Additive Manufacturing and Metal Injection Moulding

Competing production processes?

15.04.2021

„If you only remember two technologies […] they should be additive manufacturing and metal injection moulding.“

Factory of the Future, McKinsey Report, 2014

From powder to complex metal parts…

+

AM

MIM

raw material
metal powder, binder

shaping
AM / MIM

debinding
solvent, catalytic, thermal

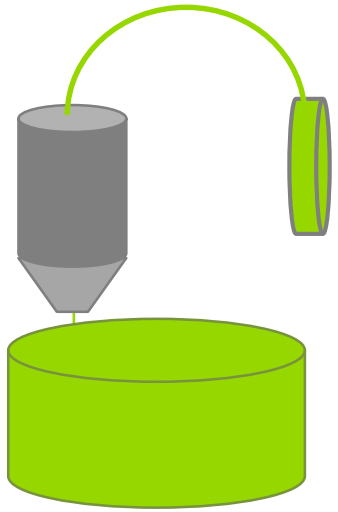
sintering
sintering furnace

metal part

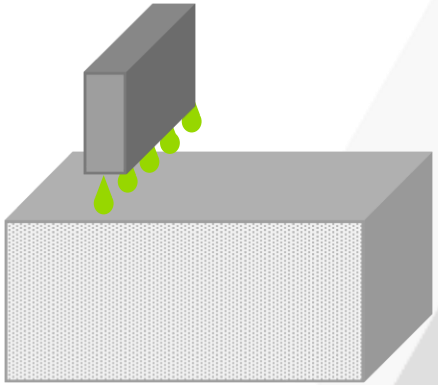
1 — 2 — 3 — 4 — 5

Sinter-based additive manufacturing (AM)

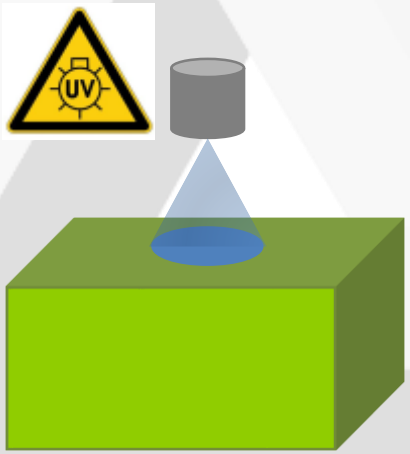
Material Extrusion



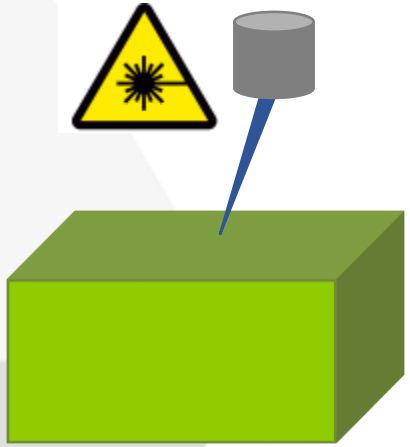
Binder Jetting



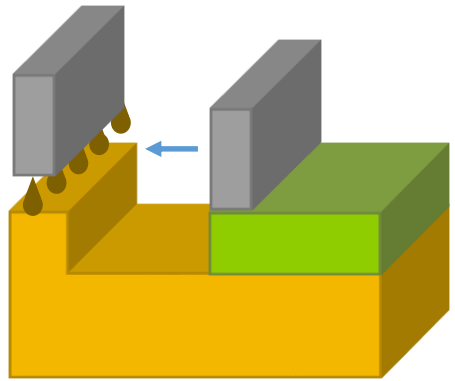
Stereo-lithography



Cold Metal Fusion



MoldJet



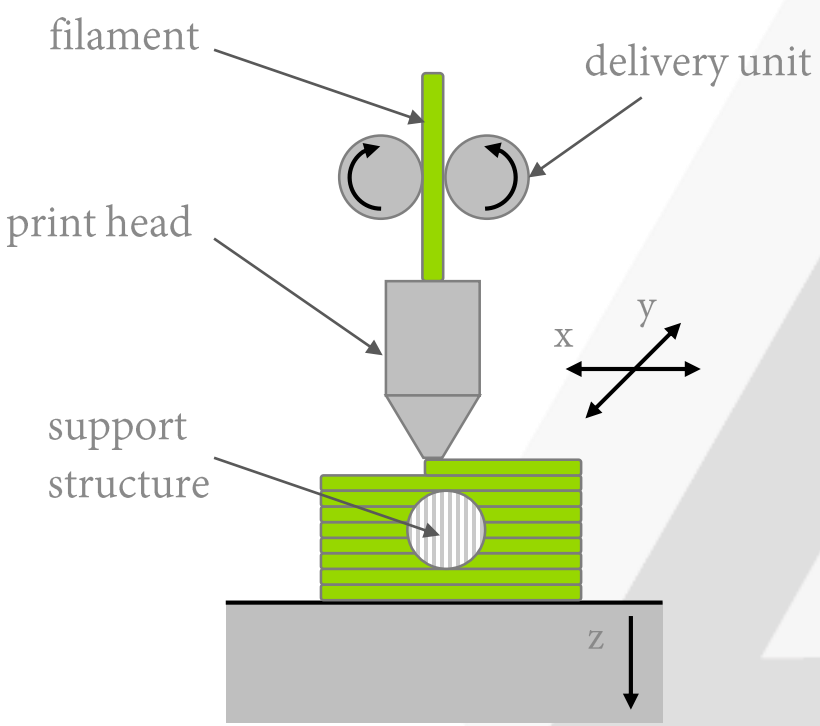
legend:

feedstock

metal powder

polymer

Material Extrusion

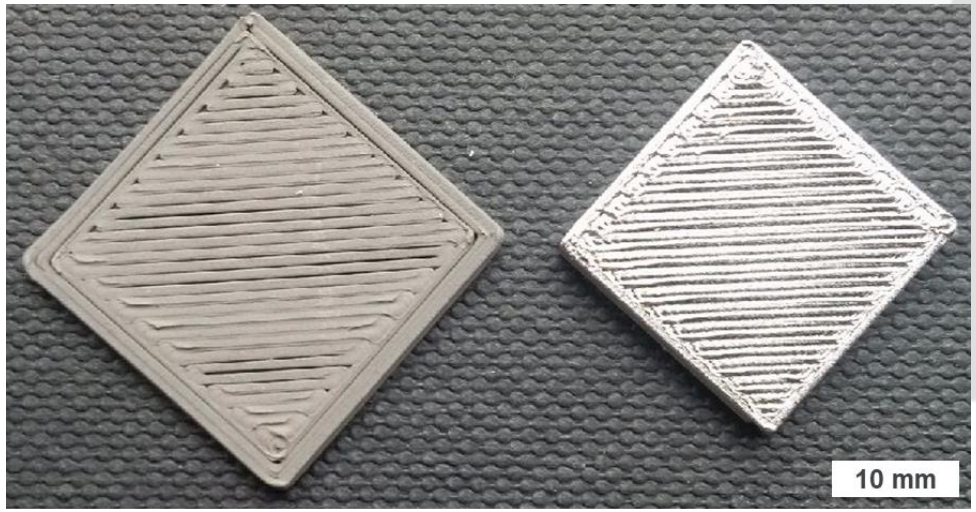


- Filament or granules (MIM feedstock) are plasticized and extruded
- Support structure necessary
- Low cost technology

Material Extrusion – from green body to sintered part…

- Solid loading in filament of approx. 60 vol-%
- Catalytic or solvent pre-debinding depending on binder system
- Thermal debinding and sintering
- Sintering shrinkage of 15 – 20%

