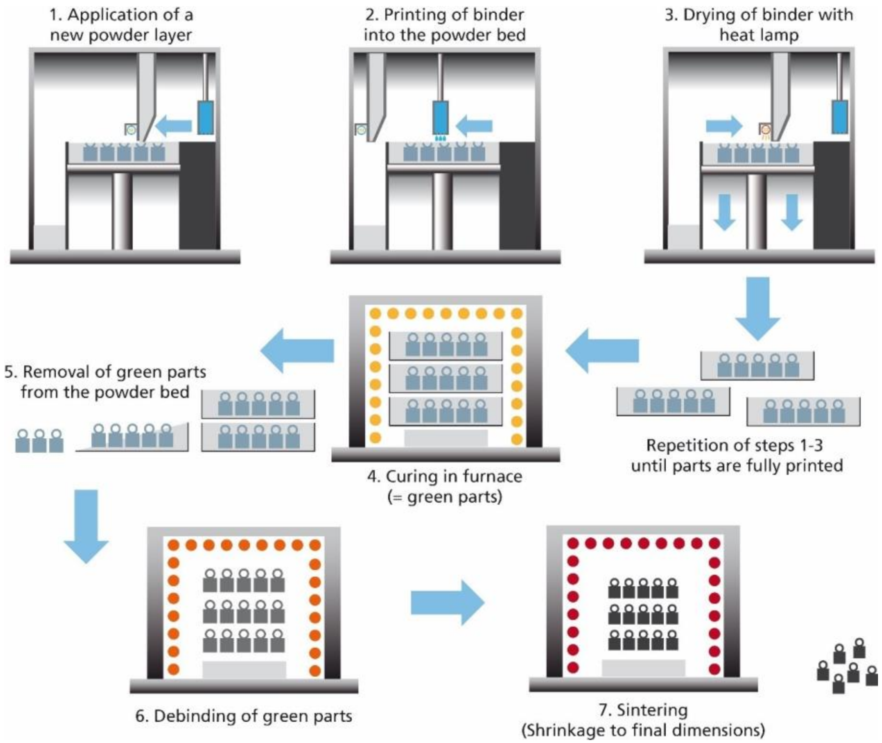
- The EBM process is based on a high power electron beam that generates the energy needed for high melting capacity and high productivity. The electron beam is managed by electromagnetic coils providing extremely fast and accurate beam control.
- The EBM process takes place in vacuum (with a base pressure of 1×10-5 mbar or better) and at high temperature, resulting in stress relieved components. For each layer in the build the electron beam heats the entire powder bed to an optimal ambient temperature, specific for the material used.
- As a result, the parts produced with the EBM process are almost free from residual stresses and have a microstructure free from martensitic structures.



The EBM process (Courtesy of Arcam)

METAL BINDER JETTING & SINTERING

- Metal Binder Jetting process is an indirect process in two steps. After applying a powder layer on the build platform, the powder is agglomerated thanks to a binder fed through the printer nozzle.
- According to ISO/ASTM 52900-18, it is an "Additive manufacturing process in which a liquid bonding agent is selectively deposited to join powder materials"
- The operation is repeated until parts are produced, which shall be then removed carefully from the powder bed, as they are in a 'green' stage.
- The metal part solidification takes place in a second step, during a debinding and sintering operation, sometimes followed by an infiltration step.



Metal Binder Jetting process (Courtesy of Fraunhofer IFAM)

METAL BINDER JETTING & SINTERING

Advantages:

- X50-100 faster than PBF
- X20 lower cost than PBF
- No supports are required
- Suitable for great complexity parts and large series
- Good resolution

Disadvantages:

