Bauparameter für die SLM-Technologie & Anwendunsgbeispiele

23. Fachtagung Rapid Prototyping, Lemgo

voestalpine Additive Manufacturing Center
www.voestalpine.com

voestalpine
ONE STEP AHEAD.

AGENDA

voestalpine

THE voestalpine Group

Headquartered in Linz, Austria

voestalpine is a leading technology and capital goods group with combined material and processing expertise, holding global top positions in its business units. The Group focuses on product and system solutions based on steel and other metals of the highest quality in technology-intensive industries and niches.

voestalpine
ONE STEP AHEAD.

OVERVIEW OF INDUSTRIES

Mobility

Energy

Building/Construction

White goods/Consumer goods

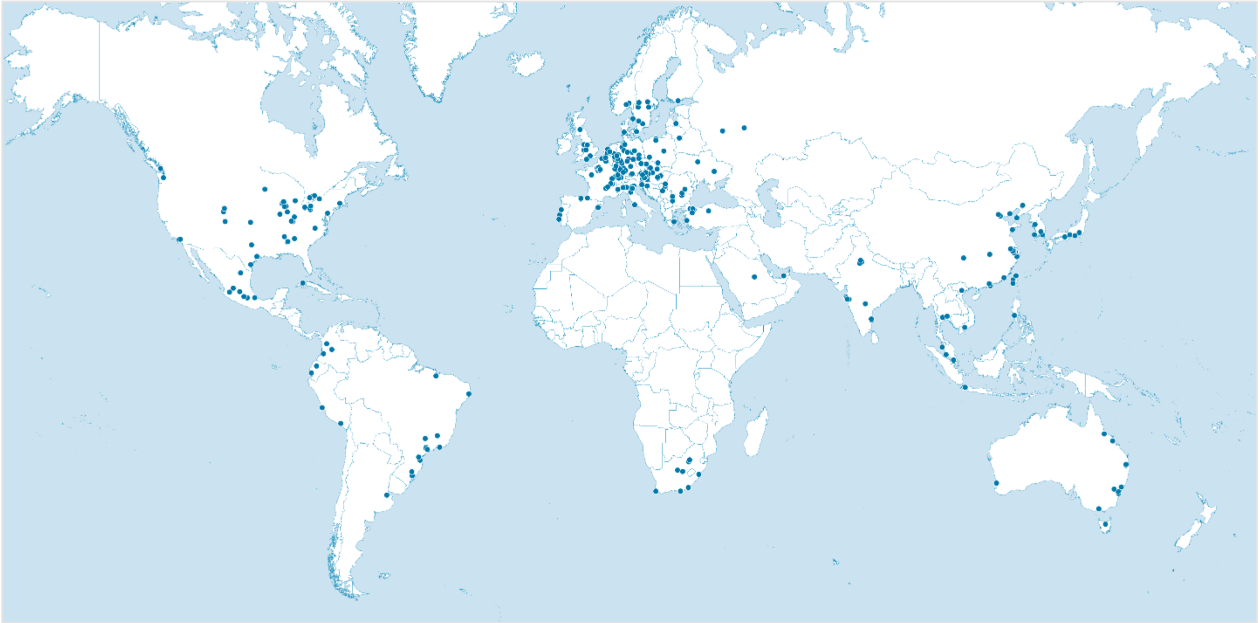
Mechanical engineering

Other

- Products made from steel and other metals for technology-intensive industries and demanding niche segments
- Focus on segments with the highest quality requirements
- Continues extension of the value chain in the direction of the end customer
- Focus on mobility and energy

voestalpine
ONE STEP AHEAD.

GLOBAL FOOTPRINT



Leading world-wide technology and capital goods company

- » 500 locations
- » 50 countries
- » 5 continents

voestalpine
ONE STEP AHEAD.

ADDITIVE MANUFACTURING
HIGH PERFORMANCE METALS AM NETWORK

Multiple locations, markets & technologies

Comment

- AM Centers of Excellence (Innovation centers) around the world
- Powder production in Europe
- To be close to the customer, we create a worldwide footprint for the design and production of parts
- We are focusing on both – powder bed and direct metal deposition
- To build up this network, efficient, strong collaboration & know-how exchange is absolutely essential

» Additive manufacturing is an important step for the transformation from a steel-producing to a technology and capital goods producing company

...Powder bed fusion
...Direct metal deposition
...Powder production

voestalpine
ONE STEP AHEAD.

vMATERIALS & AM-MACHINE CAPABILITIES

Laser Beam Melting

EOS M290

EOS M400

TruPrint 1000

SLM 280HL

Renishaw AM400

Direct Metal Deposition

Lasertec 65 3D

WAAM Systems

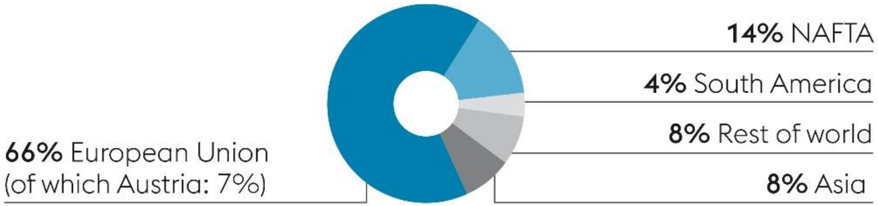
TruLaser 7040

voestalpine Additive Manufacturing Center

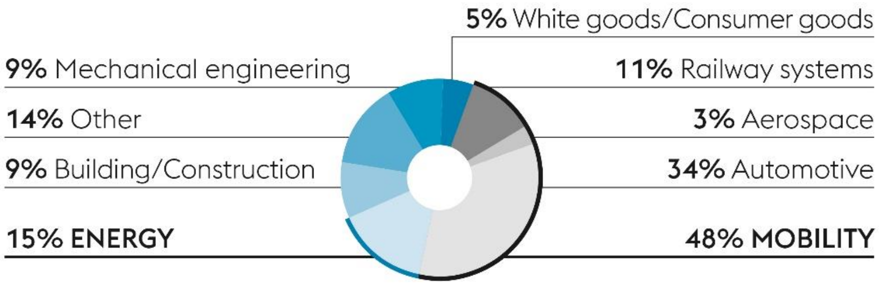
voestalpine
ONE STEP AHEAD.

KEY FIGURES
BUSINESS YEAR 2017/18

REVENUE BY REGION (BY 2017/18)



REVENUE BY INDUSTRY (BY 2017/18)

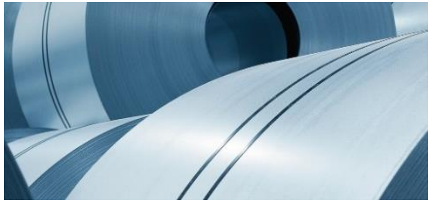


- » Revenue: EUR 13 billion
- » EBITDA: EUR 2 billion
- » Employees: 51,600

voestalpine
ONE STEP AHEAD.

ORGANIZATION

As a publicly listed holding company, voestalpine AG manages four divisions that are each world market leaders or one of the leading global suppliers.



STEEL DIVISION

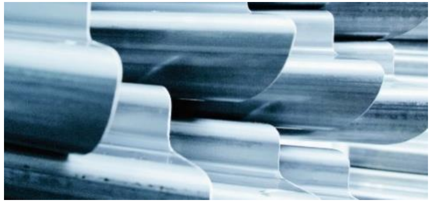
Worldwide quality leadership
36% share of Group consolidated revenue

HIGH PERFORMANCE METALS DIVISION

Global market leader
22% share of Group consolidated revenue

METAL ENGINEERING DIVISION

World market leader
22% share of Group consolidated revenue



METAL FORMING DIVISION

World's leading supplier
20% share of Group consolidated revenue

HIGH PERFORMANCE METALS DIVISION
HIGHLIGHTS 2017/18

- Significant improvement in results → solid demand from the automotive, consumer goods, and aerospace industries
- Oil & gas with upward trend
- Preparations for construction of the world's most advanced special steel plant in Kapfenberg on plan (EUR 350 million*)
- Global expansion of metal additive manufacturing (EUR 50 million*)
- Expansion of aerospace capacities (total of EUR 75 million*)

*Total investment volume over several years

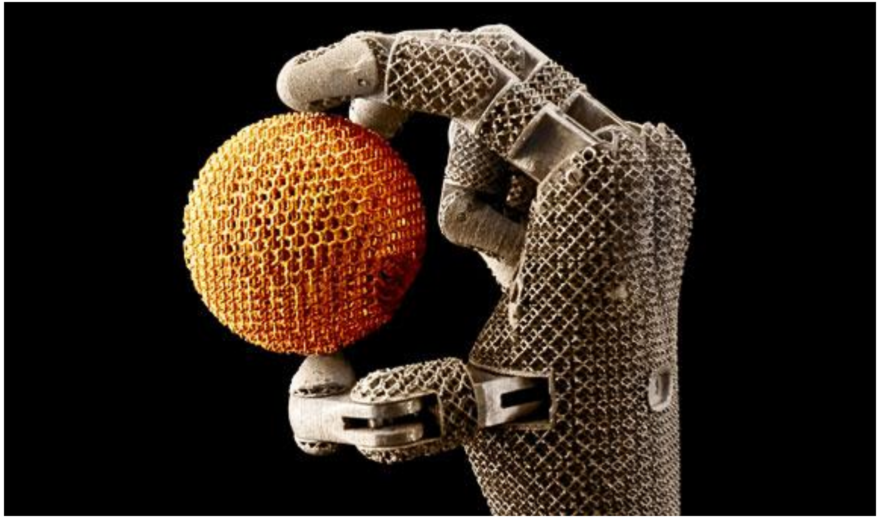
voestalpine
ONE STEP AHEAD.

TECHNOLOGY

voestalpine

WHAT IS ADDITIVE MANUFACTURING?