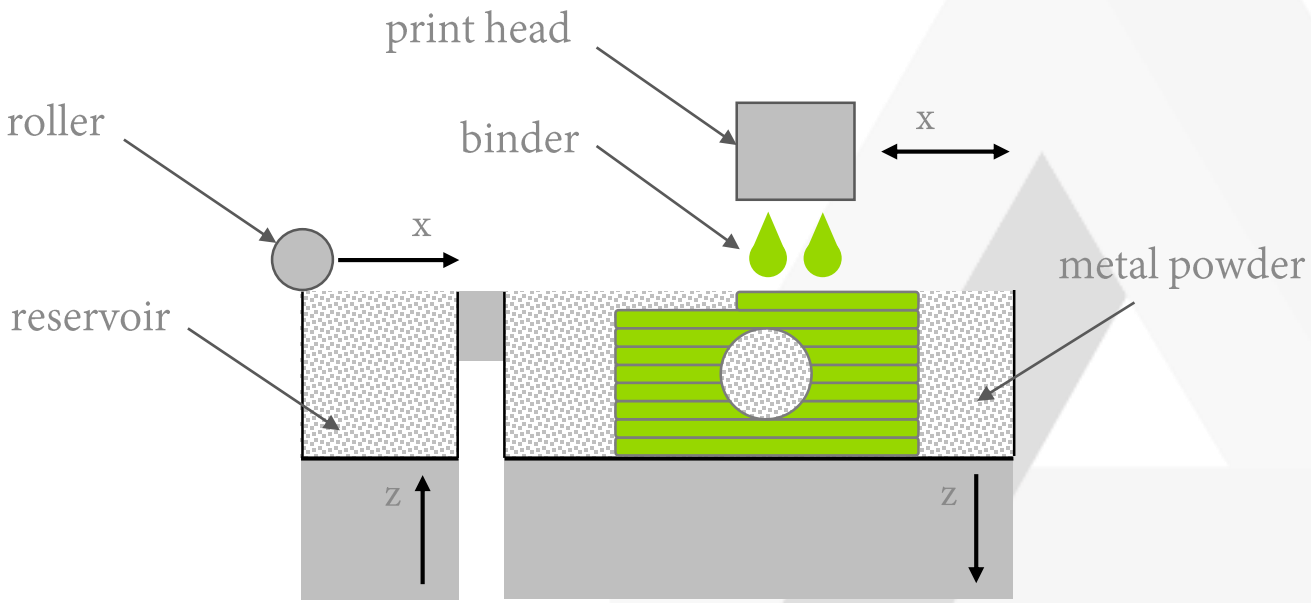
green part as sintered



green part

as sintered

Binder Jetting

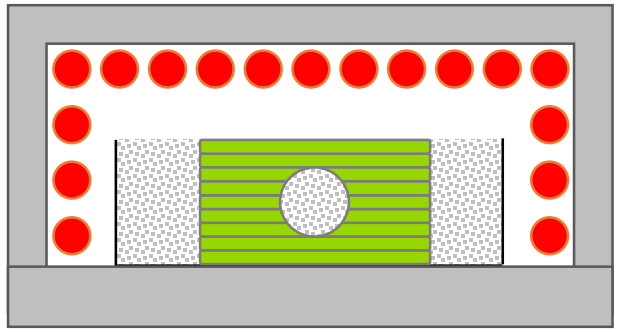


Source: ExOne

- Liquid binder is applied to a thin metal powder layer
- Binder content in green part is very low (1 -2 wt-%)
- No support structure necessary
- Efficient printing process through nesting of parts

Binder Jetting - from green body to sintered part…

1. Curing



Improvement of green strength

2. Depowdering

Source: ExOne

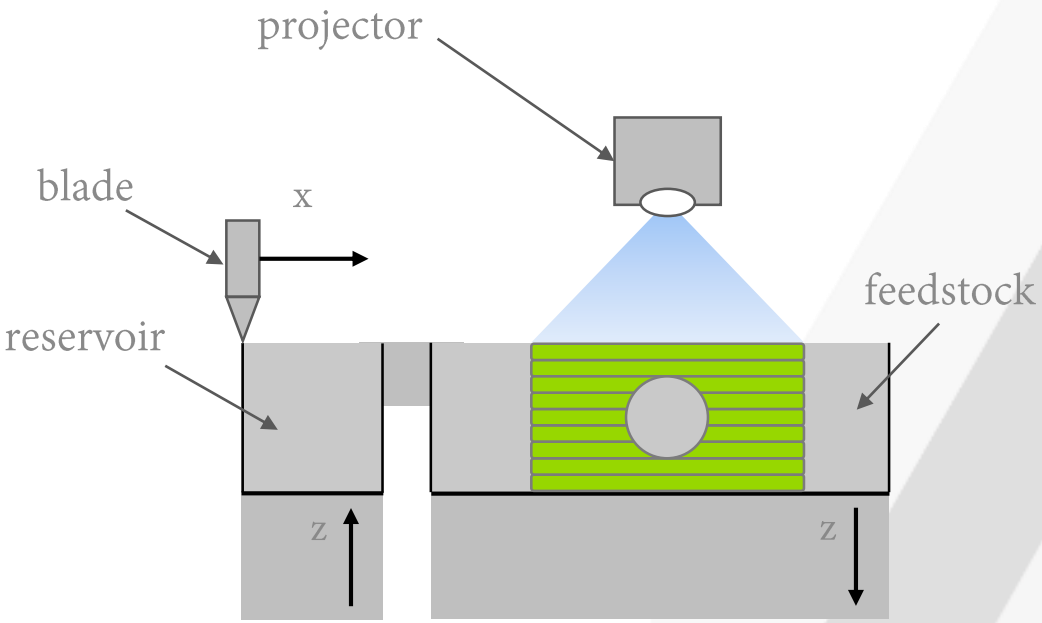
Removal of loose powder

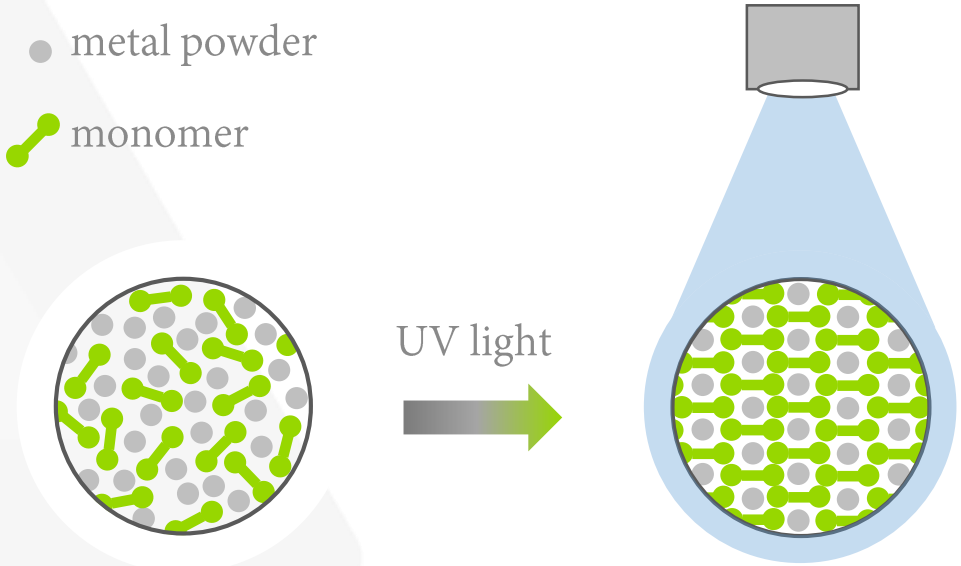
3. Sintering

Thermal debinding and sintering

- Sintering shrinkage is approx. 20%
- High densities ≥ 96% can be achieved
- Good surface quality (Ra ~ 6 µm)