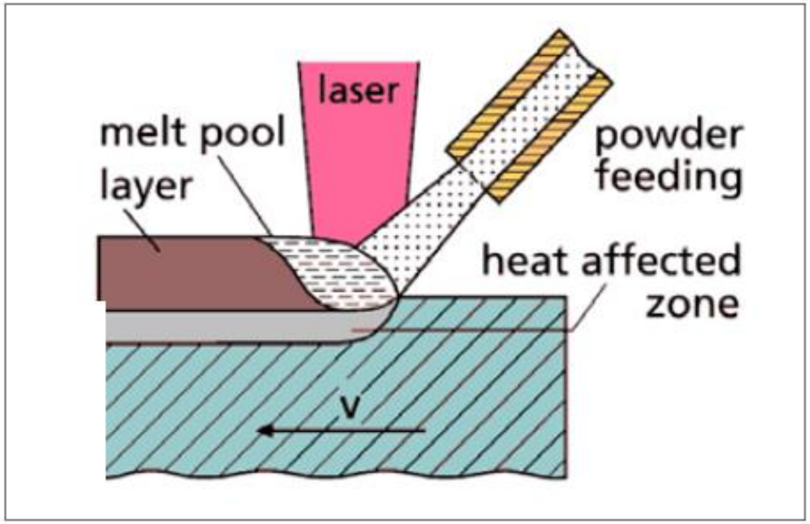
- Limited size (<400x300x200 mm)
- Various processes for final part (print → debinder → sinter)
- Complex manipulation of green parts
- Contraction control during sintering
- Limited wall thickness (5-10 mm)

Applications and sectors:

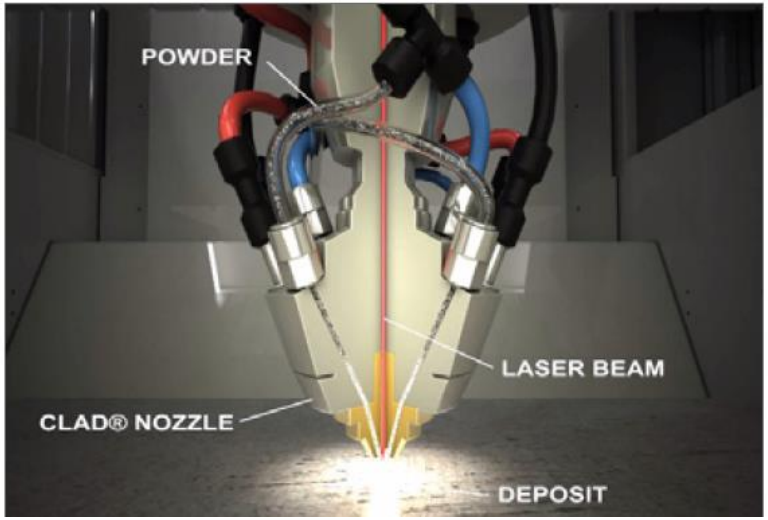
- Precision engineering
- Automotive
- Prototyping
- Medical

DIRECTED ENERGY DEPOSITION (DED)

With the directed energy deposition processes, a nozzle mounted on a multi axis arm deposits melted material onto the specified surface, where it solidifies. This technology offers a **higher productivity than powder bed fusion** and also **the ability to produce larger parts,** but the freedom in design is much more limited: for instance, lattice structures and internal channels are not possible.



Directed Energy Deposition Process (Courtesy of Fraunhofer)

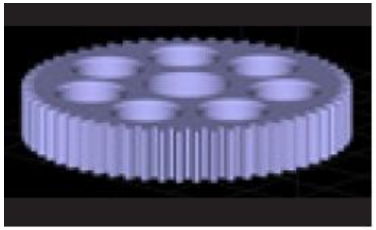


Sketch of the Directed Energy Deposition process (Courtesy of BeAM)

MAIN PROCESS STEPS IN AM

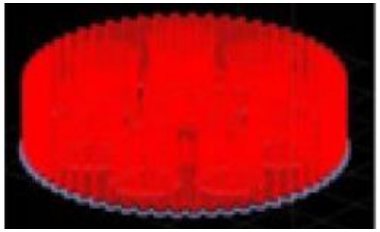
3D-Modelling

- 3D-CAD Modelling
- 3D Scan (Reverse Engineering)
- Creation of STL-Data (Triangulation)



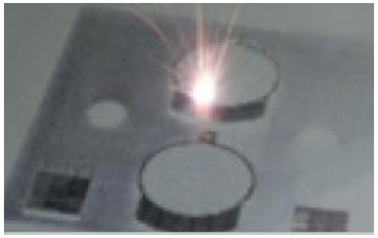
Data preparation

- Reparation of files, close holes or open surfaces
- Part orientation and support structures
- Create slices from the model, Slicing