…small & complex



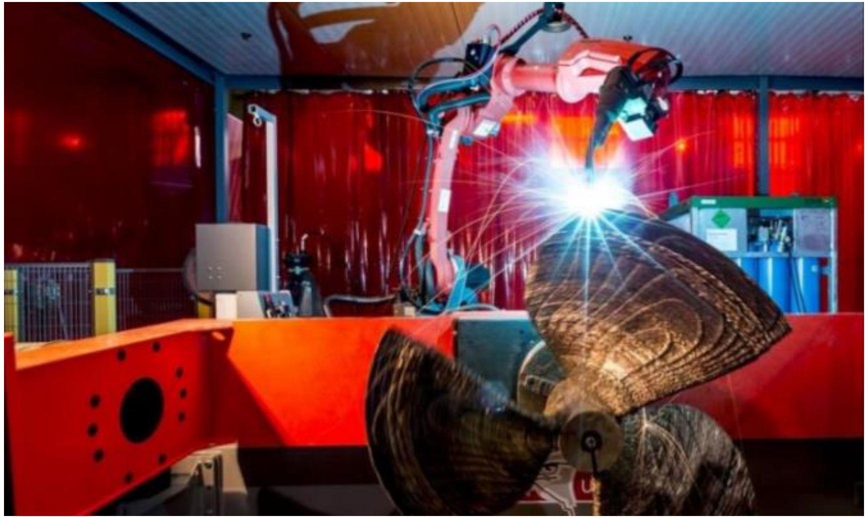
Source: http://www.mx3d.com

Source: voestalpine

voestalpine
ONE STEP AHEAD.

WHAT IS ADDITIVE MANUFACTURING?

... big, rough formed



Source: http://www.ramlab.com

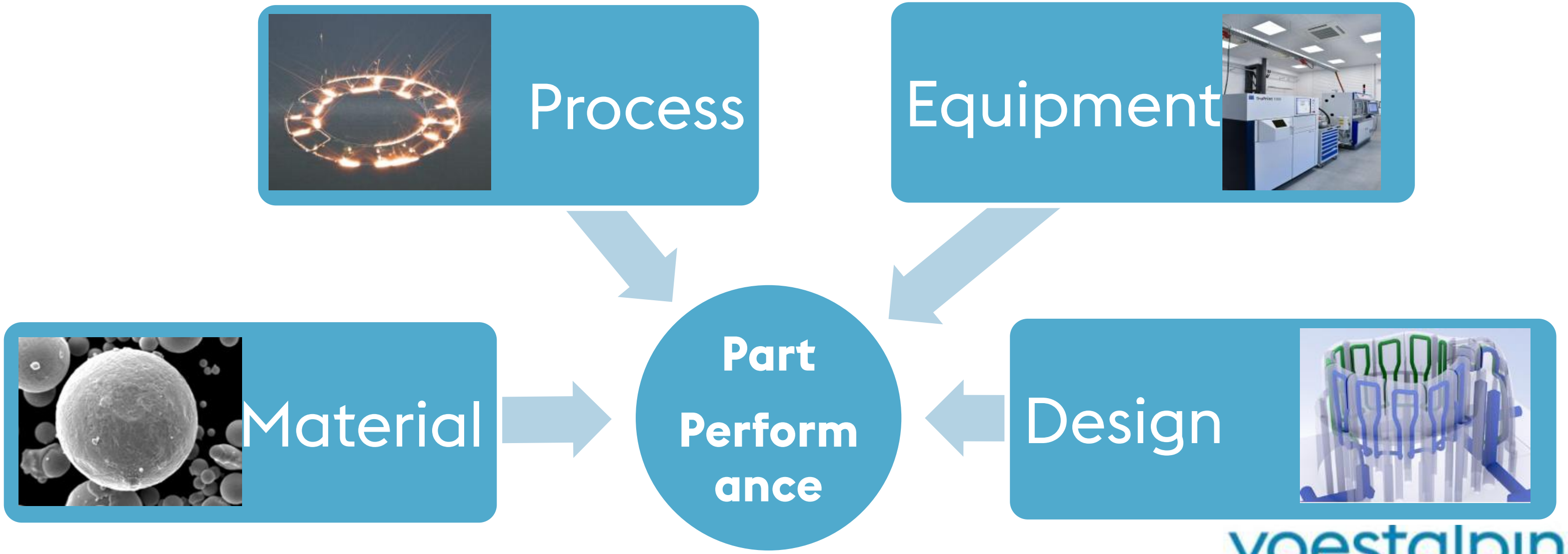
Source: http://www.mx3d.com

Don’t try to use AM for parts which are dedicated to other manufacturing technologies!

AM is only economically if you can **add value** to the part!

THE CHALLENGE WITH ALL THE AM TECHNOLOGIES

» The interaction of material, design, process and equipment is much stronger than with traditional manufacturing technologies



DEVELOPMENT & PRODUCTION OF HIGH QUALITY METAL POWDERS AT BÖHLER EDELSTAHL & UDDEHOLM

Atomising rigs at Böhler & Uddeholm

BÖHLER

UDDEHOLM

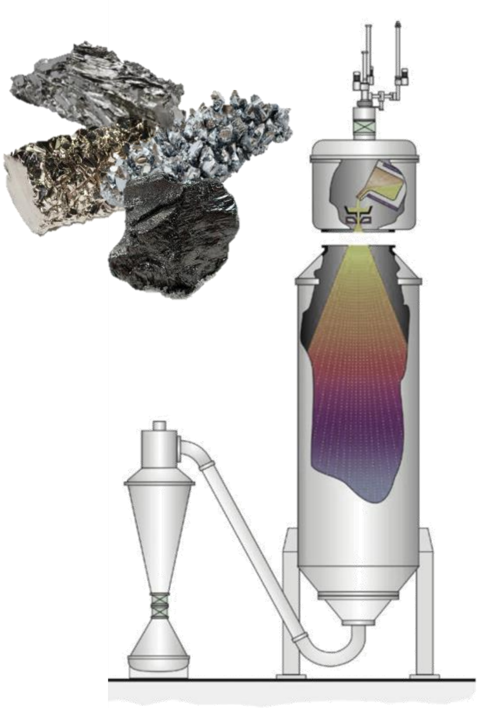
Facts

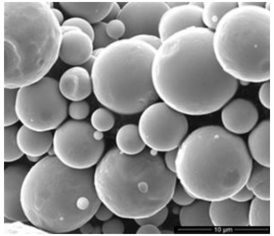
- Production started 2016
- In total a yearly capacity of roughly 80 tons of metal powder will be available for AM & PM
- VIM with max. batch size of 200-250kg
- Atomization with inert gas
- Flexible production plant – open for customized solutions (chemistry)
- Atomization of broad range of steel and Ni-Base alloys possible

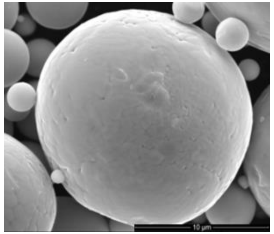
voestalpine
ONE STEP AHEAD.

Source: voestalpine

MATERIAL DEVELOPMENT & PRODUCTION







- Alloy development
- Powder production started 2016
- Atomization with inert gas
- Yearly capacity of approx. 80 t of metal powder for AM
- Wide atomization range of tool steels an Ni-Base alloys
  - Corrax, N700, W722, W360, M789 L718, L625, …
  - **many more under development**

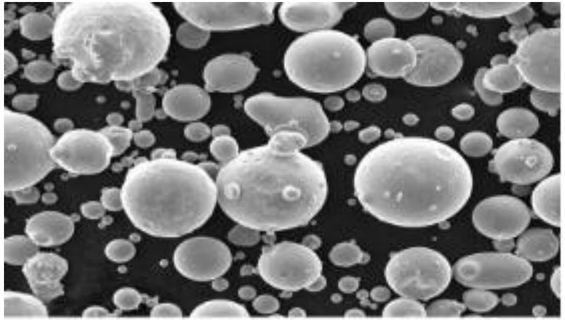
voestalpine
ONE STEP AHEAD.

Source: voestalpine

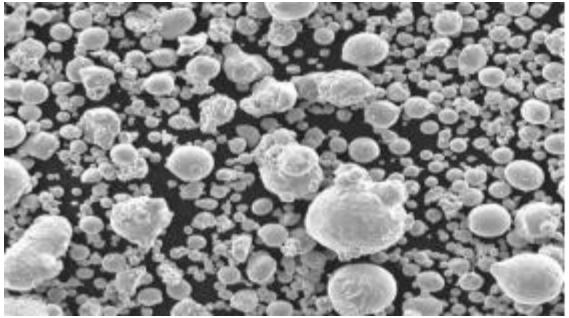
POWDER IS POWDER – REALLY?

=

?



≠



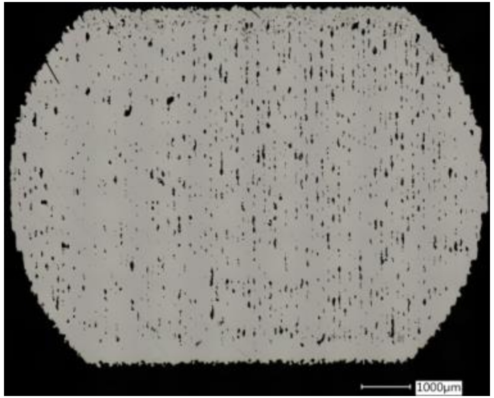
- Shape
- Particle size distribution
- Hollow structure
- Humidity
- Oxygen content
- Chemistry
- Flowability

Source: voestalpine

voestalpine
ONE STEP AHEAD.