Stereolithography



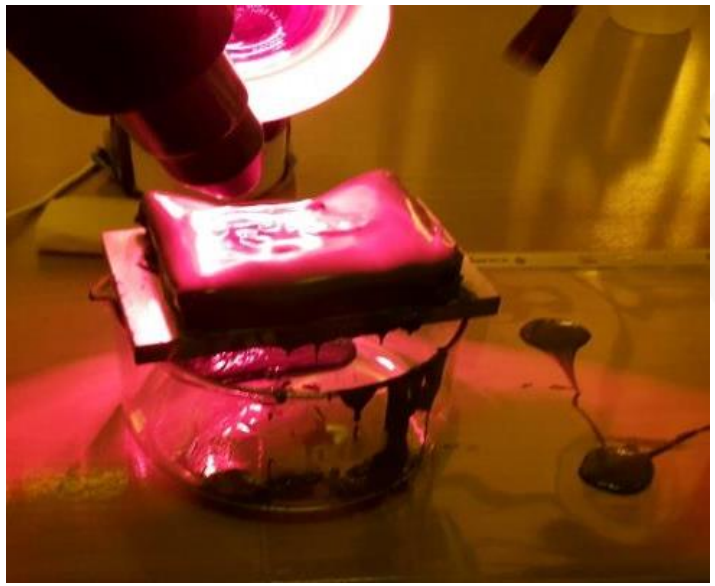


- Thin layer of feedstock (photopolymer + metal powder) is exposed to UV light
- No support structure necessary
- Efficient printing process through nesting of parts
- Best suited for small and filigree parts (< 30 g)

Stereolithography – from green body to sintered part

- Solid loading in feedstock of approx. 60 vol-%
- Only thermal debinding possible
- Sintering shrinkage of 16 – 20%
- Excellent surface quality (Ra ~ 5 µm)

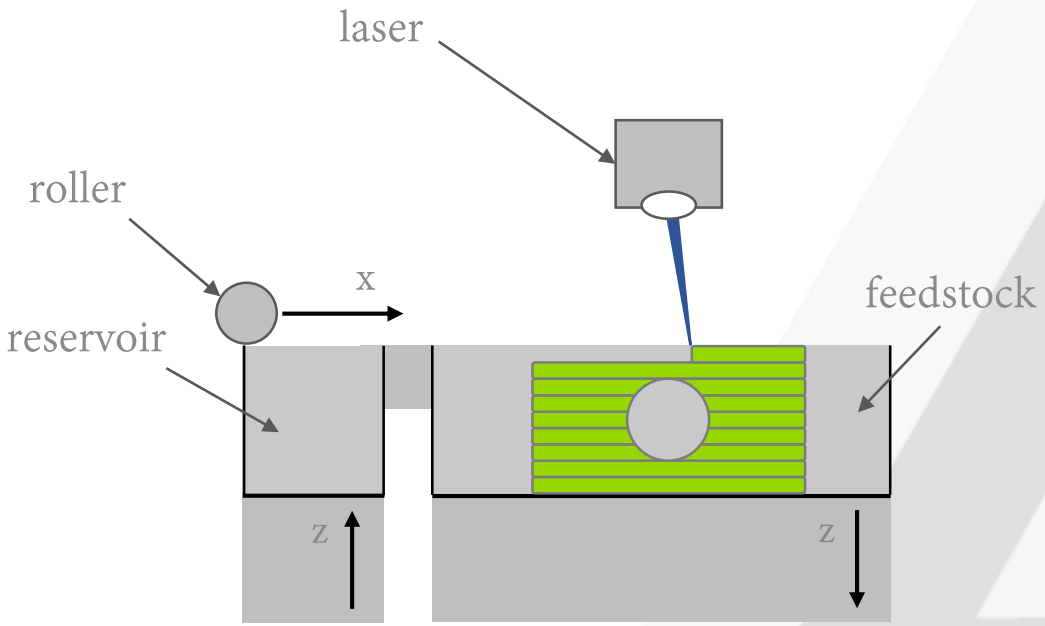
removal of excess material



cleaned green parts

sintered parts

Cold Metal Fusion

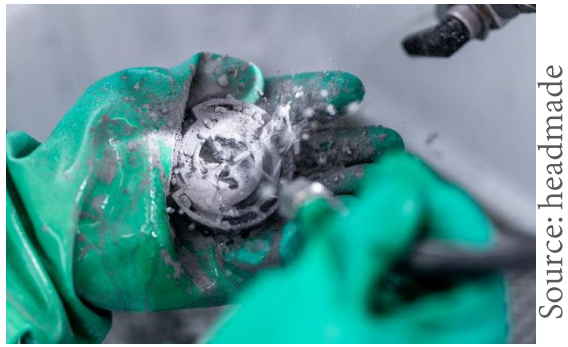


Source: headmade materials

- Thin layer of feedstock in which the binder is melted by a laser
- No support structure necessary
- Conventional 3D printers (SLS) for polymers can be used

Cold Metal Fusion – from green body to sintered part

1. Depowdering



Source: headmade materials

Removal of loose feedstock

2. Solvent debinding

Removal of base polymer

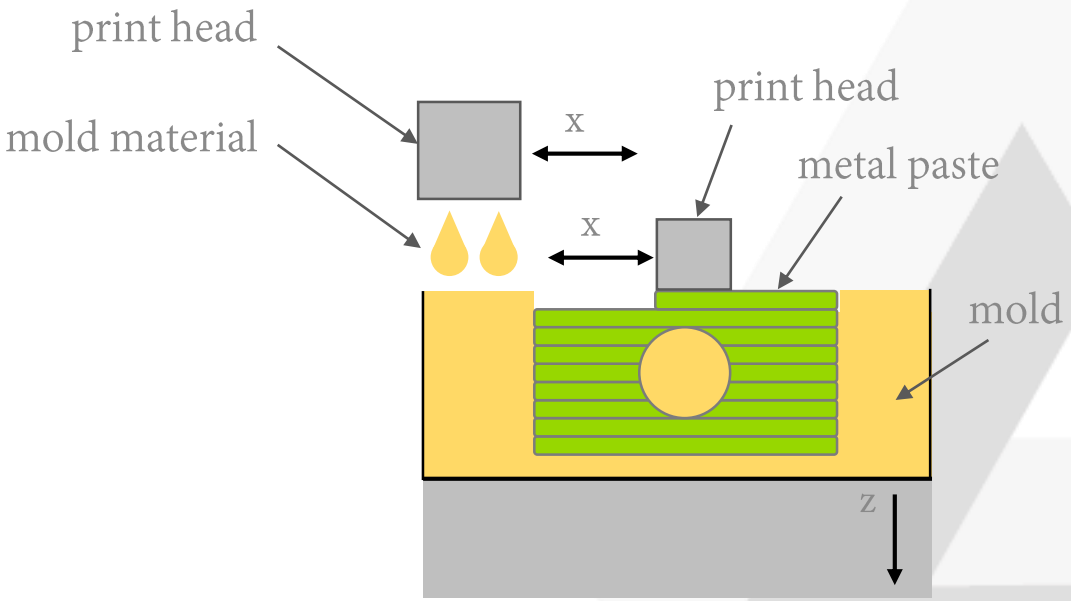
3. Sintering

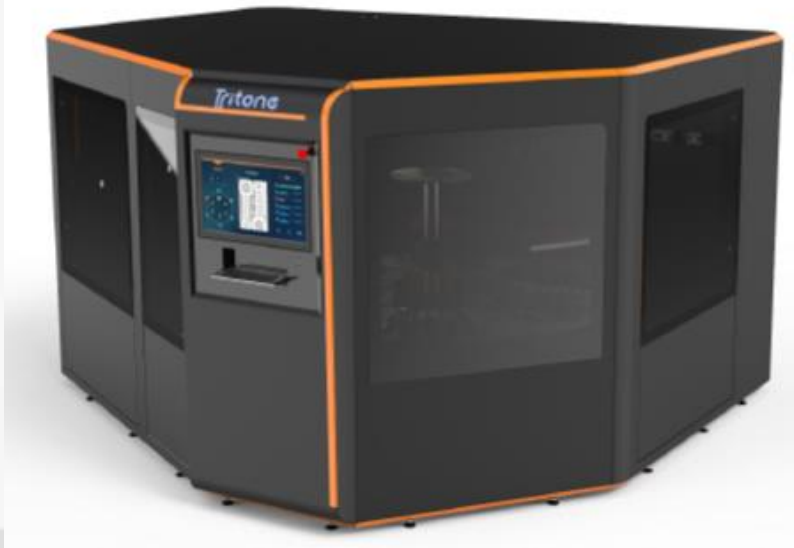
Thermal debinding and sintering

- Robust green parts, suitable for green part processing
- Sintering shrinkage is approx. 13%
- High densities ≥ 96% can be achieved