Manufacturing on AM machine

- Generation of control data
- Production of the parts



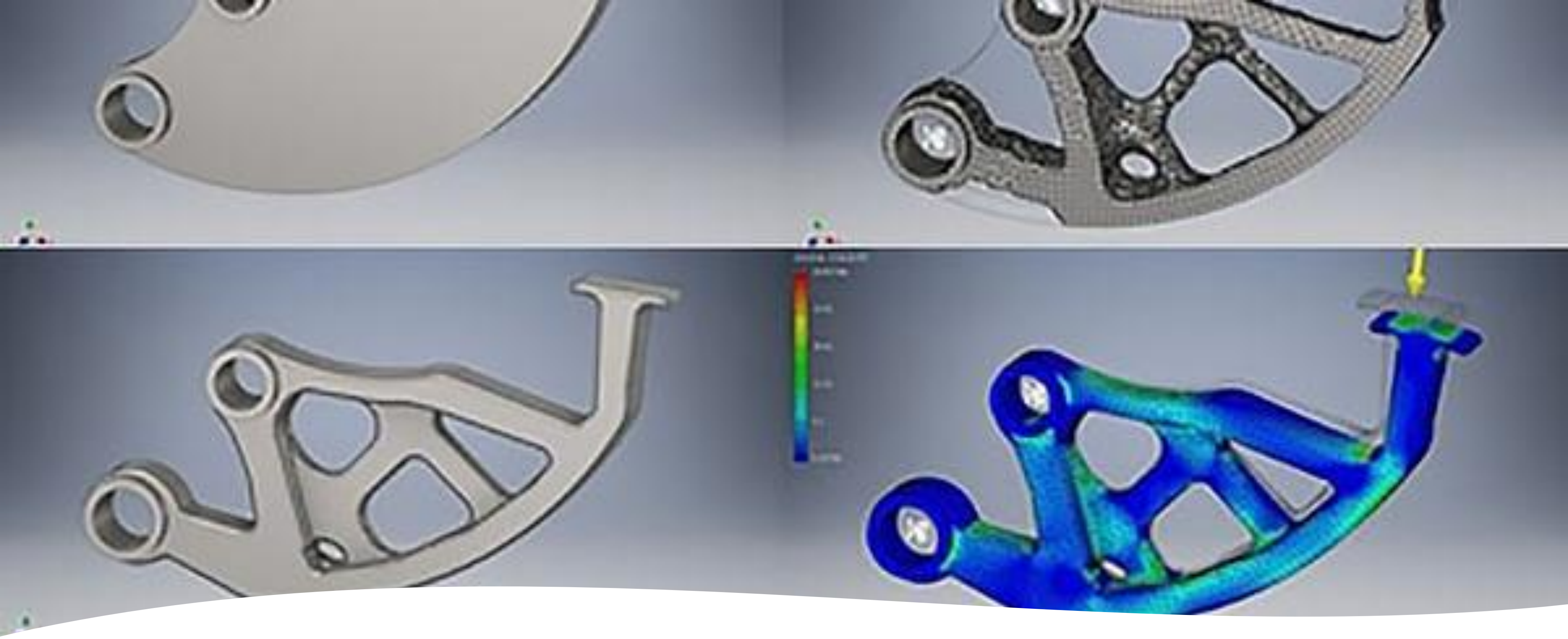
Post process

- Removal of powder, support structures and platform
- Heat treatment
- Surface finish, polishing, etc.

POST PROCESSES IN AM

Post processes are anything that changes the shape of the part after build. Inspection and quality control steps are not considered as post processes in this manner. These steps mainly cover PBF (either LB or EB) and Binder jetting

- Powder Removal
- Support Removal
- Base Plate Removal
- Heat Treatment
- Machining
- Surface Finishing



TOPOLOGY OPTIMIZATION

Topology optimization: a mathematical approach that optimizes material distribution within a user-defined design space (topology), for a given set of loads, constraints and boundary conditions, such as the result meets a prescribed set of performance (optimization) targets. This typically centers around minimizing a parts mass while maintaining its structural integrity.

What can I 3D print ? Medical field

Prosthetic hand

Source: pixabay (2020)

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What can I 3D print ? Medical and educational fields

Source: The Week (2019)

Miniature human heart model

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What can I 3D print ? Medical and educational fields

Source: Shutterstock (2020)

3D printed denture

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What problems can we solve with 3D Printing?

3D printed visors for covid-19

Work by Giselle Loh – PhD researcher at Brunel University

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What problems can we solve with 3D Printing?

3D printed link valves for emergency ventilator mask.

Photo via CRP Technology.
Source: 3Dprintingindsutry (2020)

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What problems can we solve with 3D Printing?

3D printed hands-free door handle attachment

Designs by Materialise. Source: 3Dprintingindsutry (2020)

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