MATERIAL PROPERTIES

Several years ago



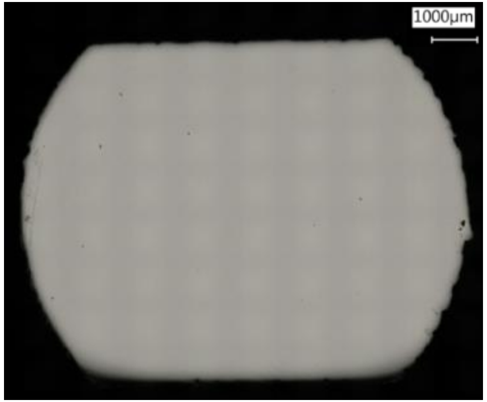
Density ~95%

Technical progress:

» Laser technology
» Optics
» Software
» Efforts in R&D

Mechanical properties close to bulk material

Today



Density ~99.97%

Source: voestalpine

Parameter development for LBM

voestalpine Additive Manufacturing Center
www.voestalpine.com

voestalpine
ONE STEP AHEAD.

Agenda

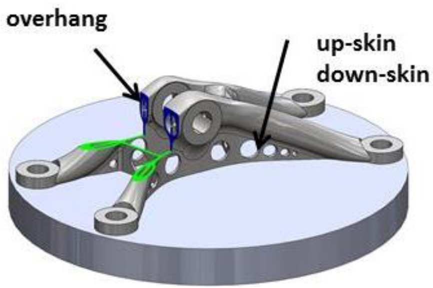
- Parameters to print specimens and parts. What is the difference?
- Approach to development parameters @ vAMC
  - Procedure – Overview
  - Process stage 1 – Screening
  - Process stage 2 – Reproducibility
  - Process stage 3 – Manufacturing

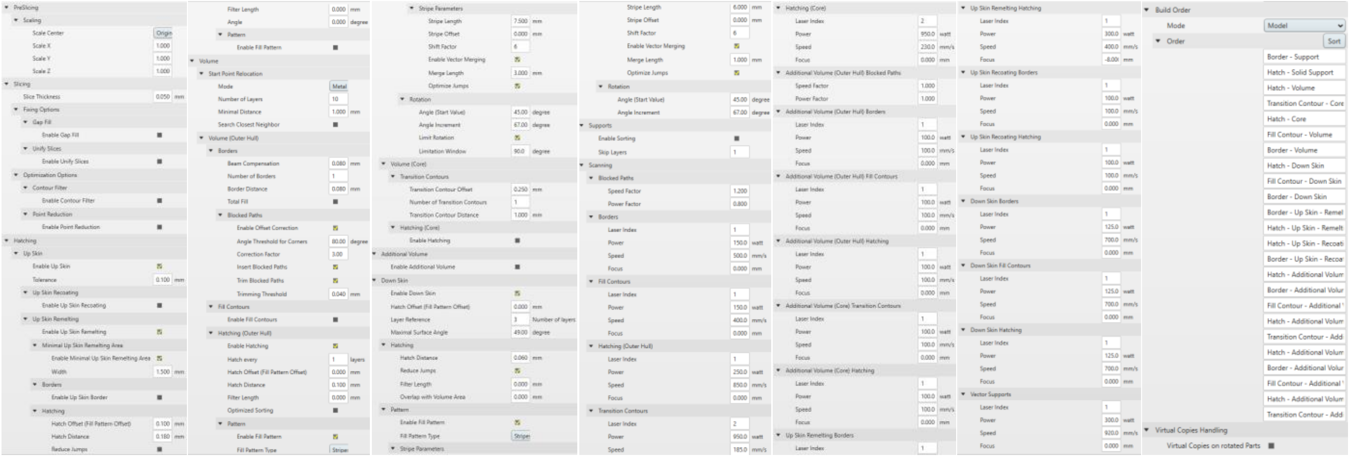
LBM Parameters

Parts vs. Specimens

voestalpine
ONE STEP AHEAD.

LBM Parameters for Parts

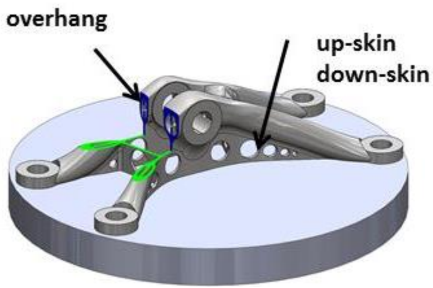




Approx. 200 parameters need to be considered!

voestalpine
ONE STEP AHEAD.

LBM Parameters for Parts

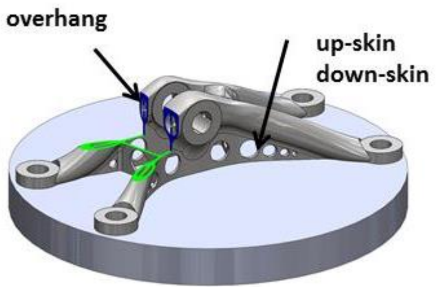


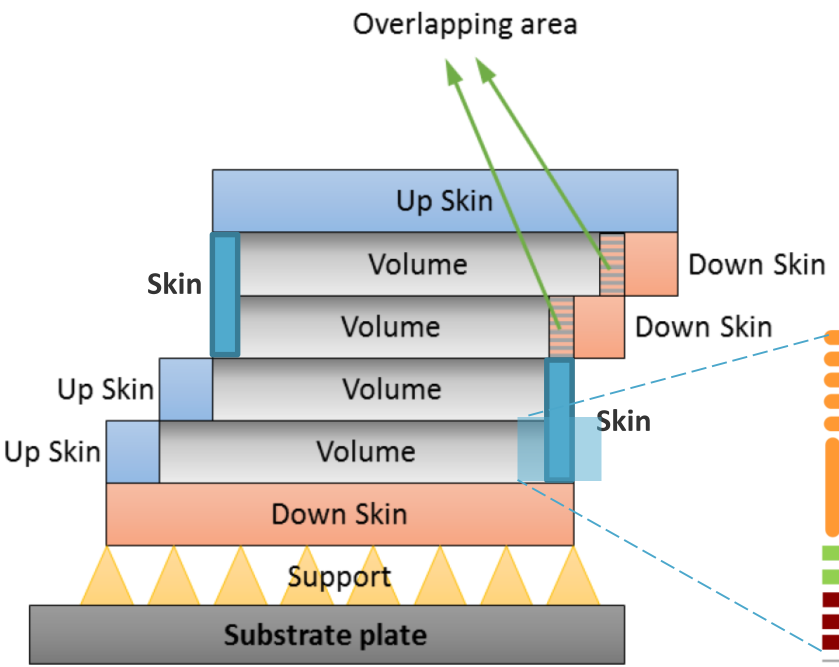
▼ Additional Volume (Outer Hull) Blocked Paths		
Speed Factor	1.000	
Power Factor	1.000	
▼ Additional Volume (Outer Hull) Borders		
Laser Index	1	
Power	100.0	watt
Speed	100.0	mm/s
Focus	0.000	mm
▼ Additional Volume (Outer Hull) Fill Contours		
Laser Index	1	
Power	100.0	watt
Speed	100.0	mm/s
Focus	0.000	mm
▼ Additional Volume (Outer Hull) Hatching		
Laser Index	1	
Power	100.0	watt
Speed	100.0	mm/s

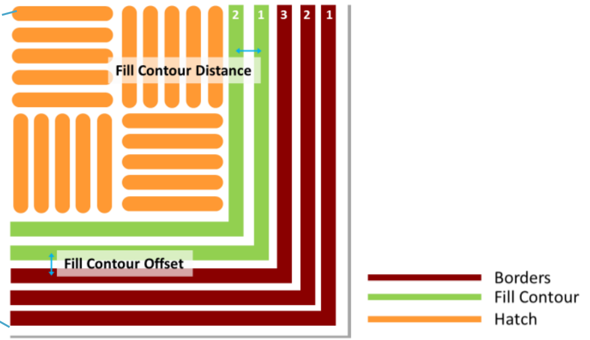
▼ Up Skin Recoating Borders		
Laser Index	1	
Power	100.0	watt
Speed	100.0	mm/s
Focus	0.000	mm
▼ Up Skin Recoating Hatching		
Laser Index	1	
Power	100.0	watt
Speed	100.0	mm/s
Focus	0.000	mm
▼ Down Skin Borders		
Laser Index	1	
Power	125.0	watt
Speed	700.0	mm/s
Focus	0.000	mm
▼ Down Skin Fill Contours		
Laser Index	1	

Approx. 200 parameters need to be considered!