Source: headmade materials

MoldJet





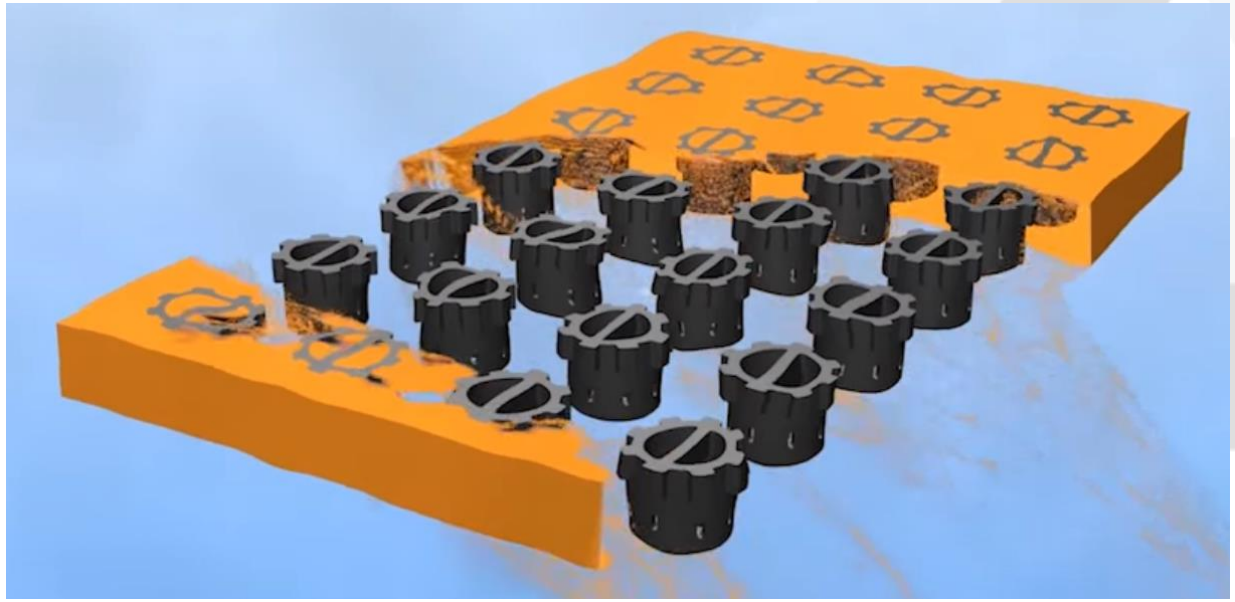
Source: Tritone

- Thin layer of mould is printed, then a metal paste is placed in the printed mould
- No support structure necessary
- Efficient printing process through nesting of parts

MoldJet – from green body to sintered part

- Robust green parts, suitable for green part processing
- Sintering shrinkage is approx. 14%
- High densities ≥ 96% can be achieved

Demoulding of green parts



Source: Tritone

Source: Tritone

Metal Injection Moulding

Green part
(metal + ~10 wt-% polymers)

Brown part
(metal + ~2 wt-% polymers)

Sintered part
(metal)

Feedstock

Injection Moulding

Pre-debinding (catalytic, solvent)

Thermal debinding

Sintering

1 — 2 — 3 — 4 — 5

Metal Injection Moulding - Feedstock

- Feedstock as raw material for metal injection moulding
- Feedstock is a mixture of metal powder and polymers with an optimized flow behaviour for an ideal mould filling
- Organic binder in the feedstock are only necessary for shaping (flowability)
- Sintered part is free from organic carbon

Metal powder

+

Binder
(different polymers)

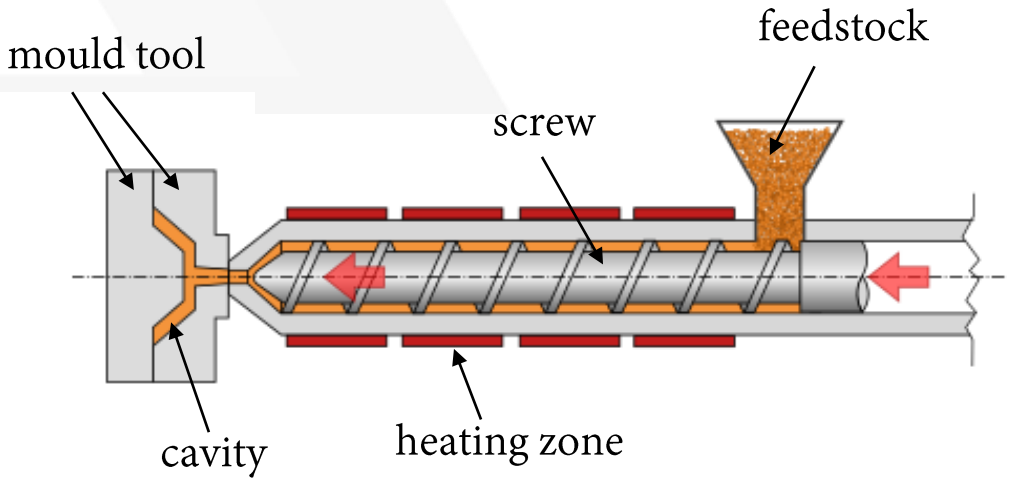
Mixing, melting

and homogenisation

Feedstock

Metal Injection Moulding – Injection Moulding

- Injection moulding is performed on conventional injection moulding machines
- Feedstock is plasticized at elevated temperature
- Molten feedstock is injected into the cavity