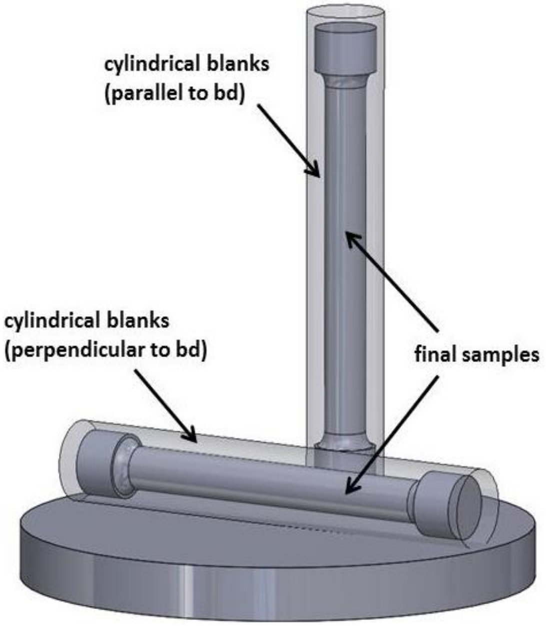
LBM Parameters for Parts



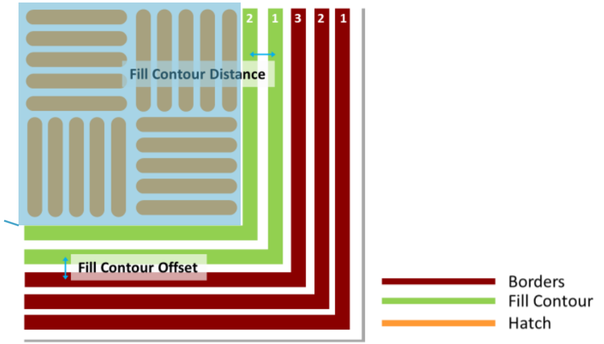




LBM Parameters for Specimens



- Laser power P_L [W]
- Scan speed v_s [mm/s]
- Hatch distance h_s [mm]
- Focus position f_z [mm]
- Preheating temperature T [°C]
- Scanning strategy



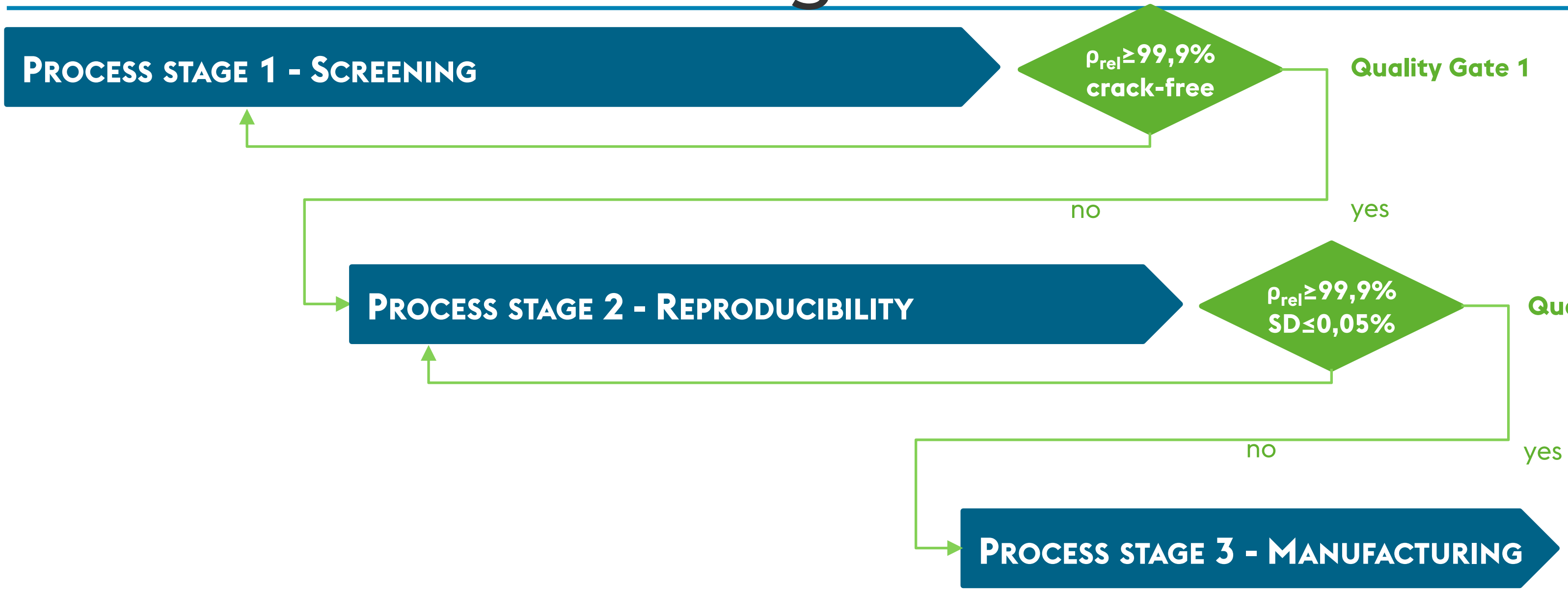
voestalpine
ONE STEP AHEAD.

Procedure

Overview

voestalpine
ONE STEP AHEAD.

Overview – Proceeding

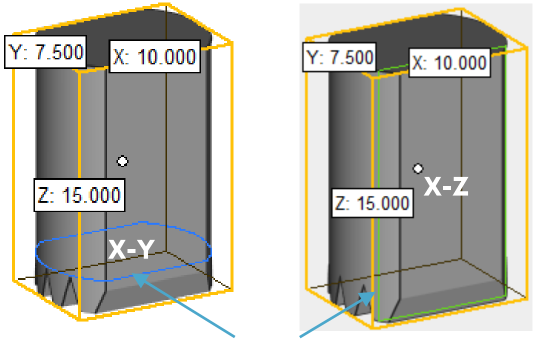


voestalpine
ONE STEP AHEAD.

Overview – Constant experimental conditions

- Machine settings
  - Coating
  - Air speed
  - Oxygen level
- Constant parameters
  - Laser focus diameter
  - Slice thickness
- Powder condition
  - Moisture content of powder fill

Specimen



Investigated cross section

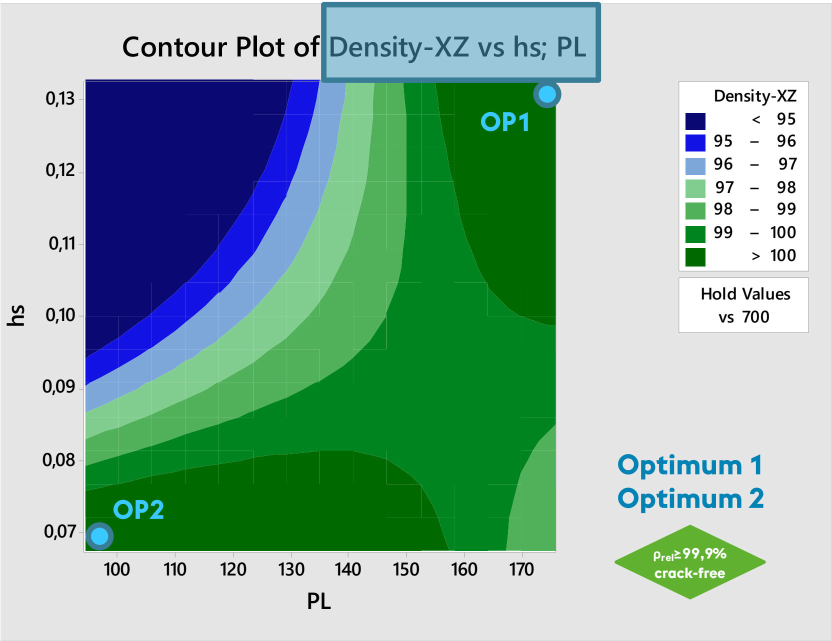
voestalpine
ONE STEP AHEAD.

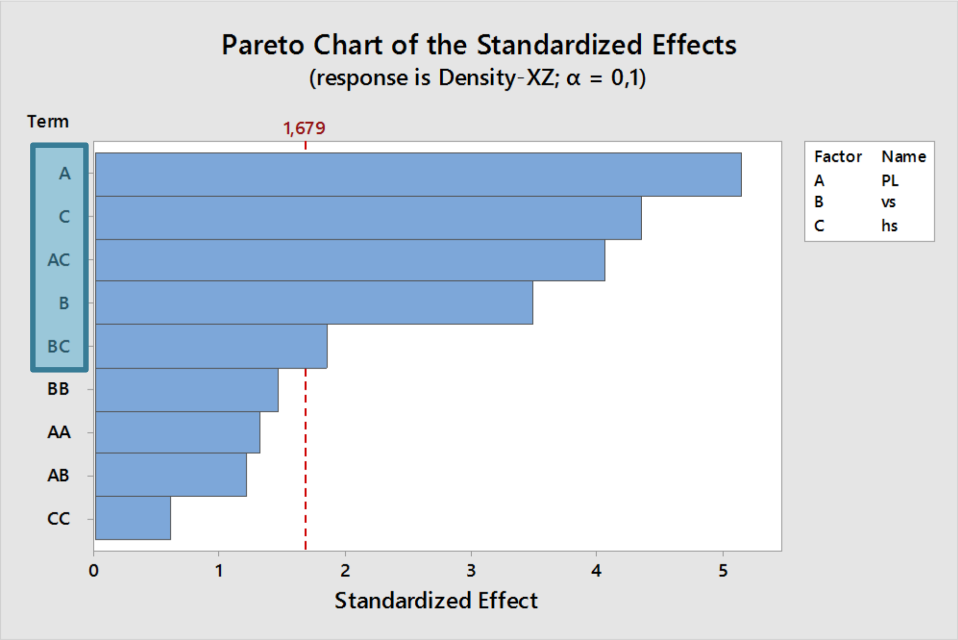
Procedure

Process stage 1 – Screening

voestalpine
ONE STEP AHEAD.

Process stage 1– Results





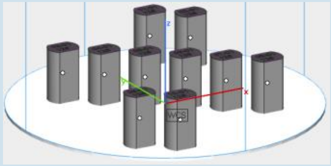
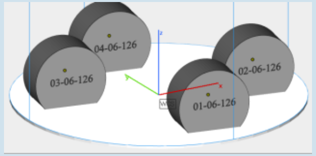
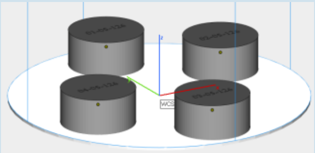
voestalpine
ONE STEP AHEAD.

Procedure

Process stage 2 – Reproducibility

voestalpine
ONE STEP AHEAD.

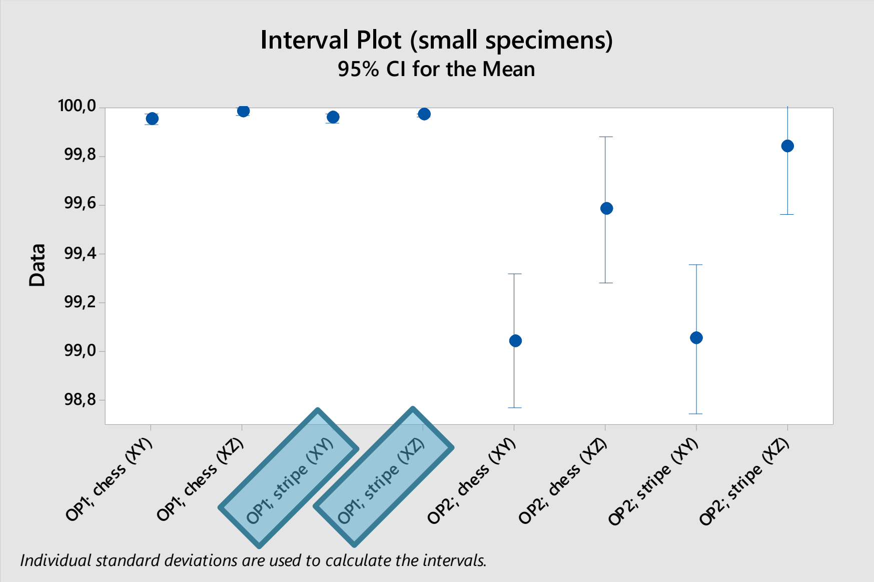
Process stage 2 – Additive manufacturing

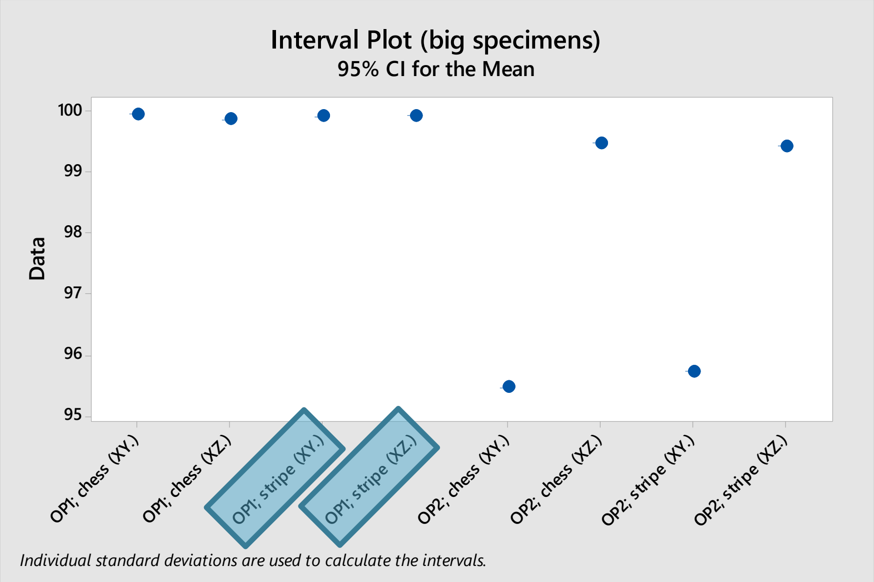
Build process 1 ≙ Block 1	Build process 5 ≙ Block 5	Build process 6 ≙ Block 6
		
10x specimen	4x specimen	4x specimen

All specimens are randomly positioned on the build plate to minimize the influence of gas flow and coating direction.

voestalpine
ONE STEP AHEAD.

Process stage 2 – Results





Best parameter set in terms of high density ($\rho_{rel,\ mean}$ = 99,96%) and reproducibility (SD = 0,02)

voestalpine
ONE STEP AHEAD.

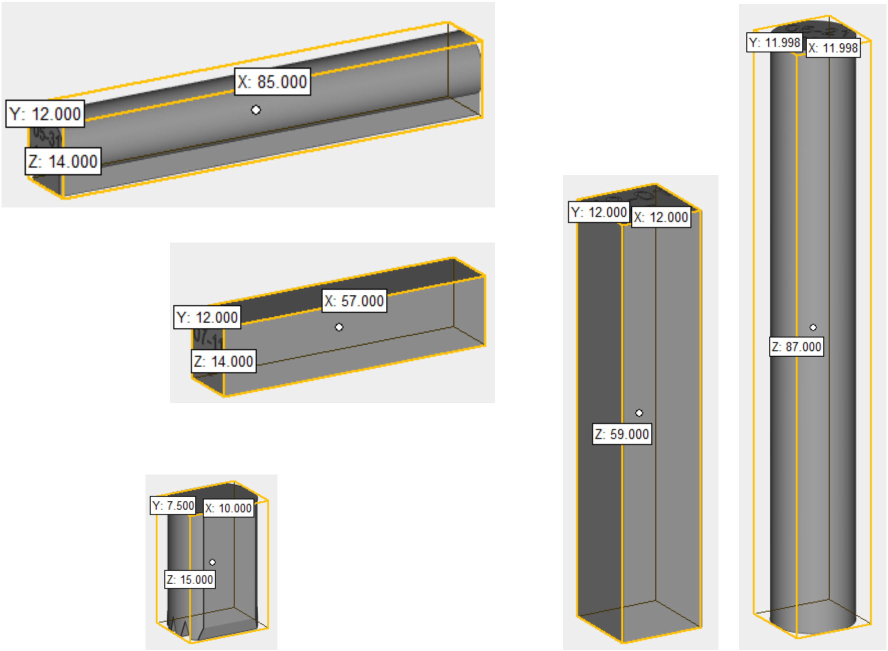
Procedure

Process stage 3 – Manufacturing

voestalpine
ONE STEP AHEAD.

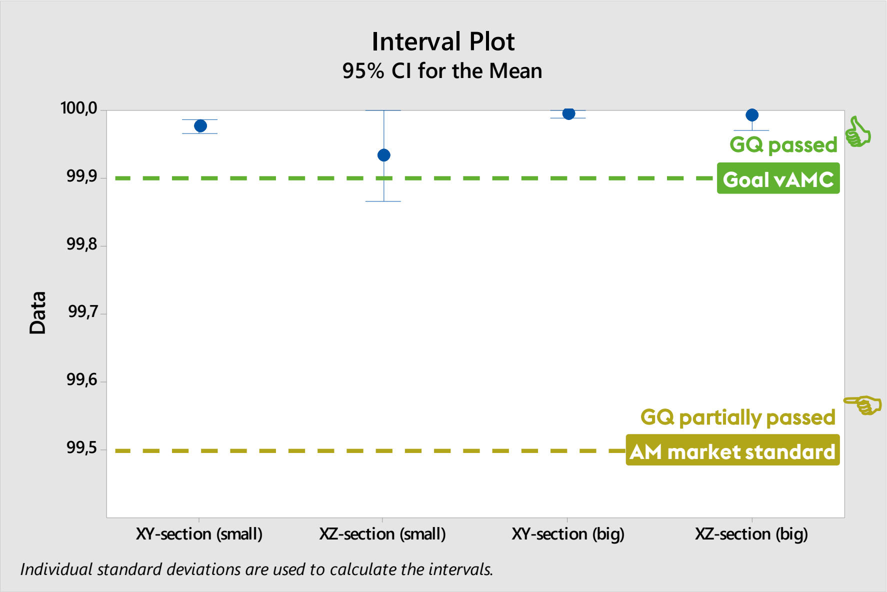
Process stage 3 – Manufacturing of mechanical specimens

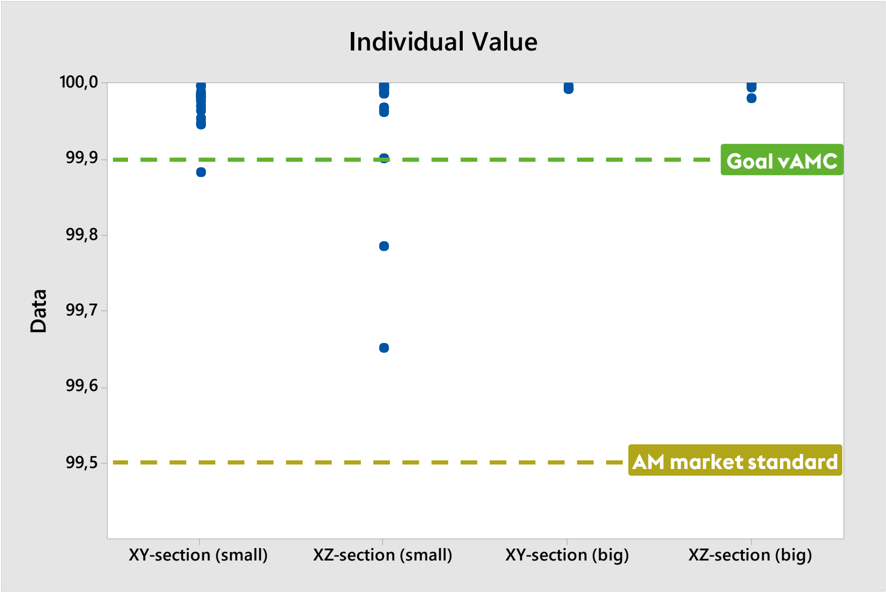
CTQs	Standards and regulations	Quantities
Tesile test	DIN EN ISO 6892-1 *VDI 3405-2*	25x vertical 25x horizontal
Charpy pendulum impact test	DIN EN ISO 148-1 *VDI 3405-2*	35x vertical 35x horizontal
Metallog-raphy	*VDI 3405-2*	>10 vertical/horizontal



voestalpine
ONE STEP AHEAD.

Process stage 3 – Results





Requested test program was completely fullfilled. Results meet completly or partitially the defined requirements.

voestalpine
ONE STEP AHEAD.