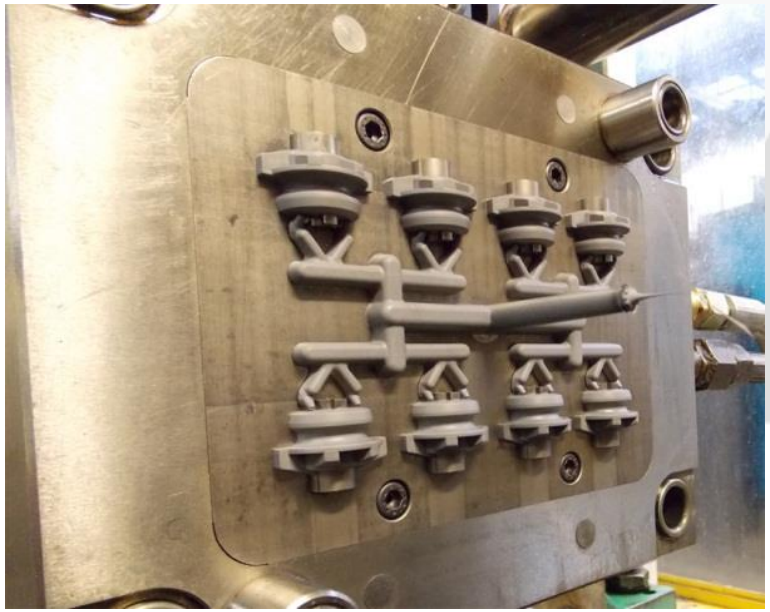


Source: www.maschinenbau-wissen.de

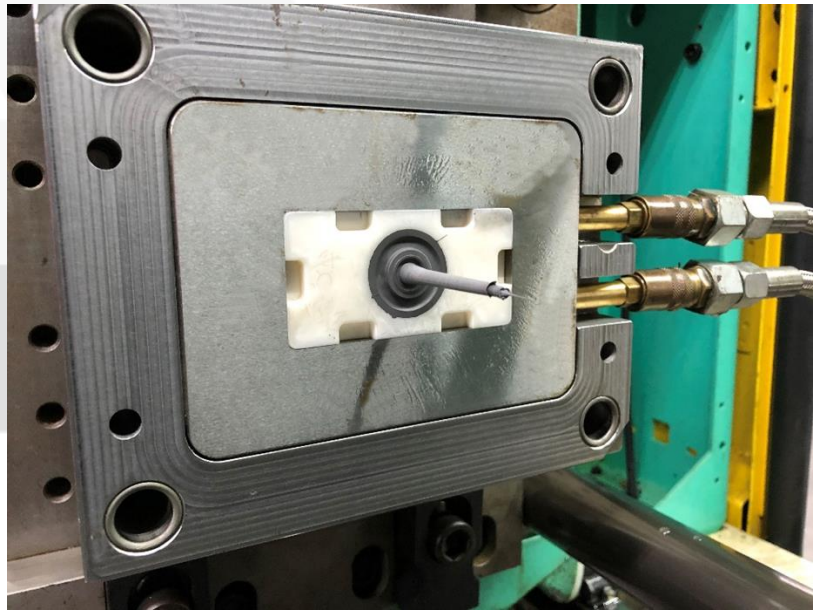
Metal Injection Moulding – Injection Moulding

- Mould tool necessary for shaping of green parts
- Depending on part geometry mould tool manufacturing can be expensive and time-consuming
  → MIM is economically reasonable for medium to large scale production
- *Alternative:* 3D printed plastic tool inserts for prototypes or small series production

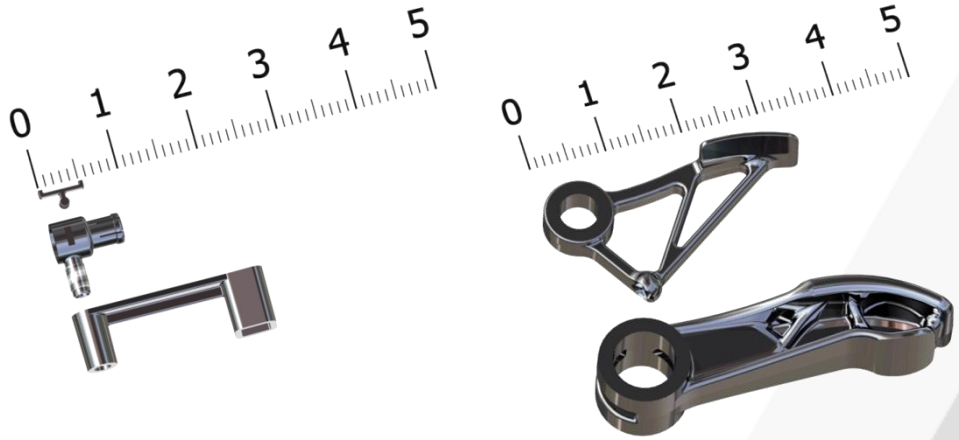
conventional tool (steel)



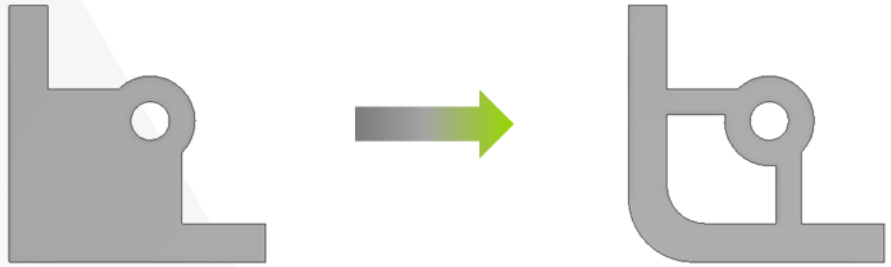
3D printed tool insert (plastics)



Metal Injection Moulding – Design guidelines

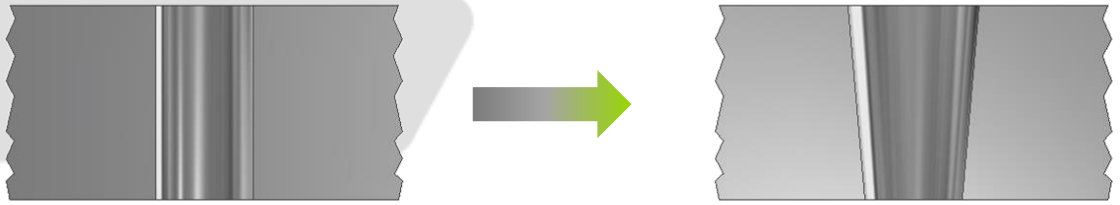


Small and light parts



Constant wall thickness

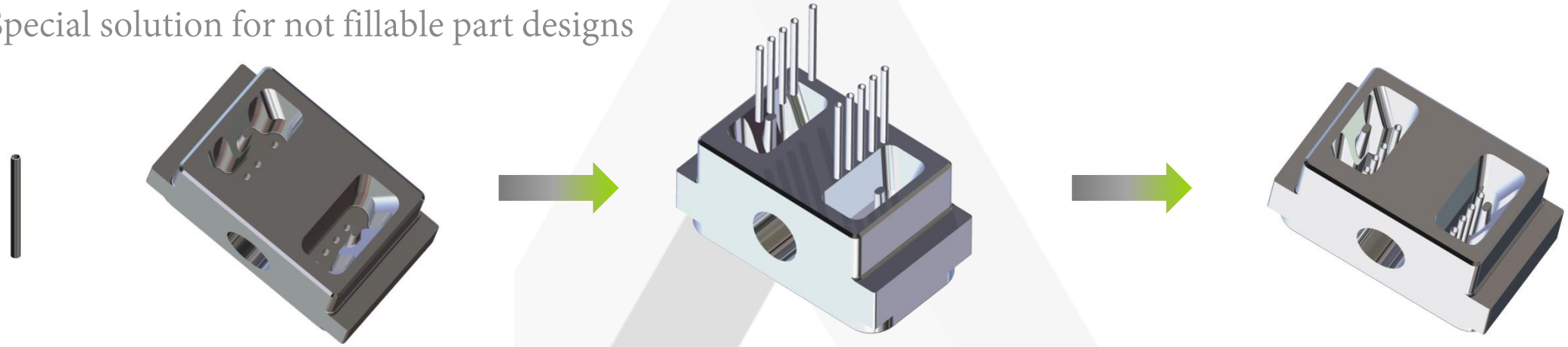
Round edges



Draft angles

Metal Injection Moulding – Co-sintering

- Special solution for not fillable part designs

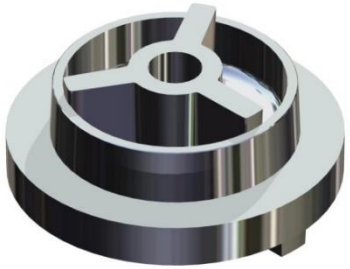


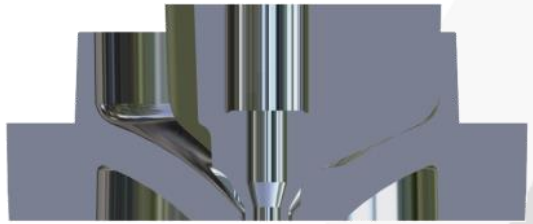
steel insert | green part | joining | sintered part