CASES

CASES

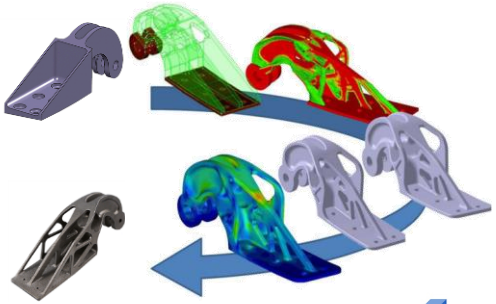
CHALLENGES

ACHIEVEMENTS

LEARNED

voestalpine
ONE STEP AHEAD.

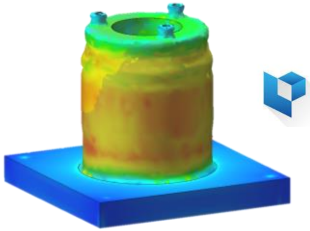
EFFECTIVE AND SUITABLE DESIGN FOR AM



INSPIRE solidThinking

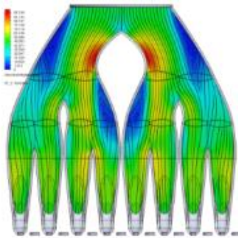
SOLIDWORKS

3YOURMIND



Materialise Magics

simufact Simulating Manufacturing

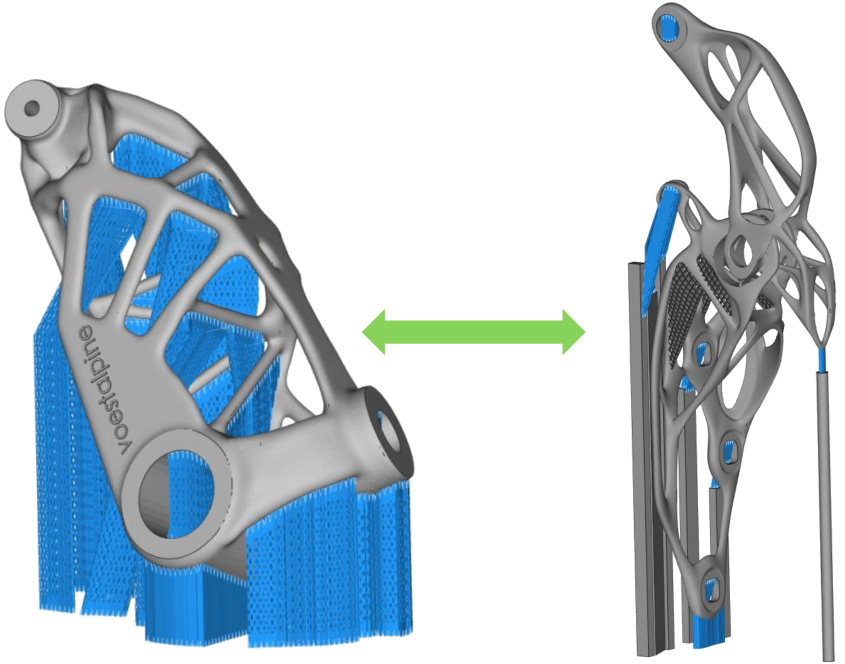


- Basic **AM design rules**
- **Simulation** know how and software tools needed to enhance AM potential
- Knowhow **connection** between design and manufacturing
- **Post Processing** know how

Source: Altair, voestalpine

voestalpine ONE STEP AHEAD.

SUPPORT OPTIMIZATION

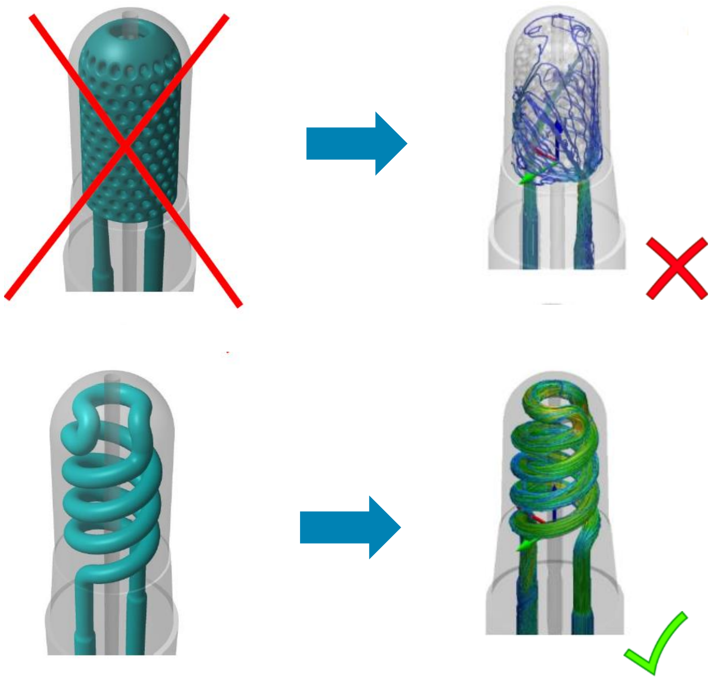


- » Topology and support optimizations may allow great material reduction but… can lead to massive support and post processing problems
- » Build direction is essential to minimize support, building time, distortion and to optimize platform utilization

voestalpine
ONE STEP AHEAD.

Source: voestalpine

STANDARD vs. CONFORMAL COOLING



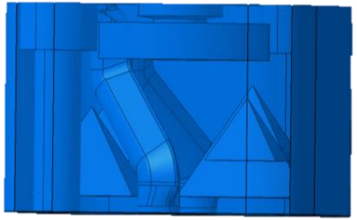
» … not every design is as efficient as it looks on the first glance

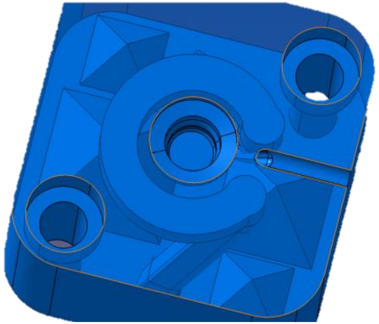
» Simulation and design experience is needed to enhance the full advantages of additive manufacturing

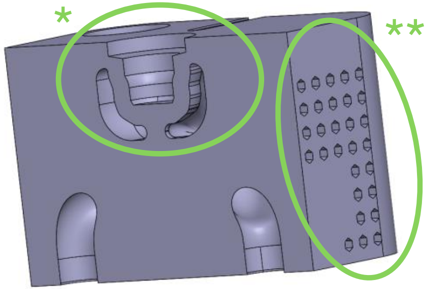
Source: Renishaw

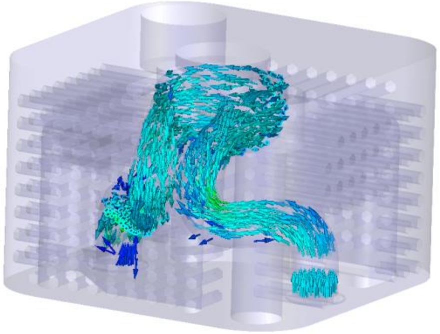
voestalpine
ONE STEP AHEAD.

CONFORMAL COOLING FROM EXPERTS









APPLICATION

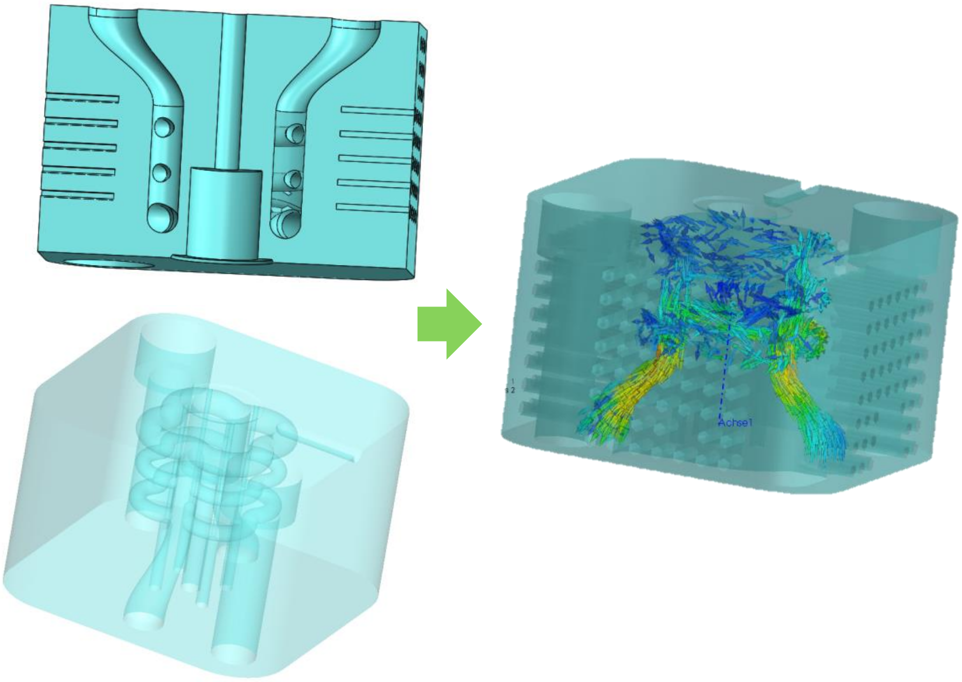
Plastic injection molding tool with conformal cooling

AM ADVANTAGES

- Reduced cooling time **20s → 6s**
- Simulation and advanced channel design* guarantees best performance
- Lightweight design** to reduce cooling losses and reduce printing time

Source: voestalpine

CONFORMAL COOLING FROM EXPERTS



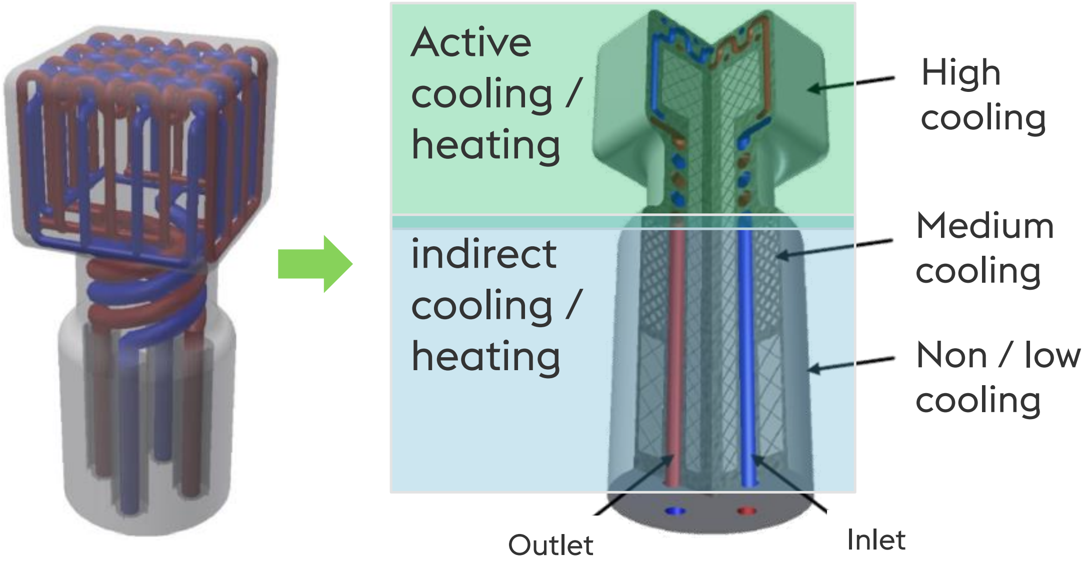
Parallel cooling often used when space-saving is necessary but it is very challenging to realize due to

- » unbalanced mass flow rate and flow speed
- » powder removal

Expert knowledge in simulation and post processing needed!

Source: voestalpine

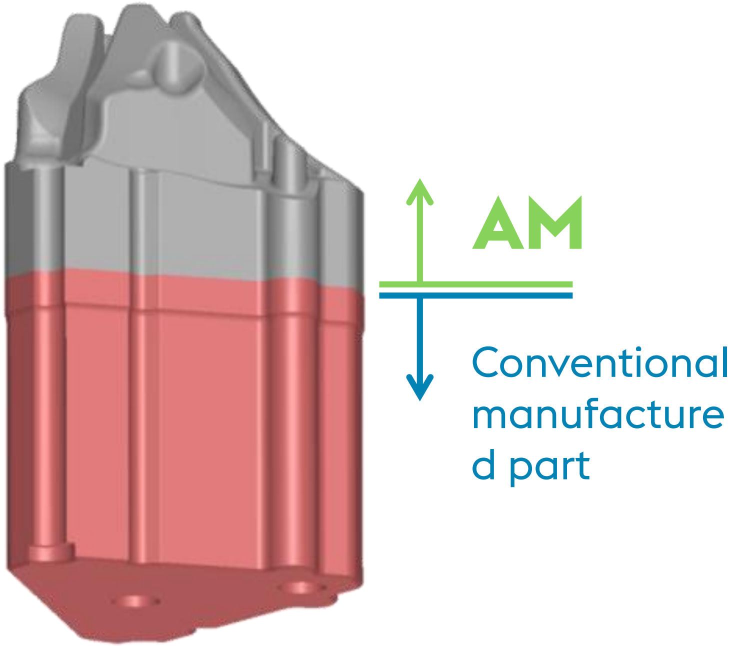
MODULATION OF COOLING DENSITY



- Tailored cooling by using different channel density and lattice density

Source: GoetheLab for Additive manufacturing, voestalpine

AM - HYBRID DESIGN



APPLICATION

- » Additive Manufacturing directly on an existing part

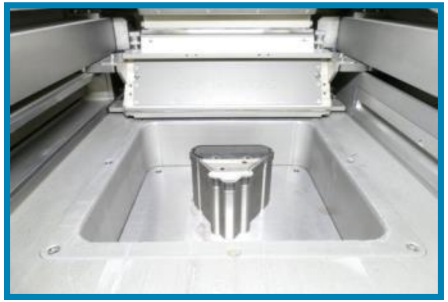
AM ADVANTAGES

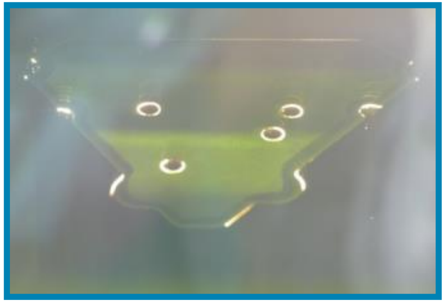
- » Conventional machining of the base
- » Reduction of the AM- volumes
- » Reduction of manufacturing costs

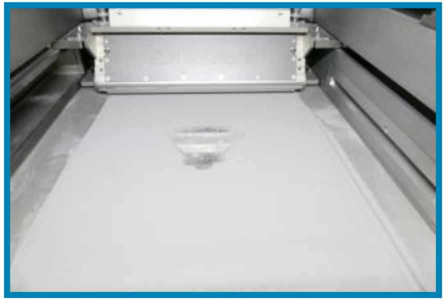
Source: voestalpine

voestalpine
ONE STEP AHEAD.

HYBRID MANUFACTURING



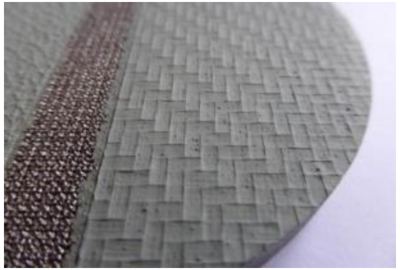


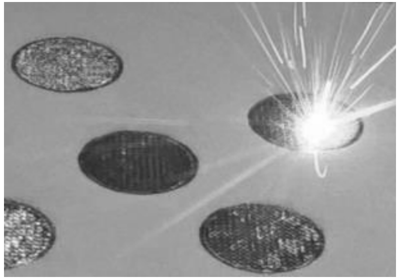


- » Positioning of the build platform and milled part
- » Import and positioning of part data
- » Lower AM - part to Z = 0mm
- » Contour check
- » Powder fill up and compressing
- » Job start

Source: voestalpine

DEFINED POROSITY





APPLICATION

Porous structure with a defined permeability

» Filtering purposes
» Vacuum pressure establishing over a big surface
» Geometrical bonding with other Materials

Source: voestalpine

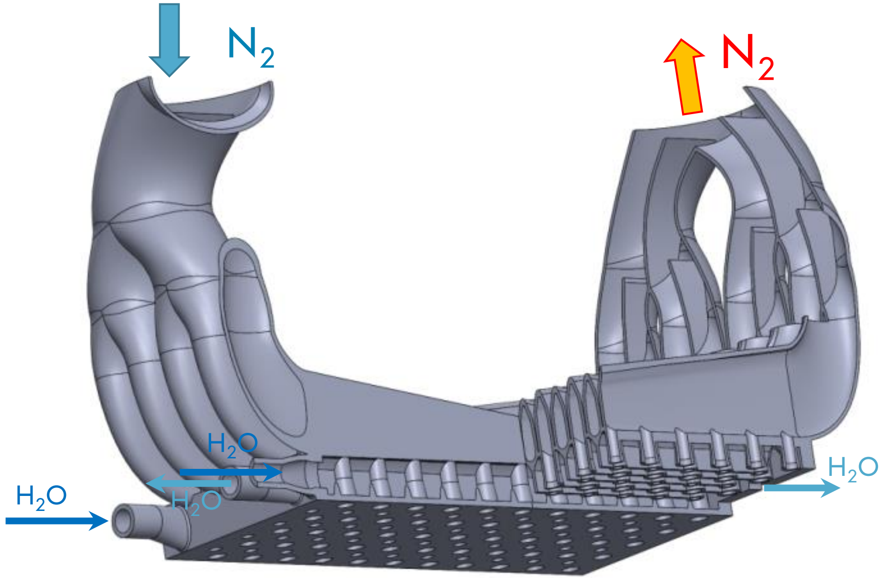
voestalpine
ONE STEP AHEAD.

Tools with coating

http://oewf.org/en/portfolio/amadee-18/

voestalpine
ONE STEP AHEAD.

TECHNOLOGY SHOWCASE: JET ARRAY COMBINED FUNCTIONS



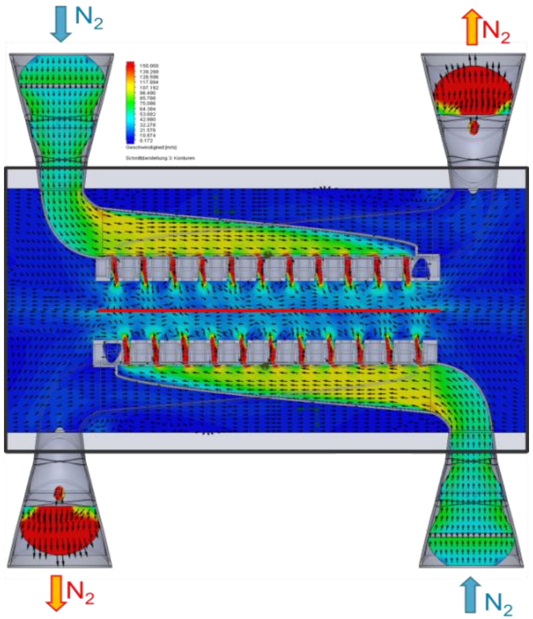
- **Basic Properties**
  - N2 -inlet and -outlet combined
  - Water cooled
  - Combinable side by side
- **Design suitable for AM**
  - Internal guiding gas flow
  - Less support structures
  - Remaining powder easy to remove

Source: voestalpine

TECHNOLOGY SHOWCASE
Boundary conditions

- **Cooling surface**
  - Sheets size: 200 x 400 mm
  - Temperature range: 800°C ...200°C
  - Cooling rate ≤ 70K/sec
  - Temperature gradient on sheet: +/- 15K
  - Combination of water cooling and gas flow

- **Challenges**
  - High temperatures
  - Small cooling distance (15 mm)
  - Large area

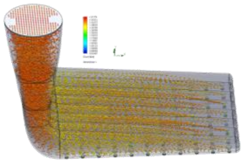


voestalpine
ONE STEP AHEAD.