- Special solution for not demouldable part designs

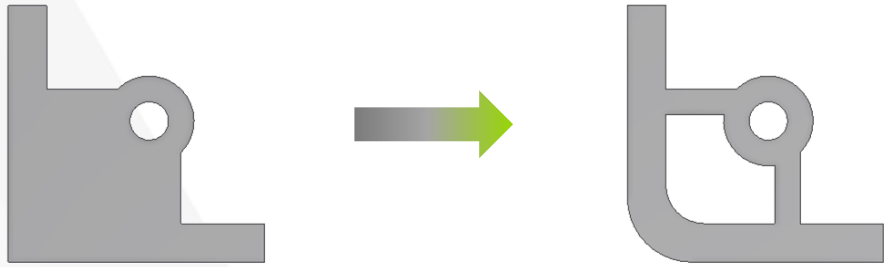
green parts | sintered part

Additive Manufacturing – Design freedom & guidelines

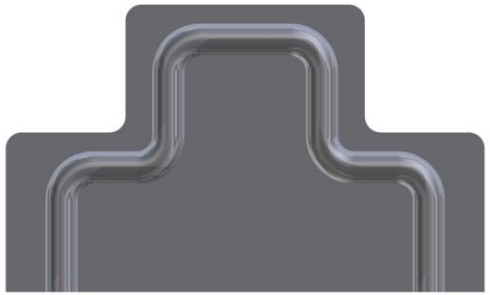




Undercut



Constant wall thickness

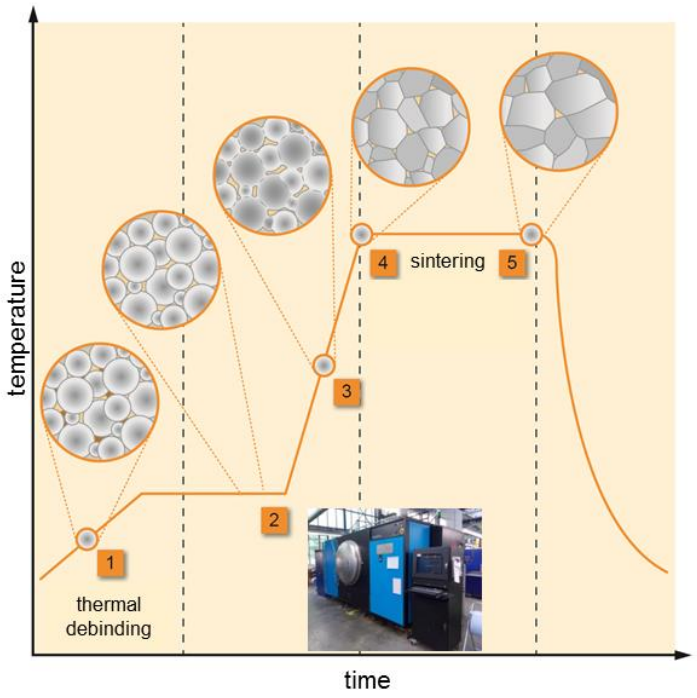


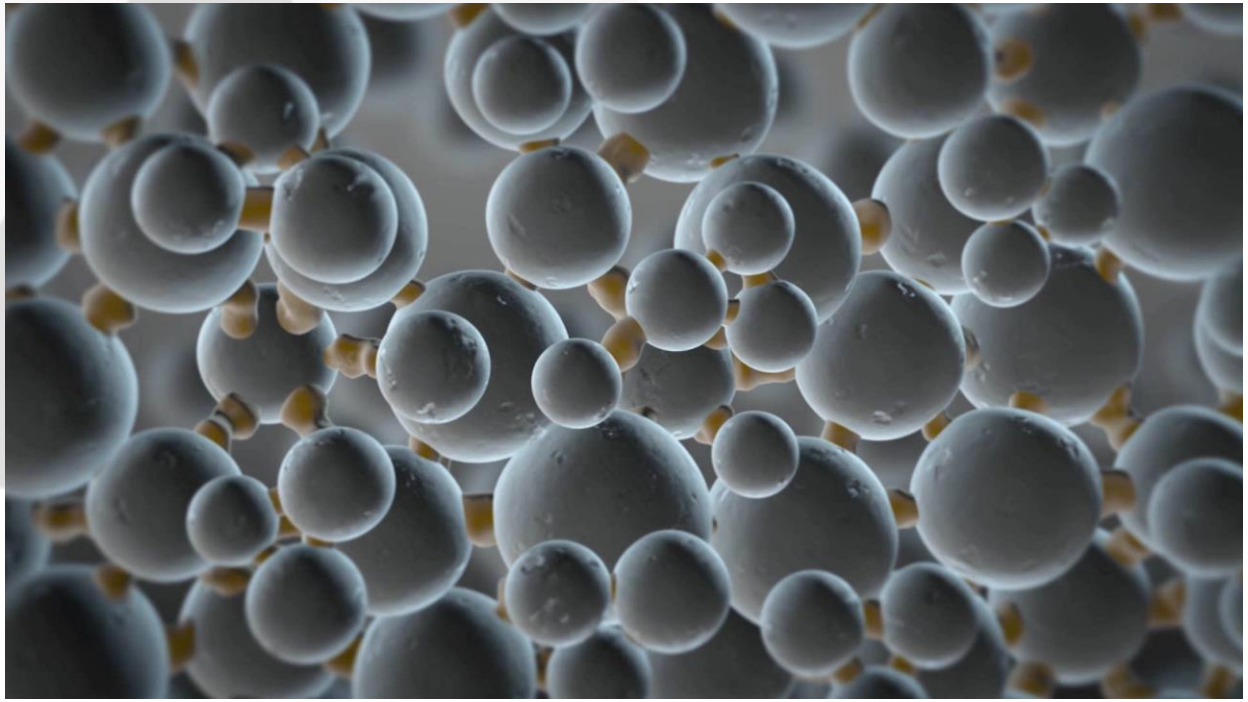
Cooling channels

Round edges

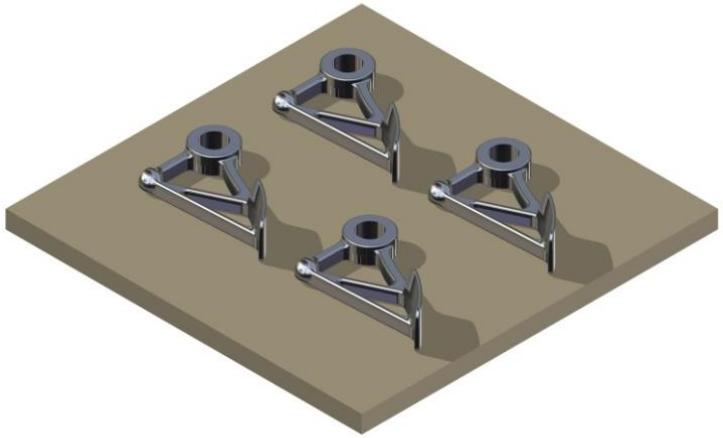
Sintering of AM and MIM parts

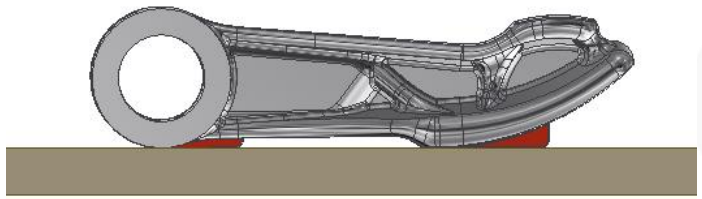
- Sintering is essential to transform green parts into a fully metallic part
  → Densification of the porous structure to receive a dense (> 96%) metal part
- Sintering temperature is close to the melting temperature of the material
  → Consideration of creep and friction to avoid sintering distortion



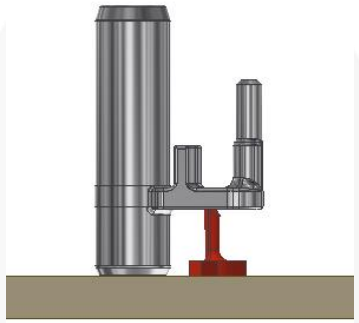


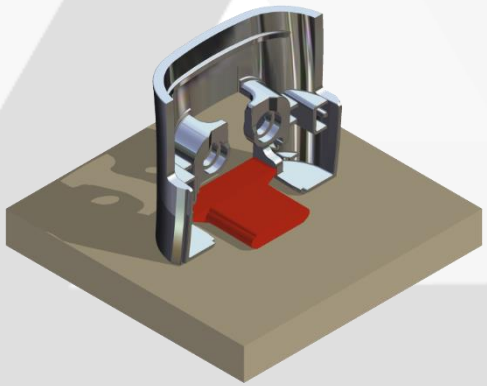
Sintering of AM and MIM parts – Design guidelines



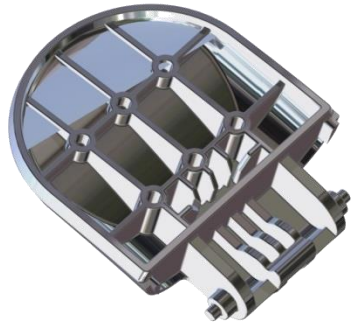


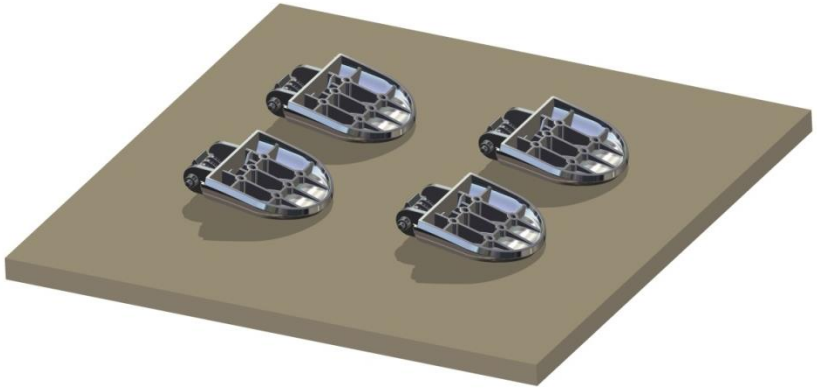
flat contact surface





support structure

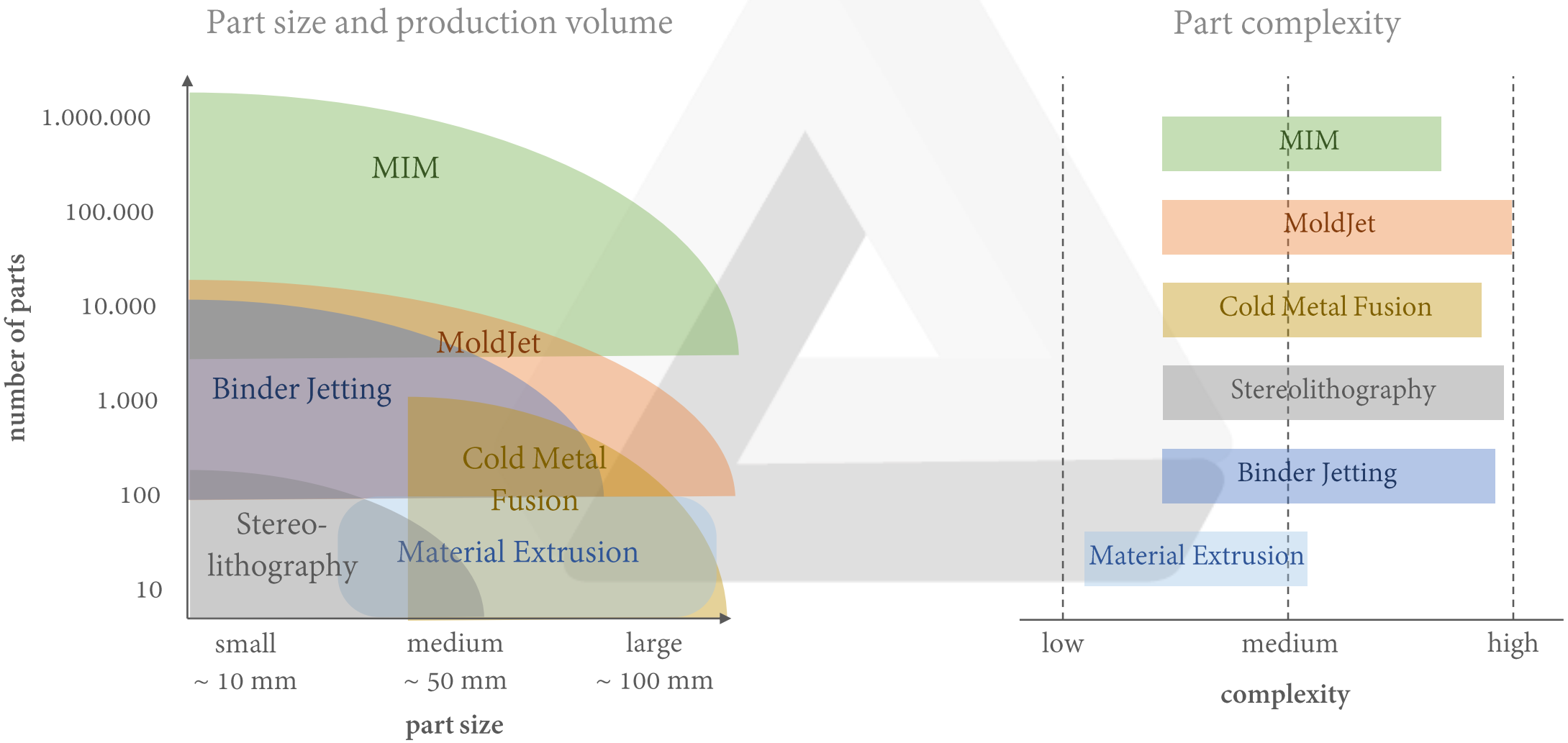




reinforcement structure

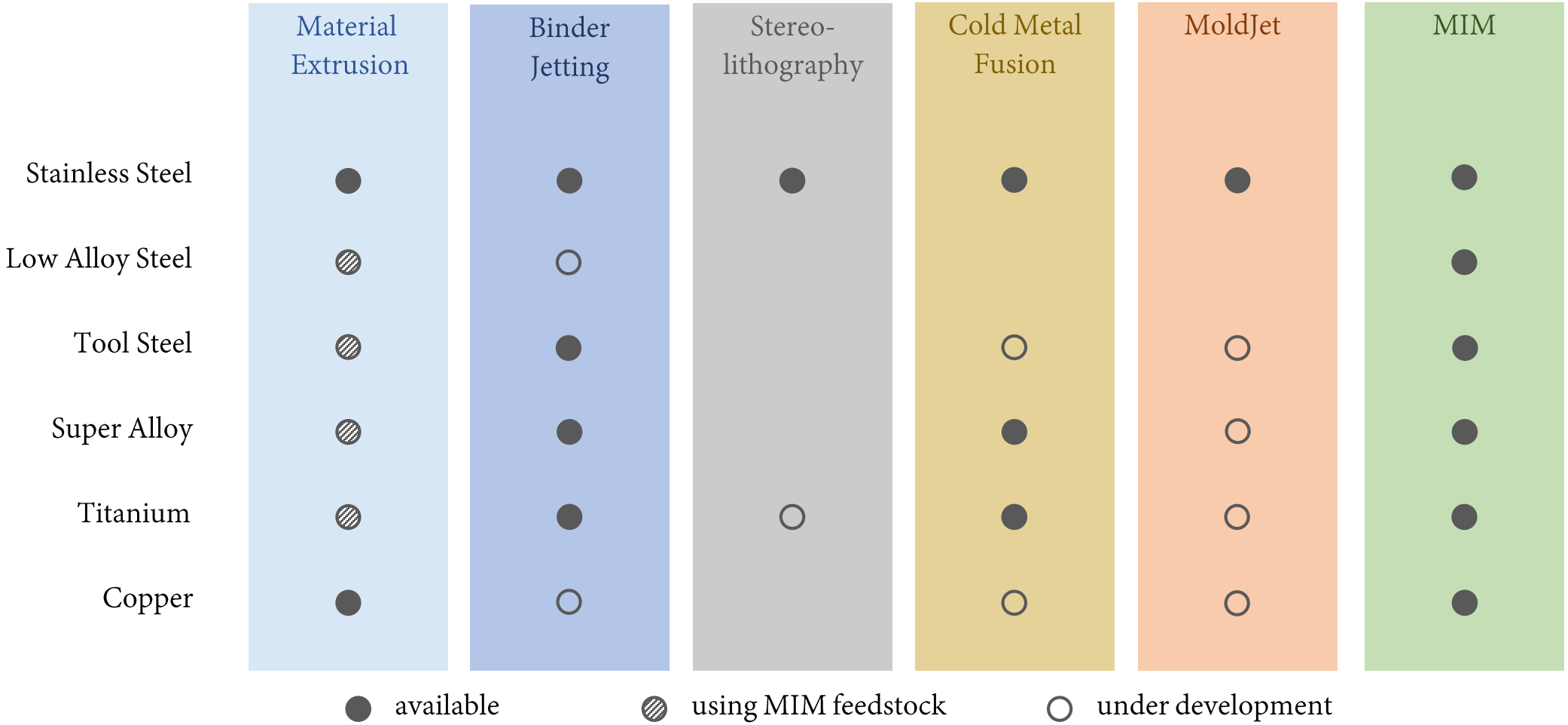
→ AM helpful to determine the best part geometry (e.g. support, reinforcement) with respect to sintering distortion prior to mould tool construction