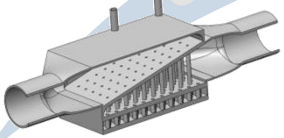
Source: voestalpine

TECHNOLOGY SHOWCASE
Design engineering and outlook

- AM-Design ≈ 4 weeks
- Simulations ≈ 1 week



Initial Design suggestion



Design optimization

thermal simulation

flow simulation

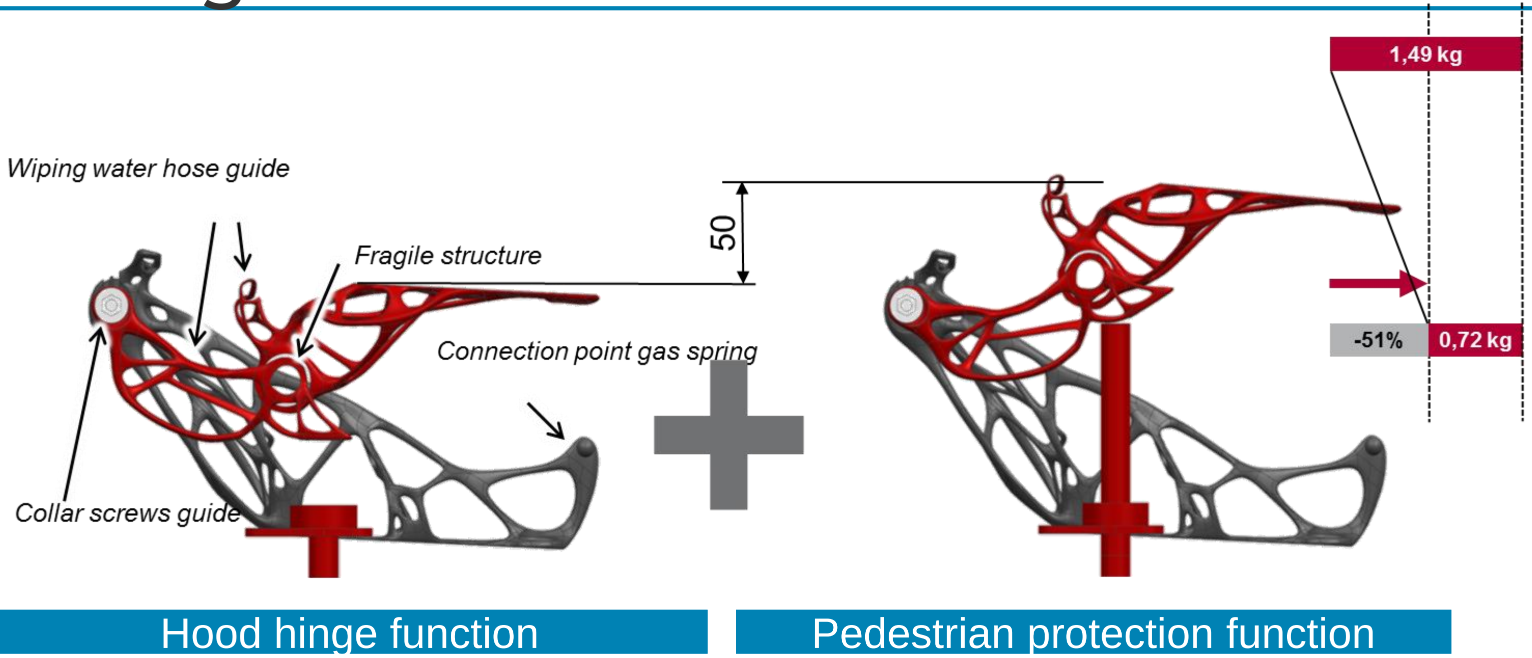
part configuration

Manufacturing

Evaluation & further optimization (if necessary)

voestalpine
ONE STEP AHEAD.

LightHinge+: FUNCTIONALITY

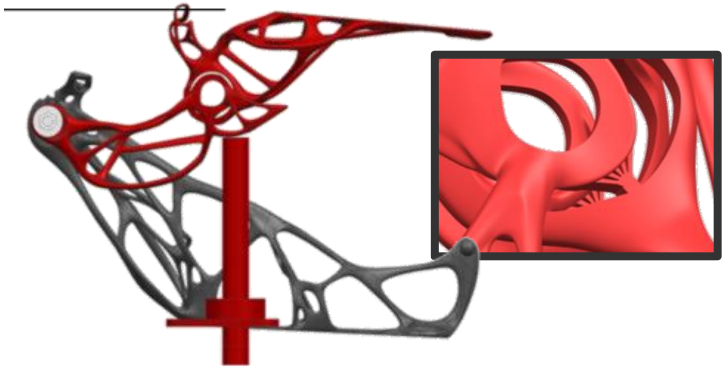


EDAG
Simufact Additive
voestalpine
ONE STEP AHEAD.

LightHinge+: WEIGHT OPTIMIZATION

Additive manufacturing only works economically if the highest degree of functional integration in the component is possible

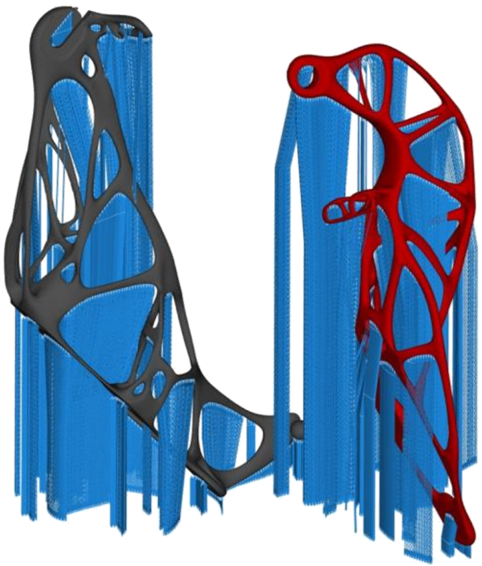
» **Topology analysis** without consideration
a. of the functional integration
b. of the manufacturing concept
brings the design engineer on a "wrong mechanical track"



Principle "breakaway structure" instead of "kinematics“
= Success factor for weight minimization

EDAG
Simufact Additive
voestalpine
ONE STEP AHEAD.

TOPOLOGY OPTIMIZATION FOR AM PROCESS CHAIN (2/2)



Experience based knowledge

Conceptual Design

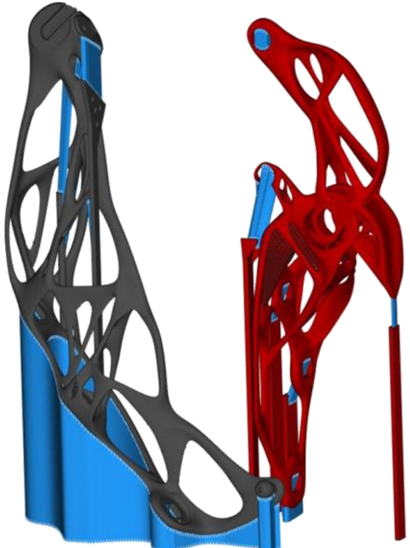
Part orientation

+

Simulative based knowledge

Adaptation constructive design

Component alignment in LAM chamber



LightHinge+

EDAG

Simufact Additive

voestalpine

ONE STEP AHEAD.

FIRST CHECKING THE ACTIVE HOOD FUNCTION IN THE TEST

- Degrees of freedom for designers: they enable the integration of an active hood function in the flat design of the front end
- Breakaway fractural structure acts as an ultra-light, printed kinematics in interaction with the pyrotechnic triggered spring elements
- Active bonnet will lift approx. 50 mm in the area of the hinges

voestalpine
ONE STEP AHEAD.

TECHNOLOGY SHOWCASE: ENGINE HOOD "LIGHT-HINGE" DEVELOPED WITH EDAG

- Bionic structure allows a **weight reduction of 50%**
- Optimized and simulated structure in terms of **strength, warpage** minimal **support**
- **Integrated** predetermined breaking point for **passenger protection** in the case of accident
- Customer demand was combined with new function in order to achieve **new USPs** in one single AM component

EDAG

Simufact Additive

voestalpine

ONE STEP AHEAD.

ADDITIONALLY: TECHNOLOGY AND INNOVATION SHOWCASE

» Innovation and Value Chains of Additive Manufacturing under consideration of RRI (Responsible research & innovation)

I AM RRI

Webs of Innovation and Value Chains of Additive Manufacturing under Consideration of RRI

www.IAMRRI.eu

Simufact Additive

EDAG

voestalpine
ONE STEP AHEAD.

voestalpine Additive Manufacturing Center

FOR FURTHER INFORMATION PLEASE CONTACT

Dr. Eric Klemp

voestalpine Additive Manufacturing Center GmbH

Hansaallee 321
40549 Düsseldorf
Germany

T.: +49 (211) 522 2331
eric.klemp@voestalpine.com

voestalpine
ONE STEP AHEAD.

Links

» https://www.youtube.com/watch?v=By0Byk8uASs

» https://www.youtube.com/watch?v=nUYvPgZiVMY
» https://www.youtube.com/watch?v=00QDs9V2MrA
» https://www.youtube.com/watch?v=2z-3vqAKkBU

» http://www.voestalpine.com/highperformancemetals/de/