Comparison of AM and MIM



Comparison of AM and MIM

Material portfolio



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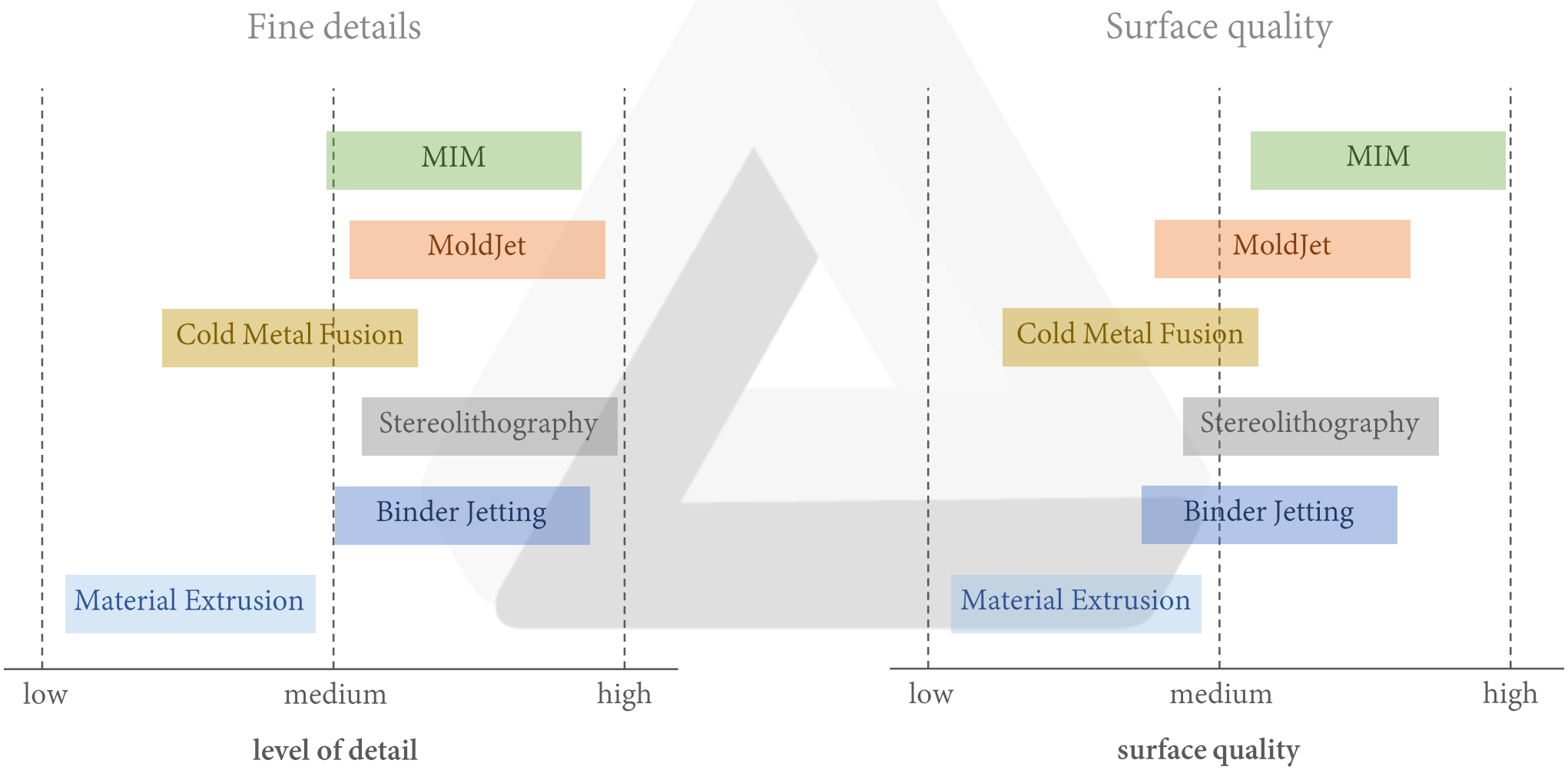
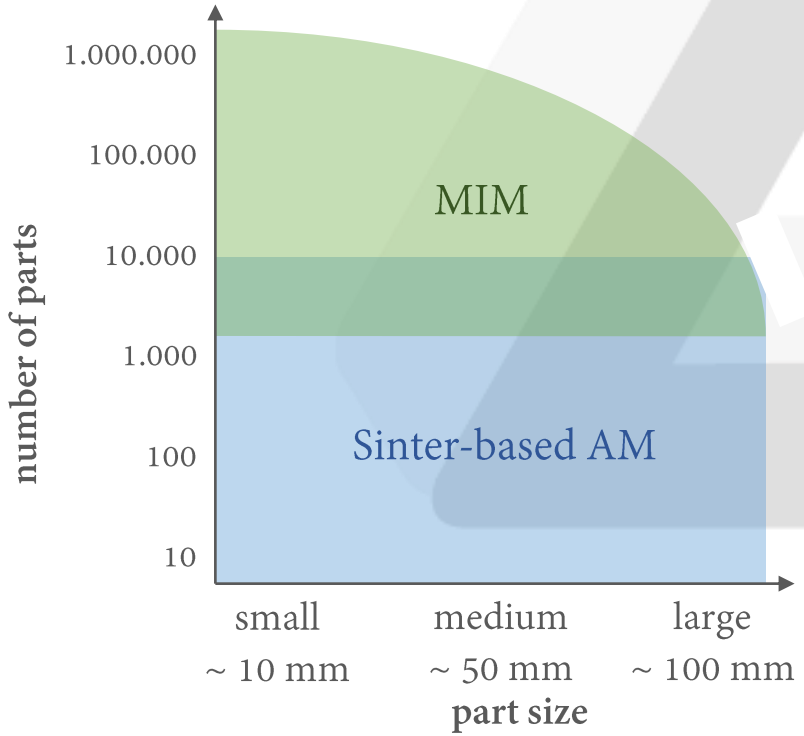


Conclusion

- Sinter-based AM and MIM is capable of producing complex metal parts
- Each technology has its pros and cons
- Sinter-based AM and MIM are complementary to each other



MIMplus Technologies GmbH & Co. KG
Turnstr. 22 – 75228 Ispringen

Tel.: +49 7231 802 100
infomim@mimplus.de
www.mimplus.com